

Ole Judichær and Danish Naval Ship Construction and Design in  
the late 17<sup>th</sup> Century

A preliminary analysis of the model of the 54-gun *Prinz Wilhelm*  
in the collection of the Royal Danish Naval Museum



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2014

**Master's thesis submitted to the Maritime Archaeology Programme  
University of Southern Denmark**

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*“In spem æternaturæ memoriæ...”*

*O. Judichær*

*1723*

## **Abstract**

During the period of activity of Ole Judichær (1690-1727), sources in the form of lines plans, ship models and construction documentation are preserved in the Danish National Archives and the Royal Danish Naval Museum. While some of these sources have been studied in other contexts, they have not been studied in conjunction. Using as study case the model of *Prinz Wilhelm*, the first ship to have been officially designed by Judichær, in conjunction with sources in form of lines plans and historical documents, and applying archaeological methodologies, an explorative study of the construction and design of a Danish warship at the end of the 17th century is possible.

## **Abstrakt**

Fra Ole Judichær's virke (1690-1727) er der kilder i form af skibstegninger, skibsmodeller og konstruktions dokumentation bevaret i Rigsarkivet og på Orlogsmuseet. Mens nogle af disse kilder er blevet undersøgt i forskellige studier, er de ikke blevet undersøgt sammen. I dette studie er modellen af *Prinz Wilhelm*, det første skib som officielt blev designet af Judichær, blevet brugt, og sammenholdt med kilder i form af skibstegninger og historiske dokumenter. Dette muliggør, sammen med anvendelsen af arkæologiske metoder, et eksplorativt studie af konstruktion og design af et dansk Orlogsskib i slutningen af det 17. århundrede er mulig.

## Acknowledgment

Apart from personal efforts, the success of any project depends largely on the encouragement and guidelines of many others. Thus, I take this opportunity to express my gratitude to the people who have been instrumental in the successful completion of this project. I would like to show my greatest appreciation to Prof. Jens Auer, my supervisor. I cannot say thank you enough for his tremendous support and help during the writing of this thesis and the past years as student of the Maritime Archaeology Programme. Personal thanks to Prof. Thijs Maarleveld for his teachings and talks, which are a cornerstone in my formation. Furthermore, I would like to express my appreciations to Dr. Jakob Seerup, curator at Orlogsmuseet and Tøjhusmuseet, which help was essential for this study.

I am grateful for the help received during the surveys of the model from my colleagues and good friends Alexander Cattrysse, Margaret Logan, Saul Bowden, and Petru Guset. I would like to thank my loved parents, who have supported me and always believed in my choices. I will be grateful forever for your love. Last but not least, a special acknowledgement to Anja ÁGrømme Buchard Christiansen who has been with me through this not always easy path.

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# 1. Introduction

The last decades of the 17<sup>th</sup> century represent a period of ferment in naval shipbuilding and design. Indeed, the maritime milieu is witnessing an arms race and increasing competitions between naval powers (Glete, 1993; Lavery, 1992) as a result of the rising of the French Navy, the continuous tensions between England and Holland, and the conflicts for the supremacy of the Baltic Sea. This development occurs both in ship theories, which were influenced by mathematical and related philosophical thought (Ferreiro, 2010) of the time, and in shipbuilding traditions, which face a period of shifting and adoptions of new practices due to causes as the increasing of the size of the armed vessel (Lavery, 1992) or the shortage of suitable timbers (Nitz, 1993).

The same vivid circumstances affected the Danish-Norwegian kingdom. Indeed, the year 1690 is considered a major milestone in Danish naval history. The Danish naval shipbuilding was "nationalised" due to a policy of employing only Danish nationals as Royal Navy's naval architects (Bjerg, 2010), to design and supervise the construction of Denmark's future warships, in predilection to foreigners who previously occupied these roles. When in 1695 the Danish Ole Judichær (1661-1729) officially signed his first lines plan, the Danish Naval shipbuilding and design seems to have moved from an empirical practice to a scientific one, attributable to his mathematical knowledge applied to ship design (Bjerg & Erichsen, 1980). A great number of ship plans and construction models were produced during his carrier and are still preserved in Danish National Archives and the Royal Danish Naval Museum. In spite of the nationalisation, the practices in ship design and construction in the Danish navy has often be deemed as secondary and influenced by the practices of the other major European navies, such as England, France and Holland (Lavery, 1992; Anderson, 1921a).

Albeit the historical shift, few studies in the past years have concentrated on these topics. A possible cause can be related to the scarcity of archaeological remains of Danish warships, on the other hand this gap is counterbalanced by the richness of historical documents. At any rate, it is the opinion of the present author that an important source has been overlooked. The historical ship models collection at the Orlogsmuseet can easily be considered unique in international context but it has never been object of a study with archaeological methods. The collection, established 25th June 1670 after the instruction of King Christian IV to

the admiralty, provides a unique three dimensional source for design and construction of Danish warships. The model assembly survived until the present day and was moved to the *Orlogsmuseet* in Christianshavn in 1989.

Ship models are, unfortunately, too often classed merely as decoration (Winthrop Pratt, 1949), but the fact that ship models are really "historical documents" (Hasslöf, 1963; Carr Laughton, 1925) should not be overlooked. Likewise, ship models should be considered valuable archaeological evidence for investigation in maritime archaeology (Roach, 2008). Ship models are a unique source, not only for their great historical interest in illustrating the form and structure of ships in such perfect detail, but also because they hold epistemological value. Considering their three-dimensional nature, a very great deal can be learnt from models that cannot be obtained from any other source, such as written materials, depictions and draughts. By studying them, it will be possible to clarify the position of the Danish navy shipbuilding and design in the period in object, using at once "hard" archaeological evidences and historical documents.

## **1.1. Aim, objectives and the structure**

The core of the present essay is an explorative analysis of the construction and design of a warship built and designed in the early year of the Danish nationalisation of naval shipbuilding in comparison with the major naval forces of the period. In order to investigate these aspects, the study is focused on the construction model of the 54-guns *Prinz Wilhelm*, one of the earliest major warships designed by Judichær, with the support of preserved lines plans. In the specific, for the comparative analysis of both construction and design of the model, as basis are used the practices of the three major navies such as England, France and Holland from which Denmark is supposed to have drawn its own customs.

As stated by Roach (2008), ship models should be considered valuable archaeological evidence for investigation in maritime archaeology. They are a unique source, not only for their great historical interest in illustrating the form and structure of ships in such perfect detail, but also for their epistemological value. Because of their three-dimensional nature, a very great deal can be learnt from models that cannot be obtained from any other source, such as written materials, depictions and draughts. The richness of documents is not counterbalanced by the archaeological remains, which for the interested period are a rare and limited

source (Steffy, 2012). By analysing the model of *Prinz Wilhelm* as archaeological remains, it should be possible to investigate the characteristics of Danish naval shipbuilding and design in the period in exam.

The recording of the structures visible in the study case model should help to answer and shed light on the principles and practices of the Danish naval construction. Consequently, the starting point of this research is the investigation of the reliability and accuracy of the information gathered from the model. For these reasons three steps are necessary to investigate these properties:

1. An introductory study of the characteristics of the major naval model collections in Europe, in the specific England, Holland and France;
2. An analysis of Danish historical sources on the use of ship models;
3. A survey of the correspondences between other lines plans and the model of *Prinz Wilhelm*.

As postulated by other researchers (Jordening, 1896; Holck, 1939; Probst, 1993), the konstruktionsmodeller are supposed to represent accurate model in scale of the ship laid in the shipyard and this preliminary analysis is aimed to produce evidences in support of this view.

Judichær's model provides the opportunity to fill the gap in knowledge of shipbuilding practice in naval Danish Shipyard at the end of the 17<sup>th</sup> century, a knowledge that otherwise is not directly available neither as documents or other archaeological evidences. In order to investigate the possibility of foreign influences and to point out elements of originality in the Danish naval shipbuilding, an explorative comparative study is necessary between the structures found in the model of *Prinz Wilhelm* and the information available from archaeological remains of warships and surviving documents in form of naval and shipbuilding treatises of the three major European naval forces.

Eventually, In order to understand whether the design and arrangement of *Prinz Wilhelm* followed established foreign practices, or is original as stated by other researchers, a commentary of the principles which guided the design of the ship is essential. Thus, Judichær's design method will be analysed with the support of preserved documents and in comparison with the customs in the major North European navies at the end of the 17<sup>th</sup> century.

Therefore, the aim of this thesis is to explore the potentiality of the construction model as "hard" archaeological evidence and to provide a preliminary

insight on Danish naval shipbuilding and design during the nationalisation period, also through the use of historical documents and comparative analyses.

To summarize, the questions to which this essay intend to give an answers are:

- ∴ What does the model of *Prinz Wilhelm* represent? Is it similar to contemporary models in other European collections? Are the construction features recorded in the model also found in other Judichær's lines plan?
- ∴ What can the model of *Prinz Wilhelm* tell us about technological traditions? Are in its construction found adoptions or adaptations of foreign shipbuilding practices?
- ∴ How do the design and arrangement of *Prinz Wilhelm* differ from other European warships? Was Judichær's design method influenced by foreign practises and the scientific knowledge of his time or was it original?

Next to this introductory chapter, the following two chapters are intended to provide an historical background on the Danish navy from the second half of the 17<sup>th</sup> century and on the organization of the naval shipbuilding in the last decades of the century. Moreover, a brief biography of Judichær is presented which will help to understand the man behind the ship.

Successively, the model of *Prinz Wilhelm* is presented and described from the outside to the inside. The remaining following chapters are built on the aforementioned research questions and the nature, construction and design of the model are analysed and discussed. Finally, the last chapter summarizes the results of these analysis and discussions. In the appendix I and Appendix II, the original Lines plan of *Prinz Carl/Prinz Wilhelm* and the lines plan of the model have been added, while in the Appendix III, a glossary has been inserted to provide a guide to the readers for the technical terms of not everyday use.

## **1.2. Literature review on the current state of research**

Despite the extraordinary nature of the Danish Naval Museum's collection, few studies have focused on it. The Model Collection's history has been the subject of detailed descriptions, including in Jordening's catalogue of 1896 (Jordening, 1896), *Orlogskaptajn* P. Holck's thesis in 1939 (Holck, 1939) and in

*Kommandørkaptajn* R. Steen Steensen's history and collection of the *Orlogsmuseet* (Steensen, 1961). Nevertheless, these studies concentrate on the history and the lists of the collection, without giving any detailed description of the models and too often focused on the history of the ships themselves. In spite of being a precious source, Jordening's and Holck's catalogues are often affected by inaccuracies and errors of attribution.

Studies on the design and construction of warships in Danish naval dockyards between the end of the 17<sup>th</sup> and the beginning of 18<sup>th</sup> century are scarce. For the interested time frame, an article by Niels Probst's (Probst, 1993) provides a generalised account of the development of ship design under the reign of Christian IV and a presentation of unknown material related to the design methods of O. Judichær. Probst's analysis of Judichær's design methods is very informative, but Probst's interpretation seems unlikely and no conclusive evidences are provided for his theory (Auer, 2008).

A more recent study is the unpublished PhD thesis of Jens Auer (Auer, 2008). The focus of his study is on small Danish cruisers in the period between 1650 and 1750. A detailed analysis of primary sources such as lines plan, protocols and letters offer an insight glance of the methods and design applied in the Danish dockyards, underlying elements of originality in Danish ship design.

Another work that has to be mentioned here is *Danske Orlogsskibe 1690-1860* (Bjerg & Erichsen, 1980). This study contains an excellent overview over the life and work of the various naval architects involved in Danish naval ship design, focusing mostly on the ornamentation of Danish warships. Although the life and works of Judichær are addressed, the key topics of this proposal are not covered.

An article of Lind (1917), on the list of the Danish fleet under the reign of Christian V, gives general descriptive information on shipbuilding and shipbuilders in the Danish naval dockyard. However, the primary data nature provides solid background information for the period till 1690. As most of his contemporaries, Lind is lacking in referencing and is strongly influenced by the naval contemporary attitude (Auer, 2008).

If historical analyses of Danish warships are rare, so are archaeological reports. For the interested period only a shipwreck is available. Despite being one of the most symbolic ships of the history of the Danish Navy, the wreck of the 90-gun *Dannebrog* was subject to limited archaeological surveys and excavations, and few details of the hull are presented in the studies available (Christoffersen,

1990; Olesen, 2009). Indeed, if great emphasis is given to the history of the ship and on the recovered materials from the site, few details are provided on the hull and its construction.

### **1.3. Methodology**

The methodological approach of this thesis can be divided into areas: recording and studying of the model.

#### ***Recording***

At the moment this project started, the model of *Prinz Wilhelm* was temporary kept inside the deposit of the *Orlogsmuseet* and prepared to be placed inside a case for a new permanent exhibition. Thanks to the curator Jakob Seerup, the model was made available for the study, although for a limited period of time.

Due to the restricted time window and the impossibility of a prolonged stay in Copenhagen, a total of 6 hours in two sessions had been spent in the deposit for the recording of the model. The model was recorded and surveyed through non-invasive techniques, in the respect of the fragility of the artefacts. The methodology of recording involved the use of three-dimensional recording techniques such as real-time total station recording and photogrammetric recording, for the external hull, and photographic surveys and traditional recording techniques, for the interior and construction details.

In order to record the shape of the hull and to produce a lines plan, A Leica TCR 407 reflectorless red laser total station was used in combination with Rhinoceros3D 4.0 CAD software and the Termite plugin (Hyttel, 2011) to allow real time recording of three dimensional data.

With this method, points recorded with the total station in reflectorless mode are imported into the Rhinoceros3D CAD software via the Termite plugin, and can be connected to polylines and/or processed with the standard drawing tools available in the software in real time. Using the points surveyed from the model a three-dimensional surface was created which represented the hull of the vessel. Thanks to Orca 3D, a naval architecture plug-in for Rhinoceros, a lines plan has been extrapolated from the surface.

For the recording of minute details of the external hull as planking and gun-ports, a Close-Range Photogrammetric approach was deemed as suitable solution. Close-Range Photogrammetry, a technology which converts images of an object into a 3D model, has often been used as a method for the geometric documentation of land sites or even artefacts, combining high accuracy and quality requirements with time or accessibility limitations (Skarlatos & Kiparissi, 2012). Algorithms for 3D reconstruction from pictures sequences have been studied for a while in the computer vision literature (Yilmaz et al., 2007; Agnello & Brutto, 2007; Remondino, 2011), however the approach presented here is an open-source Dense Stereo Reconstruction solution based on two algorithms, called SFM or Structure-from-Motion and IBM or Image-Based-Modelling.

SFM algorithm determines the parameters of a camera (position and orientation of the trigger points) and produces a cloud of points at low density from a simple collection of images taken around the object in question, while Image-Based Modelling allows to obtain a reconstruction of the scene creating a cloud of high density points starting from a simple collection of images (Ditta in Auer et al., 2012). In the recent years, continuous and enormous improvements have been made in the automated extraction of image correspondences and a considerable number of algorithms for both methods have been developed. This includes the automatic computation of camera calibration for IBM.

For this project the image datasets have been acquired using a Compact Digital camera, Easypix-VX931, with an equivalent focal length of 35 mm and fixed focus during acquisition. The freely acquired images were processed automatically using Photosynth (Uricchio, 2011), a free Microsoft web-based service (<http://photosynth.net/>) for the bundle adjustment and the SFM output, and CMVS (Furukawa et al., 2010) an IBM open-source software for a dense point cloud extraction.

Photosynth has the great advantage of performing automatic image matching and computation of camera calibration, thus accelerating the acquisition and post-processing stages. The CMVS software is based on a multi-image matching implementation and only calculates points that are visible in at least three photos.

The resulting point clouds was subsequently acquired, cleaned and meshed in the open-source software called Meshlab (<http://meshlab.sourceforge.net/>), an application created to manage point clouds and allow surface reconstruction and texturization. Moreover, a process of photorealistic texturization has been applied

on the mesh, using the acquired images set. The resulting meshed and texturized model (Figure) was scaled using known dimension on the surface, such as the length of keel. As already demonstrated in the recording of the wreck timbers from Cuxhaven (Auer et al., 2012), this method has proven to be accurate and reliable, generating a fully measurable output. Eventually, the final model was used to trace a sheer plan of the strakes and gun-ports.

Eventually, the recording and description of the construction features were done on specific sheets created by the present author.

### *Studying of the model*

Besides the archaeological analysis of the ship models, historical and iconographic sources are used wherever possible and necessary to assist with the archaeological interpretation of the construction and design of *Prinz Wilhelm*. The Danish National Archives hold a vast collection of original ship plans from the interested period and offered an essential contribute as part of the analysis of the nature ship model and the design method use by Judichær. Moreover, in the same archives are preserved original notes, letters and protocols that provide precious information related to shipbuilding, ship design, and Judichær. The corpus of these materials is a crucial part in the study and the answering to the research questions.

A secondary source used in the analysis of the study of *Prinz Wilhelm*, especially concerning the design, is the so called Holck's *Konstruktionsbog* (Privatarkiv Holck). This booklet is a collection of documents related to several vessels designed by Judichær, although not written by Judichær himself. According to Probst (1993), these documents are copies of Judichær original working tables and drawings. For *Prinz Wilhelm*, both tables and a body plan are found in this booklet. This document is part of the privat archive of Preben Holck, an officer of the Danish Navy. When retired in 1925, Holck collected several documents from the navy archives and built a personal archive with informations and references to documents for each vessel in service in the Royal Danish Navy (Auer, 2008), which is preserved at the *Orlogsmuseet*.

Another document, analysed during the study of the design principles of Judichær, is the so-called first Danish treatise on naval architecture. Only composed of 12 pages, this treatise called *Een liden Søe-Architectur* (Bragenes, 1723) was written by a cadet which was a student of Judichær. Although published

in 1723, some of the informations related to the conceiving of the hull shape are found to be used by Judichær himself, as stated by Probst (1993).

Moreover, background researches through essays and literature reviews have been carried out on topics such as ship models, shipbuilding, archaeological evidences, ship design, and scientific knowledge in naval architecture, in order to provide answers to the research questions. Eventually, foreign historical documents on shipbuilding and ship design have been used to contextualize and compare the recorded and available material.

#### **1.4. Terminology and usage**

In most of the cases the English forms of shipbuilding terms will be used. If otherwise, the word will be typed in italics to indicate the spelling in the original language. The same applies for the names of ships which are also written in italics.

In the section Appendix III, a glossary is provided which is extracted from Steffy's (2012) work "Wooden ship building and the interpretation of shipwrecks".

#### **1.5. Dimensions**

For the description of the model of *Prinz Wilhlem*, a convention in the dimensions has been used. When the dimensions of timbers or other features of the model are reported, the value is given in centimetres while in brackets the value of the scaled dimension to real size is given in meters. The reported scaled dimensions are rounded with a margin of +/- 2 millimetres.

## **2. Brief history of the conflicts and developments of the Danish Navy from the second half of the 17<sup>th</sup> century to the beginning of the 18<sup>th</sup> century**

The Naval power and organization of a state can be explained as functions of a set of factors, more or less independent however interconnected. As stated by Glete (1993), these factors are divided in five groups: (1) the international political situation, (2) the interests behind the navy and the resources they are able and willing to spend on it, (3) the qualities and traditions of the naval administration and the officer corps, (4) the warfare doctrine and (5) technology.

The end of the 16<sup>th</sup> century and the beginning of the 17<sup>th</sup> century had seen Denmark's struggle for the *Dominium Maris Baltici*. To protect the privileged position of power in the Baltic, from Sweden and other Nations, the Danish navy had to expand well beyond its previous level. The naval shipbuilding and its development toward the nationalisation is the result of the historical background which involved the navy and the Danish kingdom.

## **2.1. The war with Sweden and the Fleet rebuilding**

After the Thirty Years war, the economic disaster Denmark was facing, did not halt an extensive shipbuilding programme in order to restore the Navy. The previous war had proved the important role covered by major ship-of-the-line, which now were the focus of Frederick III (1609-1670) programme. For this occasion several shipbuilders were hired, mainly from England. The political situation in the Baltic was still unstable, especially after the succession at the Swedish throne of the ambitious Charles X Gustav (1622-1660) in 1654. Christian IV's successor, was expecting a new war and in 1656 the fleet had 21 warships, of which seven armed up to 100 guns, and 22 smaller vessels (Probst, 1996).

Frederick III reformed the Navy organization, establishing in 1655 an admiralty (Steensen, 1974). He appointed as *Holmens Admiral*, a Dane formally trained as a navy cadet. Niels Juel was trained in the Dutch Navy both in military, seamanship and shipbuilding. The new king also appointed several Dutch naval captains for operative positions in the navy. The large number of Dutch maritime terminology used in Denmark, should be connected to this occasion (Bjerg, 2010).

The same year, Sweden declared war against Poland and in 1657 Denmark entered into the conflict against Sweden. Throughout the war, minor skirmishes ended often in favour of the Danish fleet. Nevertheless, the conflict received a twist when, in the winter 1657-1658, Charles X Gustav's troops across the ice marched on Zealand. Peace negotiations started under the French and English

mediation, with a shift in favour of Sweden on the Baltic control (Jespersen et al., 2006). Eventually, in the summer of 1658 Charles X Gustav attacked on surprise Denmark in order to conquer the country and in 1659 Copenhagen was under siege. The perspective to see the whole Baltic under Swedish control pushed the Netherlands to drastically intervene, leading to a peace treaty in favour of Denmark in 1660. During the war, the Danish navy suffered massive losses and the residual fleet was of only 17 warships (Probst, 1996).

The year 1660 brought the absolutism in Denmark. Frederick III, after a coup d'état, institutionalized the absolute monarchy based on the right of inheritance of the throne. A more bureaucratic administration was established both in civilian and military sectors, with consequence also for the navy (Bjerg, 2010).

In 1663, the international-famed Norwegian Cort Sivertsen Adeler, who previously had served as a naval officer in the Venetian and Dutch Navies, was appointed *admiral* with the duty to give a modern asset and rebuild the fleet. Cort Adeler began a rebuilding and restructuring of the fleet, heavily influenced by Dutch elements since Dutch officers often received the command of a ship. Shipbuilders from the Netherlands were hired and already in 1670 the navy consisted of 69 units (Jespersen et al., 2006).

## **2.2. The Scanian War 1675-1679**

When Christian V (1670-1699) ascended the throne in 1670, his interest for the navy gave to the fleet high priority in the government programme. In 1673 the navy's administration was extended, with separated offices for the procurement and maintenance of the material and personnel. The quality of the warships were superior of the one owned by the Christian V's father, giving him a superior naval advantage on the Baltic (Bjerg, 2010).

Under the political point of view, in order to keep Sweden in an inferior position in the Baltic, Denmark joined a German anti-French alliance in 1672. On the other hand, Sweden joined an English-French alliance. This alliance dragged the two countries in a new war, when Sweden invaded the north Germany in 1674, and Denmark replied with a mobilization of troops (Jespersen et al., 2006). The war was a branch of a larger European conflict in which Sweden and France faced also the Netherlands and Spain, with which Denmark had in 1674 formed an

alliance. The war became known as the Scanian war because the main aim was to regain the lost provinces east of the Sound (Bjerg 2010).

When Cort Adeler was stricken by a disease and died suddenly in 1675, the command of the fleet was temporarily given to Niels Juel. The following year, the king appointed the Dutch admiral Cornelis Tromp as General-Admiral. The attention with which the navy was rebuilt began to pay off, and the combined Danish-Dutch fleet was highly successful. The two main naval battles of the war, Møen and Køge bay, were fought under Niels Juel without dutch assistance, placing him in a favourable light (Bjerg, 2010).

In the last years of the Scanian war, the Danish naval supremacy was clearly demonstrated. Despite the Danish success, the peace arrived in Lund the October of 1679. It was dictated by France, leaving unchanged border between Denmark and Sweden and, consequently, Denmark had to return all the conquered lands in Scania. This war underlined once again the superiority of the Danish fleet and her supremacy on the Baltic, while shown a Sweden in decline and more dependable on the European forces (Jespersen et al., 2006).

### **2.3. Niels Juels's Navy**

The bitter victor was however a turning point for the navy organization. The Naval shipyard at Bremerholm had become too small, and in 1680 it was decided to establish the foundation for Nyholm and the Navy main base at Holmen (Elling, 1932).

Naval strength was constantly increased under the supervision of *Admiral* Niels Juel who had become head of the admiralty in 1683, while Henrik Span was later appointed *Holmens Admiral* to lead the constructions of new warships. During the war, Niels Juel often complained about the poor sailing qualities of the warships built under Cort Adeler, in Dutch style. He especially criticized the 120 foot ship type and in 1681 as consequence all the future dimensions for ships were increased by approximately 10% (Probst, 2005). The Englishman Francis Sheldon was enrolled as shipbuilders in 1686. However, in 1690 Sheldon abandoned his role and Span took over the design and construction of the new warships, marking the nationalization of naval shipbuilding in Denmark. The numerous Dutch officers left the navy, but some of them remained in the ranks. Despite the fact that

a training institution for naval officers was created already in 1670, in 1683 very few cadets were trained (Bjerg, 2010)

At the turn of the century the Danish navy consisted of 30 large warships, 15 medium sized warships, 12 ships with less than 20 guns, numerous galleys, special vessels such as floating batteries and various prams, consisting altogether of 57 warships and 76 auxiliary craft (Barfod, 1997). The foreign policy during the remaining rule of Christian V was marked by an alliance with France which lasted 15 years.

## **2.4. Great Northern War 1709-1720**

After Niels Juels death in 1697, the navy was given to the nineteen-year old Ulrik Christian Gyldenløve. He was a son of Christian V and had been trained as a naval officer in France since the age of fifteen. The navy was still in good condition, and in early 1700 it was equipped to full strength once again be used against Sweden. Between 1698 and 1700 Denmark, Poland-Saxony and Russia gathered in an anti-Swedish coalition. As from agreement each party was obligated to occupy Swedish military forces on different fronts (Lockhart, 2004)

In February 1700, after Augustus of Saxony and Poland attacked Riga, Frederick IV fulfilled his part of the agreement by invading the duchy of Gottorp. In the summer of the same year, Tzar Peter I of Russia (1672-1725) also attacked. William III of England (1650-1702), who was on the verge of a war with France, was against to another war in the Baltic and quickly reacted. In July 1700 a combined Anglo-Dutch fleet took part in the bombardment of Copenhagen and supported the landing of Swedish troops on Zealand. Denmark had to enter peace negotiations and the Danish navy survived this first year of the Great Northern War without great losses (Barfod, 1997).

In the meantime the actions the Swedish king Charles XII (1682-1718) continued his campaign against Tsar Peter I of Russia, after forcing Poland-Saxony to a peace. Denmark's role remained marginal for those years of the Great Northern War. A turning point came when Denmark and Poland-Saxony renewed their alliance and in October 1709 Frederick IV attacked Scania. While the attack was successful in the early phases, Danish troops had to withdraw from Scania after a defeat in Helsingborg in 1710 (Tuxen et al., 1903).

In October 1710, the most important naval battle between the Danish and Swedish navy took place in Køge Bay. Even if the battle ended in a draw, the Danish-Norwegian fleet was able to return to Copenhagen with only lost a major warship, the 92-gun *Dannebrog*, while the Swedes lost two ships. This was possible thanks to the heroic effort of Captain Iver Huitfeldt aboard the *Dannebrog*, which although the fire on board continued to fight and distract the rest of the enemy fleet. After an hour of fighting, the ship exploded and nearly 600 men including Captain Huitfeldt were killed (Giødesen, 1885).

Between 1711 and 1716, in addition to convoy and cruising duties, the Danish navy fought several skirmishes in the waters around the island of Rügen. The Danish supremacy at sea was proven with victories in the battles of Femern and a draw in the battle of Rügen (Barfod, 1997).

The last stage of the Great Northern war was marked by a Swedish attack on Norway and a British entry into the war on the side of the allies. In 1718, Charles XII died during the siege of the Norwegian fortress Fredrikshald and the Swedish forces retreated. Naval actions during the last stage of the war included the famous attack on a Swedish transport fleet by Tordenskjold, one of the most illustrious figures in the Danish navy of the period, as well as attacks on the Swedish fortresses Stromstad and Marstrand in 1717 and 1719 (Barfod, 1997).

For Denmark, the Great Northern War ended in 1720 with the peace of Frederiksborg. Denmark had to return the conquered Swedish areas against payment, but Sweden lost its toll privileges in the Dresund and had to recede her support to Gottorp. In addition Denmark gained Schleswig (Barfod, 1997).

The period after 1720 is generally known as *the long peace*. Under the Kings Christian VI (1699-1746) and Frederick V (1723-1766), Denmark grew economically and participated in the European system of strategic alliances. In this period, the Navy had guard duties in the sound and off Copenhagen and journeys to Danish possessions and colonies overseas. Moreover, a greater attention was given to the training of Sea Cadets (Seerup, 2001).

### **3. Shipbuilding and its organisation in the Danish Navy at the end of the 17<sup>th</sup> century**

As can be agreed from the previous chapter, the Swedish threat and the preservation of the supremacy in the Baltic raised awareness of the advantage and

the necessity of a large permanent war fleet. Eventually, the rise of absolutism in Denmark, alongside the increase of armed forces, was one of the answers to the Swedish threat for the national survival. The absolutist monarchy introduced a wider bureaucratization, which influenced the navy's administration in conjunction with technology and tactics. In few words, bureaucratic control allowed centralized power (Glete, 1993).

The development and the nationalization of Danish naval shipbuilding are strictly correlated with the organisational structure of the navy (Auer, 2008). As in the rest of Europe, the rise of the large naval bureaucracies began as a rationalization of the know-how accumulated within both the private and public sectors of maritime life, however at long term shielding the naval development from the civilian one. Thus, the nationalization of the design and construction of warships was a direct consequence of the bureaucratization of the technical knowledge necessary to produce them. The authoritarian and hierarchical organisation of the Navy tended to prefer solutions from above or internal, rather than includes development of solution from below or from outside (Glete, 1993).

The following section will help to better understand this context.

### **3.1. The organization**

With the absolutism of Frederick III and his naval reform, not only the navy was reshaped but also the shipbuilding organization. In 1660, all the matters concerning to shipbuilding were moved under the responsibility of the Admiralty. The position of master shipbuilder, *mesterskibsbygger*, was in charge to design and build the ship. The process for the construction of a new warship was straightforward. After the king order for a new ship, the admiralty was in charge to prepare a charter which had to be approved by the king himself (Bjerg & Erichsen, 1980). Subsequently, the approved charter, that usually was brief and not too specific, was submitted to the master shipbuilder to design and build the vessel (Auer, 2008). The supervision of the building process was the duty of the admiral of the dockyard, also known as *Holmens Admiral*.

The 25<sup>th</sup> June 1670, the king sent an instruction to the admiralty, which laid a cornerstone in the shipbuilding organization. In the instruction, a part from the charter to be handed to the master shipbuilder by the admiralty, it was specified that a model for each “... *capital Orlogs Skib*...” had to be made and any deviation

from an approved model was prohibited (Bjerg & Erichsen, 1980). In this context, the word model is of unclear usage and can be intended as actual model of the vessel or lines plan. In fact, the ambiguity of the term can be seen on the crude draught of *Hummeren* from 1664 (RA: Søetatens Tegningsssamling A931), which was approved as follow:

*“Effter denne Model skall de anbefalde skib till Glückstad bygges...”*

At any rate, in 1673 a new instruction was issued which replicated the previous with the addition that the master shipbuilder had to produce charters and models to be sent for the approval of the king (Bjerg & Erichsen, 1980).

The year 1690, marked a turn in the Danish naval shipbuilding. Henrik Span was appointed *Holmens Admiral*, receiving specific directives and in particular the request of drawing approved by the king for each ship as follow:

*“...Nar noget nyt aarlog Skiib, Fregat, Jagt, eller andet Fahrtög, lidt eller stort shall byggis, og forferdigis, vilde vii hannem först derom et dessein, modelle eller afritz, af os allernaadigst undershrifven, og approberit tilsende, hour efter hand det da ag de vedkommende vedbörvende uden nogen forandring derved at giöre, shall lade forferdige og ville vii da og voris deputerede Allernaadigst berdre, hvis till samme biugning benödiges efter hans acquisition at anshaffe..”*  
(RA: Søetaten: Admiralitetet 11 Marts 1690, 1)

With the resignation of the last foreigner master shipbuilder in 1690, the naval shipbuilding became a national matter. In fact, the design and construction process was directly absorbed by the *Holmens Admiral*. In 1692, the position of *fabrikmester* was created with the role to supervise and control shipbuilding procedures. However, under Judichær, the first *fabrikmester*, the position quickly evolved into *konstrukteur*, *id est* naval architect (Bjerg & Erichsen, 1980). From this point, unlike most other European navies, in which constructors and naval officers had separate careers under different authorities, the Danish navy's constructors were part of the officer corps (Ferreiro, 2010).

### **3.2. From master shipbuilders to Naval architects**

Textual sources show foreign influences on Danish shipbuilding since the second half of the 16<sup>th</sup> century. This influences were the result of the State-controlled shipbuilding within the kingdom and the employment of foreigner

master shipbuilders (Lemée, 2006). This tendency lasted since the end of the 17<sup>th</sup> century, when the shipbuilding and design of warships was handed to nationals between the navy ranks.

Thomas Lindsay was the last in a long row of Scottish and English shipbuilders in royal service (Lemée, 2006). He was employed together with his son on the 17<sup>th</sup> November 1667, one year before James Robbins the Younger, another English master shipbuilder, was laid off. Nothing is known about Lindsay's influences or methods. All the vessels he was responsible for were started in 1657 and 1658, when James Robbins the younger was still active and it remains unclear whether he built ships after the design of Robbins or was actively involved in the design process. James Robbins was re-employed for a short period in 1666 and the difference in the salary between Lindsay and Robbins suggests that Lindsay acted as shipbuilder rather than designer (Auer, 2008).

With Cort Adeler, the fleet was rebuilt and redesigned according Dutch principles. Indeed, Adler recommended to the king the hiring of the Dutch shipbuilder Thies Hermansen van der Burgh, which on the 4<sup>th</sup> December 1663 the king agreed to hire (Holck, 1934). The Dutch master shipbuilder reached Copenhagen in January of the following year with his son and, already in February, started the construction of a new vessel (Holck, 1934). In 1669, his son Herman was employed as apprentice shipbuilder. However, in 1682 during the construction of the 90-gun *Christianus Quintus* after a plan and model approved by the king, Thies Hermansen van der Burgh was deemed guilty of making changes to the design approved by the king. For this reason, van der Burgh father was dismissed, while the son was degraded again to the status of apprentice for not reporting the father (Lind, 1917). At the time of his dismissal, Thies Hermansen van der Burgh had built a total of 22 ships for the Danish navy (Lind, 1917). The same year, Herman Thiessen was sent to Norway in Frederikstad and afterwards in Christiansand. There, van der Burgh son acted as shipbuilder on the new shipyard till his death in 1692 (Barfod, 1989).

In 1665, Cornelis Thomsen, another Dutchman, was employed in the shipyard of Bremerholm as apprentice shipbuilder (Lind, 1896). Already in 1669, he was entrusted with the task of building a 44-gun ship and small frigate in Norway (Auer, 2008). The leap in the career happened in 1683 as result of the dismissal of Thies Hermansen van der Burgh, where Thomsen started to act as master shipbuilder till his death in 1686 (Lind, 1917).

Albeit the background and training of the three Dutchmen is unknown, according to the *admiral* Sehestedt, Thies Hermansen could produce line drawings for his vessels and build according to drawings while Thomsen was able to use charters and rules rather than drawings (Auer, 2008). Herman Thiessen was considered the least competent of the three (Lind, 1917) and it can be assumed that he learned about drawings from the father, but it remains unclear if he actually designed ships himself (Auer, 2008).

The last foreigner master shipbuilder to enter in the Royal service was the Englishman Francis Sheldon. Born in England 1612, Sheldon acted as shipbuilder under the Pett family before being sent to Sweden in 1659 and serve the Swedish king as master shipbuilder, by request of Cromwell (Harris, 1997). In 1686, Sheldon appeared in Denmark and hired to replace Thomsen as master shipbuilder. During his staying in Copenhagen, Sheldon built mostly smaller warships and experimental vessels, such as a boat with two keels (Barfod, 1997). His stay under Royal service did not last long. Indeed, Sheldon had several confrontations with *admiral* Henrik Span and when the latter was named *Holmens Admiral* in 1690, Sheldon resigned from his position (Lind, 1917). Although Sheldon designed several vessels for both Sweden and Denmark, none of his drawings survive. He was probably influenced by English ship design methods, given his permanence under the Pett family, albeit he did not seem afraid of trying new technologies (Auer, 2008).

Before 1690, the Danish navy policy on shipbuilding and ship design was similar to the other navies. Indeed, during the 17<sup>th</sup> century the major European navies more or less permanently employed skilled artisan shipbuilders which used traditional and tacit handicraft know-how in shipbuilding (Glete, 1993). However, as stated by Glete (1993), the gradual bureaucratization of the navy went hand in hand with the rise of professional officer corps which allowed that such know-how turned into an institutionalised asset. In this way, the knowledge could be transferred from one naval officer to another (Glete, 1993), irrespective of family ties or craft secret that till that moment interested the Danish naval shipbuilding.

With the position left by Sheldon in 1690, the admiral of the dockyard Henrik Span officially started to act as naval architect. This marked the beginning of the nationalisation of naval ship design and construction in Denmark. Born in 1634 in Oldendorf, the young Span sailed on merchantmen for the Venetian and the Dutch, both in Holland and in Dutch East India. In 1672, Span became captain in the ranks of the Dutch Navy and participated in the Third Anglo-Dutch War. In 1677, Span joined the Scanian War in the ranks of Danish Navy where he was

promoted to vice-admiral (Topsøe-Jensen & Marquard, 1925). When Span was named *Holmens Admiral* in 1690, all the matters related to shipbuilding and design of warship went under responsibility till his death in 1694 (Lind, 1917). Span did not act only as naval architect but also as engineer, since he designed and built naval guns and floating docks. In only four years, Span designed two major warships and three small frigates (Lind, 1917)

### 3.3. Ole Judichær: Life and Works

In order to explore and discuss the ship design and shipbuilding under Judichær, it is interesting to introduce a brief biography Judichær, which could provide hints on his methods.

Ole Judichær was born in 1661 at Vamlingbo in Gotland, from the priest Niels Olufsen Judichær and Anne Nielsdatter Gardea. In 1676, after the region was conquest by Niels Juel, he moved to Copenhagen. In the capital he studied theology in 1683 (Bricka et al., 1887).

During his studies, Judichær come in contact with the prominent scientist and astronomer Ole Rømer, and fascinated by mathematics Judichær begun to follow Rømer's lectures at the university. Rømer used to have several students as assistants, and Judichær become one of them (Bricka et al., 1887). In 1684, the young Judichær published a mathematical-philosophical dissertation written in Latin (Judichær & Jersin, 1684), in which the Cartesian view of false senses (the Cartesian concept of the Evil Demon) is questioned and discussed.



Fig. 1: Fabrikmester Olaus Judichær. After Bjerg & Erichsen 1980.

The young mathematician started to attend Rømer's parlour, where he probably met *admiral* Henrik Span, close friend of Rømer (Tybjerg, 2011). During these meetings there are few doubts that ship design and other maritime matters were not one the subjects of conversation, since Rømer himself was quiet acquaintance with the topic. Indeed, Rømer was advisor for the *KommerceKollegiet* in 1681, for ship displacement matters, and conducted studies about navigational instruments and

navy ballistic (Friedrichsen & Olsen, 2004). During these meetings, Judichær was probably accepted under Span protection and he was allowed to occasionally preach in Holmen's Church (Bricka et al., 1887). Soon enough, Span was fascinated by Judichær's mathematical knowledge and he procured to him in 1690, a position at Bremerholm as *viceekvipagemester*. For Span, Judichær's lack of nautical experience was compensated by his mathematical and geometrical knowledge that could have been applied in ship design.

The career leap occurred in 1692, where he was officially appointed *fabrikmester*, a position that he will keep till his dismissal, and *ekvipagemester*. At this very moment, the building of the biggest Danish warship of his time was already under construction at the shipyard in Nyholm. The 90-gun *Dannebrog* was officially designed by *admiral* Span but some scholars support the idea that the architect behind Span's ship design was Judichær himself (Lind, 1917; Schultz, 1932; Probst, 1993), even if Span seemed really familiar with the topic as show his discussions with Francis Sheldon about shipbuilding (Harris, 1997).

However, only from 1695 Judichær's name is encountered on lines plans used in ship construction. The first Drawings to bear his signature are those of the sister-ships *Prinz Carl* and *Prinz Wilhelm*, launched in 1696 and built under the *Holmens Admiral* von Støcken (Probst, 1993).

In 1697, Judichær designed a 110-gun warship, the largest ship that the Danish navy ever had till that moment. Originally named *Store Christianus Quintus*, after the Danish king when she was designed, her name was changed to *Fredericus Quartus* in honour to Frederick IV's accession to the throne (Nielsen, n.d.). The career of Judichær rapidly proceeded. He was appointed in 1698 as *Kommandørkapitajn* and from 1701 taught naval architecture at the new cadet academy (*Søkadetakademi*). Eventually, in 1705 he received a seat in the Admiralty (Bricka et al., 1887).

In 1705, perhaps as result of the examination of his method by a commission ordered by the king, he was granted for two years to travel to study shipbuilding in England and Netherlands. The study-trip was abruptly interrupted only after a year, due to the outbreak of the Great Northern War and his consequent call back in service (Bjerg & Erichsen, 1980).

Judichær was also involved in direct naval combat experience. In 1710, he led a squadron at the Battle of Køge Bay as *Schoutbynacht* (Rear Admiral) aboard the 72-gun *Wenden*, which was one of his own designs. The same year he was given overall management of the Holmen dockyard, after von Støcken was

dismissed from his position of *admiral* of the dockyard, and between 1711 and 1712 he was also Head of Coastal Defence for the Elsinore and Stevns areas (Bricka et al., 1887). In this occasion, for operations in the Swedish archipelago were used a fleet made of special barges as floating mortar batteries designed by Judichær. In 1714, he definitely took over the position of *admiral* of the Holmen dockyard, assuming total control of all matters related to shipbuilding (Bjerg & Erichsen, 1980).

After the end of the war, Judichær started to review the fleet status and proposed a new re-organisation and plans for the fleet which caused some frictions within the naval officer corps. Despite his great work, it could not be hidden that there was much to criticize in Holmen (Bricka et al., 1887). In 1725 was appointed a commission to investigate in more detail Judichær's work, without any consequences. However, in 1726 it appeared that several of the employed warships were in very mediocre conditions. Thus a new commission was appointed and the responsibility was given to Judichær (Bricka et al., 1887). He argued that the cause mainly was to be sought in the scarce funds, resulting in poor maintenance. As result, the 10 November 1727, Judichær was dismissed from his duty with a pension and all his drawings and papers were confiscated (Bjerg & Erichsen, 1980; Bricka et al., 1887).

After his dismissal, he retired to Næstved, where he died in 1729. Despite Ole Judichær's longevity as the Danish navy's naval architect, he is only credited with designing 11 major battleships and 2 frigates, an apparently small number, particularly in view of the fact Judichær's tenancy extended through the Great Northern War. His method and principles of design, one of the central questions of this work, will be discussed later.

### *Judichær as architect-engineer*

Ole Judichær did not act only as naval architect. As seen above, during his career he covered several positions, such as administrative and command roles. In any case, he also seemed to act as architect-engineer. In the middle of the Great Northern War he designed the *Søbatterier Prøvestenen* and *Trekroner* (Bricka et al., 1887). The batteries were solid jetties made out from useless vessels filled with sand and stone. After the war he drew more radical plans for the reorganization of the naval dockyard at Nyholm and an extension of the naval harbour at Hukken. Nyholm was extended sufficiently to reach autonomy as a naval station and

shipyard, while the navy workshops, administration buildings and official residences remained on Bremerholm. The two oldest preserved buildings on Nyholm, eastern and western Takkelagehus, were designed by Judichær (Elling, 1932).

### 3.4. The Ship model collection

The historical model collection at Holmen was established the 25<sup>th</sup> June 1670 (see paragraph 3.1), after the instruction letter from the king and simultaneously with the transfer of shipbuilding to Bremerholmen. The construction of ship models was not an unusual practice in Denmark. Indeed, already in 1555 a ship model is mentioned. When a navy bark was to be built at Copenhagen, Governor Peder Godske at Holmenslot was ordered to send to the king at Nyborg “*en Skablon af Trae*”, according to which the bark had to be built (Hasslöf, 1963). Furthermore, Christian IV owned a collection of several ship models, mostly genuine art masterpiece, that unfortunately went destroyed by the Swedish during the 1658-1660 war (Holck, 1939).

At any rate, the model built after the 1670 king’s instruction were called *Konstruktionsmodeller*, term which designated the models built in accordance to the actual practice of building ships (Holck, 1939). The typical construction models is a raw hull with half planking left out to show the framing and presenting only constructional detail, thus no decorations or rigging. Additionally, it seems that these models were preserved in order to provide information on developments on the warships construction and as training support in shipbuilding (Holck, 1939). During the 1730s, however, it appears that the model loses its original meaning. Basically, it echoes a simple three dimensional representation of a lines plan and merely shows the plain hull shape. From this point, the emphasis is moved on the lines plan and the legal binding on the model ceased to be enforced (Seerup, 2001).

After the model session establishment, the models were assembled in the *Materialhuset* on Bremerholmen, which was implemented with a model workshop. However, unclear is when these *konstruktionsmodeller* were assembled, if before, after or during the construction of the actual ship. In 1735 the collection was so numerous that Frederick Danneskiold-Samsøe had to arrange a dedicated *Modelkammeret*. In connection with the transfer was made a list of model

assembly, which that at that stage contained 102 models, including ship models, figure heads and machineries (Holck, 1939).

In 1795 the collection was devastated by the great fire that hit Copenhagen. At least 123 models, between them 51 ship models, were lost most of which belonged to the oldest collection. Another unfortunately loss by the hand of the British happened in 1807. The model collection was assaulted and robbed, with the loss of other 50 models. In spite of these unfortunate accidents the collection still include 136 ship models, 38 models of figure-heads and sterns, and 73 models of constructional details and other equipment, which are now preserved at the *Orlogsmuseet* in Christianshavn since 1989 (Steensen, 1961).

## **4. The model of *Prinz Wilhelm***

Initially, the model of *Prinz Wilhelm* had been identified by Jordening (1896), in his catalogue about the ship models collection, as the model of the sister ship *Prinz Carl*. Eventually in 1939, Holck (1939) identified the model as *Prinz Wilhelm*. Undeniably, the model in scale 1:24 resulted to match the length between the posts of *Prinz Wilhelm* that was 4 *fod* and 9 *tom.* longer than *Prinz Carl*. The identification of Jordening could have been vitiated by the golden painted name *Prinz Carl* at the stern, which cannot be dated. The year of the manufacture of the model cannot be dated with any precision. However, the first mention of the model is found in the first list of the ship models collection ordered by Danneskiold Samsøe in 1735 (RA: Orlogsværftets aflevering 1945, gruppe 'Personel og materiel' nr. 5B: *Inventarium over modellerne, liste over modeller af skibe, dokker m.m., 1700 ff.*).

### **4.1. Brief background on the 54-gun *Prinz Wilhelm***

The 54-gun ship, named after one of the Christian V's twin sons, was launched in Nyholm the 15<sup>th</sup> October 1696. *Prinz Wilhelm* was the seventh ship of the fleet built in Nyholm (Nielsen, n.d.). The warship was constructed under the *Holmens Admiral* von Støcken. However, the approved drawing (RA: Søetatens Tegningssamling A992) dated 31<sup>st</sup> December 1695 bears Judichær's signature. The

only drawing preserved is the elevation plan that shows a 50-gun *fregat* with the dimension of *Prinz Carl*. Unknown is if other drawings were available, but probably they went destroyed during the fire of 1795 (Probst, 1993). Both Holck (1939) and Jordening (1896) reported the name of J. Schiødt as *Skibbygmesteren* responsible for the construction of the sister ship *Prinz Carl*, but no accounts are available for the shipbuilder of *Prinz Wilhelm*. The two sister ships were built at the same time by different masters as competition in order to accelerate the construction. The winners, awarded by the King, were J. Schiødt and the foreman Peter Sievertz (Holck, 1939).

*Prinz Wilhelm* had taken effective service during the Great Northern War, being almost continuously fitted to combat. In 1700, the warship was fitted for war and joined to the Navy's 5th Squadron. In 1709 it was re-equipped, and until 1713 it was part of the main fleet (Christiansen & Bjerg, 2010). It participated to several skirmishes such as the battle of Fehmarn/Kolberger Heide in 1715 and the battle of Rügen in the same year. *Prinz Wilhelm* was also part of Tordenskiold's squadron during the blockade of Göteborg in 1719. Eventually, it was dismissed from the fleet in 1734 and scrapped (Christiansen & Bjerg, 2010).

As reported by Holck's *Konstruktionsbog* (Privatarkiv Holck), the main dimensions of *Prinz Wilhelm* were:

Length between the posts:	139' 3"	43.72 m	20 guns of 18-pounder 20 guns of 12-pounder 12 guns of 6-pounder
Moulded breadth:	36'	11.30 m	
Draught forward:	15' 6"	4.86 m	
Draught aft:	16' 8"	5.23 m	
			Displacement: 700 læster

## 4.2. Description

### 4.2.1. General remarks

The model of *Prinz Wilhelm* has a total of 27 gun-ports per side and it is arranged on two gun-decks, lower and upper-deck, along with a quarter-deck and a poop-deck. In Holck's *Konstruktionsbog* (Privatarkiv Holck) a total of 52 guns are counted, albeit the model clearly shows a total of 54 gun-ports, thus naming *Prinz Wilhelm* a 54-gun ship.

The model is entirely planked on the port-side, whereas on the starboard-side the part of the hull under the main wales is devoid of planking. The area left open by the absence of planks shows the framing system of the hull and the structures of the stem and stern posts. Moreover, this portion of the hull is covered by 6 ribbands. Also the decks are partially planked, with the exception of the poop-deck. The gaps between the decks made possible to take some measurements, as it will be deepened in the following sub-sections.



Fig. 2: View of the planked side of the model of *Prinz Wilhelm*. Ditta 2014.

This two-decker has a pronounced round and full bow. The sheer of the vessel runs smoothly and slightly curved till the quarter-deck, where it starts to rise relatively high with prominent bulwarks. Thus, the general impression is of a ship with a marked high stern and a low bow. However, this asymmetry appears to be well-balanced by the heaviness of the construction of the bow. Additionally, the model shows only construction details related to hull and its structures. No internal partitions are visible, as well as for the masts and rigging elements with exception for those pieces directly structured on the hull.

The two-decker is covered by a thick layer of yellow paint and varnish. This coating is not original and was applied after the fire of 1795, in order cover the damage and trace of burning (Holck, 1939; Jordening, 1896). This thick coating

layer makes hard to identify the seams of several planks, scarfs and the type wood used for the construction.

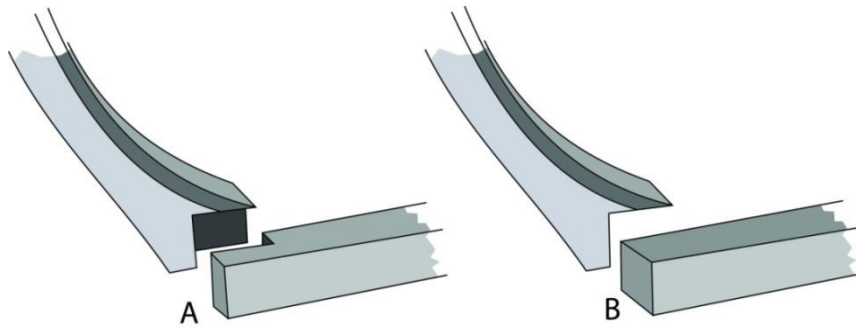
*Prinz Wilhelm* is the only model of the ships designed by Judichær to show carved ornaments and a figurehead. According to Jordening (1896), the partially preserved decorations were directly designed by Judichær. The figurehead is a beautiful intricate of fine carving and sculpting, which depicts a Roman dressed warrior riding a seahorse. The details are so accurate that are easily decipherable such as the Roman-style helmet of the equestrian and his coat, the saddle and the brackets. The equestrian also seems to wear a breastplate almost covered by the coat. As well, on the starboard-side quarter gallery is visible a small delicate work of carving. The decorations is limited to the lower finishing and divided in two scenes. The lower scene is a floral pattern, while the upper scene is composed of floral carvings at the corners and an elephants bearing a tower at the centre. The rest of the stern and counter of the model are not decorated, as well as the port-side quarter gallery. The stern has only open screen bulkheads and the balconies seem to have never been included into the model. Moreover, several elements of the ship such as taffrails, hancing pieces, and rails are carved with a combination of *ovule*, *cavetto* and *ogee* moulding styles.

The general dimensions of the model are: 204 cm (48.96 m) in length overall, 48 cm (11.52 m) in breadth overall and 62.5 cm (15 m) in depth overall. However, using the historical method for ship measuring, the length between the posts is 182 cm (43.68 m). For the breadth, the historical method would consider the moulded breadth or else without the planking and given the impossibility to estimate precisely the thickness of the planks, the overall breadth should be taken inconsideration. For the depth, see the following sections.

In the following paragraphs are going to be described all the visible and accessible construction elements of the model, in accordance to their locations.

#### **4.2.2. Keel, stem and stern posts**

The keel is composed of two pieces with a total length of 165 cm (39.6 m). The smaller of the pieces, that compose the keel, is positioned abaft the amidships and has a maximum length of 37.8 cm (9.096 m). The joint between the two pieces is a keyed hook scarf, with the wedges still in position. The length of the scarf is 4.9 cm (1.176 m). The moulded dimension of the keel at amidships is 2 cm (0.48

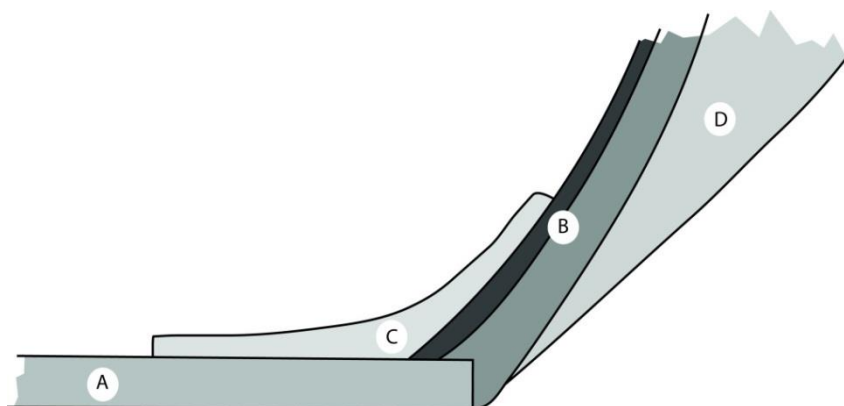


**Fig. 3:** A – Typical boxing scarf between the stempost and the keel. B – Illustration of the scarf visible on the model of *Prinz Wilhelm*. Ditta 2014.

m) while at both posts is 1.9 cm (0.456 m). The sided dimension are 1.5 cm (0.36 m) at the rabbet of the sternpost, 2.5 cm (0.6 m) amidships and 2.1 cm (0.504 m) at the joint with the stem.

At the bow, the keel is scarfed to the stempost with a scarf similar to type called boxing scarf (Fig. 3). Unlike the boxing scarf, where the stem interlocks with keel on three sides, here the stem interlocks with the keel only on the top and on the front. The scarf is 2.7 cm (0.65 m) in length while the height is the full sided dimension of the keel of 1.9 cm (0.456 m). It is not clear how the joint was secured, since bolts, nails or any kind of mortise is not observable. At the stern the keel ends with a short skeg. On the starboard-side of the keel, the rabbet is partially carved for the length of the keel stopping long before the posts. On the contrary, on the port-side the rabbet seems to be carved for the whole length of the keel. The approximate dimension of the rabbet at amidships is 0.5 cm (0.12 m), the back rabbet is 0.3 cm (0.07 m) and the distance between the back rabbet line and the bearding line is 0.7 cm (0.17 m).

The stempost is made out a single piece of wood with a total height of 38.29 cm (9.19 m). The moulded dimension at keel is 4.7 cm (1.13 m); at the top is 2.1



**Fig. 4:** Illustration of the structures at the bow. A - Keel; B - Stempost; C - *Stemphout*; D - Cutwater. Ditta 2014.

cm (0.504 m). The inner sided dimension is 1.6 cm (0.384 m). The top head of the stem is shaped in order to receive the bowsprit and for the last 5.5 cm (1.32 m) has a molded dimension of 2.3 cm (0.55 m). Sitting on the inner face of the stem

and on the keel, an element identifiable as sort of apron/knee reinforces the structure at the bow. At first sight it could appear composed of two pieces.

However, a close look shows that the possible seam is only the result of damages and dust. According to the Dutch tradition of the 17<sup>th</sup> century, this timber can be identified as the *slemphout* (Hoving & Wildeman, 2012). The *slemphout* has a minimum molded dimension of 0.6 cm (0.144 m) and an average of 1 cm (0.24 m). The sided dimension is 2 cm (0.48 m) and a total length of 13.5 cm (3.24 m).

Along with the stem, the cutwater is composed of a solid piece of wood. Thus in the cutwater there are no distinction between the forefoot (lower part) and the knee of the head (upper part). Starting from the two main wales, the cheeks extend on the cutwater. The cheeks are carved with the *ovule*, *cavetto* and *ogee* mouldings style. On the knee of the head, there are visible two bobstay holes and a squared gammoning hole, both used to fasten and secure the bowsprit in position over the stem.

In the same way as the stempost, the sternpost is made out a solid piece of wood. Its dimensions follow the narrowing of the keel and it is supported by several pieces of not easy identification. The inner face of the post has a clearly outlined rabbet. The bottom part of the post on the port-side, notched to the keel, has allocated the garboard and the second strake into a rabbet that is not carved on the starboard-side. The molded dimension at the bottom, included the rabbet, is 5.8 cm (1.4 m); at the top is 3.5 cm (0.84 m). The sided dimension at the bottom is 1.4 cm (0.336 m) while the top head, as in the case of the stempost, extend to 2 cm (0.48 m). On the inner face of the stem and touching the keel, two triangular pieces act as inner sternpost/deadwood. The whole structure is secured by a recognizable sternpost knee of 9 cm (2.19 m) in length and 5 cm (1.2 m) in height.

### **4.2.3. The Transom**

The stern of the model is planked on both sides, creating an obstacle in the reading of the single elements that compose the transom. However, some construction features are easily clarified by the vision through the gun-ports, even if limited. The transom of *Prinz Wilhelm* is a square tuck and is not totally flat since it has a slight camber at the helm port. The lower edge of the counter is not a simple decorative element but a structural element of the transom, identifiable as wing transom. Additionally, the upper edge is the deck transom. The lower part of the fashion pieces are clearly visible on the side without planks, while the upper part are directly covered by the planking, thus it is not clear if or how they connect

with upper stern timbers. Looking inside the model at the stern, at least 3 transom timbers are visible. The middle transom timber functions also as lower deck clamp. Furthermore, some counter timbers are visible (at least 8) which connected to the outer counter timbers, extend till the poop deck. The square tuck is planked with eleven strakes laid diagonally to the post. The planking of the counter, of the foundation pieces and of the filling pieces is simplified, since those elements are covered by single sheets of wood. To conclude, one gun-port per side is placed at the transom, closer to the sternpost.

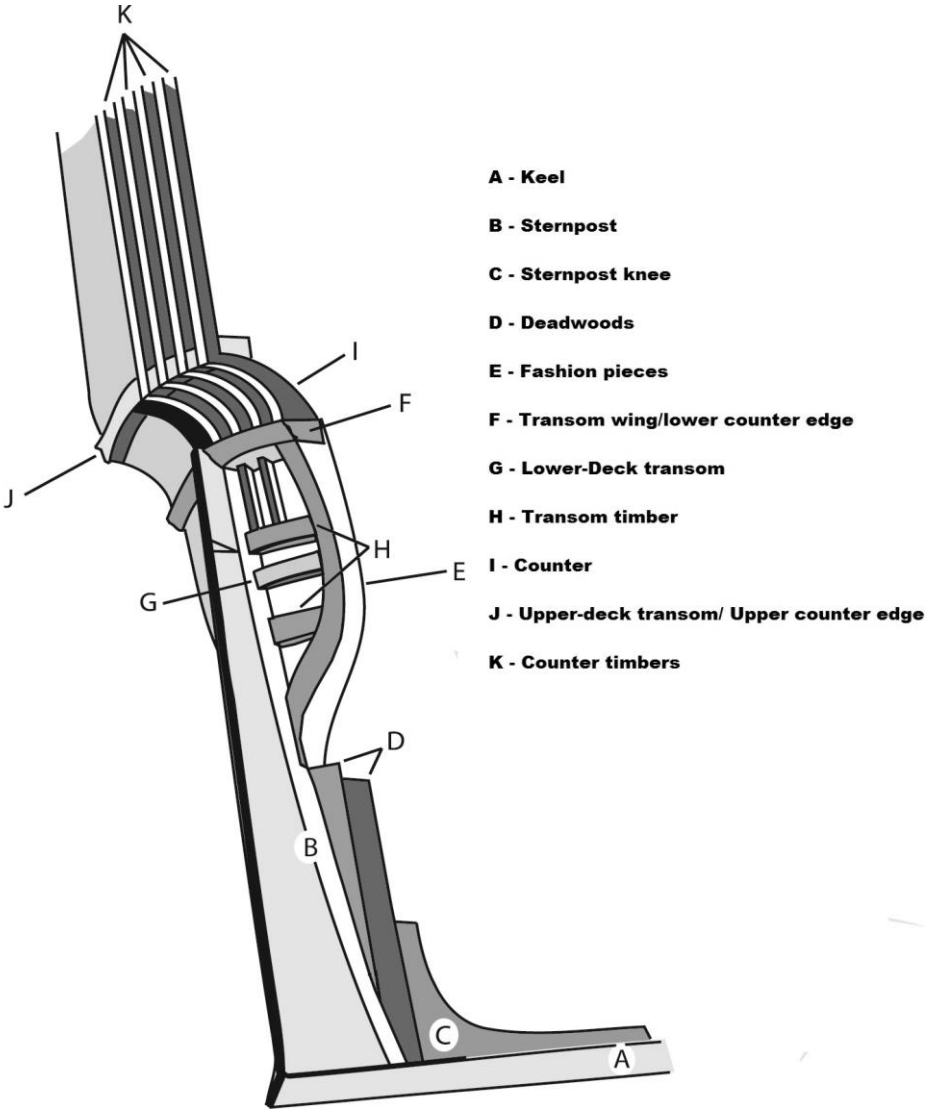
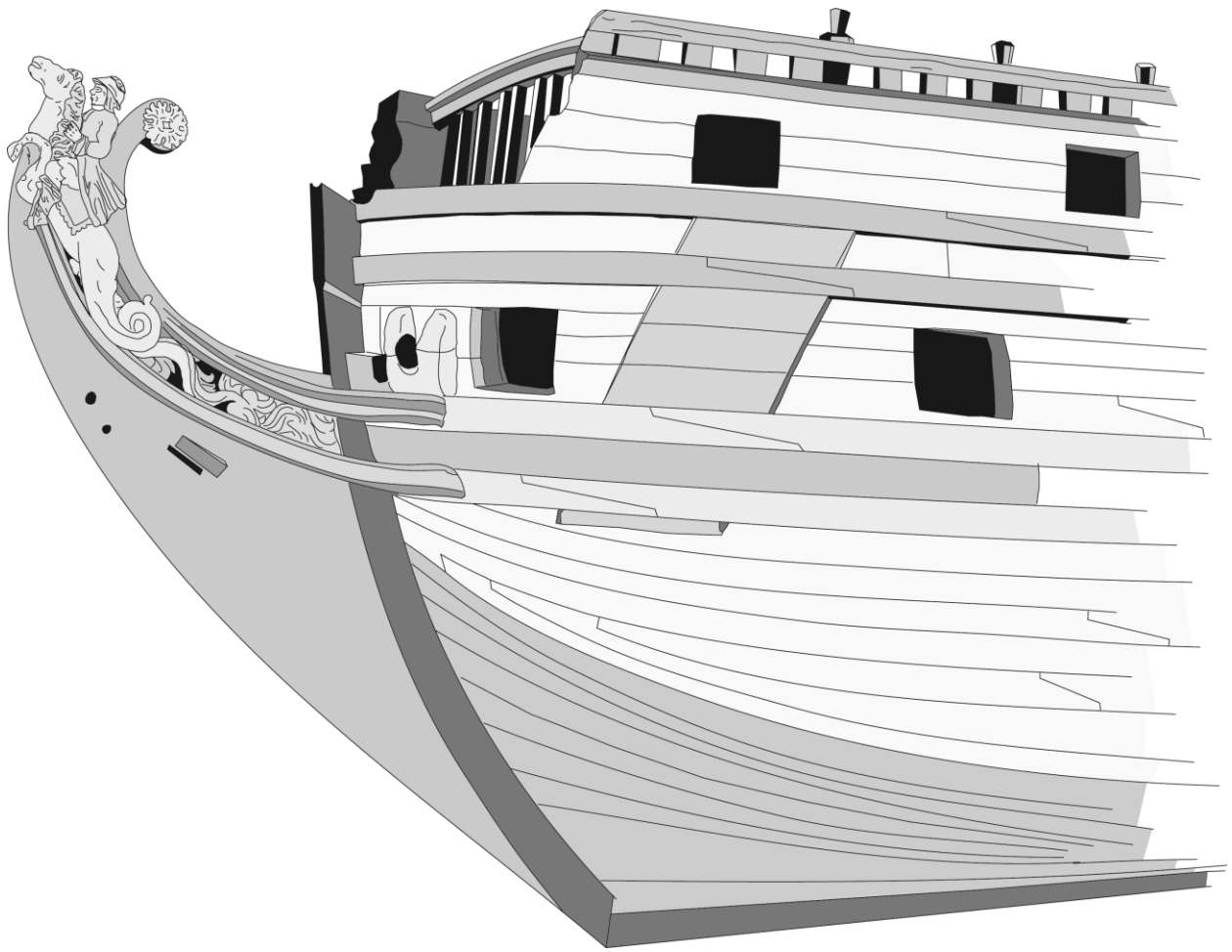
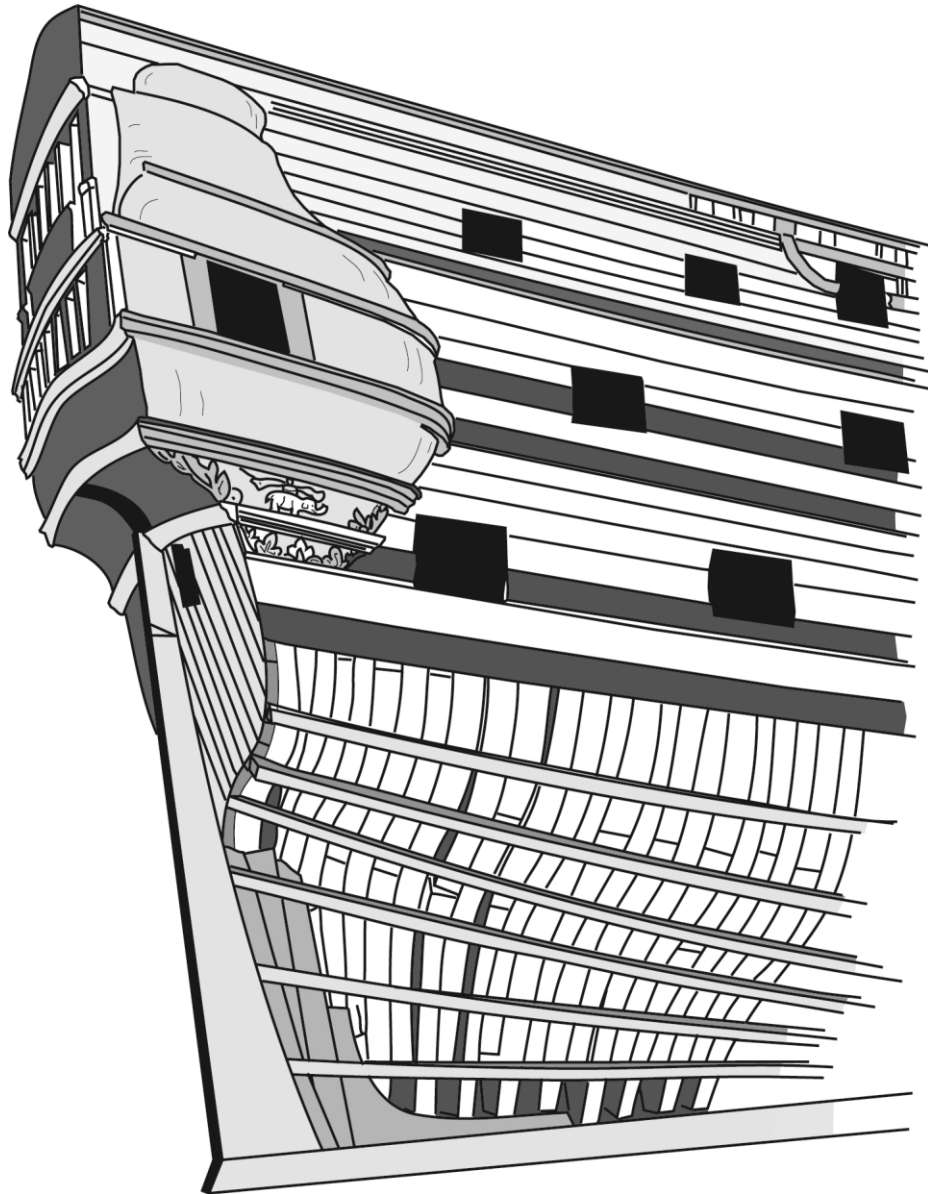


Fig. 5: Illustration of the structures at the stern. Ditta 2014.



**Fig. 6:** Illustration of the figurehead and bow, port-side of the Model of *Prinz Wilhelm*. Ditta 2014.



**Fig. 7: Illustration of the stern and quarter gallery, starboard-side of the model of *Prinz Wilhelm*. Ditta 2014.**

#### 4.2.4. The framing

The framing of the hull of *Prinz Wilhelm* is one of the most interesting structures of the whole model. As already stated, the framing system is visible only on the starboard-side from bow to stern till the lower main wale. Up to the wale, the model is completely planked as the port-side.

At first sight, the framing system of the model appears as a compact mesh. Moreover, several frames seem to have moved from their original position, probably as result of deformations and vicissitudes that interested the model. A closer look, easily explains the pattern of the framing. Basically, *Prinz Wilhelm* is built with double frames separated from the next double frame by a small gap. The double frames are composed as follow:

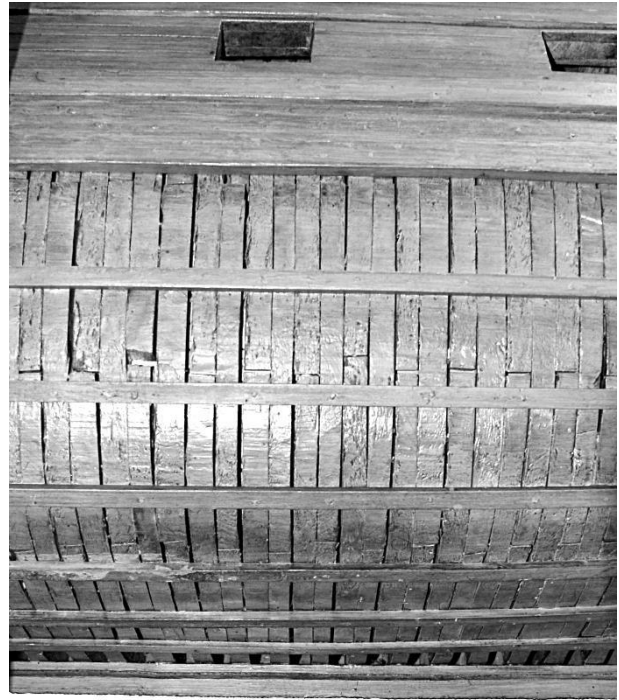
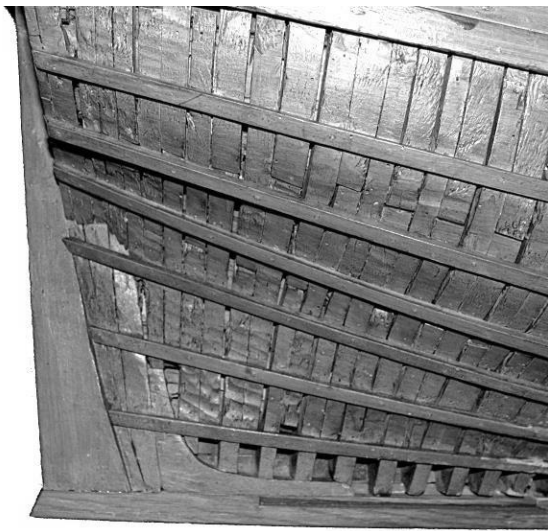
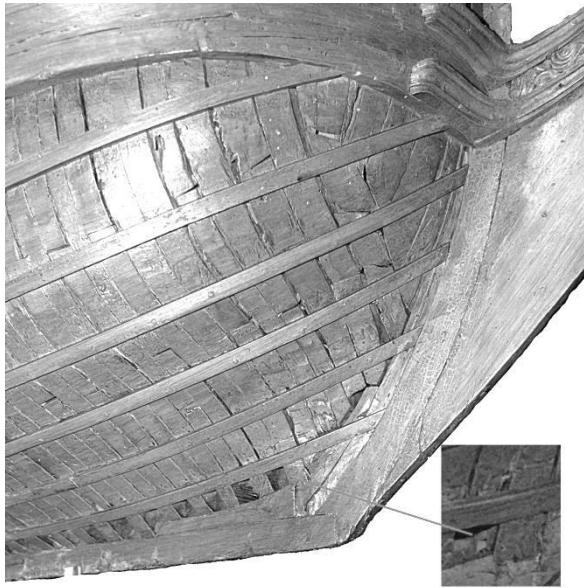


Fig. 8: Framing of the hull around amidships. Ditta 2014.

Double frame	
First frame	Second frame
Floor timber	First futtock
Second futtock	Third futtock (visible only due to the sliding of some timbers)
Top timber (visible only due to the sliding of some timbers)	



**Fig. 9: Above - Framing of the hull at the bow. In the box is visible the notched floor timber on the *slemphout*; Below – Framing of the hull at the stern. Ditta 2014.**

All the components of a single frame are butt-head jointed. The two frames making up the double frame are not interconnected, which explains the sliding and the movement suffered in the ages.

The grouping pattern of the double frames changes at what it can be recognised as the master frame, just forward amidships. The fore and aft first futtocks are placed in order to always face the master frames. Thus, as it can be seen in the illustration (Fig. 10), the master frame floor timber is flanked by first futtocks on both sides, which are again flanked by other two floor timbers.

The floor timbers are laid on top of the keel, the *slemphout* and the sternpost knee. The floor timbers lying on top of the inner sternpost/deadwood are scored and set down upon it. Apart from these floor timbers, only another one is scored which lay on the *slemphout*, in correspondence of the foot of the stempost (Fig. 9). At the stern, the floor timbers assume an extreme “Y”

shape, while amidships they are flat on the keel. The first futtocks are not touching the keel, with the exception of those close to the sternpost or those running partially on the end of the apron and stempost. After the floor timber notched on the *slemphout*, six more timbers extent and high on the *slemphout* and stem in close order, without gaps. The frames at bow are square till the starting of the hawse pieces. On the sided face of last frame, the foot of the hawse pieces are installed. These timbers have a molded dimension larger than the other frame timbers. The two main hawse pieces are hosting the hawse hole and are made out a solid and unique block of wood. In addition, it must be said that also at the stern, the 5 frames before the fashion piece are placed close together leaving no space between each frame.

The width of the gaps between the double frames, the height of the butt-head scarf between the timbers, the sided dimension of the timbers and also the distance between the keel and the first futtocks considerably is not consistent. Each frame seems to be modelled individually in its components, without any suggestion of standardization. However, the single timbers composing a frame have the same sided dimension of its floor timber or first futtock. The only dimension recorded is the sided, since the molded dimension was not accessible.

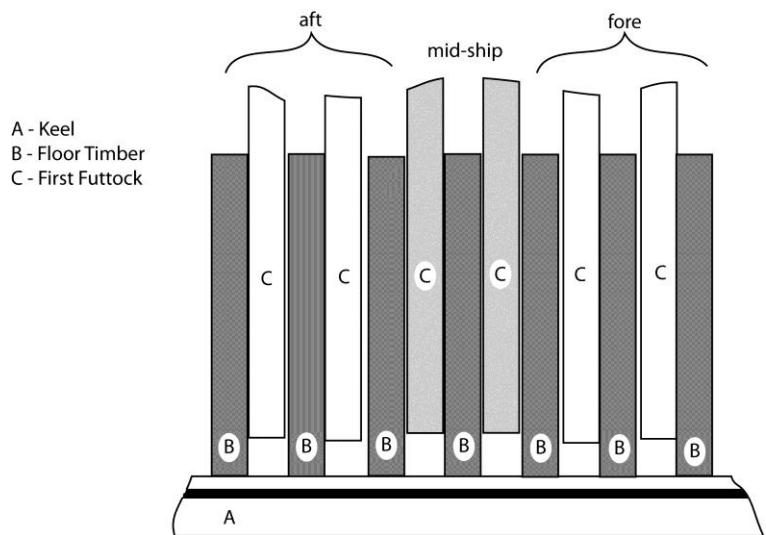


Fig. 10: Illustration of the framing pattern at the master frame. Ditta 2014

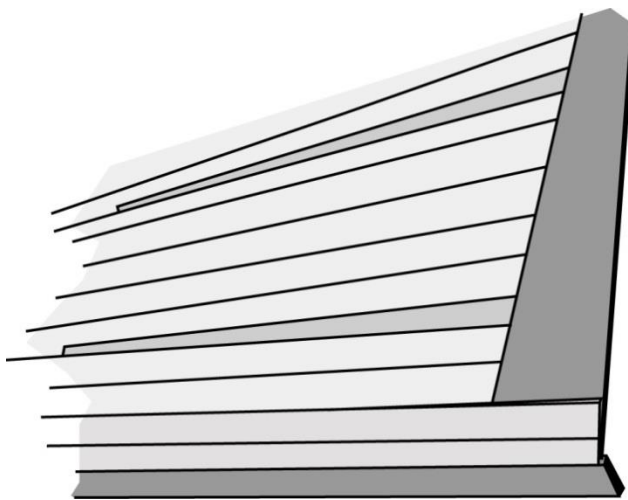
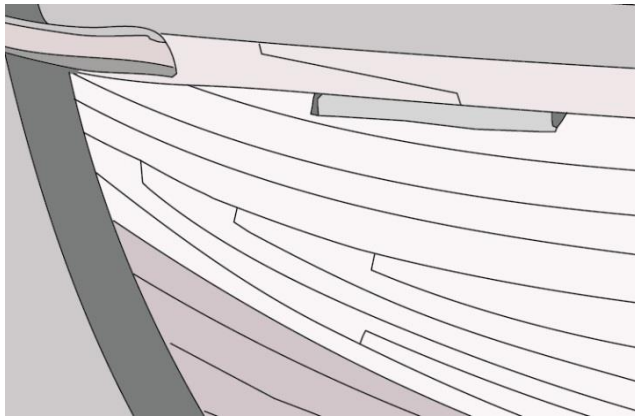
The sided dimension of the floor timbers varies between 1.2 cm and 1.4 cm (0.29 m and 0.336 m) whereas for the first futtocks the range is between 1.1 cm and 1.4 cm (0.264 m and 0.336 m). The gap between the double frames is between 0.2 and 0.4 cm (0.05 m and 0.10 m). The spacing between the double frames at the bow and stern is smaller than in the body of the ship. The room and space, given of the variations of the scantling, is not uniform as well. The hawse pieces hosting the hawse hole have a width of 2.5 cm (0.6 m). The average distance at amidships between the toe of the first futtock and the outer edge of the keel is 2 cm (0.48 m).

#### 4.2.5. The planking of the hull

Studying the planking of *Prinz Wilhelm* has resulted in a relatively difficult task. Because of the thick layer of yellow paint and varnish, not all the strakes are detectable. Same argument applies for the scarfs between the planks.

Below the lower main wale, the port-side of the hull is entirely planked with at least 17 strakes. Each strake is composed of 4 planks jointed together with a flat scarf. The first two lower strakes run from the rabbet at the stem till the end sternpost, rabbeted into it for the whole length. At the stern, in order to reduce the width of the planks two half-stealers are used (Fig. 11). At the bow the situation is

similar, where at least two half-drop strakes are visible. Moreover, still at the bow 3 strakes are joggled together with a snipe in order to fit the narrowing of the planking.

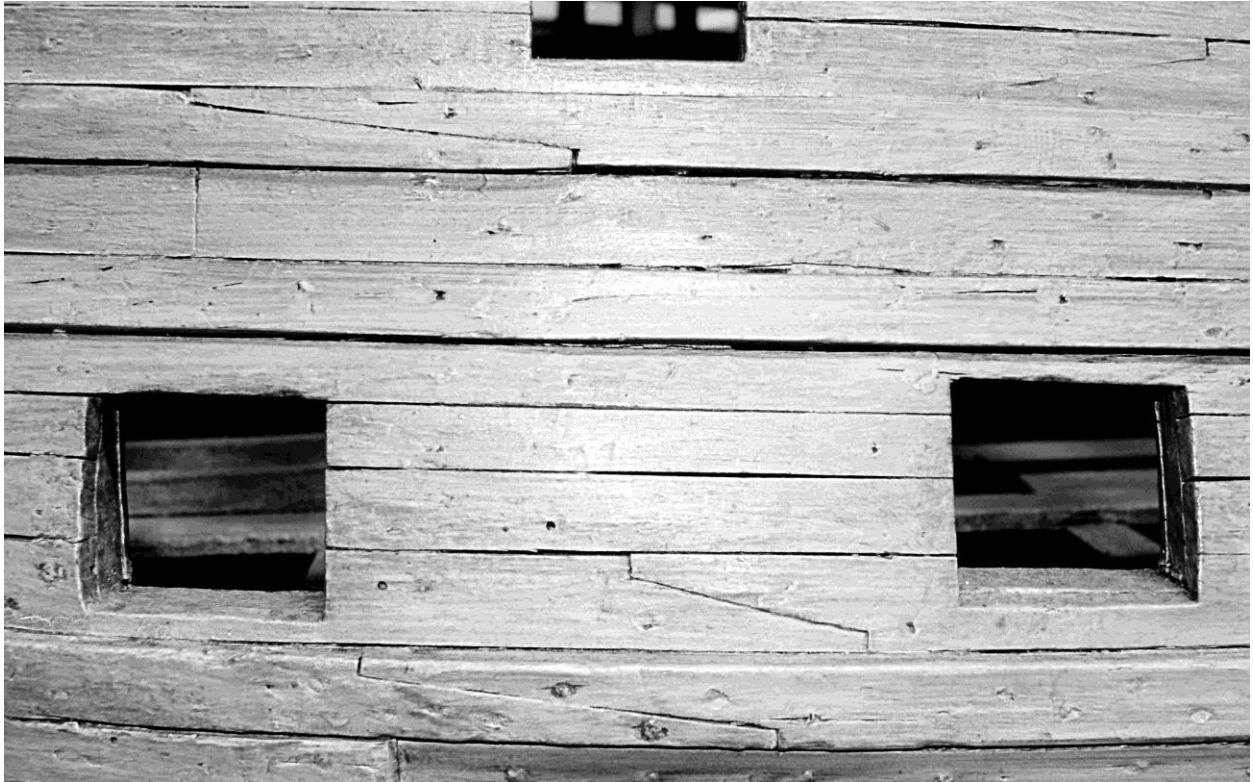


**Fig. 11: Strakes reduction (snipe, stealer and drop). Above - Illustration of the planking at the bow; Below - illustration of the planking at the stern. Ditta 2014.**

The garboard strake has a width of 1.5 cm (0.36 m) at the bow, 2 cm (0.48 m) amidships and 1.1 cm (0.264 m) at the stern. The thickness at the stern is 0.4 cm (0.10 m). The second strake has a width of 2 cm (0.48 m) at the bow, 2.1 cm (0.504 m) amidships and 1.7 cm (0.41 m) at the stern. The maximum width of the other strakes ranges between 1.7 cm (0.41 m) and 2.5 cm (0.6 m). Their thickness, measured at the stern is 0.4 cm (0.10 m).

*Prinz Wilhelm* is girded by 4 wales: 2 main wales and 2 sheer-wales. All the wales are directly jointed to the frames. The lower main wale runs uninterruptedly from the stem to the transom wing and is composed of 6 planks jointed together by a flat scarf. The width of the wale is 1.6 cm (0.384 m) and the

total thickness is 1.2 cm (0.29 m). Between the lower main wale and the upper main wale, the space is filled by a strake of at least 2 planks jointed with a flat scarf. The width of the strake is 2 cm (0.48 m) and the thickness is 0.8 cm (0.19 m). At the bow the thickness of the strake increases, levelling the difference between lower and the upper main wales. The upper main wale is divided in two pieces by the last aft gun-port of the lower deck. Eventually other two aft gun-ports intersect the wale and are partially cut into it. The main segment of the wale is composed of 5 planks connected by flat scarfs. The width of upper main wale is 1.6 cm (0.384 m) and the thickness is 1 cm (0.24 m).



**Fig. 12: Flat scarfs joints between strakes of the planking and the wales, lower-deck at the bow. Ditta 2014.**

Between the main wales and the sheer-wales, the lower-deck is located. A total of 4 strakes cover the side, of which 3 result cut by the gun-ports. The last upper strake is composed of at least 3 planks and runs from stem to stern, even if partially intersected by the gun-ports. All the visible joints between the planks are flat scarfs, with the exception for the upper planks at the bow, which is but jointed. The lower strakes has a width of 1.8 cm (0.43 m) while the others only 1.2 cm (0.29 m).

The lower sheer-wale, likewise the lower main wale, runs uninterruptedly from the stem to the quarter gallery. Only two flat scarfs are detectable, close to the bow. The width is 1.5 cm (0.36 m) and it protrudes over the side for 0.4 cm (0.10 m). Between the lower and upper sheer-wale, a filling strake is located which appears to be composed of 3 planks butt jointed. The recorded width for this strake is 1.8 cm (0.43 m). The upper sheer-wale is divided in two pieces by the last aft gun-port of the upper deck and partially crossed by other 2 aft gun-ports. Because of the conspicuous thick layer of paint covering this area, only one flat scarf is surely detectable. The width of the wale is 1.3 cm (0.31 m) and it protrudes over the side for 0.3 cm (0.07 m).

The upper-deck broadside is planked by 3 strakes, cut and intersected by gun-ports. The largest plank has a width of 1.4 cm (0.336 m) while the rest of the

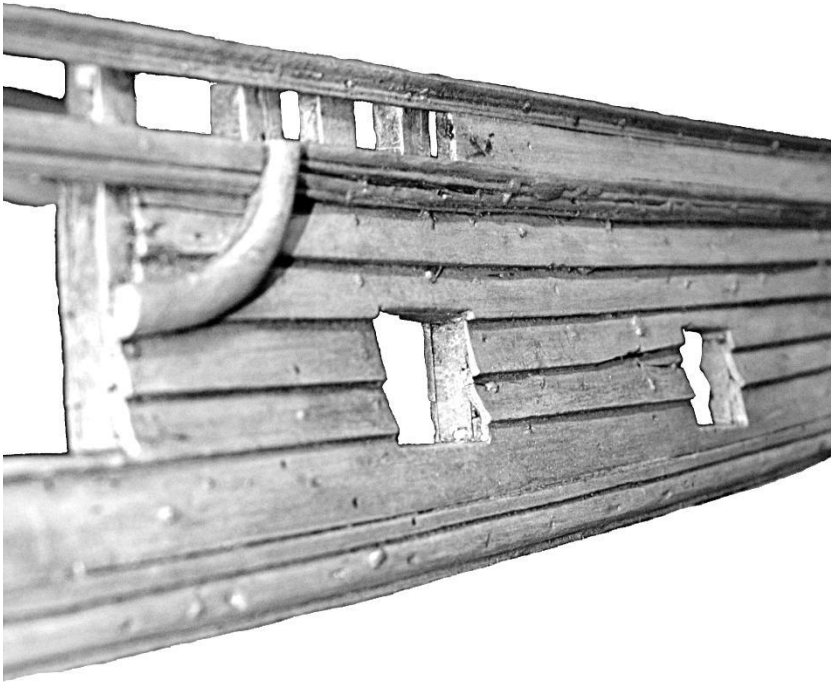


Fig. 13: Planking of the quarterdeck port-side bulwark. Ditta 2014.

planks only 1 cm (0.24 m). Few visible flat scarfs connect the planks composing a strake. The uppermost continuous strake, describing the sheer of the upper deck is the waist-rail. This rail is decorated with the usual moulding style visible in all the protruding elements on the ship and seems to have suffered several damages possibly during the 1795 fire. Because of the heavy stucco layer,

the detection of scarfs is not possible. The width of the sheer-rail is 0.8 cm (0.19 m) and the thickness is 0.5 cm (0.12 m). These dimensions apply as well as for the other rails visible on the upper work. It must be noted that the hancing pieces (namely the step made by the drop of the rails at the quarterdeck, poop-deck, and waist-rail) are small quadrant shaped pieces.

The planking of the quarterdeck bulwark is made out 5 strakes laid in clinker fashion. The lower strake has a width of 1.2 cm (0.29 m) while the remaining only 1 cm (0.24 m). The thickness is maximum 0.2 cm (0.05 m).

All the planks and wales are secured to the frames with metal nails of a diameter of less than 0.1 cm (0.024 m).

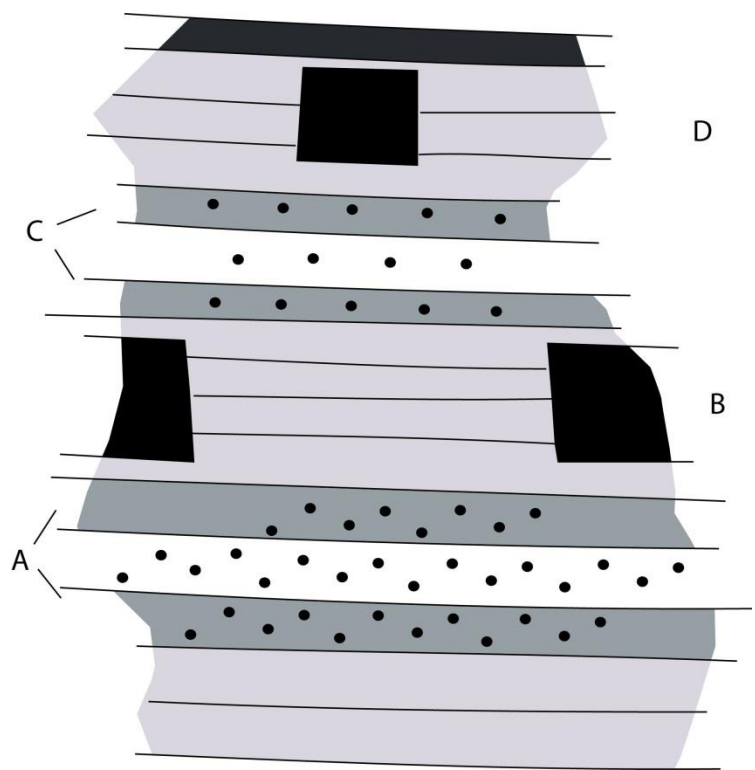
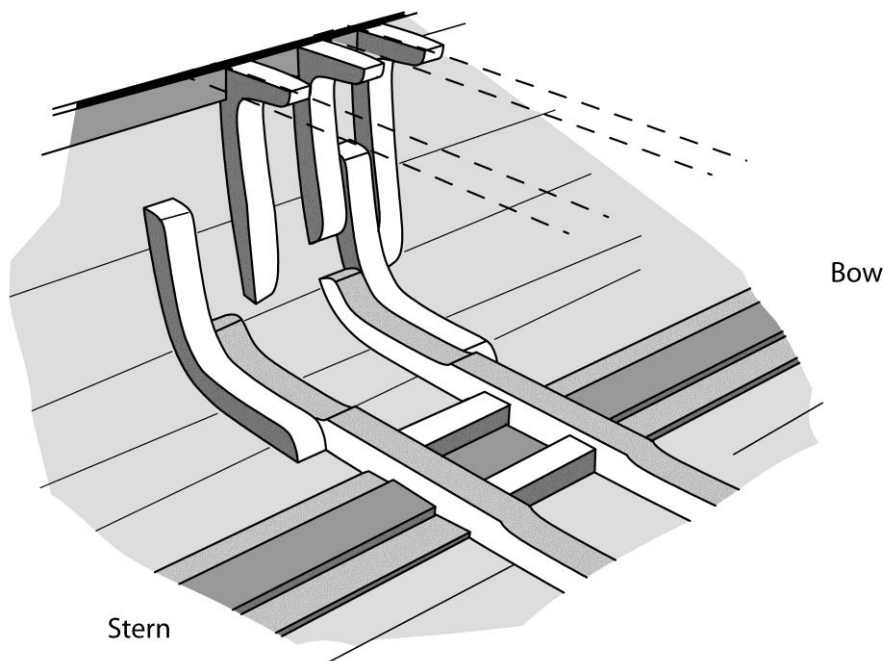


Fig. 14: Illustration of the nails pattern. A - Main wales; B - Lower-deck; Sheer-wales; D - Upper-deck. Ditta 2014.

The only nails pattern easily detectable is the one that interested the wale. As it can be seen in the illustration (Fig. 14), from the lower main wale till the upper an alternate double column of nails is visible. From the lower sheer wale till the upper, only a single nail column is detectable.

#### 4.2.6. The hold

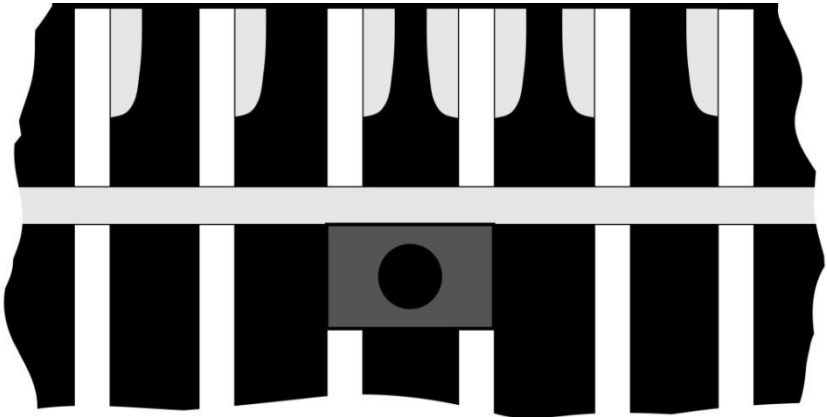


**Fig. 15:** Illustration of the *Kattespoor* in the hold of *Prinz Wilhelm*. At the center, the structure of the main mast-step is composed of the two floor riders and the chocks. Moreover, the bilge riders, near the floor riders, and the hanging knees, for the support of the lower-deck, are visible. Running from bow to stern is the shallow keelson flanked by limber-strakes. Ditta 2014.

Observing the structures in the hold, the first noticeable feature is the keelson. The keelson is running from the stem to the stern. Due to the thick layer of dust deposited in the hold, it is not possible to understand if the timber is scarfed. Its appearance is of a flat plank as wide as the keel. On both side, the keelson is flanked by a strake of the same width and less thick. These two strakes can be identified as limber-strakes. The whole hold is covered by ceiling planks, at least 13 strakes per side. At the heel of the bilge, a ceiling plank covering the area looks thicker than the surrounding planks, but the same width and it can be identified as the footwale. The last three strakes to seal the hold are the deck clamps, of which the upper strake supports the lower deck beams. The deck clamps result to be thicker and wider than the surrounding ceiling planks and the upper

strake has mortises in order to receive the beams. The few scarfs visible of the ceiling planks are of the flat type.

Running from port to starboard-side, a series of floor-riders are laid in the hold. Their heads end at the turn the bilge, thus assuming the curve of the round of the lower hull. The central body of the rider has the sided dimension larger than its



**Fig. 16: Illustration of the hold hanging knees changing pattern at the main-mast, as visible from the lower-deck. Ditta 2014.**

arms and is notched on the keelson. On the fore face, each floor rider is flanked by a bilge rider per side. The starting point of the lower head of a bilge rider corresponds to the tapering of the thicker central body

of a floor rider. The bilge riders extend till over the round of the bilge. There is no scarf between the floor and the futtock rider as they seem only laid side by side and fastened to the hold through iron nails. At least 8 floor riders are counted. However, for the very part at the stern it is not possible to state the precise number due to the scarce visibility during the recording. The molded and sided dimension for both riders is 1.5 cm (0.36 m). The central body of the floor riders has a molded dimension of 1.7 cm (0.41 m).

The deck beams of the lower-deck are made from a solid piece of wood. All the deck beams are squared with 2 cm (0.48 m) per side and show a slight camber at the centre. The deck beams are supported by the deck clamps, in which they are mortised, and by the hanging knees. The hanging knees flank the beams and extend down to the hold till the bilge. They have a squared shape of 1.4 cm (0.336 m) per side. The knees on the upper on the face touching the ceiling are scored to allow the run of the deck clamp. In the same way, the upper face is



**Fig. 17: On the background, detail of the port-side compass timber laid diagonally at the bow. Ditta 2013.**

scored to receive the waterway. The hanging knees fore to main-mast are flanked on the aft face of the beams while, aft to the main-mast, the knees are flanking the fore face of the beams (Fig. 16).

Interesting is the composite structure of the main mast-step (Fig. 15). In the Dutch shipbuilding tradition of the 17<sup>th</sup> century, the assembly visible in the hold of *Prinz Wilhelm* has a specific name, *kattespoor* (Hoving & Wildeman, 2012). The assembly consisted of a mast-step a hole hewn in the keelson, reinforced on both sides by a chock and on the fore-and-aft by floor riders. Moreover, the floor riders were flanked on both sides by bilge riders connected with a vertical futtock rider. In the case of *Prinz Wilhelm*, only the carved hole in the keelson and the futtock rider are missing. As already stated, the bilge riders are placed on the fore face of each floor rider though with one exception. The aft bilge riders of the *Kattespoor* assembly are placed on the aft face of the floor rider.

To conclude, the only other elements visible in the hold are some structures at the bow. At the heel of the sweep of the bow, a larger floor rider is laid on the Keelson/stemson and followed towards the sweep by 3 breasthooks. The whole assembly is secured on both sides by a compass timber laid diagonally towards the bow with the lower heads pointing at the keelson (Fig. 17). The height of the hold, measured at the mid-ship, is 18 cm (4.32 m) from the keelson to the camber of the lower edge of the deck beam.

#### 4.2.7. The lower-deck



Fig. 18: View into the lower-deck, through a starboard-side gun-port. Ditta 2014.

The lower-deck is partially planked, exclusively by structural strakes. 11 gun-ports and 1 at the stern per side are positioned alongside the deck. The dimensions of the gun-ports are 4.4x3.8 cm (1.056x0.91 m). The distance between each gun-port from the lower aft edge to the lower fore edge

of the succeeding one is 12 cm (2.9 m). The fore most gun-port is positioned almost parallel to the bow and is 15 cm (3.6 m) distant from the succeeding gun-port. At the bow close to the stem, two hawse holes per side are located.

The hanging knees are placed alongside the deck, supporting the upper-deck beams and with the toe over the spirketting. Their dimension is squared with 0.9 cm (0.216 m) per side. The knees are not simply flanking the beams but are scored to receive in part and support the beams. When a beam is sited close to a lower gun-port a lodging knee of the same dimension of a hanging knee is placed to support the beam. As for the hold, the upper-deck beams are supported and mortised into the deck clamps. The upper-deck beams have a squared dimension of 1.5 cm (0.36 m).

Apart from the deck clamp, other two strakes are ceiling the broad side. The lower one appears to be as thick as the deck clamp and can be identify as the spirketting. The first strake of the deck, secured on both sides under the spirketting is the waterway. This strake is composed of multiple planks jointed together with flat scarfs and results to be

considerably wide with 2.5 cm (0.60 m), while the thickness is of 0.8 cm (0.20 m). Through the full length of the deck, two binding strakes are laid on it and separated from the center-line by 6 planking strakes. The dimensions of the binding strakes are 1.5 cm (0.36 m) in width and 0.5 cm (0.12 m) in thickness.

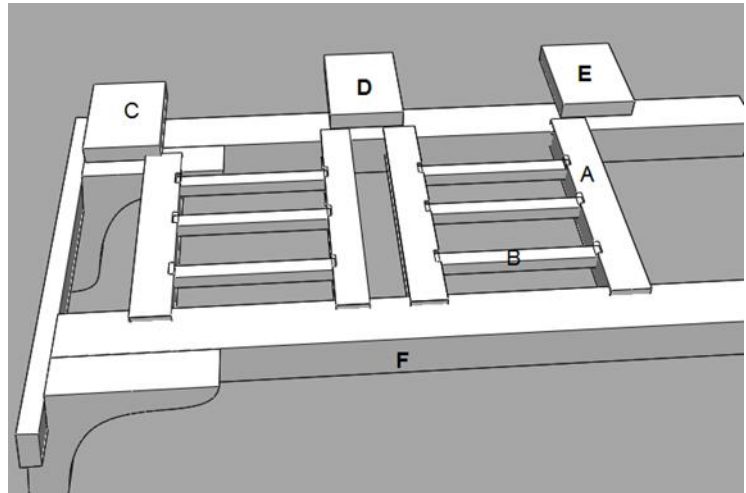


**Fig. 19: View of the lower-deck structures at the stern, as seen from the last starboard-side gun-port. Ditta 2014.**

These strakes reinforce several hatches, the main-

mast partner and the mizzen mast-step and they are notched onto the beams. It is composed of several long planks flat scarfed together. Moreover, on the starboard side a third strake, running from bow to stern, is located between the waterway and the binding strakes and sitting right on the carlings. This mid-binding strake recalls the same function of longitudinal reinforcement as binding strake, since is scored to receive the beam and has the same thickness of the two binding strakes but less wider.

All the upper faces of the lower-deck beams are scored in order to receive a sort of carling plank (Fig. 20). The thick planks visible are short, since they run from beams to beams and are angled scored into the beam. The few visible ledges, concentrated on the aft part of the lower-deck, are angled notched on these thick planks placed near the water way, under the mid-binding strake and near the binding strake, as it



**Fig. 20: Illustration of the carlings/ledges system of the lower-deck. A - Thick carling plank; B - Ledge; C - Waterway strake; D - Mid-binding strake; E - Binding strake. Ditta 2014.**

can be seen in the illustration. Thus, a short ledge runs from the waterway to the mid-binding strake, where a new short ledge runs from there to the binding strake.



**Fig. 21: Detail of the riding bitts. Ditta 2014.**

Through the deck 5 hatches are visible, one at the forehead, two aft and fore the mast, one at the mid-aft of the ship and one close to the stern. Moreover, the riding bitts (Fig. 21) is located at the bow and supported by two long cross-beams. The main-mast partner is composed of a unique solid sheet of wood, with an opening for the mast of 3.5 cm (0.84 m) in diameter. The fore-mast partner is a simple hewn hole of 3 cm (0.72 m) of diameter, through the planks of the bow between the stem and the riding bitts.

The last noteworthy structural elements are at the bow and at the stern. The bow construction is reinforced by two large breast-hooks, of which the upper one supports also the upper-deck. At the stern, the transom is reinforced by two transom knees per side. The transom knees are placed up and down the last gun-port, carved to be adapted to the presence of the gun-port. The height of the deck at amidships is 8.5 cm (2.04 m), from the deck to the lower edge of the upper-deck beam at the camber.

#### 4.2.8. The upper-deck



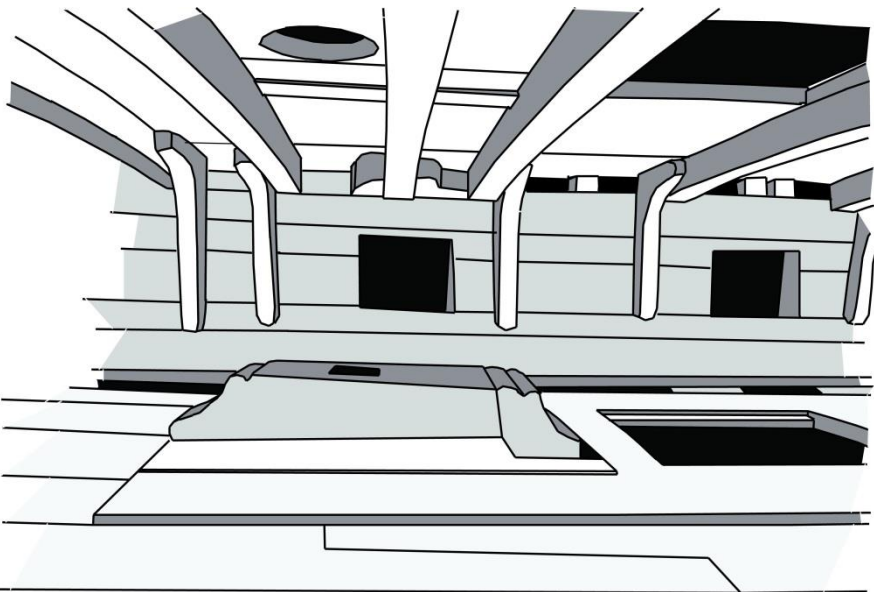
Fig. 22: Illustration of the upper-deck and the edge rail of the quarter-deck. The only two visible deck planks are the waterway and the binding strake, which is rabbeted to receive the hatches. Ditta 2014.

The upper-deck, contrary to the lower one is partially planked in the aft area. Indeed, the main area of the deck is planked only by the waterway and binding strakes while at the stern, corresponding to the area usually allotted for the officer cabins and the wardroom, the deck is fully planked on the starboard-side. The

binding strakes are 2.5 cm (0.6 m) wide and 0.5 cm (0.12 m) thick. As for the binding strakes of the

lower-deck, these strakes reinforce several hatches and are composed of several long planks flat scarfed together (Fig. 22). Conversely, these planks do not seem notched on the deck beams but are simply laid on them. The waterways are also positioned on top of the beams and inserted under the spirketting. The waterway has a width of 1 cm (0.24 m) and thickness of 0.5 cm (0.12 m), while the spirketting has a width of 0.3 cm (0.07 m) and extrudes from the side of 0.2 cm (0.05 m). Next to the starboard-side waterway, a planking strake is positioned. The waterway assumes the rounding of the waterline at the deck while the second strake adapts to the shape of butted side and on the opposite side is straight. This leaves a squared space between the planking strakes and the binding strakes, thus consenting to lie on the deck only straight planks.

As for the lower-deck, the carlings and ledges are visible only on the starboard-side, through all the deck. The structural system is different from the one of the lower-deck. The ledges extend from the waterway to the binding strake and are supported by a carling plank under the two aforementioned deck planks. Moreover, the ledges are supported by a proper carling scored in the middle of the deck beam (Fig. 25).



**Fig. 23: Illustration of the mizzen mast-step on the upper-deck, under the quarter-deck. Ditta 2014.**

In the deck area under the quarter-deck, the hanging knees for the quarter-deck beams are positioned with the same pattern found in the lower-deck. The knees have a squared dimension of 1 cm (0.24 m). The knees are scored for allowing the passage of the deck clamp. The quarter-deck beams are made of a solid piece of wood of 1 cm (0.24 m) per side. As measured for the lower-deck, the height of the deck is 8.5 cm (2.04 m).



**Fig. 24: detail of a “finger and thumb” fashion kevel. Ditta 2014.**

The mizzen mast-step is located on this deck (Fig. 23). It’s a solid block of wood with a carved square mortise on the upper face. The block is supported by a total of 3 beams, of which 2 are positioned at the respective endings of the mast-step while a beam supports the block in correspondence of the mortise.

There are 10 gun-ports per side with a dimension of 3.7x3.2 cm (0.90x0.77 m). The distance between each gun-port from the lower aft edge to the lower fore edge of the succeeding one is 12 cm (2.88 m).

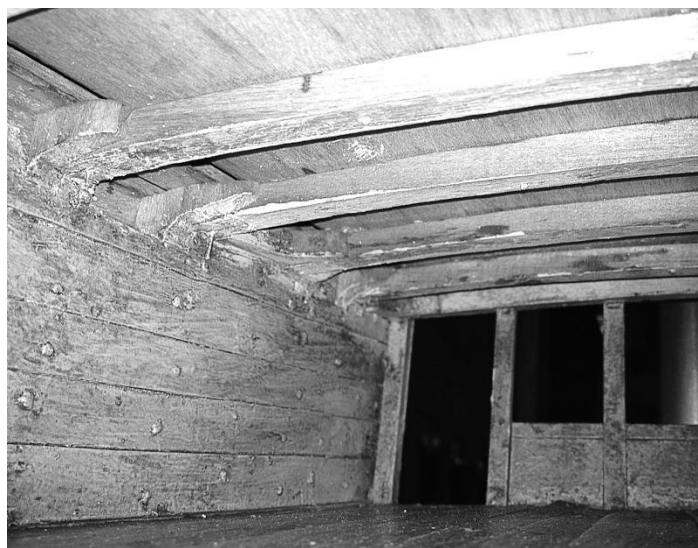


**Fig. 25: Detail of the carlings/ledges system on the upper-deck. Ditta 2014.**

In the area of the open forecastle, there are 4 fore-bitts per sides which extend over the rails. The deck is delimited at the bow by the bulkhead afore, delimited by fore-head rail, with a width of 1 cm (0.24 m) and thickness of 1.5 cm (0.36 m), and 10 squared fore-stanchions of 0.6 cm (0.144 m). Alongside the deck walls, 2 “finger and thumb” fashion kevels (Fig. 24) per side are secured on a thicker planks running right underneath the base of the gun-ports, one at the forecastle and one at amidships.

#### **4.2.9. The quarter-deck**

The quarter-deck is almost completely covered by wooden sheets, with the exception for the central area (4 consecutive hatches without coamings) fore the mizzen-mast partner. The covering seems more recent than the rest of the model. In fact, the inner face of the wooden sheets reveals a pinkish wood with less aging signs even if is covered by a thick layer of yellow paint.



**Fig. 26: Inside view of the quarter-deck under the poop-deck, towards the starboard-side of the stern. Ditta 2014.**

Moreover, looking from the upper deck towards the quarterdeck, on the starboard-side are visible the carlings and ledges

for the quarterdeck. However, at the stern, corresponding to the area usually allotted for the captain cabin, the deck is fully planked by worn out strakes which are made of the same material as for the rest of the model.

The mizzen-mast partner is obtained from a single sheet of wood. The diameter of the hole for the mast is 2.3 cm (0.55 m). On this deck 5 gun-ports per side are in place, with a dimension of 3x2.5 cm (0.72x0.6 m). One gun-port is placed under the poop-deck while the other 4 are placed on the open deck, of which 3 are obtained under the drift rail.

The beams for the poop-deck have a square dimension of 0.5 cm (0.12 m) and are supported by the deck clamps and short knees flanking the beams. A part from 2 lodging knees per side, the other knees are standing on the deck clamps without an arm extending down on the quarter-deck height. The knees seems to be made out the same material as for the covering of the deck and. The deck walls are planked with 5 strakes and a waterway. The height of the deck to the inner camber of the poop-deck beam is 8.4 cm (2.016 m).

To conclude, it must be noticed that the drift rails extend high over the quarter-deck till the drop with the upper-deck.



**Fig. 27: Detail of the quarter-deck from starboard-side. Ditta 2014.**

#### **4.2.10. The poop-deck**

The poop deck is covered by two large wood sheets, which seem made of a different wood from the rest of the model. These wooden covers do not appear to

be original and could be easily added during the restoration after the 1795 fire. The only other structures visible at this deck are the counter timbers.



**Fig. 28: View from the bow of the upper-deck, quarter-deck and poop-deck. Ditta 2014.**

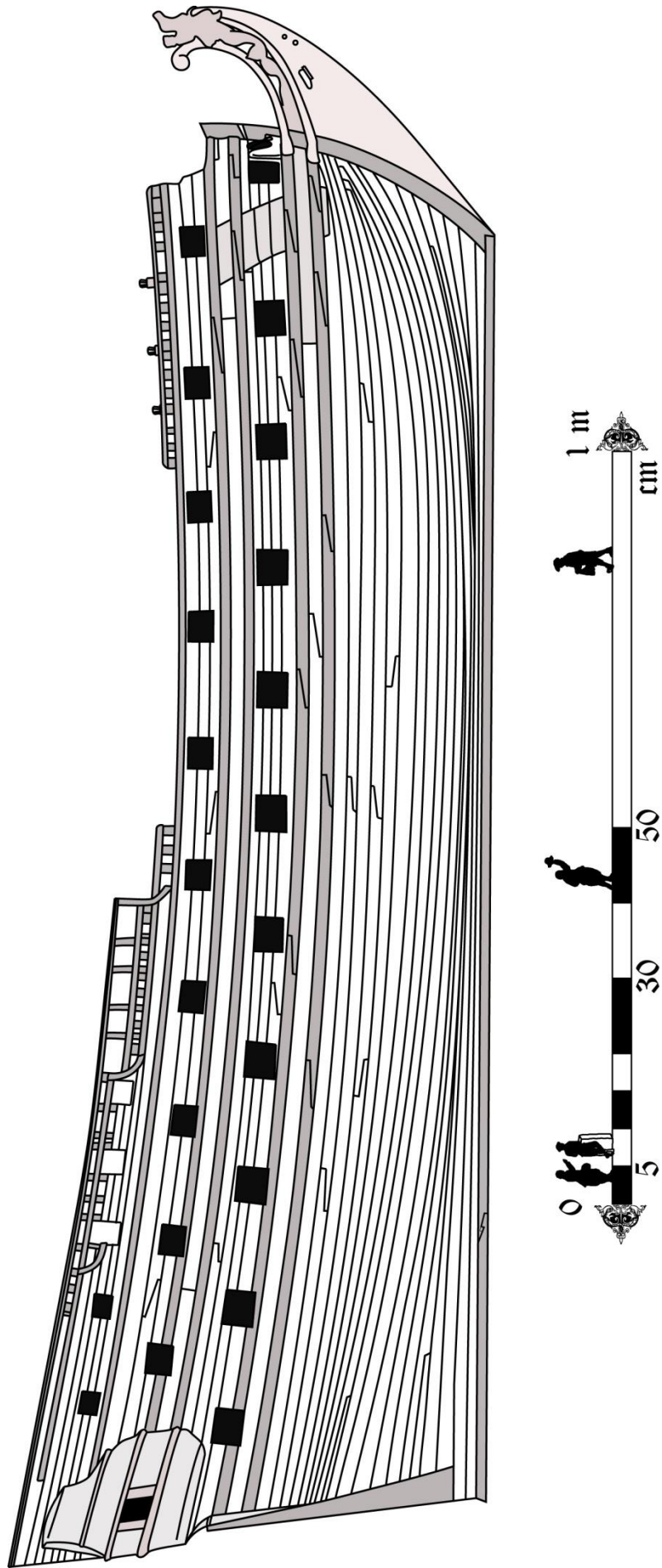


Fig. 29: In scale sheer plan of the planking. Ditta 2014

## 5. *Prinz Wilhelm*: a real konstruktionsmodel?

Before entering into the analysis of the construction of *Prinz Wilhelm*, a premise is necessary. Ship models have been extensively used as object of study by historians for describing the evolution of navies (Lavery & Stephens, 1995), on the contrary archaeologists have been reluctant in using models as primary source. This reluctance can be addressed to the difficulties in the placing of a boat or ship model as a reliable object in all its features, especially where no other evidences are available (Roach, 2008). Consequently, can a ship model considered as an archaeological evidence for the study of shipbuilding practices?

Based on the same supposition, it must be investigated inside the limit of the existing evidences if the model of *Prinz Wilhelm*, and consequently the *konstruktionsmodeller* in general, can be considered a close representation of the real ship. Thus, in the following sections the nature of contemporary navy ship models in other European collections is briefly investigated. Then, moving on the *konstruktionsmodel* of *Prinz Wilhelm*, it will be discussed the reliability and the purpose of the model with the support of historical sources and existing contemporary lines plan produced by Judichær.

Ship models are, unfortunately, too often classed merely as decoration (Winthrop Pratt, 1949), but the fact that contemporary ship models, are really "historical documents" (Hasslöf, 1963; Carr Laughton, 1925) should not be overlooked. Three-dimensional models always embodied and displayed knowledge and are strategic objects of knowledge from which to investigate the cultures of the sciences and technology (Chadarevian & Hopwood, 2004). Already Lavanha in his *Livro Primeiro* published in 1608 (Esteves, 2011), which can be considered one of the first treatise in naval architecture, introduced the idea of models as a check on building proposals. A concept probably absorbed from civilian architecture (Johnston, 1994) and closer to the recommendations of the renaissance architect Alberti, which in his book *De re aedificatoria* published in 1541 clearly stated the advantage of using a scale model of the building before the construction, in order to study its shape and even the possible weight (Alberti & Tappe, 1541).

Nevertheless, ship and boat models have been made for different reasons and purposes and religion is one of the oldest (Lavery & Stephens, 1995). It was common practice, at the end of the middle ages, the deposition of representation of ships in a church, in order to thanks for the surviving to a catastrophic event or to ask for protection (Lavery & Stephens, 1995). These *ex voto* offerings are known

as Church models or *Kirkeskibe* in Denmark and, in the past, they have often been used as sources for historians to study the form of ships from the 15<sup>th</sup> and 16<sup>th</sup> centuries onwards (Roach, 2008). For Scandinavia, especially for Denmark, and North Europe there are several studies (Henningsen, 1950; Kroman, 1993; Johnsrud, 1996; Thalund, 1989; Harley, 1994). However, these models completely differ from the character of *Konstruktionsmodeller* as the ones from the period in examination are often made from a solid wood block, exaggerated in decorations and idealistic ship or commercial vessel representations.

Looking into dedicated publications on naval ship model collections in Europe (Boudriot, 1997; Franklin, 1989; Köster, 1926; Smeed, 1979), it is clear how the focus essentially lies on the models from the biggest naval powers such as England, France and Holland. Despite the richness of model collections around Europe the majority date from the second part of the 18<sup>th</sup> century (Boudriot, 1997) and models from period of interest are rare (Boyd, 2001). Given the naval nature of the model *Prinz Wilhelm*, result of a King's order and conceived within the dockyard, in the following chapter, the nature of dockyard models from the three major foreign navies is investigated, in order to give a comparative basis in the study of the Danish model.

### **5.1.1. An international overview on other contemporary models**

In England, the convenience of using models to show the design and construction details of a ship was already recognised, as testified by the oldest surviving models, in the later years of the interregnum (Lavery & Stephens, 1995). By this time it is clear that a tradition of building scale ship models was already in existence and the stylized convention is the proof a longer tradition (Salisbury, 1954).

At any rate, in many cases the purpose of these models, which are known as Navy Board models or Admiralty models, is not clear. A too often reiterated idea is that models were made as preliminary designs for approval by the King, or later by the Navy Board, before the ship to understand the proposed construction (Franklin, 1989). According to the some scholars (Franklin, 1989; Lavery & Stephens, 1995), it is hard to believe that an accurate model would be prepared as a preliminary design and the only time and cost factor in building them would preclude it.

Nevertheless, in some cases models were certainly made as design support, for instance testified by official orders requesting shipwrights to produce models, then again without giving any specification regarding the style. One of the oldest examples is an order issued in 1645, where shipbuilders were required to present *moddles* before the construction of the ship (Franklin, 1989). As for the Danish King's instruction of 25<sup>th</sup> June 1670 (see chapter 2.1), the word *moddles* could have meant also a simple drawing. Another Navy Board order issued in 1716, requested to the master shipwrights to submit a *solid* model of the ship before its construction (Perrin, 1919).

The distinctive characteristic of the Navy Board model is the framing of the hull. The basic style of construction remained unchanged for over one hundred years with variations in the building of the deadwoods (Franklin, 1989), thus recognising a specific stylised construction (Wassell, 1979). The hulls are generally left unplanked below the wales, allowing a closer inspection of the interior. Furthermore, in contrast with the Danish *Konstruktionsmodeller*, a great attention is given to the decorations and rigging of the models. Franklin (1989), in his extensive catalogue on the Navy board models, proposed at least two suggestions regarding the possible purpose behind the making of these models rich in details. As known from several sources, numerous eighteenth-century models were built under commissions, thus made on request by relevant personality and customers and consequently after the ship. Another suggestion is that other models could have been built at the same time as the ship itself and completed in every detail and ornament years later, but the hull was built in stages corresponding to the work on the ship.

In any case, their reliability as a source for shipbuilding practices of the time has been questioned. Anderson (Anderson, 1954), in a lively discussion about the framing of the Navy Board models held on the pages of the *Mariner's Mirror*, expressed the opinion that the only reliable information is limited to the room and space. Baker (Baker, 1954) instead, involved in the discussion, suggested that the models represented "stylized" expressions of real framing practices. Batchvarov (2002), in his remarkable master thesis on the framing of 17<sup>th</sup> century man-of-war, analysed the framing of these models and detected four different groups in accordance to the framing practice. In his opinion, models in frame present the least likelihood of having been built merely as ornaments, sacrificing accuracy for looks. Two patterns typology of framing can be identified. Comparing the frames of different models with the written evidence shows that some models indeed displays actual framing practice of the second half of the 17<sup>th</sup> century, with some

variations. The models falling in the second pattern are more problematic. In fact, these models seem to give more information regarding the appearance of the ship, rather than the information on the actual construction.

In France, an interesting collection of models with a clearer background than their English counterpart are known as *Modèle d'Arsenal*. The origins of the arsenal models dates back to the late 17<sup>th</sup> century and were created under the impulse of the minister of Louis XIV's navy Colbert. Indeed, one of the first written evidence is an order dated 1678 issued by Colbert to three of the major royal shipyard (Boudriot, 1992). According to the order, each shipyard had to create a model representing the five different rates of warships, in order to set a reference for new constructions. Thus, the models were not representing real warships but a sort of prototype. Eventually, In 1689 an establishment was dispensed by the minister of the navy, where it was imposed to every master shipbuilder before starting the construction of a new ship to produce a "*modèle en bois et un plan en coupe perpendiculaire avec une coupe horizontale*" of the vessel, in order to check the proposal and to approve it (Boudriot, 1992).

Boudriot's article *modèles et architecture navale* (Boudriot, 1992) is the only comprehensive study on the history and purpose of the arsenal models. He distinguished three different categories according to the purpose and style of the models. The models belonging to the first category, or "*modèles de conception*", are those which can be considered a generic three-dimensional representation of a ship plan, which are roughly realised. The second category is composed by those models that Boudriot calls "*d'instruction*" which often represent idealized ships. Consequently, the scope of use of the models has widened between training staff of the arsenal and training of future leaders of the kingdom, in order to familiarize them with the use and components of warships in the naval forces. In this class fits the model of *Le Royal* (Fig. 30), preserved at the Rochefort national maritime museum, which in its 1:12 scale represents in every constructional details an hypothetical 70-gun ship of around 1710 (Boudriot, 1978). The last category is more mundane than the previous, formed by "*prestige*" models, namely models made to be exhibited. Generally, it can be said that all the three categories are models built on frame and planked and fitted according to their purposes.



Fig. 30: Model “*d’instruction*” *Le Royal*. Rochefort national maritime museum. After Boudriot 1978.

The 17<sup>th</sup> century is considered the golden age of the Netherlands maritime power and ship models were built in large numbers (Hoving, 2005), but only few pieces survived the time. The models produced in the 17<sup>th</sup> century played an almost exclusively decorative role and they were not built as prototype for a project, since the Dutch admiralties did not need to solicit orders (Hoving, 2005). However, an exception existed in a Dutch *Two-decker* model, known as the *Hohenzollernmodel*. The Elector of Brandenburg, Friedrich Wilhelm II von Hohenzollern (1640-1668), in the 1660s wanted to establish a private fleet and several Dutch shipwrights were contacted. For this reason, a large model (1.67 metres) of a hypothetical Dutch two-decker was delivered to him (Winter, 1991), as a sort of “*bozzetto*” between client and builder. The model, preserved in the national museum of Berlin, was realised with a great accuracy in every details from the rigging to the interior. Even the guns and tools used on board were miniaturised. Unfortunately, the *Hohenzollernmodel* was lost during the Second World War.

The use of models as a guide for a Dutch shipwright in building a ship, according to Hoving (Hoving, 2005), is a myth since no shipwright has ever built a ship according to a model. In his study about the model of *Willem Rex*, Hoving states that not even a model of the size of the *William Rex* (4.5 metres) could ever have served as pattern for a real ship. In fact, *Willem Rex* is a perfect example of a showpiece model. The model made on commission, dated 1698, is an impeccable reproduction in every constructional and decorative detail of a Dutch two-decker. The model was built based solely on the specifications (charters) and without lines plan, on the other hand not representing any real known ship. Another model as the *William Rex* is *Prins Willem* (Ketting, 1981). The model was made from a block of lime wood formed by planks glued together and then hewn to the required form. Thus, the construction has nothing in common with how a ship was built in reality,

but still a great deal in the details was given to the rigging, decorations and fitting of the model. For this model, the crafter was concerned uniquely with the visual representation of the ship (Hoving, 2005).

## 5.2. What does a *Konstruktionsmodel* represent?

As seen from the previous overview, the purpose of contemporary navy models in European context spaced from items of prestige to educational tools, often representing ideal ships or ship after their launching. Thus, a natural question arise looking at *Prinz Wilhelm* and consequently to the other *konstruktionsmodeller* built under Judichær: What do they represent?

Almost all the preserved *konstruktionsmodeller* have been identified and inserted in catalogues since the first list compiled under Danneskiold Samsøe in 1735 to the comprehensive catalogue by Holck in 1939. The fact that the models have been identified, a problem often affecting the Navy Board models (Carr Laughton, 1925), must imply the resemblance, at least in general, with the real arrangement and dimensions of the ship.

The King's instruction of 25<sup>th</sup> June 1670 (see paragraph 3.1) and the first English order regarding models dispensed in 1645 share the same issue regarding the interpretation of the term *model*. However, the English order clearly states that a model should be made before the construction of the ship, while the Danish instruction simply states that a model should be done for each ship to be built. This is different in France, where the order from 1689 clearly states that a model (in wood) should be produce as a tool for the approval of the future ship.

As already introduced, according to Holck (1939) the construction models were built in accordance to the actual practice of building ships and preserved in order to provide information on developments on the warships construction and as training support in shipbuilding. Lind, in his article *Om Nogle danske Orlogsskibe paa Kong Christian den Femtes tid* (Lind, 1917), stated that between 1670 and 1690, after the charter, the shipbuilder (*skibsbygmesteren*) had to make also a model in scale. Both charter and model were inspected by the Admiralty and then submitted for the approval of the king. While after, when the position of *Konstruktør* took over the design and fitting of the new ship, also the models were left to his competence and made after his instruction.

Moreover, in the same article other two interesting facts are reported. The first is regarding a commission held in March 1682, composed both of officers and shipbuilders, among which Cornelis Thomsen. The commission was convened as result of some freedoms that Thies Hermansen van der Burgh took in the construction of a 90-gun ship, after the king's approved design. The commission, in order to investigate the possible fault of the master shipbuilder, compared the "*halvfærdige skib med modellen*", which van der Burgh himself had made, and the approved plan. Eventually, Cornelis Thomsen took over the construction ship and completing it following the model.

Again, the use of model emerges in a quote regarding the 90-gun *Dannebrog*, presumably a document written by *admiral* Span, as follows:

*"Og til des større Fuldkommenehed har jeg ladet opsætte her paa Bremerholm efter større Maalestok og Skala en Model og to Afridser, det ene paa alle Spanters Vidde, Hulhed Drag og Rejsning, det andet paa Dækkets samt Barkholternes Beløb og Portenes Inddeling; som kan tjene Bygmesteren til Viser og fuldkommen Underretning; saa snart muligt ske kan, skal ligesaadanne Afridser paa andre Sarters blive forfærdiget"*

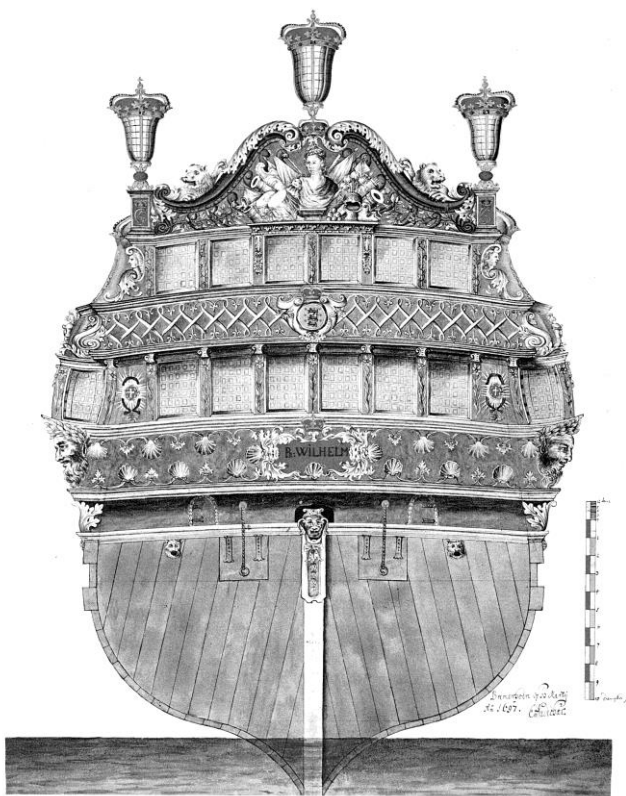
It seems that use of the models were an integral part in the approval process and used for the construction of the ship, as a sort of three-dimensional arrangement plan. Thus, the models were precise copies of the future ship and done by the same shipbuilder. However, it must be bore in mind that both Holck's and Lind's texts suffer of the same lack in reference, therefore precluding an easy identification of the sources.

These evidences cover the period soon before Judichær and the main question would remain unaddressed. However, other two historical documents can help to shed light on the matter. The first document is a letter written by the Frederick IV the 14<sup>th</sup> July 1705 (RA: Søetaten: Søkrigskacelliet 1705a, 66) addressed to Judichær. In the letter, the king is enquiring Judichær in seven points, mainly on matter such the possibility to build ships with lesser and similar draught, the possibility of creating standardized ship classes and timbers economy. The fifth point is extremely interesting:

*"Haver J(udichær) at overlegge, om icke efter saadan Ritz, naar den af Os allernaadigst er approberet, een Model giøres, og derpaa et hvert stöcke timmer, efter sin lengde, breede og krumhed, numeret og Specificeret vorde kunde, paa det*

*sliigt derefter udi een bog, rubric=viis, indføres og nem sig saadant som een regle og rette snor herefter [...]*”

First of all, here the term *Model* obviously refers to a three-dimensional model, since the term *Ritz* is evidently a form of *Afrids* which indicates a drawing (ODS, 1919). Secondly, the king in this enquiry is suggesting that the model, which is done after his approbation of the lines plan, is to serve as a miniature version of the ship, in which timbers can be fitted and subsequently measured, in order to standardise and simplify the “production process”. Then, this would



**Fig. 31:** The decorations scheme of the stern of *Prinz Wilhelm*, 1697. RA: Søetaten Kort- og tegningssamling: H33.

become a model for a certain class of warship, for which all timbers can be pre-produced following the model dimensions. Interesting is the remembrance to the French order issued by Colbert in 1678 (see chapter 4.1.2) and the idea of creating models as the French models “*d’instruction*”.

The second document, which can help to conclude this puzzle, is a reply of Judichær to the King. In a letter dated 30<sup>th</sup> July 1705 (RA: Søetaten: Fabrikmesteren på Holmen 1700-1800b, 24), Judichær answers and defends his choices in ship design. Strangely enough he does not directly answer to the fifth point of the king, but when

discussing on the design of *Christianus Quintus* (lately *Fredericus Quartus*), he claims:

*”[...] og efterudi Skibet endnu ligger der udi Hocken in Natura og stort bestick, derforunden havis Modell deraf, hvor udi alle partes kand examineris saa er jeg J Allerdybste underdanighed Redebond, at drage med plaiser de mangler til Correctur, som nogen med Solido Raisons der udi maatte find [...]*”

Here is evident that the building of a model was a common practice. This last statement helps to explain the nature of these *Konstruktionsmodeller*. Indeed,

the way how the models are built consents to examine the structural elements of the ship, a fact that is confirmed by Judichær's remark.

### 5.2.1. The model and the lines plan

At any rate, the evidences presented above are not the only one available. Another source can help to disentangle the nature of Judichær's models, the lines plan collection.

Given the lack of direct archaeological evidence, the lines plan collection can help to partially answer to a fundamental question: Are the features visible on the models also visible on the lines and arrangement plans produced by Judichær? As already introduced, the lines plan after the king's approval had a binding value, thus the new ship had to be built according to it. From the episode of the 1682 commission and the words of *admiral* Span, it must be assumed that the relation

between lines plan and models is of mutual similarity.

Unfortunately, there are not preserved original lines plans of *Prinz Wilhelm*. The only available material is the sheer plan A992 of the sister-ship *Prinz Carl* (see Appendix I), even if named Prinz Carl/Prinz Wilhelm, and two drawings H32 and H33 (Fig. 32 and Fig. 31) of the decorations at the stern and quarter gallery of *Prinz Wilhelm*. These last two drawings are signed by Judichær and dated 13<sup>th</sup> March 1697, hence made after the launching of the ship.

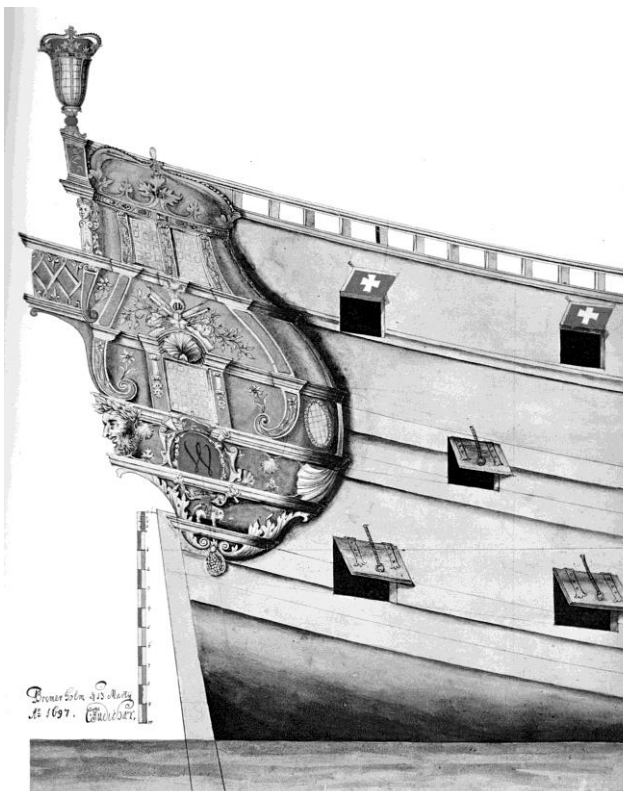


Fig. 32: The decorations scheme of the stern of Prinz Wilhelm, 1697. RA: Søetaten Kort- og tegningssamling: H32.

The general profile closely recalls *Prinz Wilhelm* even if shorter in length. The number of gun-ports on the lower and upper

deck is the same in both model and plan. In the plan, the construction of the hence-rails at the quarterdeck are shorter than the one of the model of *Prinz Wilhelm*, and thus showing two gun-ports less and a shorter poop-deck. Albeit the dimensional differences between *Prinz Carl* and *Prinz Wilhelm*, the fitting of main and sheer wales result identical, as well as for the sheer-rail. The main difference lays in the sheer wales of ship in the plan, where the lower and the upper sheer-wales are less spaced compared with *Prinz Wilhelm*. Indeed, both in the model and the sheer plan, the abaft last three gun-ports cut and intersect in the same manner the upper main-wale and upper sheer-wale. Moreover, the dimensions of the gun-ports from the sheer plan match the ones of the model, as well as the width of the four wales and sheer-rail. The draught shows a false-keel attached to the keel, an element not present on the model, but the sided dimensions of the keels match the ones of *Prinz Wilhelm*. The same similarities in the sided dimensions are found at the stem and stern posts, as well in the length of the posts.

Till here, it seems evident that, although the ship in the plan and *Prinz Wilhelm* differ in length, they show similarities in the fitting and in the dimensions of the main timbers. On the other hand, the drawing of the decorations at the quarter gallery (Fig. 32) of *Prinz Wilhelm* does not confirm what previously said. This drawing shows a totally different construction of the wales and positioning of the wales and sheer-rail. As it can see from the illustration (Fig. 33), the lines extracted from the ortho-photogrammetric projection of the model of *Prinz Wilhelm* do not match the decoration drawing. The only close feature in the drawing is the width of the lower wales and the dimension of the gun-ports, which are close to the ones in the model. Thus, the drawing shows almost a different ship. This mismatch can be easily explained. Taking as example, but it can be applied to the other preserved lines plan and decoration drawings, the sheer plan (RA: Søetaten Kort- og tegningssamling: A904) and the decoration of the quarter gallery (RA: Søetaten Kort- og tegningssamling: A907) of the 72-gun *Wenden* designed by Judichær and launched the 30<sup>th</sup> May 1706 (Christiansen & Bjerg, 2010) two observations are possible. First of all, the decoration drawing displays identical constructions and fittings of the timbers as visible in the sheer plan. Secondly, the sheer plan is signed by Judichær the 26<sup>th</sup> August 1705 and approved by the king Frederick IV the 14<sup>th</sup> September 1705, while the decoration drawing is signed by Judichær the 8<sup>th</sup> June 1707 and approved by the king the 8<sup>th</sup> August 1707. This highlights two important facts: the ship was decorated only after the launch, thus finished while on water, and that the king was responsible also for the decorations approval, thus the ship depicted should have been conforming to the previous approved plans. In both decorations drawings of *Prinz Wilhelm*, the approval text

and signature of the king are missing, thus they should not be considered at the same manner as a king's approved lines plan or drawing.

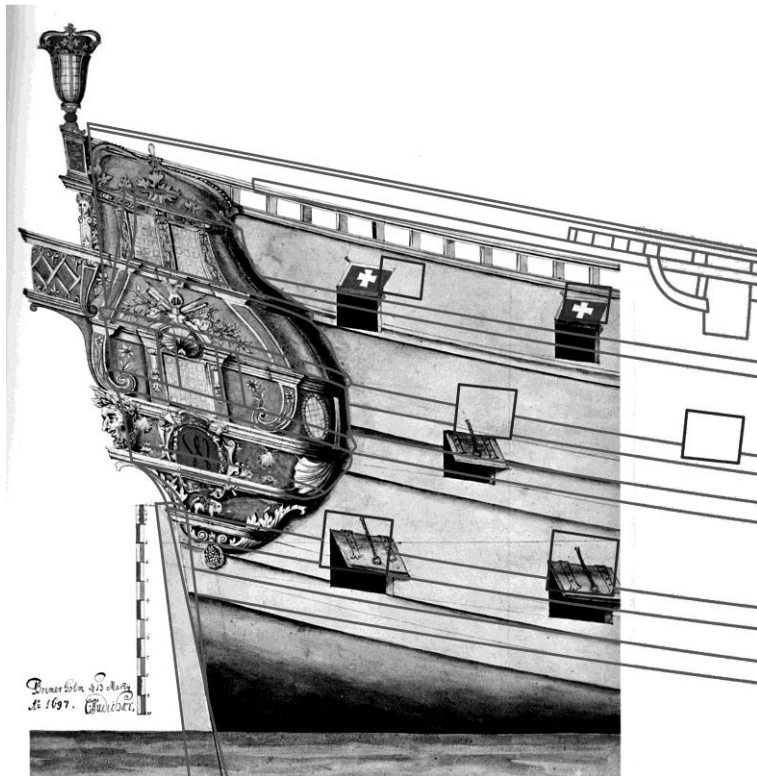


Fig. 33: the scaled outlines of the model of *Prinz Wilhelm* overlaid on the drawing H32. Ditta 2014.

Some of the decorations of the lower finishing, in the drawing H32 (Fig. 32), match with the few ones preserved on the model, such as the elephant and the floral motif. However, the ship depicted does not match with the model of *Prinz Wilhelm*. Thus, the drawing can be considered a close informative depiction of the future decorations of the ship but, since it is not approved by the king, the ship represented it could be a generic not reliable draft.

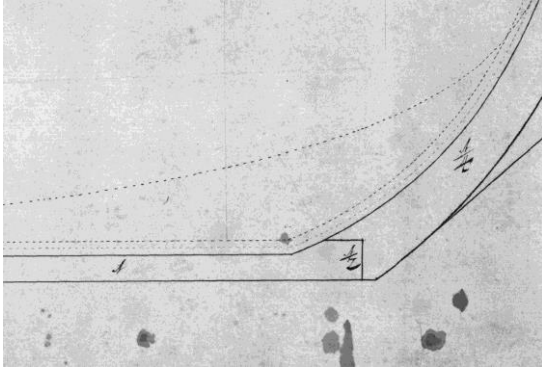
At any rate, the surviving sheer plan of *Prinz Carl/Prinz Wilhelm* does not give any useful information regarding the arrangement of the internal structure of the ship. On the other hand, later sheer plans and breadth plans of other Judichær ships show the arrangement of timbers in the hold and between the decks as well the deck structures and the mid-section. The first preserved plan to show this characteristic is of the frigate *Postillionen* dated 1701 (RA: Søetaten kort- og tegningssamling: A1230II). The plan shows in once the sheer view, half breadth view and the mid-section of the ship.

As it follows, are presented the similarities encountered between the structures visible in the model of *Prinz Wilhelm* and the ones visible in other Judichær's plans.

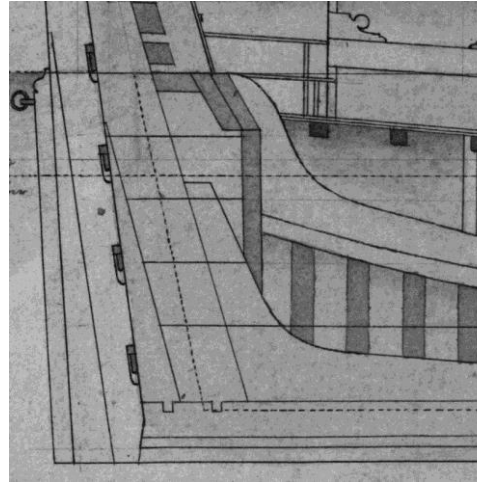
#### *The keel and other related structures*

The particular scarfing of the stem-post and the keel (Fig. 34 and Fig. 35) is a feature visible in all Judichær's Lines plans and models. The skag (Fig. 36), the *slemphout* and the deadwood knee at the stern (Fig. 35 and Fig. 37) are elements

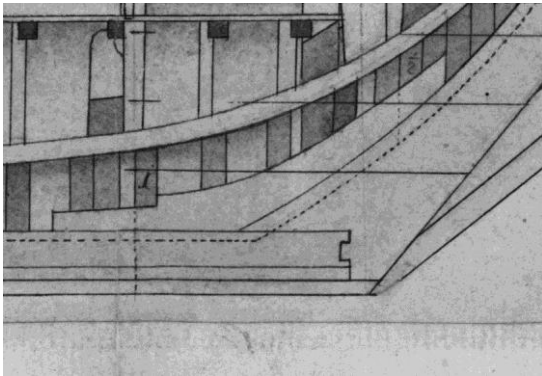
correspondingly visible in several lines plans as found on *Prinz Wilhelm*. As in Fig. 38, the garboard and the second strake are the only two planks to cover the stern post as well. The only elements never encountered on the preserved lines plans is the construction at the stern-post or rather the two filling deadwood between the post and the deadwood knee.



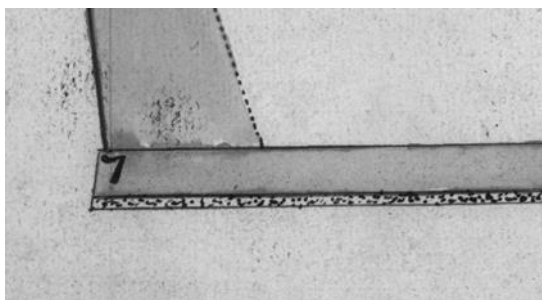
**Fig. 34: RA: Søetaten kort- og tegningssamling: A942I.**



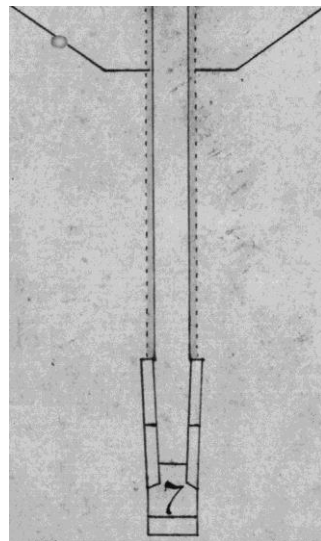
**Fig. 37: RA: Søetaten kort- og tegningssamling: A910**



**Fig. 35: RA: Søetaten kort- og tegningssamling: A910.**



**Fig. 36: RA: Søetaten kort- og tegningssamling: A992.**



**Fig. 38: RA: Søetaten kort- og tegningssamling: A738.**

### *The structures of the decks*

The detailed structures of the deck recorded on *Prinz Wilhelm* have been found on several plans as well. As visible on the lower deck half-breadth plan A914 (Fig. 40) of a 50-gun ship, the same arrangement is encountered such as the two binding strakes, the mid-binding strake and the waterway which is only dotted. In fact, since the waterway is not fully drawn, it is possible to observe the deck clamp and the dovetail mortise between the deck-clamp and the deck beam. Moreover, probably as result of a graphical convention, only the amidships carlings and ledges system is represented (Fig. 42) as visible in the lower deck of *Prinz Wilhelm*. On the other hand, represented on the deck plan A910 of the frigate *Raae* (Fig. 39) is found the same structures pattern as for the upper deck of *Prinz Wilhelm*.

On both plan A914 (Fig. 40) and A910 (Fig. 39), it is noticeable the pattern of the hanging knee head flanking the beams. As in the model and verifiable in other lines plans, the pattern of the knees changes just before the main-mast where a hatch is also in place. Another identical feature found in the model and in the plans is the construction for supporting the mizzen mast-step, with the insertion of a smaller beam to centrally reinforce the mast-step block. Moreover as visible in Fig. 41, the structure of the main mast-step (floor riders and two wooden chocks) in the hold is comparable to the one found on *Prinz Wilhelm*.

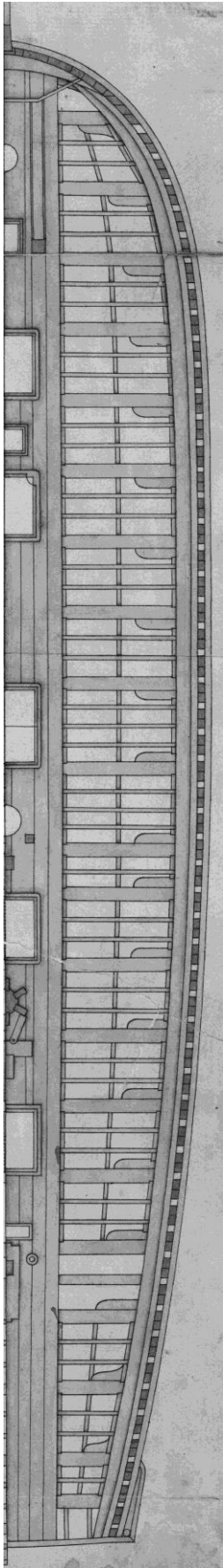


Fig. 39: RA: Søetaten kort- og tegningssamling: A910.

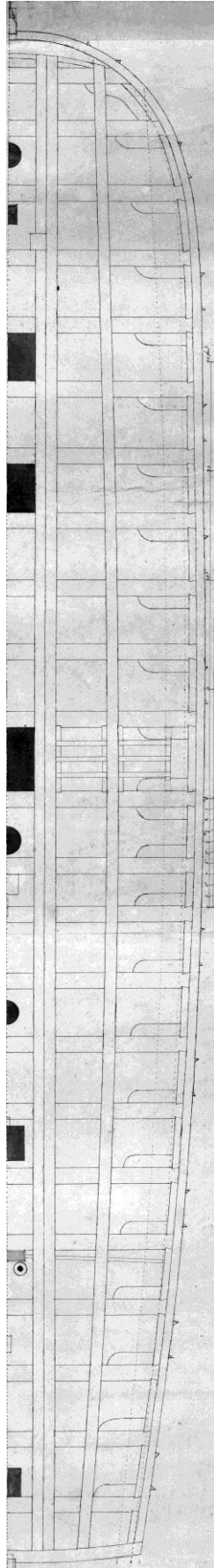


Fig. 40: RA: Søetaten kort- og tegningssamling: A914.

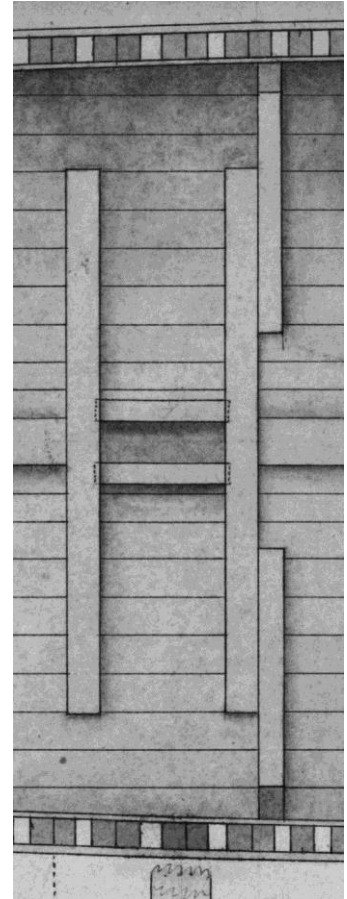


Fig. 41: RA: Søetaten kort- og tegningssamling: A910.

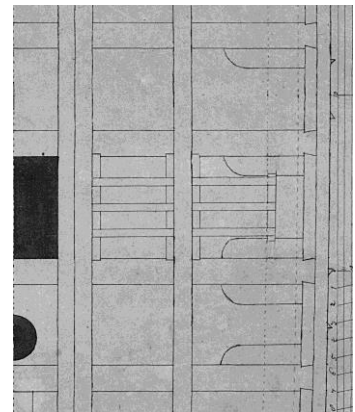
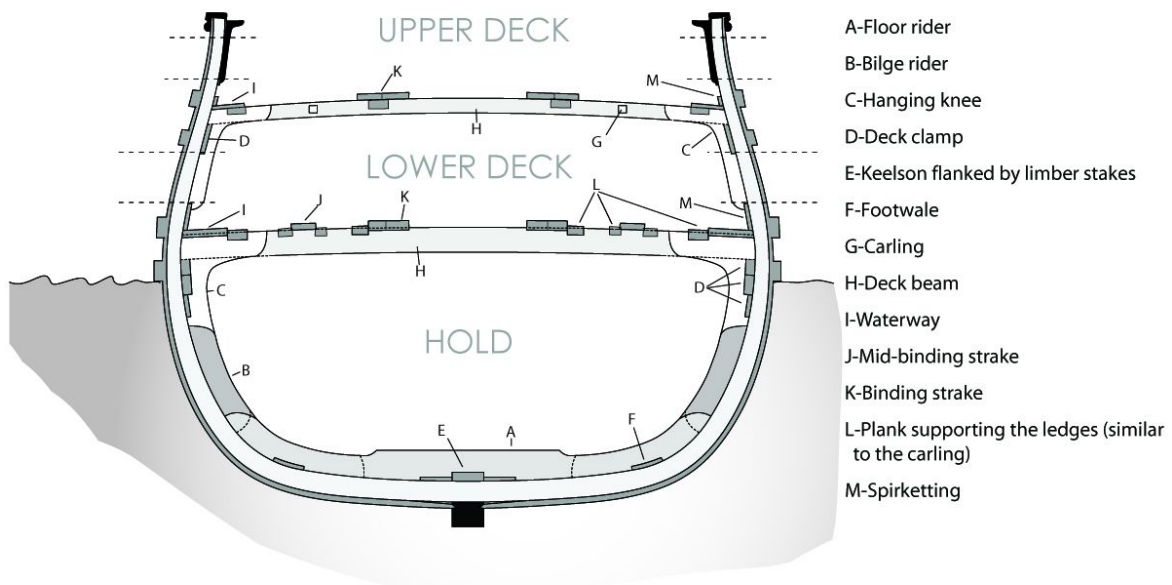


Fig. 42: RA: Søetaten kort- og tegningssamling: A914.

### *The midship section*

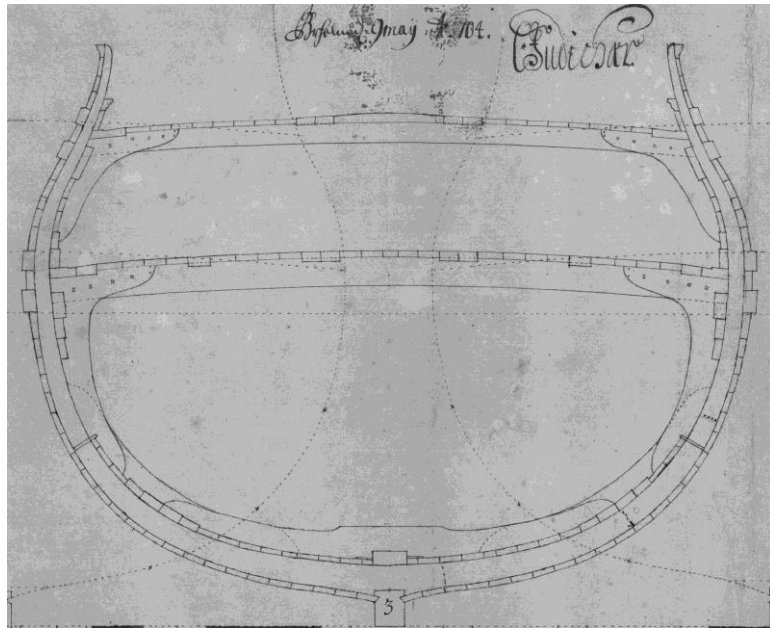
To conclude this summary on the correspondences between lines plans and structures recorded in the model, the midship section should be analysed. The Fig. 43 is an illustration of the midship of *Prinz Wilhelm*, which even if not in scale, shows the arrangement of the ship and presents close similarity with what found on the plans. In fact, as observed the keelson seemed to be a flat plank and is encountered as well in the midship section of other two 50-gun ships of Judichær (Fig. 44 and Fig. 45). *Prinz Wilhelm* has three planks composing the deck-clamp in the hold and only one in the lower deck, as visible in the plan A853 (Fig. 45). Moreover, also the riders and knees disposition is close to the one observable in several plans. Then again, the binding strakes and the waterways are scored on the deck beams, as in the model. Thus, all the visible structures in the midship section of *Prinz Wilhelm* display strong affinities with those found in the plans.



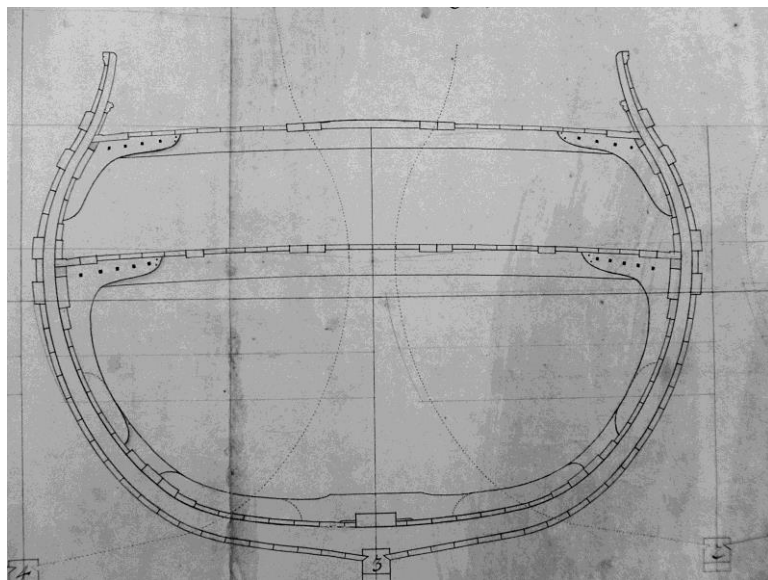
**Fig. 43: Illustration of the midship section of *Prinz Wilhelm* (not in scale). Ditta 2014.**

As last remark, in *Prinz Wilhelm* the floor timbers are simply laid on top the keel, whereas all Judichær's plan post 1700 (which are the most detailed) illustrate the floor timbers scored into the keel. The only similar construction of the floor timbers as in the model is found on the plan A1169II (Fig. 46) of the 64-gun *Prinz Christian*, dated 1697. In the plan, the floor timbers are laid on top the keel and, in

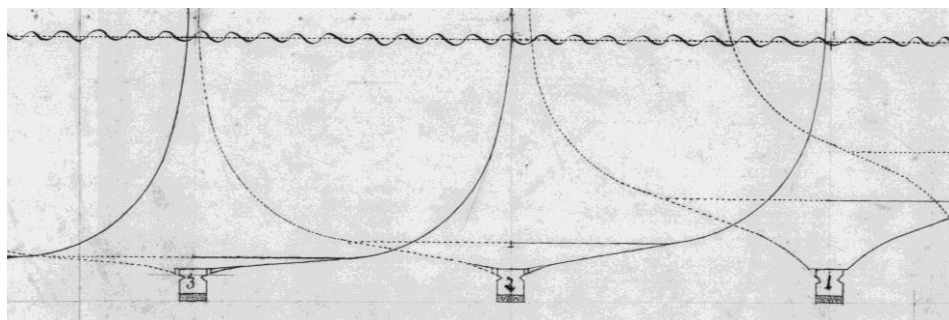
the section where the timbers are drawn as straight pieces, the space between the garboard plank line and the timber is filled by a triangular piece, leaving a space for the limber hole. In the model of *Prinz Wilhelm*, this triangular chock has not been observed because of the difficulty in access to this information on the planked side.



**Fig. 44: RA: Søetaten kort- og tegningssamling: A914.**



**Fig. 45: RA: Søetaten kort- og tegningssamling: A853.**



**Fig. 46: RA: Søetaten kort- og tegningssamling: A1169II.**

### 5.3. Final remarks

The Danish *konstruktionsmodeller* are a unique collection in international context. The characteristics of the Danish models recall in some degrees the French admiralty models. Before Judichær, it seems evident that models were built in accordance with the drafting of the ship as a sort of three-dimensional arrangement and structure plan, an idea close to the French “*modèles de conception*”. The Danish models were built before the ship and used as support in the construction process, as visual tool, and used as reference to check the similarity of the construction carried on the shipyard with the approved project. However, as put forward for the Navy Board models the time and the cost in building them would have been a difficulty to face. Thus, these models should have not been so accurate and rich in details as *Prinz Wilhelm*.

This can be easily seen comparing one of the few surviving models previous to Judichær. As seen in Fig. 47, Sheldon’s model shows a crude construction compared with Judichær’s models. In fact, several elements are built from single blocks of wood, such as the bow, few details of the internal construction are in place and the hull is not fully framed. Thus, the model suggests a simplified three-dimensional construction plan as it would be expected from a model used as a pattern in the building process.

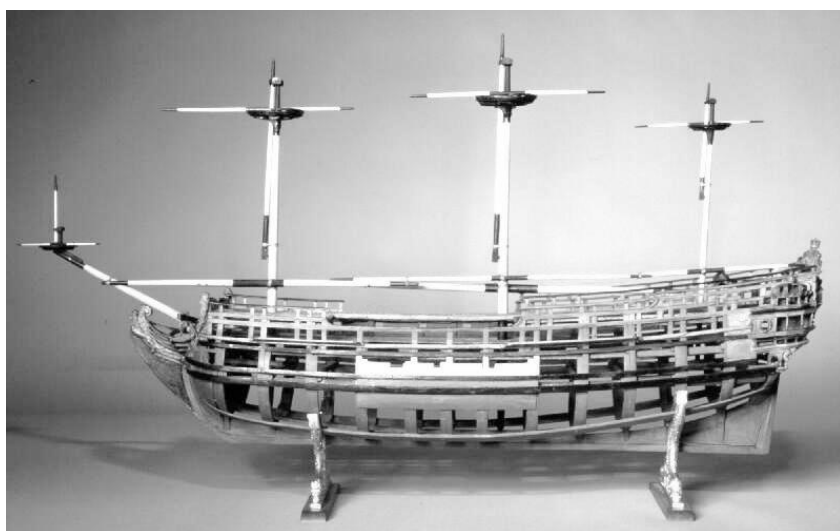


Fig. 47: Model of *Tree Løver* (1689) in the collection of the Danish Naval museum. Rigsarkivet, Orlogsmuseet & Marinens Bibliotek 2004.

Under Judichær, the ship model assumes a different aspect. As it is suggested by the King’s and Judichær’s letters, the models are reliable copies of the future ships. Each timber is replicated in scale on the model and it can be analysed when it is needed. A strong point in favour of this idea is the scantlings of the

framing of *Prinz Wilhelm*, which will be further analysed in the following chapter. The fact that each floor timbers and first futtocks of the frames are carved out with

different scantlings without any apparent standardization leads to the conclusion that they had been copied from the timbers planned to employ on the shipyard. At any rate, it remains unclear if during Judichær's period the models were built before or after the approval of the King of the draughts, as suggest by the King's letter.

In both cases it is evident that the models had to be a reliable copy of the ship and, as demonstrated from the comparison with the lines plan, an informative source on the shipbuilding practice employed in the shipyard.

## 6. Construction and Design Analysis of *Prinz Wilhelm*

As introduced in chapter 2 and 3, the presence of English and Dutch master shipbuilders in the navy has been a constant until the nationalisation period. This could be translated in a strong foreign influence on Danish ship construction and design. However, as pointed out by Auer (2008) in his PhD thesis on small cruisers in the Danish navy between 1650 and 1750, the situation is not obvious as it appears. Essentially Auer concludes, as result of an extensive comparative study of the development of the Danish cruisers, that although foreign shipbuilders such as Thies Hermansen van der Burgh imported ship design methods and traditions from their homeland, they quickly developed personal designs and adaptations which had no straight correlations in other European navies. Thus, foreign practices were not simply copied but absorbed as basis for personal reinterpretation (Auer, 2008).

According to Holck (1939) and Jordening (1896), both *Prinz Carl* and *Prinz Wilhelm* were nearly built according to the French construction and design principles. Although the ships were designed by Judichær as proved by its signature on the only surviving plan, Holck (1939) believed that the use of French principles was a result of the influence of *admiral* von Støcken which had been under French military service between 1691 and 1692.

The French influence in Judichær's design style is surely proved at least in his decoration style and shape of the stern, as demonstrated by the work of Bjerg and Erichsen (1980). Bjerg and Erichsen through an analysis of the Judichær's decoration drawings of the figurehead, the quarter gallery and the stern, found strong similarities with French analogous contemporary drawings, which are also found in the Danish archive. However, Bjerg and Erichsen concluded that even if the French influence is evident, maybe as not direct result of Judichær but of the Holmen *mesterbilledhuggere* (*master sculptors*), the resulting style incorporate Danish iconography and decoration patterns, which developed in a unique combination.

If on one hand the study of the design of Judichær can be easily based on the plenty of remaining lines plans and historical documents, the same cannot be said regarding the ship construction. In fact, the absence of properly documented archaeological sites leaves only to the models this duty. The previous chapter laid a foundation to approach to the model of *Prinz Wilhelm* as an archaeological remain of a Danish warship of the end of the 17<sup>th</sup> century. Consequently, analysing its construction and design through a comparative study, it will possible to answer

those questions related to shipbuilding practice and design during the nationalisation of naval shipbuilding in Denmark.

**6.1. Preliminary analysis of the construction of *Prinz Wilhelm***

The complexity of the model and the limited time spent in its recording pose a limitation to this study. In fact, a comprehensive study on the construction of the model of *Prinz Wilhelm* would require a deeper analysis supported by a detailed recording that was not achievable due to the resources available and the limit imposed by the nature of this project. Therefore, the following analysis must be seen as an introductory study to the topic.

In order to understand the tradition and innovative aspects behind the construction of *Prinz Wilhelm*, a comparative analysis of the timbers construction is necessary. Consequently as it follows, the main components of the constructions of *Prinz Wilhelm* are analysed with the support of archaeological evidence and historical documents, such as contemporary naval architecture shipbuilding treatises.

**6.1.1. Analysis of the hull construction and decks structures**

*The framing*

The framing of *Prinz Wilhelm* is one of the most interesting peculiarities shown by the model. As already described, the framing seems build according a double frame system with butt joints and overlapping scarfs as it follows:

Double frame	
First frame	Second frame
Floor timber	First futtock
Second futtock	Third futtock
Top timber	

The singularity of the framing lays in the scantlings, which is not consistent through the hull, the small spacing between the double frames and the absence of lateral fastening between the frames timbers which poses a question in the reliability of the interpretation.

The fact that several frames are not “paired” without any obvious pattern while other frames are tightly attached forming perfect double frames, it makes evident that the explanation of this anomaly should lay in the conservation of the model. Thus, the fact the timbers of the double frame are not interconnected by any physical joint could be related to use of water glue or any other kind of natural adhesive that dissolved with the time.

During the post-processing of the data acquired from the model, a pattern in the framing has been noted. As it can be seen in all Judichær’s draughts, usually eight sections are drawn: seven section numbered from 1 to 7 along with a section named  $\frac{1}{2}$ , and in some cases a second called  $\frac{1}{4}$ , afore the section 1 (see Appendix I). Using an orthographic projection of the photogrammetric model of the framed hull of *Prinz Wilhelm*, the hull has been divided in eight sections as done by Judichær. The outcome was interesting, since the division resulted in the identification of seven station double frames and the transom wings. The station frame  $\frac{1}{2}$  matched with the scored floor on the *slemphout* in the same position as visible in Judichær’s plans. Likewise, the station frame 3 coincided with the master frames. Between two station frames, 9 double frames are counted. Besides the station frame  $\frac{1}{2}$ , which is clearly marked on the model because notched on the *slemphout*, and the station frame 3, which marks the changing in the disposition of the framing pattern, the other station frames are not so easily identifiable. Neither uniformity nor diversity in the scantling is indicative of these station frames, since their scantlings vary as for the rest of the frames. Along with the rest of the double frames, there is no presence of lateral fastenings between the timbers.

Then a question arises: is the Danish use and construction of double frames similar to other European counterparts? Moreover, is the absence of physical joints between the timbers indicative for a real practice in the shipyard? For these reasons, a brief overview on the foreigner practices of the double framing is needed.

The use of three futtocks and double frames appears in England around about the second half of the 1670s (Anderson, 1953), a system widely used in framing of the first four rates (Batchvarov, 2002). According to Lavery (1984), before the introduction of a third futtock and double frame system, each futtock was fitted individually to the framing system simultaneously to the planking since the frames were not laterally fastened and the first futtock were filling the space

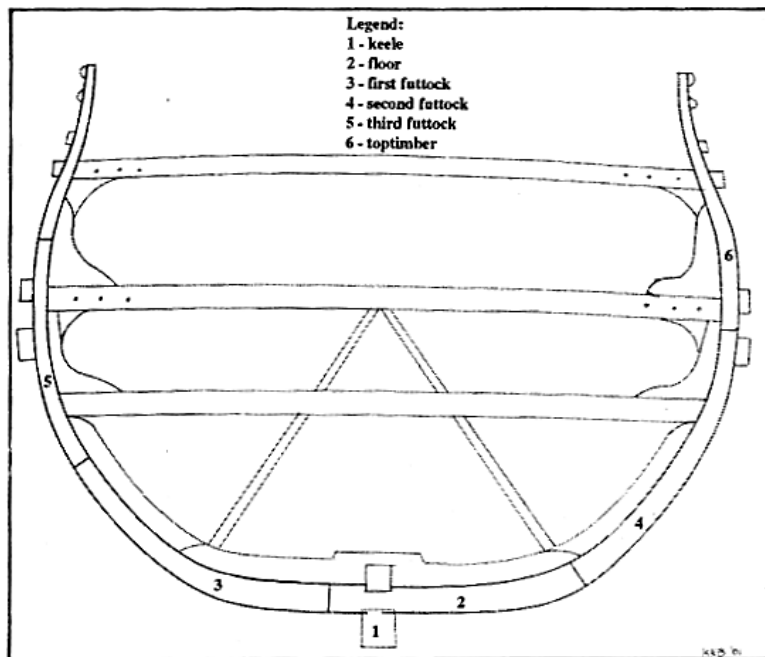


Fig. 48: Section of a third-rate redrawn from an original of Keltridge. After Batcharov 2002.

between the floor timbers. Although one of the earliest documental evidences of use of a double frame system is a contract from 1676 (Anderson, 1953), a collection of drawings dated around mid-1680 prepared by the shipwright William Keltridge, according to (Batchvarov, 2002), are the first graphic evidences that show a double frame system with butt joints and overlapping scarfs. Despite the numerous preserved

contracts, lateral fastening between the frame timbers are not described and well-documented archaeological evidences for warships of the late 17<sup>th</sup> century are not available (Batchvarov, 2002).

On the double frame construction another interesting source, though a later one, gives an interesting insight: the shipbuilding treatise of William Sutherland (Sutherland, 1711) *The Ship-builders Assistant* which was first published in 1711. Although it can be questioned if what he described can be applied to the late 17<sup>th</sup> century as well, Batchvarov (2002) in his analysis of the framing of 17<sup>th</sup> century warships has no doubt that Sutherland describes a shipbuilding practice that was likely introduced in the early 1690s and had become the dominant way of building ships by 1711. Sutherland (1711) clearly specifies that the timbers of small ships were fastened and raised entire with the top timbers, thus as pre-erected frames, while for big ships the timbers up to the breadth were fastened together before they were raised. The moulded floors were bolted on the keel and with the support of ribbands passed around the wrongheads the rest of the floors were filled in. Eventually, the pre-assembled futtocks (first and second together for big ships,

futtocks and top timber for smaller ships) were mounted on their respective floors, every third or fourth floor, and breadth ribbands were placed on each side for support and guide (Sutherland, 1711). The first futtock was not laterally fastened to the floor since it would not have been possible due to the lack of sufficient room between the first futtock and the next floor, thus the whole structure was mainly kept in position by ribbands and possible temporary connection (Kenchington, 1993). Then, the filling timbers were added with the planking (Sutherland, 1711), in view of the fact that the filling frames could not stand unless supported by the planking. Sutherland in his treatise was also concerned about the spacing between the frames. An earlier practice to place the floors and first futtocks very close together is mentioned (Sutherland, 1711), a practice that for Batchvarov (2002) was used in the period between 1697 and 1703 when most of the navy was rebuilt and repaired. However, this practice was cause of rotting and Sutherland advices to leave air spaces between these timbers (Sutherland, 1711). Thus, according to Sutherland only every third or fourth floors was built as a true double frame, probably the stations from the draught, while, between the double frames, spaced filling frames were added with the planking.

Investigating the scantlings for the double framing with three futtocks, a slight reduction in the sided dimension of each timber can be noticed. For example, a document of Keltridge in preserved the National Maritime Museum can give useful information: a small manuscript notebook entitled *William Keltridge His Book April 24* dated 1675. The notebook contains topics from the proportions for ships, to tables of scantlings for first through sixth rates. Due to the impossibility to access the document, the information reported here are extract from the work of Batchvarov (Batchvarov, 2002).

Timbers	Sided Dimensions
Room and Space	25 in – 63.5 cm
Floors	12.5 in – 31.75 cm
Lower futtock	12.25 in – 31.11 cm
Second futtock	12 in – 30.48 cm
Third futtock allow	12 in – 30.48 cm
Third futtock aloft	11.25 in – 28.57 cm
Top timber allow	10.5 in – 26.67 cm
Top timber aloft	6.75 in – 17.14 cm

The table above refers to the scantlings of the timbers for a 4<sup>th</sup> rate extracted from Keltridge’s notebook. As it can be seen, the space available between the

double frames is really scarce, thus resulting in a solid bottom, while the timbers slightly decrease dimensions and both the third futtocks and top timbers taper.

Sutherland's scantlings table (Kenchington, 1993) suggests that the sum of sided dimensions of the floor timber/first futtock is nearly 20 in (50.8 cm), while the room and space is 21.3 in (54.1 cm), thus leaving 1.3 in (3.3 cm) of space between the next timber. The siding of the futtocks and top timbers reduced slightly with increasing height above the keel, thus slightly tapering (Kenchington, 1993).

Both Lavery (1984) and Goodwin (Goodwin, 1987) agree that in the 17<sup>th</sup> and early 18<sup>th</sup> centuries, first futtocks were offset from keel of about 18-24 in (45.72-60.96 cm). While from the first quarter of the 18<sup>th</sup> century onward the first futtocks began to approach the keel and eventually fastened to it through a cross chock that joined port and starboard first futtocks (Lavery, 1984). At the same time, the overlapping scarfs disappear from the contracts and chock scarfs are substituted for them (Batchvarov, 2002) and, by the middle of the 18<sup>th</sup> century, lateral fastening were common in warship construction (Lavery, 1984).

In France, the double frame system was likely introduced at the end of the 1670s, as suggested by the specification for a light frigate dated 1679 and signed by leading French shipwrights Hubac, Levasseur and Laurent (Boudriot, 1993). The document gives specifications for the scantlings, and the use of two futtocks and overlapping frames is noted. However, the document does not specify the sided dimensions of the frames but only the molded.

At any rate, the earliest archaeological evidence of the use of three futtocks and double frames is the wreck of the "*barque longue*" *La Belle*. The vessel was built at La Rochelle (France) in 1684 and it went lost in 1686 at Matagorda Bay in Texas (Pevny, 2011). The site was excavated and raised for conservation during 1996 and 1997, under the direction of the Texas Historical Commission (Pevny, 2011). The wreck showed thirty double frames still in position, which were spaced at intervals of 48.8 cm along the keel. The floors were fastened with a single iron bolt on the keel and the frames were composed of a floor with overlapping first, second, and third futtocks (Grieco, 2003). At amidships, a frame defined by Boudriot (2000) as "*à triple épaisseur*" was identified as the master frame. In this frame, the floor and futtock are reinforced by a pair of second and fourth futtocks on either side (Grieco, 2003).

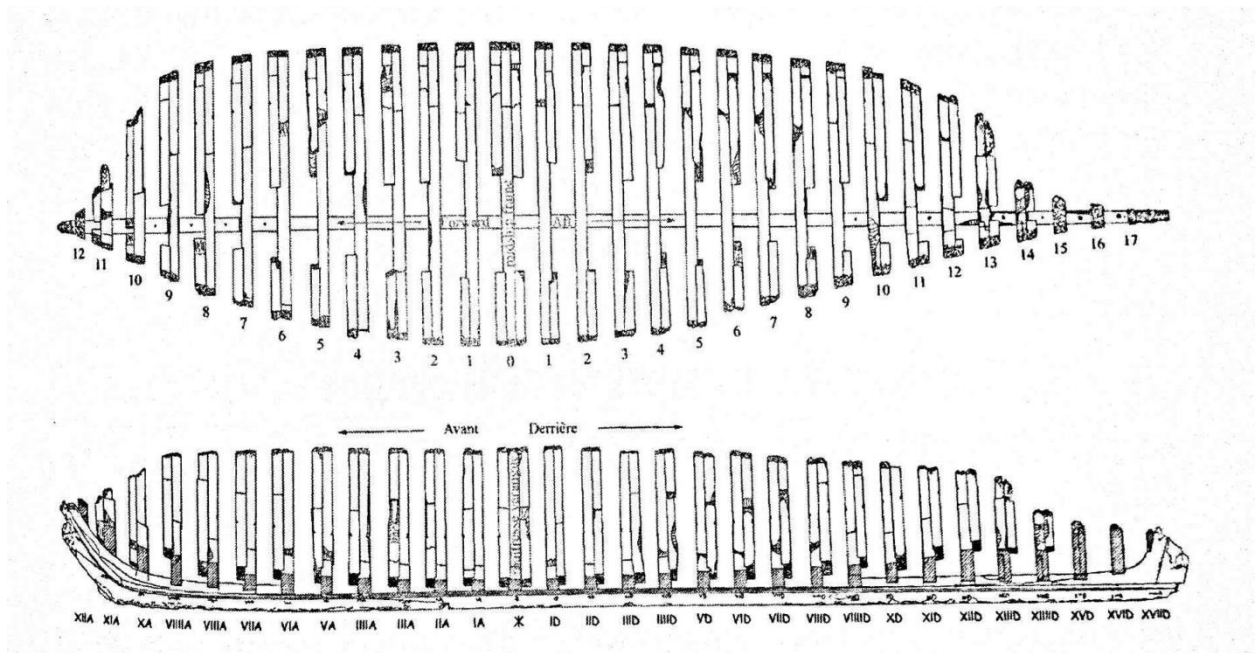


Fig. 49: Plan of the framing of *La Belle*. After Pevny 2011.

Noteworthy is the framing pattern (Fig. 49). Fore the master frame, the first futtocks are placed on the forward face of the floor, while aft the master frame the first futtocks are placed on the aft face of each floor. All timbers of the double frames are butt jointed and laterally fastened by three evenly spaced iron bolts (Grieco, 2003). The sided dimensions of all the floor timbers ranged between 14.9 and 19 cm, while for the futtocks between 13.6 and 16.3 cm throughout the vessel (Grieco, 2003). The frames between the apron and the deadwood knee were not scored on the keel but simply laid on top of it and no limber holes were found in the floors, a characteristic that Boudriot (Boudriot, 2000) defines as a Dutch feature. Surely, the gap between the garboard and the bottom of the floor of 2.7 cm served to the purpose of allowing the bilge water to flow through (Grieco, 2003). In the reconstruction proposed by Boudriot (Boudriot, 2000) and Grieco (Grieco, 2003), the futtocks and top timbers do not appear to taper and no further spacing is visible between the frames.

Another shipwreck is a perfect example of the French use and construction of double frames. The 54-gun *Hazardous* (Owen, 1988) was lost out Bracklesham Bay (UK) in 1706 whilst in English service, as it was captured in 1703 from the French. Indeed, the vessel was built in Port Louis in 1698 as the 50-gun *Le Hazardeux*. The shipwreck was surveyed and partially excavated first in 1987 (Owen, 1988) and again between 1990 and 1991 (Owen, 1988) by a team led by Norman Owen. Despite the fact the wreck consist has fairly extensive hull structure surviving, Owen describes only the section identified as the stern.

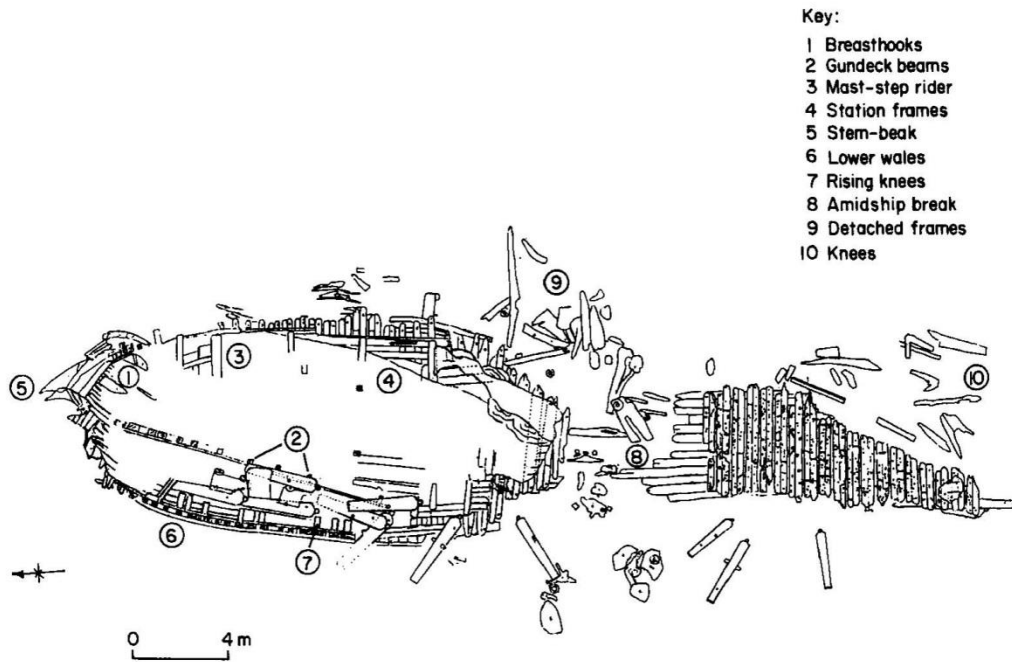


Fig. 50: Site plan of *Hazardous*. After Owen 1991.

The frames are in pairs and spaced between 10 and 12.5 cm from each other and the spacing resulted consistent throughout the wreck (Owen, 1988; Owen, 1991). The double frames sided dimensions was between 48 and 53 cm (Owen, 1988), even though in the later report Owen (Owen, 1991) gives at 52 cm the sided dimension of a double frame. Moreover, the timbers of the double frames were laterally fastened with iron bolts (Owen, 1991). Although Owen (1991) recognizes three station double frames separated by four filling frames, as pointed out by the analysis of Batchvarov (2002), this interpretation is doubtful. Indeed, what Owen identifies as filling frames are as well double frames and they appears so probably due to the freakish survival of the frames (Batchvarov, 2002). Thus, *Le Hazerdeux* was probably framed as *La Belle*. Given the presence of lateral fastening in the double frames on both ship, and as demonstrated for *La Belle* (Grieco, 2003; Boudriot, 2000), the building sequence of the frames would see a phase of pre-assembling of the timbers on the shipyard and then the erection of the designed double frames on the keel.

Further evidence on the construction sequence of the framing is given by what Boudriot (1998) considered the first French graphic representation of double frames. The drawing (Fig. 51) depicts the progress of the works on the 90-gun *Foudroyant* at the end of October 1690, works that started in Br est in the July of the same year, under the supervision of the master shipwright Blaise Pangalo (Boudriot, 2000; Lemineur & Coulomb, 2007).

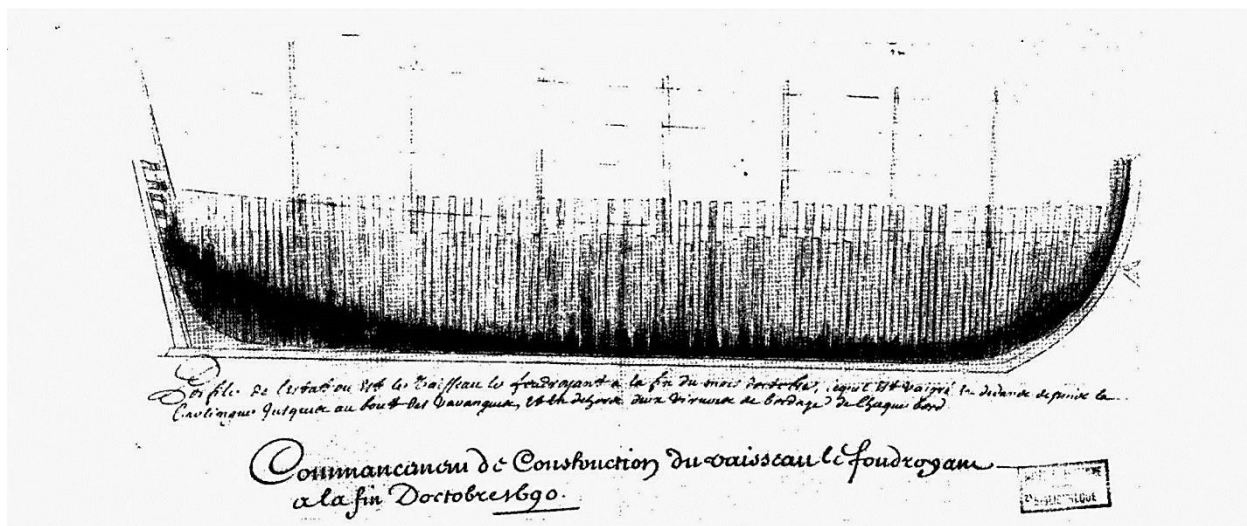


Fig. 51: The drawing on the status of the works of the 90-gun *Foudroyant*. After Boudriot 2000.

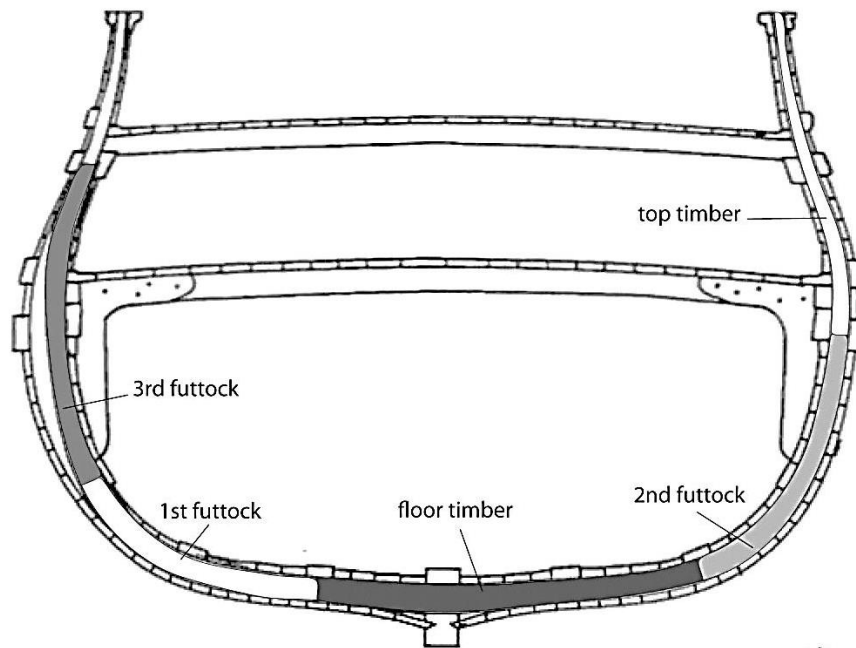
Seven double frames and the transom wings seem to have been pre-erected, double frames composed by floors, three futtocks and top timbers. Although not clearly visible in the picture, the frames are kept in position by ribbands (Lemineur & Coulomb, 2007). Between the pre-erected frames, double frames composed by floor timber/first futtock/second futtock are inserted. All the frames are separated by a small space (Boudriot, 1998).

For the 17<sup>th</sup> and early 18<sup>th</sup> century, there are no evidences of the use of three futtocks and double frames in Dutch ships, nevertheless few remarks are possible. Although the Dutch shipbuilding deserves a wider discussion, only a brief introduction can be given as a result of the limits imposed by the nature of this essay. At least from the second half of the 17<sup>th</sup> century and according to historical sources, two shipbuilding traditions coexisted in Holland. As reported by Witsen (Hoving & Wildeman, 2012) in his treatise from 1671, the *Noordrkwatier* practice involved the laying of keel and stems and the flush-laid planking of the bottom of the vessel jointed by cleats. Only when the construction of the bottom was concluded, the frames were placed. Opposite to Witsen, in the treatise dated 1697 of the shipbuilder Cornelis van Yk, a different approach is suggested for the *Maaskant* area. In *De Nederlandsche scheepsbouw-konst open gestalt* (van Yk, 1697), the first stage described is similar to the one reported by Witsen and only the garboard strake is secured to the keel. Subsequently, two identical master frames were secured on the keel after a series of calculations for finding their positions. The next step was the erection of a breadth ribband and the insertion of two tail frames. Eventually, further ribbands were set in position to consent the positioning of the remaining frames.

According both to Witsen and van Yk, the interconnection of floor timber/first and second futtock seem to have been suggested at least in the mould master frame (Hoving & Wildeman, 2012). Conversely, based on the archaeological evidences, the absence of lateral fastened joints and the little uniformity in the sided scantlings of the timbers are two of the three diagnostics markers of Dutch shipbuilding tradition (Maarleveld, 1996).

In a recent article, Thijs Maarleveld (2013) suggests an indicative index that could help in recognizing Dutch-flush shipbuilding in field archaeology. The index takes in consideration the number of frames in 4 meters of ship length and put in comparison the archaeological information from supposedly Dutch-built ships and others European vessels built between the ends of the 16<sup>th</sup> and the 17<sup>th</sup> century, without taking into consideration the ship size. As Maarleveld (2013) states, the diagnostic features taken in account do not pretend to explain the variety of shell- and bottom-based approaches loosely combined under the term Dutch-flush and the index alone is not enough for a “diagnosis” on the tradition in which the ship was conceived. At any rate, the result is interesting and gives food for thought. Indeed, the index shows that Dutch-built ships have between 18 and 23 timbers over 4 m of ship length (Maarleveld, 2013). Whereas, albeit with some exception, for vessels built under different traditions such as the Ibero-Atlantic to the French, the number of timbers over 4 m of ship length is inferior to 18. Thus, if the same method is applied to the scaled to real size model, *Prinz Wilhelm* has an average of 12 timbers for 4 meters of ship length and therefore virtually placing the Danish warship outside the Dutch praxis.

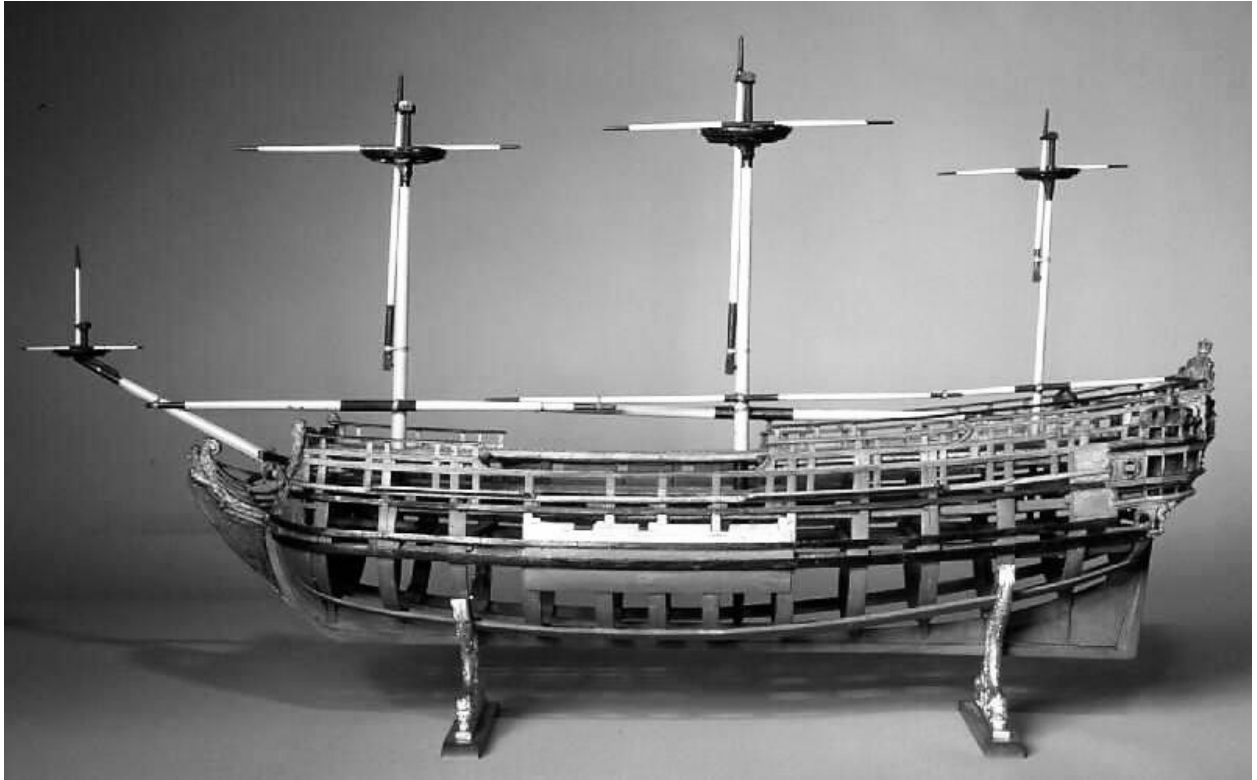
Moving back to Denmark, the use of double frames in the Danish naval construction at the end of the 17<sup>th</sup> century was already conjectured by Batchvarov (2002) as result of the analysis of the section drawing of the *Dannebrog* (RA: Søetaten kort- og tegningssamling: nr 316, 1692). Indeed, in the drawing (Fig. 52) the three futtock arrangement is clearly depicted as identically found in *Prinz Wilhelm*. The first futtock is placed offset from the keel, the second futtock reach the lower main wale while the third futtock reach the lower sheer-wale. The drawing does not give any sided dimensions and it is not clear if space is left between the frames (Batchvarov, 2002). Batchvarov concludes that the Danes adopted the use of three futtocks and double frame at the same time as did the other great maritime powers of the Atlantic and the North (Batchvarov, 2002).



**Fig. 52: Illustration of the mid-section of *Dannebrog*, redrawn from original after Bjerg & Erichsen 1980. Ditta 2014.**

Albeit the wreck of *Dannebrog* has been located, interested by artefacts recovering and object of several surveys between 1986-1988 and 2000-2006 (Olesen, 2009), any attention was given to the ship structure. The only information that can be gathered from the published articles is that floors and three futtocks, although scattered on the site, have been identified (Christoffersen, 1990). Moreover, it appears that the sided dimension of the frame timbers ranged from 21 to 57 cm (Olesen, 2009). However, it is not stated where and which timbers have been measured.

The illustration of *Dannebrog* is not the only evidence. Another construction model, preserved at the *Orlogsmuseet* in Copenhagen, points to the introduction of the double framing prior to the construction of *Prinz Wilhelm* and even *Dannebrog*. In fact, the model of *Tree Løver* (Fig. 53) launched in 1689 and built by Francis Sheldon, although built in a simpler and schematic style, clearly shows a double framing system with three futtocks, similar to *Prinz Wilhelm* even in the pattern of the first futtocks. As in *Prinz Wilhelm*, the first futtocks are placed on the side towards the direction of the master frame. If taken for granted the authenticity of the features showed by this model, the introduction of the double framing and the inverse pattern between fore and aft for the first futtock could already be linked to Sheldon.



**Fig. 53: Model of *Tree Løver* (1689) in the collection of the Danish Naval museum. Rigsarkivet, Orlogsmuseet & Marinens Bibliotek 2004.**

*From the keel to the deck: a commentary on the other structures*

If the framing of *Prinz Wilhem* leaves some open questions, which cannot be easily fulfilled if relying only on the model, interesting is to give a look to the other wooden structures of the model in order to understand and possibly to insert into the international context the construction features of the model.

Looking at the keel of *Prinz Wilhelm* some considerations are possible. It is clear by the presence of the skeg and the variation in the scantlings between the mid-section and the ends that the keel construction is close to the Dutch and French practices. Indeed, for the period between 1670 and 1710 the keel of British warships had squared dimensions and the skeg was not in use (Goodwin, 1987; Lavery, 1984). While, as it can be seen from archaeological evidences and graphic sources (Lemée, 2006; Grieco, 2003; Boudriot, 1993), the construction recalls evident Dutch and French practices, especially regarding the use of the skeg and in the widening of the keel amidships. However, as found on *La Belle* (Grieco, 2003) and the visible in the *Album de Colbert* from 1670 (Colbert et al., 1988), in the last decades of the 17<sup>th</sup> century the French introduced the use of a forefoot which raised and connected to the stem-post. Instead, under this point of view, the construction

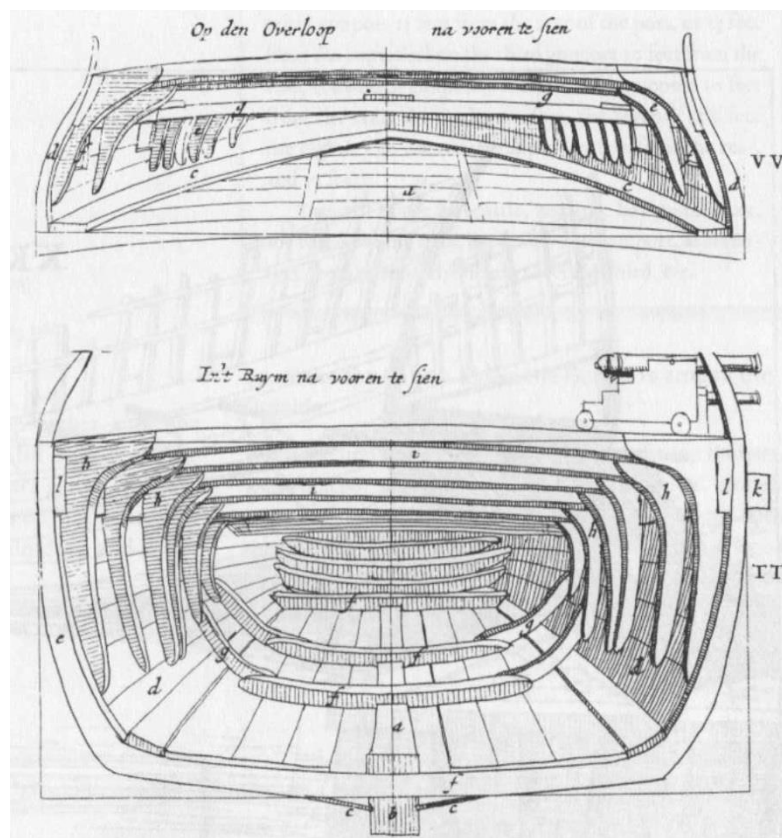
visible on *Prinz Wilhelm* can be linked to the Dutch practice which contemplates a box scarf with stem-post (Hoving & Wildeman, 2012). However, as it has been noted during the description of the model (see paragraph 4.2.2.), the type of scarfing between the keel and the stempost only resembles the box scarf type and similar examples are not found in literature or archaeology.

Looking at the scantlings of the keel and keeping in mind the similarities with the Dutch tradition, the sided dimension at amidships is closer to what is reported by the Dutchman Witsen in his shipbuilding treatise first published in 1671. Witsen (Hoving & Wildeman, 2012) prescribes for a ship of 155 Dutch feet (43.88 m) between the posts, close to the dimension of *Prinz Wilhelm*, a sided dimension of the keel amidships of 23 ½ Dutch inches (60.48 cm), close enough to scaled dimension of keel in the model. For the molded dimension of the keel Witsen specifies that is equal to a ¼ more than the thickness of the inner side of the stem (Hoving & Wildeman, 2012). In *Prinz Wilhelm*, the central part of the keel has a molded dimension of 48 cm (after scaling), which exactly corresponds to the inner dimension of the stem, 38.4 cm after scaling, with a ¼ added to it. The thickness of the inner side of the stem is the basic measurement in Witsen, since all scantlings are derived from it (Hoving & Wildeman, 2012). The formula given by Witsen to find this fundamental unit is 1 Dutch inch of thickness every 10 Dutch feet of the length between posts, or rather in metric system 1 cm every 112 cm (Hoving & Wildeman, 2012). Thus according to this formula the resulting thickness inside the stem should be 39 cm, which is close to the actual 38.4 cm of *Prinz Wilhelm*.

In the model description, the knee placed between the stem and keel has been named with a Dutch terminology. The timber called *slemphout*, literally rising wood, was used as reinforcement for the scarf between the keel and them in vessel sharp rake (Hoving & Wildeman, 2012) as in the case of *Prinz Wilhelm*, different from the apron used by the English and French which had arms extending longer both on the post and keel and often made out several pieces (Goodwin, 1987; Boudriot & Berti, 1995). The same can be said regarding the solid sternpost knee, which compared with the French result to be smaller and not articulated in several pieces (Boudriot, 1973; Grieco, 2003) and obviously different from the British counterpart since a considerable deadwood structure working as knee was fastened to keel (Hoving & Wildeman, 2012; Goodwin, 1987).

The planking of *Prinz Wilhelm* suggests, again, an influence attributable to the contemporary French and Dutch shipbuilding practice. The attachment of the garboard and second strake across the sternpost, as visible in the model, is a

characteristic already encountered on Dutch built ships between the 16<sup>th</sup> and 17<sup>th</sup> century (Lemée, 2006) and used as well on French vessels at least from the last two decades of the 17<sup>th</sup> century, probably as direct influence from the Dutch (Boudriot & Berti, 1995). Then again, although the thicknesses of few planks have been measured only at the stern, their dimension (0.4 cm or else in scale 9.6 cm) corresponds to what is prescribed by Witsen. According to his formula the thickness of the planks is  $\frac{1}{4}$  of the thickness inside the stem (Hoving & Wildeman, 2012) that gives exactly the thickness of the planks of the model. Even the lower wale matches the prescription of Witsen (Hoving & Wildeman, 2012), since its width is equal to the thickness of the inner side of the stem.



**Fig. 54: Hold and upper-deck structures, as illustrated by Witsen . After Hoving & Wildeman 2012.**

Close similarities with a Dutch built ship are found again in the structures of the hold. The general visual impression of the disposition and construction of the floor riders, bilge riders and hanging knees call to mind the illustration from the treatise of Witsen (Fig. 54). The long arm of the hanging knee are a characteristics that is not typical for French built ship, where shorter hanging knee were preferred as visible in the *Album de Colbert* (Colbert et al., 1988) (Fig. 55) and in several French draughts (Boudriot & Berti, 1995; Boudriot, 1993), or in English built ship where small knees were used (Goodwin, 1987). However, the scantlings of these elements do not match with Witsen prescription. In fact, if Witsen prescribes for

the riders a squared dimension of  $\frac{2}{3}$  the of the inner side thickness of the stem (Hoving & Wildeman, 2012), the scantlings of these timbers found in *Prinz Wilhelm* show larger scantlings. The same applies for the scantlings of the structural timbers between the hold and the decks, such as decks beams and hanging knees, which are larger than Witsen recommendations.

Once again, the composite structure of the main mast-step, the *kattespoor*, and the shallow keelson are Dutch influenced components, as clearly illustrated by Witsen (Fig. 56) and in the case of the keelson as found in Dutch built ships like the *Vasa* (Steffy, 2012). It must be noted that the use the two compass timbers at the bow in the hold, which are laid diagonally and laterally securing the breasthooks, are neither described nor found in any contemporary sources or archaeological examples.

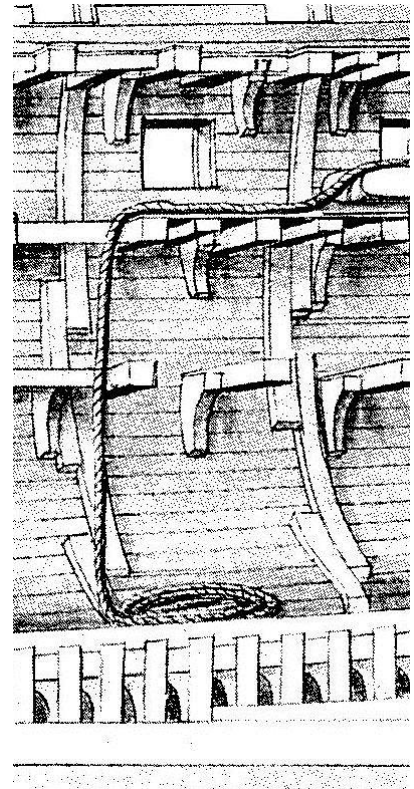


Fig. 55: Cutway of the vessel illustrated in the *Album De Colbert*. The small hanging knees are clearly visible. After Colbert et al. 1988.

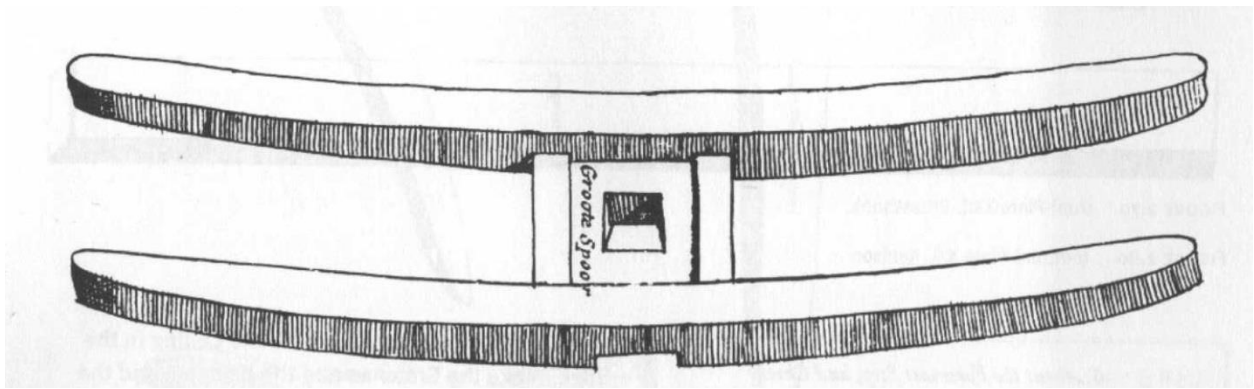
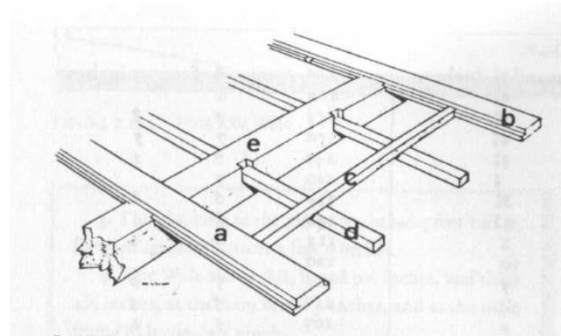
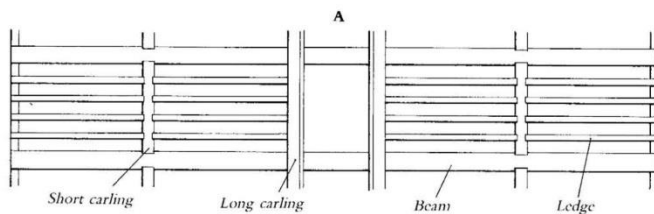


Fig. 56: The *Kattespoor* as illustrated by Witsen. After Hoving & Wildeman 2012.

Another interesting feature of *Prinz Wilhelm* is the construction and arrangement of the carlings/ledges system. In fact, the use of strakes to secure the ledges as a sort of short carling between the waterway and the binding strakes, as clearly visible in the lower deck, is not found in any other contemporary examples but closely remind the English practice. The English (Fig. 57) used to notch the ledges directly to the lodging knees from one side or short carlings and on a short carling or long carlings on the other (Franklin, 1989; Goodwin, 1987). The English short carlings were heavy scantlings cross-beams flush laid between the beams and usually fitted up to the mizzen mast (Franklin, 1989). While, in Dutch built ships

the ledges (Fig. 57) are notched on and supported by the waterway and the binding strake (Hoving & Wildeman, 2012). The feature visible in the Danish model suggests a compromise between the two methods.



**Fig. 57: On the left, the English carlings/ledges system (after Franklin 1989). On the right, the Dutch carlings/ledges system: A – Binding strake; B – Waterway; C – Ledge; D – Carling; E – Deck beam. After Hoving & Wildeman 2012.**

Noteworthy is the use of the mid-binding strakes found only on the lower deck of *Prinz Wilhelm*. The English did not employ binding strakes in their construction during the period in exam, while they are found on Dutch and French built ships (Hoving & Wildeman, 2012; Boudriot, 1973). On the other hand, the mid-binding strakes seems to have been only used by the French as described by the French naval architect Blaise Ollivier in his treatise on the Dutch and English shipbuilding dated 1727 (Ollivier, 1992) and probably introduced at the end of the 17<sup>th</sup> century (Boudriot, 1973).

As last observation, the clinker planking of the upper works of the quarter and poop deck is a typical Dutch trait, which is found only in few French examples and never used in England (Anderson, 1921b).

## 6.2. Analysis of the Design

The limits of a comprehensive comparative analysis of the design and proportions between other European 50-gun warships and *Prinz Wilhelm* are given by the scarcity of surviving lines plan for the period in exam, especially for Dutch ships, and the different conventions in ship dimensions. Consequently, such kind of analysis would require the compiling of ship lists and the creation of index tables, an operation that would go beyond the explorative nature and limits of this essay.

Therefore, the design and arrangement of the model of *Prinz Wilhelm* is discussed in comparison with available sources, with the purpose of offering an introductory overview on the features of a warship built in the early period of the Danish nationalisation of the naval shipbuilding.

### 6.2.1. A commentary on the basic design and arrangement of *Prinz Wilhelm*

The rake of the stempost is only 14 cm (3.36 m), resulting in a sharp raising bow. The outer edge of the stem is formed by a large diameter sweep of 53 cm (12.72 m) which is not tangential to the keel. The radius of the stem sweep is found to be equal to the sum of the rake and the of the post height. However, it is not clear how the rake was calculated since no Dutch, French or English prescriptions give as result this kind of design. At any rate, the rake of the stem is a bit less of 1/12 of the length on the keel and 1/13 of the length between posts.

The only close contemporary example, of the use for the design of the stem of a large sweep not tangential to the keel and short rake, is found in England (Lavery, 1984). The bow design of a fifth rate vessel drawn by Keltridge in 1684 is actually characterized by the same large sweep and short rake (Fig. 58).

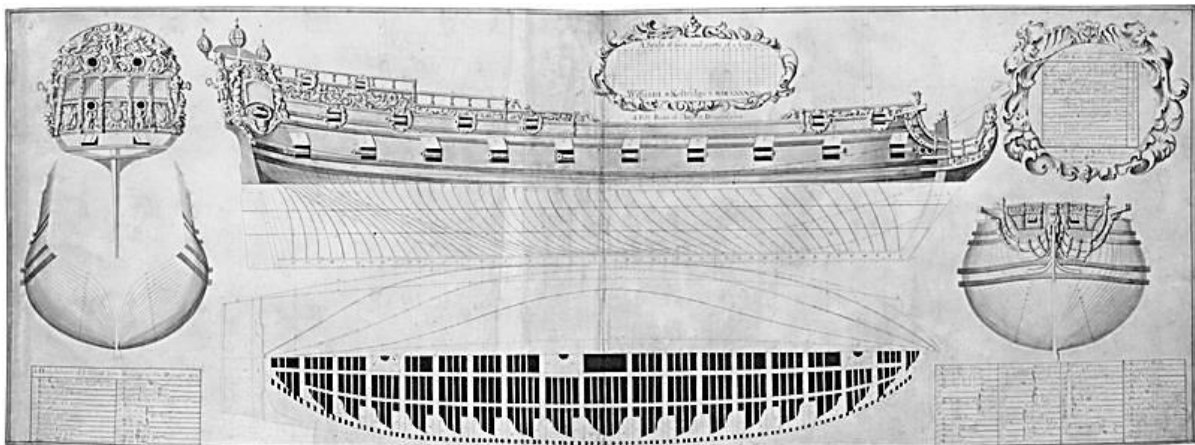


Fig. 58: Body plan, sheer lines, and half-breadth for an unnamed 44-gun fifth rate (circa 1684), drawn by William Keltridge. After National Maritime Museum, Greenwich, London.

At any rate, given the impossibility to directly access the manuscript of Keltridge previously mentioned (see paragraph 6.1.1), the direct comparison of the two methods is not possible.

In the model of *Prinz Wilhelm*, the rake of the stern is only 4.6 cm (1.10 m). As for the stem, prescriptions or formula used in the three major navies do not applies for the model. The rake is found to be  $\frac{1}{3}$  of the rake of the stem, which remind of the French practice after the 1673 establishment where the rake for the stern was found taking  $\frac{1}{4}$  from the rake of the stem (Boudriot, 1993).

Noteworthy is the design of the wales. Only the upper main and sheer wales are intersected by the gun-ports while the lower wales run interrupted from bow to stern. The fact that the last three gun-ports on both deck intersect the upper wales is a characteristics not encountered in other foreign design. Generally in the last decades of the 17<sup>th</sup> century, both in English (Winfield, 1997) and French vessels, the last two gun-ports of the lower deck intersected the upper main wale. Especially for the French vessel this arrangement was explicitly recommended in the regulations of 1673 (Boudriot, 1993).

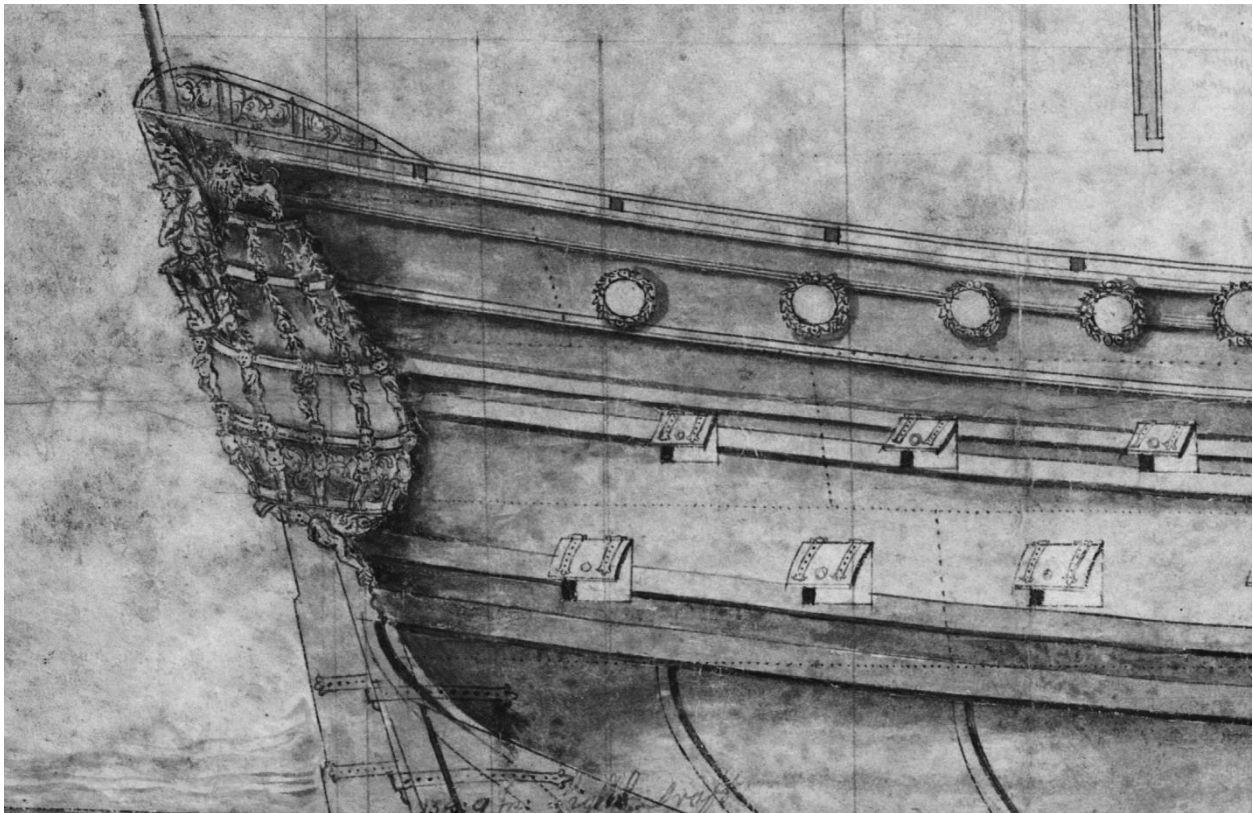


Fig. 59: Detail of the stern from the sheer plan of a 70-gun English warship, probably from the 1677 programme. (RA: Søetaten kort- og tegningssamling: A920)

However, from some drawings of the French naval Architect Coulomb (Fig. 60) after 1680, it seems that the last three lower deck gun-ports were intersecting the lower main wale in major warships (Lemineur & Coulomb, 2007). On the other hand, the French vessels were characterized by an almost straight sheer of the wales compared with the sheer of *Prinz Wilhelm*.

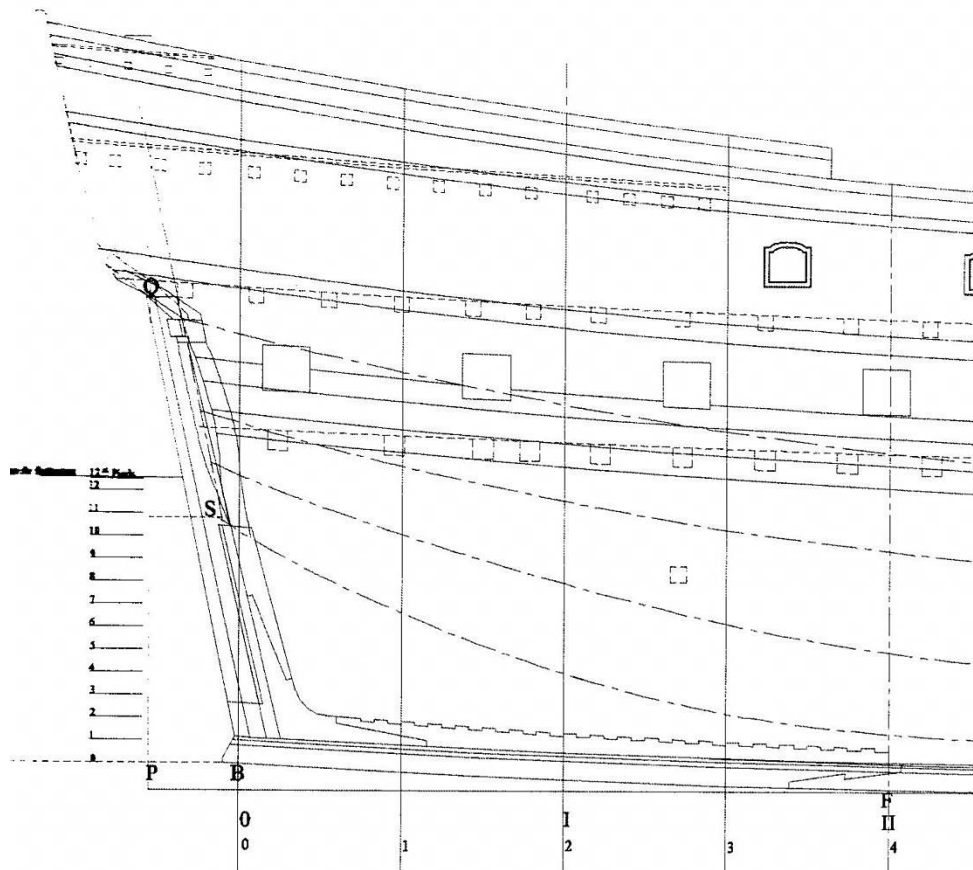


Fig. 60: Details of the sheer from the lines plan of the fifth rate *Le Francois* (1683), as reconstructed by Lemineur from the works of the French naval Architect Coulomb. After Lemineur & Coulomb 2007.

Another trait of *Prinz Wilhelm*, which is not observed in the arrangement of foreign contemporary warships, is the absence of the forecastle deck. Essentially, in the last decade of the 17<sup>th</sup> century for 50 guns vessels, an unarmed forecastle deck was placed both on French and English vessels (Boudriot et al., 1994; Winfield, 1997). Regarding the Dutch warships, given the lack of lines plan, is not clear if a forecastle deck was in place, but based on graphic sources it seems that in the last decades of the 17<sup>th</sup> century the Dutch used to build a forecastle deck on vessel of at least 40 guns (Fox, 1980).

On French and Dutch two-decker, the mizzen mast-step was located on the lower gun-deck, a custom still in use in 1727 (Ollivier, 1992). In England during the 17<sup>th</sup> century, the mizzen mast-step seemed to have been situated on the lower deck as well (Goodwin, 1987). However, as visible on a drawing (Fig. 61) of a fourth rate by the English naval architect Anthony Deane, from his treatise of naval architecture dated 1670 (Deane & Lavery, 1981), it seems that the mizzen mast-step was located down into the hold. The location of the mizzen mast-step in the

model of *Prinz Wilhelm* is on the upper deck and no similar arrangement has been encountered in other European vessels.

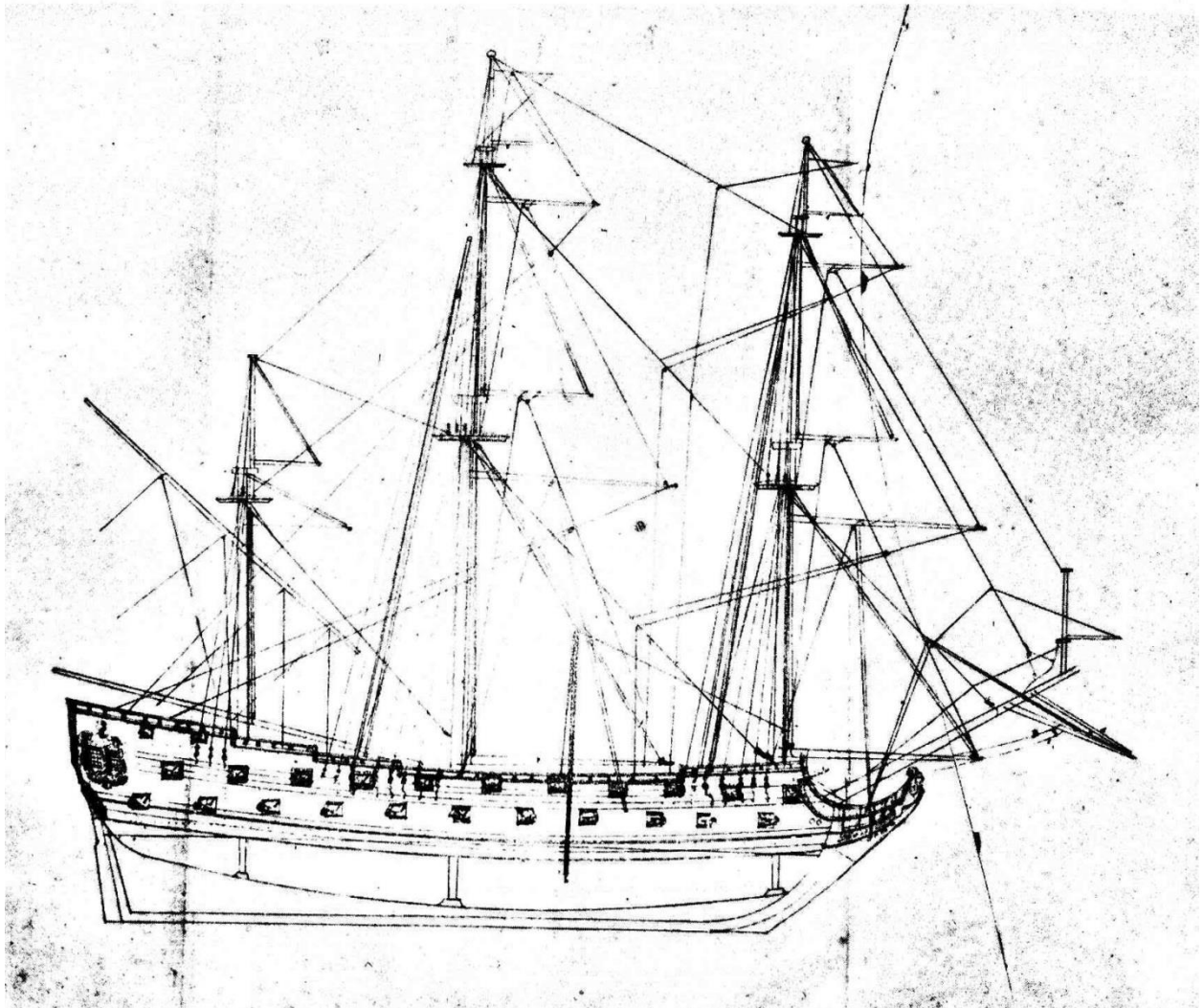
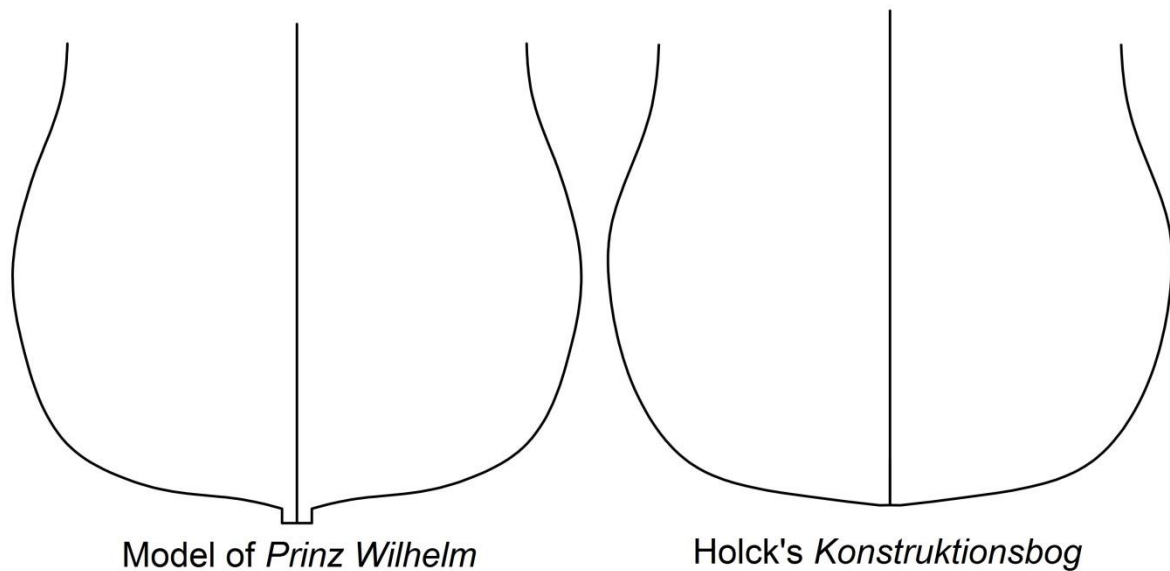


Fig. 61: Sail and rigging plan of a fourth rate from Deane's Doctrine. After Deane & Lavery 1981.

### 6.2.2. A glimpse in Judichær's hull design method

As previously stated, official body or breadth plans are not available for the sister-ships *Prinz Carl* and *Prinz Wilhelm*. At any rate, in Holck's *Konstruktionsbog* (Privatarkiv Holck) within the tables regarding the displacement calculations and the radius for the design of the frames, a body plan bearing the names *Prinz Carl* and *Prinz Wilhelm* was included. It must be said that the author of this essay accessed a facsimile of the *Konstruktionsbog*, as at the moment the original copy cannot be located. In this copy of the booklet, the aforementioned body plan is not included. Hence, the only available graphic source comes from the

article of Probst (1993), *Nordeuropæisk spanteopslagning i 1500- og 1600-tallet*, where also the design principles of the sister-ships are analysed.



**Fig. 62:** Midship section of *Prinz Wilhelm* as recorded from the model and from the *Konstruktionsbog* (not in scale). Ditta 2014.

Although the image from Probst seems to be slightly distorted (Fig. 65), the master section has been traced in order to be used in a simple visual comparison with the recorded midship section of *Prinz Wilhelm*. Looking at the Fig. 62, some considerations are possible. The master section of the model is marginally fuller and with a squarer tumblehome in comparison with the *Konstruktionsbog* section. It must be borne in mind that the lines of the midship section were supposed to represent the shape of the frames (Auer, 2008), thus without taking in account the planking. Given that the section from the model stands for the planked *Prinz Wilhelm*, the thickness of the planking and possible distortions due to the conservation of the model must be taken in consideration as factors in the differences between the two sections. At any rate, the two body lines share strong similarities, especially in the V rising shape of the lower hull.

### *The Design principles*

Therefore, an important question need to be answered, how was the hull shape conceived and designed?

Probst (1993), in the aforementioned article, defined the principles behind the two sister-ships analysing both the table and the draught from the *Konstruktionsbog*. As visible from the sheer plan of *Prinz Carl* and the table for the construction of the sections from the *Konstruktionsbog*, eight sections were defined on the keel. Each station frame was formed by four components: the *underdrag* or deadrise which was a straight line between the station frames 2 and 4 and a sweep for the station frame 6 and 7; the *bugdrag* or floor sweep; the *sidedrag* or breadth sweep and the *overdrag* which defined the sweep of the top timber (Auer, 2008).

	Spant				Spejlet			
	No. 3	No. 4	No. 5	No. 6	No. 7	No. 2	No. 1	No. ½
Halve Viden paa Skiergangen	18	17 9	16 8	15	12	17 9	16 8	15
Huul fra Skiergangen til Kiølen	16	16 5	17 7	19 8	23	16 3	17 1½	17 11
Rejsningen over Kiølen	10	1 2	2 9	7 5		1 7	4 2	6 8½
Skiergangen over Vandlinien	2 8	2 11	4	5 10		3 1	4 1½	5
Sidedragets Radius	27	26 6	25	22 6	18	26 6	25	22 6
Bugdragets Radius	9	9	9	9	8	9	9	9
Overdragets Radius	9	9 4		12 1	16	9 3	9 6	0 5
Underdraget er en ret Linie	Ja	Ja				Ja		
Underdraget er en ret Linie til Rejsning af No. 3 Radius til Kiøl							18	
Underdraget er en ret Linie over Kiølen siden Radius fra Kiøl								8
Underdragets Radius				18	8			
Støttedragets Radius	20	25	30	35		20	20	20
Cronlinien over Skiergangen	12 5	12 6½	12 8	12 11		12 5	12	12 5
Sætter ind paa Cronlinien	3 6	3 7	3 3	3		3 4	3 3	
Sætter ind paa Skiergangen	1 9	2 9	1 8	1 6		1 9	1 8	
Støtter høj over Cronlinien			5 6				2	
Vandlinie til Rejsningen			10 11	6 5	1 6	11 7	8 10	6 2½
Halve Viden paa Cronlinien								12 10

**Fig. 63:** Table from the *Konstruktionsbog* related to the dimensions of the sweeps and other elements for the design of the hull of *Prinz Carl/Prinz Wilhelm*. After Probst 1993.

As seen from the table (Fig. 63), the floor sweep remained constant at ¼ of the master frame width (No. 3), while the breadth sweep was ¾ of each frame's width and was thus reduced following the diminishing width of the frames towards the ends of the vessel (Probst, 1993).

Quoting again Probst (1993), the sweeps were guided by the rising and narrowing of the floor and breadth and subsequently a method analogous to the English second version of the "whole molding", which was used at the end of the 17<sup>th</sup> century. Additionally, Probst states that several models of sweep radii and sweep reductions can be observed from the charts of *Judichær* which were not fixed as for the English design method known as second version of "whole molding". The floor sweep varies between 1/2 and 1/5 of the breadth while the breadth sweep ranges between 5/8 and 1/1 of the breadth of each frame (Probst, 1993).



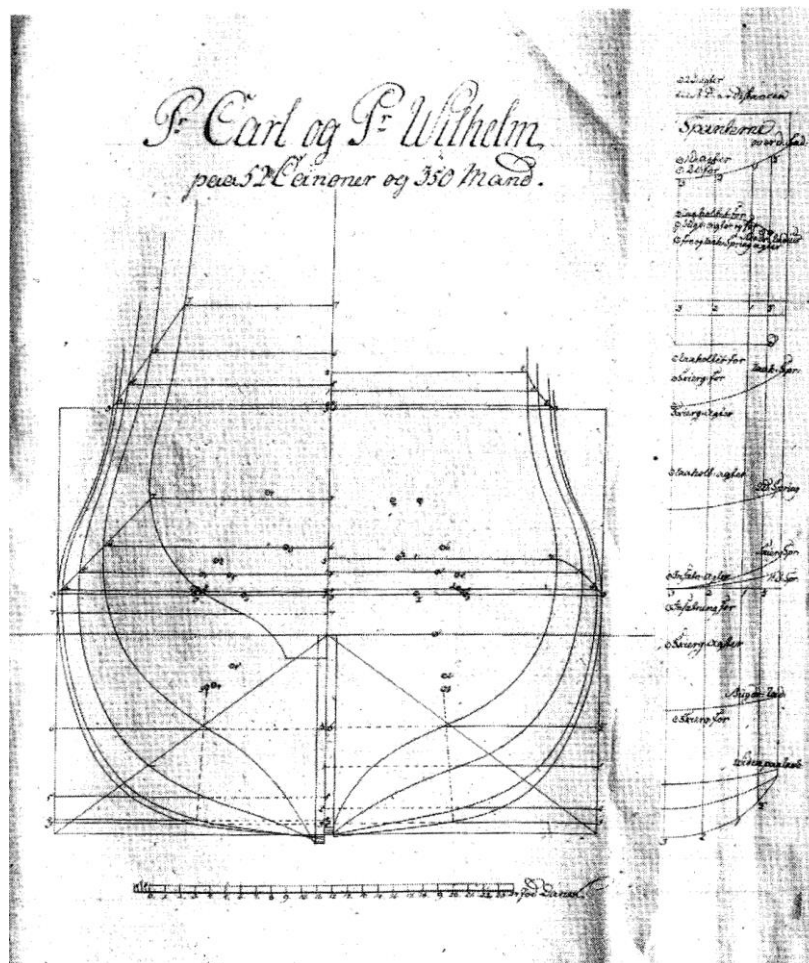


Fig. 65: Body plan of Prinz Carl/Prinz Wilhelm from Holck's *Konstruktionbog*. After Probst 1993.

Moreover, Probst (1993) does not hesitate to bring Judichær's design near to the English method of the second version of "whole molding" where the narrowing and rising lines of the floor and breadth are essential components of the design process. The early version of "whole molding", in use in the 16<sup>th</sup> and early 17<sup>th</sup> century, depended only on the rising-line of the floor and the rising and narrowing lines of the breadth (Lavery, 1984). The earlier method of "whole molding" was gradually abandoned in favour of the second version due to disadvantages in the fairing of the hull and unsuitability for heavy armed ships (Lavery, 1984). The introduction of the new method is difficult to date and the first solid evidence is found in Deane's *Doctrine of Naval Architecture* from 1670 (Deane & Lavery, 1981). As it can be observed in Fig. 66, the rising and narrowing of the floor and breadth were used to guide the sweep along the hull and were the crucial element in the design of the underwater hull (Lavery, 1984). However as stated by Lavery (1984), the use of these lines was a poor basis on which to design a ship since they were theoretical lines that only around amidships coincided with the shape of the hull. Focusing again on the rising-line of the floor, as it can be observed in Sutherland's draught (Fig. 67) and in other several plans of

the period (Lavery, 1984), the projection of the line on the body plan appeared as a diagonal line parallel to another diagonal line which represented the centers for the floor sweeps. This system, which produced a stereotyped hull form, was slowly abandoned only after the half of the 18<sup>th</sup> century (Lavery, 1984).

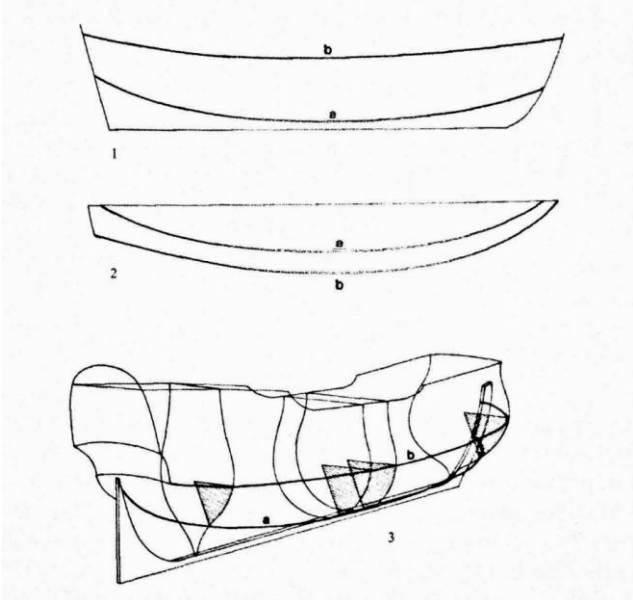


Fig. 66: Sheer (1) and half-breadth (2) plans with rising line of the floor (a) and rising line of the breadth (b); Three-dimensional view showing rising and narrowing lines of floor and breadth. After Hovig & Lemmers 2001.

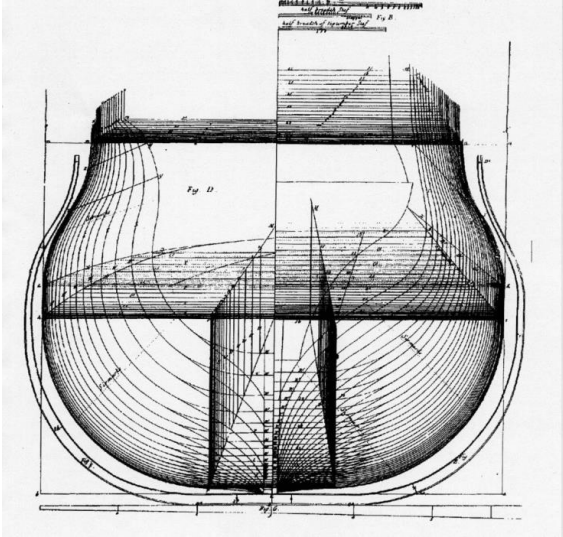


Fig. 67: Body Plan from Sutherland's treatise from 1711. The lower diagonal lines are the narrowing of the floor, while the upper diagonal lines are the lines for centers of the floor sweeps. After Sutherland 1711

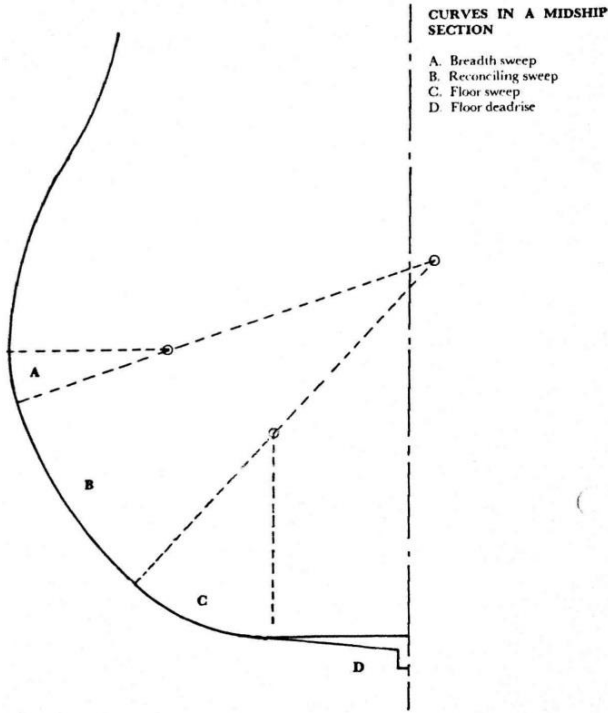
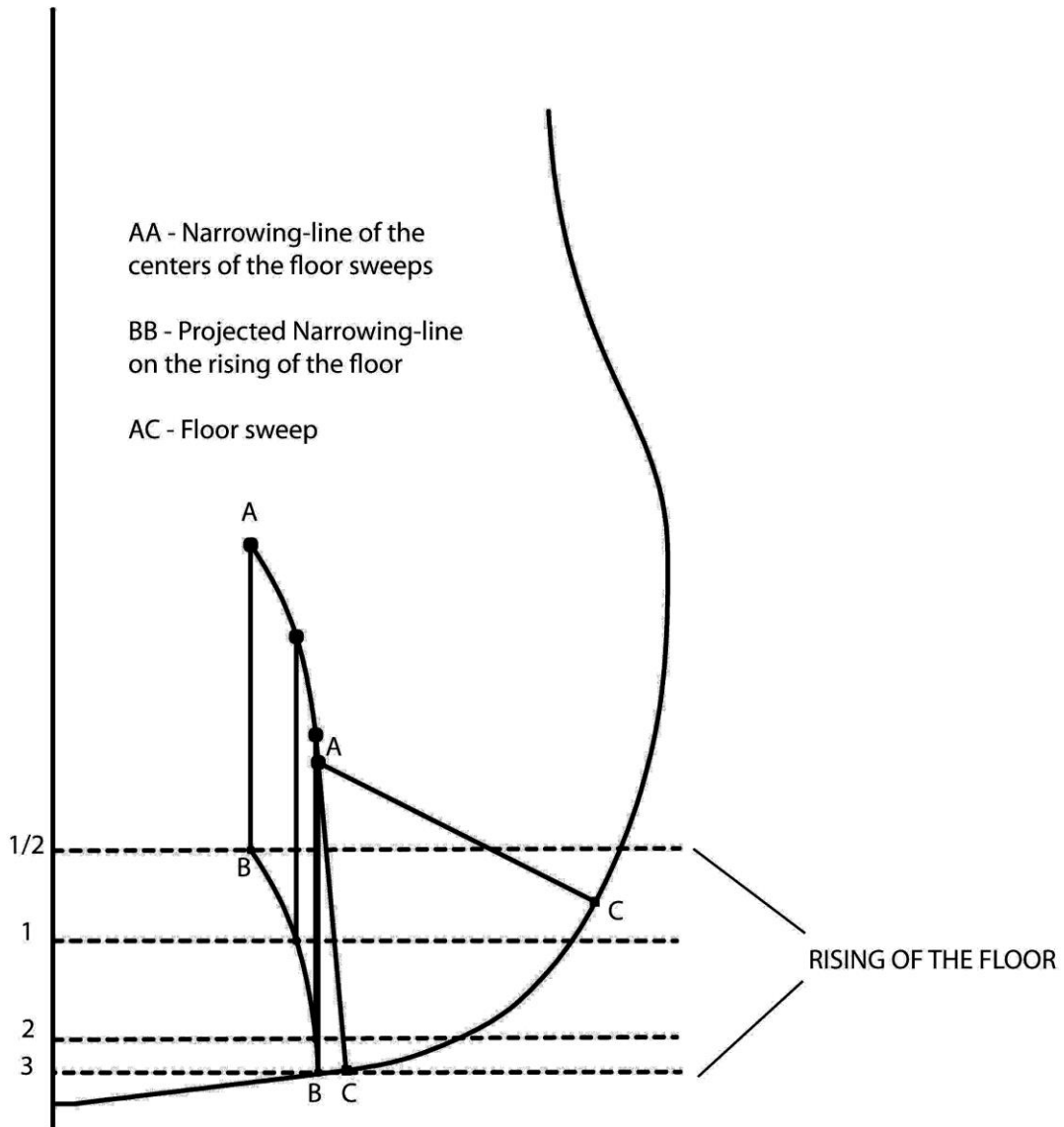


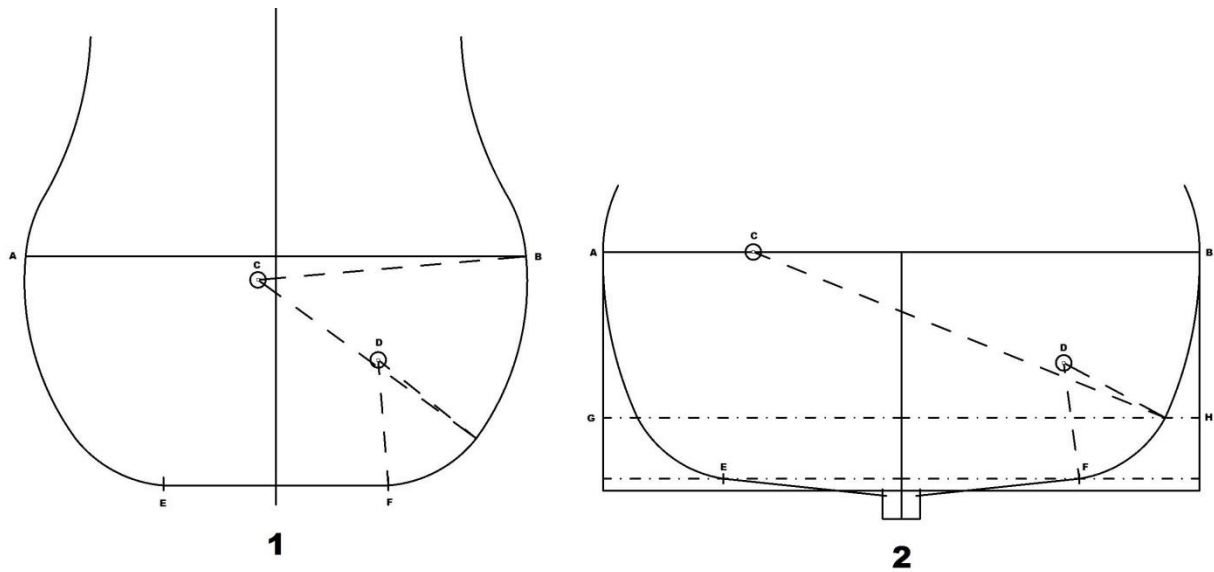
Fig. 68: A typical midship section of an English warship. After Lavery 1984.

On the contrary, nothing similar is encountered in Judichær's hull design. Inspecting again the body plan of *Prinz Wilhelm/Prinz Carl* from the *Konstruktionsbog*, it is possible to observe the centers of the sweeps for the *bugdrag* (floor sweep) and *sidedrag* (breadth sweep). In Fig. 69, the master frame and the *bugdrag* centers for the fore sections have been traced from the body plan and it is evident that the centers of the sweeps are not conceived on a diagonal. The starting point for the master frame *bugdrag* sweep does not touch the drawn rising-lines of the floor and similarly for the *bugdrag* sweeps for the reaming sections, in clear contrast with the English method where the starting point of the floor sweep is perpendicular to the rising of the floor in the point that defines the narrowing of the floor (Lavery, 1984). Moreover, the distance between the rising of the floor and the *bugdrag* centers (AB on Fig. 69) remains constant and is found to be equivalent to the radius of the sweep. Thus, the narrowing of the floor is not defined on the traced rising-line, while a possibility is that the centers of the *bugdrag* were positioned according to a predefined narrowing curve, using the rising-line of the floor for defining their height. In fact, the line BB in the illustration (Fig. 69) should represent the hypothetical narrowing of the floor, a line never conceived neither in the lines plan nor tables. However, it is still unclear how the coordinates for the *bugdrag* were founded and a deeper analysis is necessary.



**Fig. 69:** Midship section of *Prinz Carl/Prinz Wilhelm* with the fore centers of the floor sweeps and rising of the floor. Drawn from the body plan in the *Konstruktionbog*. Ditta 2014.

Another main difference with the English method is found in the designed component of the underwater hull. In fact, since the 16<sup>th</sup> century (Lavery, 1984) the underwater hull was designed by three sweeps: the floor sweep, the reconciling sweep and the breadth sweep (Fig. 68). The centers for the sweeps were defined by a series of proportions related to the breadth and to the narrowing of the floor, starting from the floor sweep and the reconciling sweep as final step (Deane & Lavery, 1981). In contrast, for *Prinz Carl/Prinz Wilhelm* the underwater hull is composed by only two sweeps. Under this aspect, a closer similarity can be found both in the master frame design of the Frenchman Dassié and Witsen.

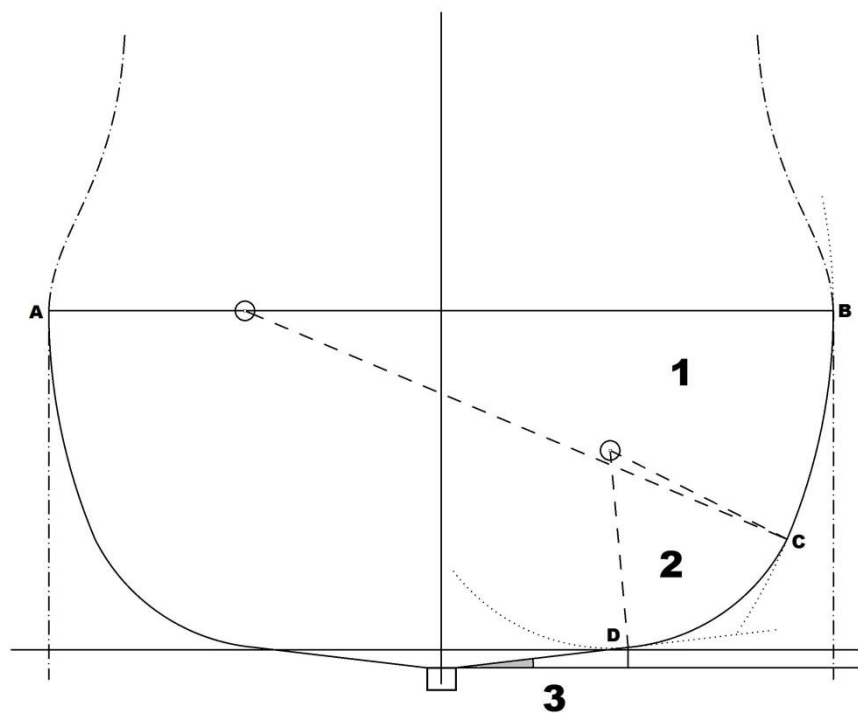


**Fig. 70:** 1) Master section from Dassié; 2) Master section from Witsen. AB –Breadth; C- Center for the breadth sweep; D – Center for the floor sweep; EF – Narrowing of the floor. Ditta 2014.

The work of Dassié first published in Paris in 1677 and known as *L'Architecture Navale* (Dassié, 1677), is considered the first public treatise in naval architecture and shipbuilding matters (Polak, 1976). In the treatise, a method is described for the drafting of a warship with length on the keel of 115 *pieds de roi* (37.36 m). The method of Dassié involves the use of both narrowing and rising of the floor and breadth, which are defined in the early stage of the designing process, and the construction of 14 sections (Dassié, 1677). Using the information from those lines and through a geometrical method which not involves the use of proportions, in the beginning the center for the floor sweep is found and thenceforth the center for the breadth sweep is derived (Fig. 70). Although close to the English second version of “whole molding”, the underwater hull is constructed with only two sweeps and the starting point of the floor sweep is not perpendicular to the rising of the floor.

On the other hand, the method described by Witsen (Fig. 70) is limited to the master frame section (Hoving & Wildeman, 2012). Although there are no proof or evidence that point to the use of a mathematical method on Dutch shipyard and in neat contrast with the shipbuilding practice based on the shell-first approach described by Witsen himself (Hoving & Wildeman, 2012), in his treatise Witsen demonstrates a method for defining the master frame. The starting point for this method is the definition of the breadth, the depth in the hold and the rising of the floor of the master section (Hoving & Wildeman, 2012). Subsequently, the center of the breadth sweep is defined as a proportion of the breadth at  $\frac{3}{4}$ . The breadth sweep is traced down to a bit more than  $\frac{2}{3}$  of the depth (GH on Fig. 70). The

narrowing of the floor is defined as  $\frac{3}{5}$  of the half breadth and traced from the rising of the floor to the keel. The center for the floor sweep is extracted by the narrowing of the floor and the ending point of the breadth sweep, and consequently the floor sweep is constructed. This method is not described in any other contemporary sources and if applied in the construction of the master frame for the *pinas*, which Witsen uses as basis in his treatise, this method produces a different hull shape from the actual drawn section (Hoving & Wildeman, 2012). Moreover, it must borne in mind that Witsen's Treatise is a simple collection of practices and rules of thumb gathered in use in Holland, which was not meant to be used as a prescriptive treatise (Maarleveld, 2013). However, Witsen's method, although only limited to the master frame, shares the same concept of using the narrowing of the floor for defining the starting point for the floor sweep as seen in Dassié and in the English method. However, in the method proposed by Witsen the starting point in the construction is given by the breadth sweep which is found by a mean of proportions and, as well as the method of Dassié, the starting point of the floor sweep is not perpendicular to the rising of the floor.



**Fig. 71:** Hypothetical designing sequence of the master section of *Prinz Wilhelm*. 1) Center for the *sidedrag* found as proportion of the breadth AB; 2) Definition of the center for the *bugdrag* sweep; 3) *The underdrag* is traced according to a pre-established angle at the keel. Ditta 2013.

In the light of the methods previously explained where to place Judichær's method for the construction of the underwater hull?

An easy answer is not possible but surely the method seems closer to Dassié and Witsen, even if Judichær does not seem to define the narrowing of the floor in a conventional manner. Nonetheless, a hypothetical designing sequence can be proposed (Fig. 71). In the case of *Prinz Carl/Prinz Wilhelm*, a fundamental unit for the definition of the radii of the sweeps is the value of breadth, according to an established proportion. Consequently, the first step in the construction of the master frame section would be similar to the method proposed by Witsen where, after defining the breadth and depth of the section, the center of the *sidedrag* is found and traced. Given that the presented methods use the narrowing of the floor as starting point of the floor sweep, in Judichær's method this passage do not seem to apply. Thus as already introduced, a possibility is that the narrowing value for the *bugdrag* is given by the narrowing of the centers on a curve biases using only the rising of the floor to define their height. As last step, the *underdrag* is traced according to a pre-established angle at the keel, as it can be suggested by the lack of intersection between the rising-line of the floor and the *underdrag/bugdrag* encountering point. At any rate, only an extensive analysis of Judichær's lines plans might prove or give further insight in his method.

#### *Some considerations on the origins of Judichær's method*

From the analysis of Judichær's method for the design of the hull, the originality of such approach is clear. Although the originality of the method is recognized, Probst (1993) does not accredit Judichær for it. Indeed, Probst believes that such method is a re-discovery of a long-lived tradition that calls "Continental method". On this basis, Probst (1993) applied the same method to extract the elliptical rising lines for the reconstruction of two believed Dutch built vessels: *Gyldenløve* built in 1670, based on a crude draft of Thomsens, and *Mary* from 1510 using as starting point the wreck of *Gideon*. For the construction of the sections, a series of arbitrary proportions are chosen and the sweeps traced by Probst, even given the impossibility of determining in what manner the centers of the sweeps were found. Eventually, the lines plans of the two arbitrary reconstructed ships are presented as proof of the fact that this method had been already in use long time before Judichær, since their reconstruction was possible. Albeit the well-structured analysis of Judichær's method, through a Pindaric flight Probst comes to poorly based conclusions, as already pointed out by Auer (2008) in his PhD thesis.

Assuming that Judichær did not use a method of his own invention, but derived from a previous practice in Denmark, are available any concrete evidences that can point to this conclusion?

The evidences for the use of a method similar to the one applied by Judichær are found in the lines plans of *Maagen* (RA: Søetaten kort- og tegningssamling: A924), from 1690, and *Dannebroge* (RA: Søetaten kort- og tegningssamling: A930), from 1692, both officially designed by *admiral* Span (Christiansen & Bjerg, 2010). The draught of *Mageen* was approved in September 1690, only two month after Judichær entered in the navy services (Auer, 2008). The number of the sections for the design of the hull is limited to 7 and the draught shows only the rising-line as for Judichær's plans. The rising-line is clearly depicted and it seems to be built with the method of the two quarter of ellipses. According to the analysis of frame section carried by Auer (2008), the underwater hull is built with only two sweeps and the rising-line of the floor does not touch the *bugdrag* sweep. The radius of the *bugdrag* is found to be  $1/3$  of the frame width and the radius of the *sidedrag* is  $2/3$  of the frame width and the sweeps follow the reduction of the width towards stem and stern (Auer, 2008).

The draught of *Dannebroge* shares even closer similarities with the draughts produced by Judichær. For this draught are visible the typical 8 sections, the rising-line and the breadth-line as for Judichær's plans. The rising-line is also constructed with the method used by Judichær of elliptical sections as pointed out by Olesen (2009). Olesen (2009) analysed the design of the frame sections and, also in this case, the underwater hull was found to be constructed by only 2 sweeps. The radii of both sweeps are reduced according to the maximum width at the station and are found to be  $3/4$  of the width for the *bugdrag* and  $1/4$  of the width for the *sidedrag* (Olesen, 2009). Moreover, analysing the midship section, the starting point of the *bugdrag* does not match with the rising-line. Olesen (2009) is of the opinion that such method was a direct application of a Dutch method, in specific the method supposedly invented by Witsen in combination with the English method of the second version of whole-moulding. However as already discussed in the previous paragraph, if Witsen's master frame design recalls the use of the 2 sweeps for the underwater hull, by contrast the conceiving approach behind the Danish method does not observe the use of the narrowing of the floor.

The design of both vessels appears to fit the system of Judichær, given the reduction of the sweeps according to the maximum width at the designed station which is a characteristic found in several Judichær's draughts (Probst, 1993). Moreover, the handwriting of the numbers in the lines plan of *Dannebroge* (1692)

is oddly comparable with the one of Judichær (Fig. 72.) and it can suggest that the plan was drawn by Judichær for Span. Lind (1917) was of the opinion that Judichær actively acted in the design process under Span and concluded that the reason Judichær's name is found on a lines plan only 6 years after the enrolment in the Navy is related to his lack of prestige between the ranks.

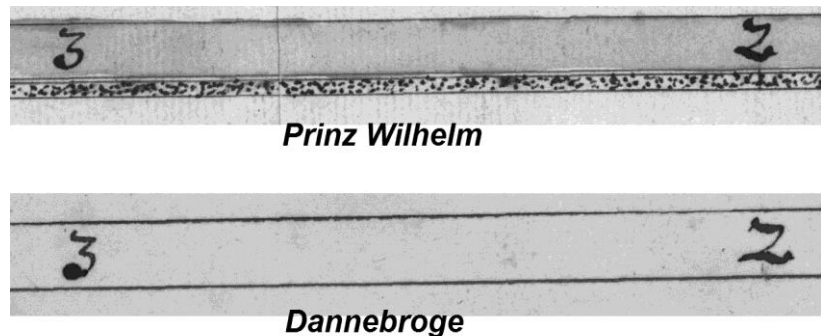


Fig. 72: Comparison between handwritings of the section numbers on the keel, as found on the sheer plan of *Prinz Carl/Prinz Wilhelm* (RA: Søetaten kort- og tegningssamling: A992) and the sheer plan of *Dannebroke* (RA: Søetaten kort- og tegningssamling: A929). Ditta 2014.

A noteworthy episode, which involved Judichær when was already acting as naval architect, can support this interpretation. As already introduced (see paragraph 3.3), in 1705 after the inspection of the fleet, Frederick IV ordered a commission to answer at several enquiries, among them also to examine “*Efter hvilken Regel og paa hvad for it fundament voris Schibsbbygning nu er indrettet*” (RA: Søetaten: Søkrigskancelliet 1705a, 66). Several members of the commission were not fond of Judichær's design. Especially rear *admiral* Sehested criticised Judichær's lack of nautical experience:

“...*Command. Judicker hafv læst sin Skibbygning mossen af sig self og udaf bögger*” (RA: Søetaten: Søkrigskancelliet 1705b, 66)

And he judges Judichær as:

“*Een Nütteling og goed Mand, og at hand hafver mange geode Fundamenter, som han forstaar Mathecaticken og Mechanicken ofuermaade vel, men som hand er ingen Siömand, og var aldrig uden for Øster Siöen eller Cattedattet med mit vidne, saa har hand aldrig haft Leylighed at see huad bevegninger een huer Slags proportion af Skibe var undergiefue udi Storm or huult vand..*”

Indubitable, Judichær was a man of his time and the answer of the choices behind his method probably lays in his scientific background and the scientific influences of the period.

Judichær is considered the first Danish Naval architect to have introduced for the first time in Denmark, volume calculations for the designed ships and consequently waterlines in the lines plan (Probst, 1993). Judichær began indicating the drafts and

displacements of his designs with the draught of *Prinz Carl/Prinz Wilhelm*. However, the best example is visible in his plan for the 90-gun *Elephanten* from 1702 (RA: Søetaten kort- og tegningsssamling: A924). In the plan is visible the notes of the drafts at three different displacements: launch, “best cruise,” and full load of 1,420 *lasts*. Although the method used for these calculations is unknown, Ferreiro (2010) suggests that Judichær probably used a method similar to Deane’s method of inscribed triangles, as certainly done by his successor Knud Benstrup. Judichær probably learned how to calculate the displacement of a hull by his mentor Ole Rømer (Bjerg & Erichsen, 1980). As already introduced, Rømer was appointed advisor for the *KommerceKollegiet* in 1681, when the King demanded to establish an easy method to estimate ship displacement for taxation (Friedrichsen & Olsen, 2004). In a letter dated 18<sup>th</sup> October 1684 (Friedrichsen & Tortzen, 2001) between the scientist and the *Oberrentemester* Peter Brandt, Rømer clearly states the advantage of the method suggested by Witsen in his book from 1671. Moreover, in a letter dated 15<sup>th</sup> November 1684 addressed to the king, Rømer presented an essay in 5 points where in the last point discussed on the subject of the Archimedes’s principle (Friedrichsen & Tortzen, 2001). The knowledge of the Archimedes’ principle is found also in the already mentioned memorandum of Judichær to the Admiralty as reply to the king’s enquiry of 1705.

Frederick IV, in the document from the 14<sup>th</sup> July 1705 (RA: Søetaten: Søkrigskancelliet 1705a, 66) addressed to Judichær the following question:

*“Med sin ande at overbygge, om icke een Methode er at udfinde at voris Schiibe liige saa drægtig være og liigesaa mange Canoner og af liige Calibre före kunde, som nu, og dag icke at gaa saa dybt..”*

The young naval architect, before answering to king’s enquires, gave a scientific explanation in four points:

*”At alle Solida som svimmer i Vand trycker saa mange (...)Vand af sin stad som de selv vejer.*

*eller et Skib vejer saa meget som dend Cubus Aqvæ des borttryckes.*

*dend Cubus Aqvæ som borttryckis er saa stor som Cubus af Skibet under Vandet.*

*Jo saltere Vandet er jo tyngere. Hvilcket gör nogen Differentz, imellem Skibetz dragtighed udi dend Spanske Siöen og Øster Siöen, og er ungefehr imod hinanden som 25 til 26 saa et Skib hvis Corpus Cubicum under Vandet er 1500*

*(...) og ster kand bære udi Spanske Siöen, over 50 Laster meere end udi Øster Siöen som drags til Confideration ved Skibbyggeriet hos os, helst efter dj Øster Siöen, hvor Hans Maj. Flaade mest Reguleris paa, nærmest kommer overeens med det ferske Vand, hvorfor mand ved Skibsberegningen an gros bis dato har brugt 64 Cubic Fod paa hver Last, hver Last till 4000 (...) beregnet udi Vegt...”*

Clearly, Judichær was aware of the volume as the cause behind the floatation of a vessel and even aware of the effect of the salinity of the water on the sinkage of the vessel, consequently falling into the category of erudite minds who recognized the fallacy of the Aristotelian theory on the buoyancy of bodies. Aristotle ascribed the consequence of the sinking or rising of a body in the water to the density of the material, a theory which was in vogue alongside with Archimedes’s principle at the end of the 17<sup>th</sup> century and appreciated by several naval architects (Ferreiro, 2009).

Why did a mathematician, who was able to perform calculation for the displacement of the hull with a solid background in the theory of buoyancy, use a design method for the hull not influenced by his background? The use of the segments of an ellipse for the tracing of the rising-line can offer a stimulus for reflection.

Although several Italian renaissance architects already used the elliptical shape in their construction, the European civil architects of the seventeenth century conceived a passion for the elliptic forms, which was imitative of the mathematical and astronomical enthusiasm for this geometrical figure (Proia & Menghini, 1984). In astronomy, starting from Copernicus’s heliocentric theory at the end of the 16<sup>th</sup> century, the focus moved on the form of the orbit of planet. Kepler after reconstructing the orbit of Mars, with the help of the observations of the eminent Danish astronomer Tycho Brahe, came to the conclusion that the only possible form had to be elliptical (Mazer, 2011). These ideas reached the Italian milieu, both through Kepler’s works and through direct contacts with Galilei (Proia & Menghini, 1984). Contemporary to the banishment of the works of Kepler, Copernicus and Galilei in 1616, Italian architects started to develop an interest for this elliptical form as possible result of the resonance of these works (Proia & Menghini, 1984). However, during the high Baroque and late Baroque the oval shape started to be used in architecture which was considered as the approximation of the ellipse (Fernández, 2008). At the same time, the ellipse is always found in building treatises of the seventeenth century, but it was rarely used because of the difficulty of reproducing it (Fernández, 2008). The ellipse was conceived through

the help of triangles and circles (Guillerme et al., 1989) while the geometrical difficulties of laying out an oval were solved by the simplest methods, which were close in approximation to the ellipse but more practical (Fernández, 2008). Indeed, the complication of the geometry was always tempered by the common sense of the builder and the necessity of quickly erect a solid structure (Fernández, 2008).

In the 17<sup>th</sup> century England, a long debate started among shipwrights about the best form for the rising-line of the floor. In a treatise from 1628 of an anonymous shipwright, the ellipse form, extracted by a mathematical method using trigonometry, is suggested as the most suitable (Lavery, 1984). At any rate given the lack of early lines plans, for the rest of the 17<sup>th</sup> century the elliptical rising-line does not seem to be proposed again. At the end of the 17<sup>th</sup> century, Sir Anthony Deane adopted a mechanical approach (use of sweeps) since the circle was used for the rising-line (as well for the rest of the hull), which according to Deane's words was found to be the best shape after he tried both elliptical and diminishing (Deane & Lavery, 1981).

In the contemporary France, for a short period the use of the ellipse in naval architecture went behind the rising-line. In 1680, for the first time the method of Louis XIV's engineer Renau d'Élissagaray was applied for the construction of a man-of-war (Vérin, 2008). Renau's method was the result of a long debate regarding the best shape for the hull of a vessel which blazed between mathematician and naval "engineers" in the last decades of the 17<sup>th</sup> century (Ferreiro, 2010). The royal engineer came to the conclusion that the best ship form had to be an ellipse and elaborated his own method for the design of the hull, where segments of ellipse had to be used. The curves were designed through the use of a special ellipsograph, after established reference points for each curve and a long set of algebraic equations for the machine (Brioist & Vérin, 2008). As stated by Ferreiro (2010), Renau's arguments were founded in the most current mathematical ideas of his day. Indeed, the Royal engineer obtained from the works of Descartes the idea of the "geometrical curve" as opposed to a "mechanical curve" (Ferreiro, 2010). According to Descartes's definitions (Descartes, 2007), a geometrical curve can be constructed by an algebraic equation or by the operations of elementary geometry, while a mechanical curve is resulting from the use of an instrument. Thus, Renau's ellipses were the result of equations and exemplification of "geometrical curves" from Descartes, not the practical "mechanical curves" that could actually be drawn by the mean of sweeps (Ferreiro, 2010). However, albeit the construction of several frigates and the successful 56-gun *Le Bon* (Vérin, 2008), Renau's method was abandoned. The problem was the inconvenience of a

full scale ellipsograph and the mathematical knowledge required to work out the equations for the French constructors which, albeit were highly trained with practical knowledge of arithmetic and geometry, often had little formal education and the mathematical basis necessary for this method theory was far beyond a practical approach (Ferreiro, 2010).

In this outlook, the method used by Judichær can be placed in a middle ground. In this method are found both mechanical and geometrical curves in the Cartesian meaning. The frame section for the hull is evidently traced by the means of sweeps, thus a mechanical curve and consequently of easy construction for the master shipbuilders, while the rising-line of the floor (which was not a line to replicate on the shipyard) is conceived as a geometrical curve, as is found by the mean of analytic geometry and not simply traced by an instrument. The elliptical shape is a constant of the 17<sup>th</sup> century civil architecture which probably seeped into the naval architecture milieu. However, the segments of ellipse traced by Judichær do not belong to the early baroque tradition, traced by the mean of sweeps and triangles, or to the trigonometrical approach proposed in 1628, but to the Cartesian geometry. This is not surprising since Judichær had knowledge of Descarte's works (see paragraph 3.3) and he was possibly aware of the French scientific debacle, from which emerged Renau d'Élissagaray, through his mentor Rømer, member of the French Academy of Sciences until 1681 (Friedrichsen & Olsen, 2004).

To conclude, at the actual state of the evidences here presented, it appears clear that the method applied by Judichær cannot belong to an older tradition as suggest by Probst (1993) and, thus, cannot be applied in the reconstruction of a 1514's vessel. Judichær's method is fruit of his time, with possible French and Dutch influences but definitely outstanding from the contemporary practices applied in North Europe.

## 7. Conclusions

At the end of this explorative study, many topics have been touched and for the sake of clearness, a summary is needed to answer the questions to which this thesis is aimed towards.

### 7.1. The *Konstruktionsmodell* of Prinz Wilhelm

There is no doubt that the Danish *konstruktionsmodeller* are a unique collection in international context. Indeed, if the characteristics of the Danish models recall in some degrees the French *modèles de conception*, it must be reminded that in France the first evidences for the request of a model before the construction of the ship is dated 1678, eight years after the Danish King's instruction of 25<sup>th</sup> June 1670.

Therefore, the Danish *Konstruktionsmodeler* were not items of prestige or built year after the construction of the vessel, as it is suggested for the Navy Board models, but are a three dimensional arrangement and construction plan. In fact, from the early documentations it appears that the Danish models were built before the ship and used as support in the construction process, as visual tool, and used as reference to check the similarity of the construction carried on the shipyard with the approved project. Moreover, as it is suggested by the King's and Judichær's letters from 1705, the models are reliable copies of the future ships. Each timber is replicated in scale on the model and can be analysed when necessary. A strong point in favour of this idea is the scantlings of the framing of *Prinz Wilhelm*.

Thus, it appears clear that the model of *Prinz Wilhelm* was built with the purpose of showing the constructional details of the future vessels. The legal binding value that both models and lines plan had cannot be ignored. Indeed, other evidences on the fact that the model of *Prinz Wilhelm* had to be a reliable copy of the ship is found in the comparison with the lines plan of other vessels designed by Judichær, given that several elements visible on the model are found as well on the lines plan.

For these reasons, the model of *Prinz Wilhelm* and, consequently, the other *Konstruktionsmodeller* can be fully considered an informative source on the shipbuilding practice employed in the shipyard.

## **7.2. Shipbuilding and ship design during the nationalisation period: influences, adaptations, and originality**

From the comparative analysis of the construction of the model of *Prinz Wilhelm* with the practices in three major North European Navies, the result can be summarized in a strong presence of elements adopted from the Dutch and French tradition, combined with elements of originality.

Although the richness of details shown by the model of *Prinz Wilhelm*, it remains unclear if the timbers composing the double frames were laterally fastened to each other. As it has been discussed, the framing system of *Prinz Wilhelm* closely recalls the contemporary French practice, both in the adoption of three futtocks and small space which separates each double frame. Thus, these similarities in the construction with the French practice, can suggest the possibility of lateral fastening. However, elements of originality are also present. Indeed, if the master section is composed by a sort of triple frame as found on the French vessel *La Belle*, the changing of the framing pattern fore and aft the master frame, has not been documented in other shipbuilding tradition. This arrangement was probably already in use before 1695, as suggested by the model of Sheldon from 1690, but at actual state of the evidences it can be considered a Danish feature.

On the other hand, strong Dutch influences are found in the construction of the keel and related structures, and the hold. Indeed, the scantlings of the keel and the planks seem to have been found using the formula prescribed in Witsen's treatise, which was already known in Denmark since its first edition as discussed during the analysis of the design (see paragraph 6.2.2.). Although the constructions visible in the hold appear Dutch influenced, from the keelson to the *kattespoor*, the scantlings of the timbers result to be larger than the prescriptions found in Witsen. Moreover, the presence of the two diagonal riders at the bow is an outstanding feature which is not found in literature and could be considered a Danish element.

Another element of originality is found in the carlings and ledges system visible on the lower deck. Indeed, the construction of these reinforcing structures is not directly comparable with known practices of the period. Moreover, still on the lower-deck a French influence is found in the adoptions of mid-binding strakes.

Although the clinker planking of the upper works of the quarter and poop deck and the high stern construction are typical Dutch traits, the general

appearance of *Prinz Wilhelm* has persistent French traits, especially in the stern decorations and in the sheer of the wales. However, the arrangement found in *Prinz Wilhelm* cannot be easily compared with the other European vessels. Indeed, the absence of a forecastle deck for a ship of the size of *Prinz Wilhelm* is not observed in other navies, as well as the positioning of the mizzen mast-step on the upper-deck.

The design of the stern and stem of *Prinz Wilhelm* is not directly comparable with the design in use in other country. Beyond doubt, the rakes of the stems are found to be smaller compared with the Dutch, English, and even French design. However, the design of the stempost closely recalls the drawings of the English shipwright Keltridge from 1680's, although further investigations are needed to establish this similarity.

From the analysis of Judichær's method for the design of the hull, the originality of such approach is clear as well as the authorship of Judichær. Although the underwater hull is conceived with the use of two sweeps like Dassie's and Witsen's designs, the use of the rising-line definitely sets apart this method from the methods known, and even further from the English tradition.

Indeed, the use of the ellipses is precisely the element that points to the attribution of this method to Judichær, and also to its originality. The elliptical shape is a constant of the 17<sup>th</sup> century civil architecture which probably seeped into the naval architecture milieu. However, the segments of ellipse traced by Judichær do not belong to the early baroque tradition but to the Cartesian geometry. This is not surprising since Judichær had knowledge of Descartes's works, and he was possibly aware of the French scientific debacle on the ellipses as most suitable shape for a vessel, through his mentor Rømer. Thus, Judichær found a middle ground between the mechanical and geometrical curves of Descartes. The frame sections for the hull are evidently traced by the means of sweeps, thus a mechanical curve, while the rising-line of the floor is conceived as a geometrical curve, as is found by the mean of analytic geometry and not simply traced by an instrument.

Thus, Judichær's method is fruit of his time, with a possible French and Dutch influence but definitely outstanding from the contemporary practices applied in North Europe.

To conclude, a differentiation is noticeable between the Danish naval shipbuilding practice and design practice at the end of 17<sup>th</sup> century. The long

tradition of employing Dutch shipbuilders has left strong influences in the Danish Dockyard and, strangely enough, Sheldon and the earlier English shipwrights seem to have left no inheritance in the building practices. In the construction of *Prinz Wilhelm* are found several elements linkable to the Dutch shipbuilding sphere with a high degree of adaption. On the other hand also French elements are found, especially in a key feature like the framing and in several features of the design. This can suggest an influence coming from above, maybe imported by officer trained in France as stated by Holck (1939). For the design method of the hull, instead the situation appears different since the influences are lying on a theoretical level and applied in practical and original design.

A similar case that exemplifies the situation of *Prinz Wilhelm* is found in the wreck of the Swedish 80-guns *Prinsessan Hedvig Sophia* built in 1692. Although the ship was built by the Englishmen John Francis Sheldon the younger, a member of the Sheldon dynasty, at the end of the two excavation missions the construction was found heavily Dutch influenced (Auer & Schweitzer, 2011; Auer & Schweitzer, 2012). Thus, if the Swedish preferred to build ship with an English appearance (Jakobsson, 1999), conversely for its structure the situation was different. Instead, to the Danish *Prinz Wilhelm* was given a French look merged to a Danish original design, while for its construction Dutch and French elements were preferred, although with some adaptations and even introduction of new construction elements.

### **7.3. Final remarks and recommendations for further works**

At the end of this preliminary study, several questions, encountered during the analysis of the model and design of *Prinz Wilhelm*, have not found definitive answers and new questions arose.

Regarding the model, still remains unclear when the actual model was build, if before the approval of the lines plan or soon after the approval, and before the laying of the foundation on the dockyard. As well as, the presence or not of lateral fastened joints between the timbers remains unclear.

Additionally, a comprehensive comparative analysis of the design and proportions between other European 50-gun warships and *Prinz Wilhelm*, through the compiling of ship lists and the creation of index tables, could better explain the differences of the Danish design. The same situation is valid for Judichær's design

method. Indeed, a deeper study into Judichær design could clarify the system behind it and how the centers for the sweeps were actually defined.

Throughout the study of this thesis, an acute lack of well-documented archaeological material has been noted for the end of the 17<sup>th</sup> century, both Danish and international. Indeed, although the existence of archaeological sites which could unveil information on shipbuilding such as the site of *Dannebrog*, the attention is often focused only on the study of the artefacts. If this thesis demonstrates that a great deal of information can be learned from historical documents and ship models preserved in the National Danish Archive and Royal Danish Naval Museum, only adding into the equation a careful archaeological analysis of preserved shipwrecks would lead to more consistent conclusions on the construction of the vessels during the period of nationalization. In the course of the surveys on the model of *Prinz Wilhelm*, other models of ships built under Judichær have been envisioned and several different approaches in the construction of the framing and deck structures have been noticed. Thus, given the value of these models as complementary archaeological evidences, a wider study integrating *Konstruktionsmodeller*, lines plans and historical documents, and archaeological evidences from shipwrecks could result in a description of the evolution and changes in shipbuilding practices in the Danish Dockyard as well as the underlying design methods. This could lead to a reconstruction of the *chaîne opératoire* of a Danish warship, from its conceiving to the final craft, passing through the study of the raw materials and the constructional techniques applied.

## 8. References

### *Abbreviations*

RA = Rigsarkivet, Danish National Archive, Copenhagen.

### *Archival sources*

RA: Orlogsværftets aflevering 1945, gruppe 'Personel og materiel' nr. 5B: *Inventarium over modellerne, liste over modeller af skibe, dokker m.m., 1700 ff*

RA: Søetaten: Admiralitetet Kongelige resolutioner. 11 Marts 1690, 1

RA: Søetaten: Fabrikmesteren på Holmen Sager vedrørende skibsbyggeri, Copi af Judichærs svar til Skibsbygningskommissionen 1705. 1700-1800b, 24

RA: Søetaten: Søkrigskancelliet Kongelige ekspeditioner, Søetaten vedkommende, 117. 1705a, SK66

RA: Søetaten: Søkrigskancelliet Kongelige ekspeditioner, Søetaten vedkommende, 149. 1705b, SK66

### *Ship plans*

RA: Søetaten kort- og tegningssamling: A1169II

RA: Søetaten kort- og tegningssamling: A1230II

RA: Søetaten kort- og tegningssamling: A738

RA: Søetaten kort- og tegningssamling: A853

RA: Søetaten Kort- og tegningssamling: A904

RA: Søetaten Kort- og tegningssamling: A907

RA: Søetaten kort- og tegningssamling: A910

RA: Søetaten kort- og tegningssamling: A914

RA: Søetaten kort- og tegningssamling: A920

RA: Søetaten kort- og tegningssamling: A924

RA: Søetaten kort- og tegningssamling: A929

RA: Søetaten kort- og tegningssamling: A930  
RA: Søetaten kort- og tegningssamling: A942I  
RA: Søetaten kort- og tegningssamling: A992  
RA: Søetaten Kort- og tegningssamling: H32  
RA: Søetaten Kort- og tegningssamling: H33  
RA: Søetaten kort- og tegningssamling: nr. 316, 1692

### *Bibliography*

- Agnello, F. & Brutto, M.L. (2007) Integrated surveying techniques in cultural heritage documentation. In: *Proceedings of ISPRS International Workshop 3D-ARCH on 3D Virtual Reconstruction and Visualization of Complex Architectures ETH, Zurich, Switzerland*. pp.141–147. Available from: <<http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.153.6050&rep=rep1&type=pdf>> [Accessed 19 November 2012].
- Alberti, L.B. & Tappe, E. (1541) *De re aedificatoria libri decem*. Argentorati [Strasbourg]: excudebat M. Iacobus Cammerlander Moguntinus. Available from: <<http://archive.org/details/dereaedificatori00albe>> [Accessed 13 February 2014].
- Anderson, R.C. (1921a) Comparative Naval Architecture. *The Mariner's Mirror*, 7 (10), pp.308–315.
- Anderson, R.C. (1921b) Comparative Naval Architecture, 1670–1720. *The Mariner's Mirror*, 7 (2), pp.38–45.
- Anderson, R.C. (1953) The Framing of Models. *The Mariner's Mirror*, vol. 39.
- Anderson, R.C. (1954) The framing of models - and of actual ships. *Mariner's Mirror*, 40 (2), pp.155–156.
- Auer, J. (2008) *Fregat and Snau: Small Cruisers in the Danish Navy 1650-1750*.
- Auer, J., Ditta, M. & Logan, M. (2012) *Esbjerg Maritime Survey Reports 1. Survey Report: Cuxhaven BSH-Nr. 1557*. Maritime Archaeology Programme, University of Southern Denmark, Jens Auer. Available from: <[http://www.academia.edu/1242007/Esbjerg\\_Maritime\\_Survey\\_Reports\\_1.\\_Survey\\_Report\\_Cuxhaven\\_BSH-nr.\\_1557](http://www.academia.edu/1242007/Esbjerg_Maritime_Survey_Reports_1._Survey_Report_Cuxhaven_BSH-nr._1557)> [Accessed 20 November 2012].

- Auer, J. & Schweitzer, H. (2012) *Fieldwork report Prinsessan Hedvig Sophia 2011*. Maritime Archaeology Programme. Available from: <[http://findresearcher.sdu.dk:8080/portal/en/publications/fieldwork-report-prinsessan-hedvig-sophia-2011\(9411f445-eed9-4160-bc9c-cd0816a65342\).html](http://findresearcher.sdu.dk:8080/portal/en/publications/fieldwork-report-prinsessan-hedvig-sophia-2011(9411f445-eed9-4160-bc9c-cd0816a65342).html)> [Accessed 4 March 2014].
- Auer, J. & Schweitzer, H. (2011) *Prinsessan Hedvig Sophia: Fieldwork Report 2010*. Maritime Archaeology Programme.
- Baker, W. (1954) More on the framing of models. *Mariner's Mirror*, 40 (1), pp.80–81.
- Barfod, J.H. (1989) Bygning af orlogsskibe i Norge i slutningen af 1600-tallet. *Maritim Kontakt*, 13, pp.5–15.
- Barfod, J.H. (1997) *Niels Juels flåde*. Gyldendal A/S.
- Batchvarov, K.N. (2002) *The Framing of Seventeenth-century Men-of-war in England and Other Northern European Countries*. Texas A & M University.
- Bjerg, H.C. (2010) *A History of the Royal Danish Navy 1510-2010*. Statens Forsvarshistoriske Museum.
- Bjerg, H.C. (1973) Den første bog på dansk om skibsbygning. *Årbog / Handels- og Søfartsmuseet på Kronborg*, 32, pp.140–144.
- Bjerg, H.C. & Erichsen, J. (1980) *Danske orlogsskibe 1690 - 1860*. Lademann.
- Boudriot, J. (2000) *'La Belle', 1684*. J. Boudriot.
- Boudriot, J. (1978) Le Royal, modèle d'instruction de Rochefort. , 132.
- Boudriot, J. (1973) *Le vaisseau de 74 canons; traité pratique d'art naval*. Grenoble, Editions des Quatre seigneurs.
- Boudriot, J. (1998) *Le vaisseau Trois-ponts du chevalier de Tourville, précédé de: Mélanges sur l'architecture navale française au XVIIe siècle*. Paris, J. Boudriot.
- Boudriot, J. (1992) Modèles et architecture navale. *Neptunia*, 186 (2), pp.20–23.
- Boudriot, J. (1997) *Modèles historique au Musée de la Marine*. Paris, ANCRE.
- Boudriot, J. & Berti, H. (1995) *Les vaisseaux de 74 à 120 canons: étude historique, 1650-1850*. Paris, A.N.C.R.E.
- Boudriot, J., Berti, H. & Bigot de Morogues, S.F. (1994) *Les vaisseaux de 50 et 64 canons: étude historique, 1650-1780*. Paris, A.N.C.R.E.

- Boudriot, J., Berti, Hubert (1993) *The history of the French frigate, 1650-1850*. Rotherfield, J. Boudriot.
- Boyd, N.N. (2001) *The Model Ship: Her role in History*. Antique Collectors Club.
- Bragenes, L. (1723) *Een liden Søe-Architectur*.
- Bricka, C.F., Laursen, L. & Steenstrup, J. (1887) *Dansk biografisk Lexikon*. Kjøbenhavn, Gyldendalske Boghandels Forlag (F. Hegel & Søn). Available from: <<http://runeberg.org/dbl/8/0556.html>> [Accessed 21 June 2013].
- Brioist, J.-J. & Vérin, H. (2008) Mémoire sur la construction des vaisseaux dans lequel il y a une méthode pour en conduire les façons. *Documents pour l'histoire des techniques. Nouvelle série*, (16), pp.143–168.
- Carr Laughton, L.G. (1925) The study of Ship Models. *The Mariner's Mirror*, 11 (1), pp.4–28.
- Chadarevian, S.D. & Hopwood, N. (2004) *Models: The Third Dimension of Science*. Stanford University Press.
- Christiansen, H. & Bjerg, H.C. (2010) *Orlogsflådens skibe gennem 500 år: den dansk-norske flåde 1510-1814 og den danske flåde 1814-2010*. Statens Forsvarshistoriske Museum.
- Christoffersen, J. (1990) Nyt om vraget af orlogsskibet dannebrog. *Maritim Kontakt*, XIV, pp.55–63.
- Colbert, J.B., France, Service hydrographique et océanographique de la marine & Chateau de Vincennes (Vincennes, F. (1988) *Album de Colbert, 1670*. Nice, Omega.
- Dassié, F. (1677) *L'architecture navale, contenant la manière de construire les navires, galères et chaloupes, et la définition de plusieurs autres espèces de vaisseaux*.
- Deane, A. & Lavery, B. (1981) *Deane's Doctrine of naval architecture, 1670*. London, Conway Maritime Press.
- Descartes, R. (2007) *The Geometry of Rene Descartes*. Cosimo, Inc.
- Elling, C. (1932) *Holmens bygningshistorie, 1680-1770*. København, [Langkjærs bogtrykkeri].
- Esteves, C.R.A. (2011) O Livro Primeiro de Architectura Naval de João Baptista Lavanha e a arquitectura naval ibérica no final do século XVI, princípios do

- XVII: o perfil do arquiteto naval. Available from: <<http://repositorio.ul.pt/handle/10451/4495>> [Accessed 12 December 2013].
- Fernández, S.H. (2008) Oval Domes: History, Geometry and Mechanics. *Nexus Network Journal: Architecture and Mathematics*, 9 (2).
- Ferreiro, L.D. (2010) *Ships and Science: The Birth of Naval Architecture in the Scientific Revolution, 1600-1800*. Reprint. The MIT Press.
- Ferreiro, L.D. (2009) *The Aristotelian Heritage in Early Naval Architecture, from the Venetian Arsenal to the French Navy, 1500 - 1700*. Max-Planck-Inst. für Wissenschaftsgeschichte.
- Fox, F.L. (1980) *Great ships: the battlefleet of King Charles II*. Greenwich, Conway Maritime Press.
- Franklin, J. (1989) *Navy Board Ship Models, 1650-1750*. Naval Institute Press.
- Friedrichsen, P. & Olsen, O. (2004) *Ole Rømer: videnskabsmand og samfundstjener*. Gad.
- Friedrichsen, P. & Tortzen, C.G. (2001) *Ole Rømer: korrespondance, videnskabelige afhandlinger og supplerende dokumenter*. Det Danske Sprog- og Litteraturselskab.
- Furukawa, Y., Curless, B., Seitz, S.M. & Szeliski, R. (2010) Towards Internet-scale multi-view stereo. In: IEEE, pp.1434–1441. Available from: <<http://ieeexplore.ieee.org/xpl/downloadCitations>> [Accessed 20 November 2012].
- Giødesen, P.F. (1885) *Ivar Huitfeldt*. Gyldendal.
- Glete, J. (1993) *Navies and nations: warships, navies, and state building in Europe and America, 1500-1860*. Stockholm, Almqvist & Wiksell International.
- Goodwin, P.G. (1987) *The construction and fitting of the English man of war, 1650-1850*. Naval Institute Press.
- Grieco, G.P. (2003) *Modeling La Belle: Reconstruction of a Seventeenth-century Light Frigate*. Texas A & M University.
- Guillerme, J., Verin, H. & Sartarelli, S. (1989) The Archaeology of Section. *Perspecta*, 25, p.226.
- Harley, B. (1994) *Church Ships: A Handbook of Votive and Commemorative Models*. Canterbury Press Norwich.

- Harris, D.G. (1997) Francis Sheldon in Denmark 1686–1690. *The Mariner's Mirror*, 83 (3), pp.293–302.
- Hasslöf, O. (1963) *Wrecks, Archives and Living Tradition: Topical Problems in Marine-historical Research*. Society for Nautical Research.
- Henningsen, H. (1950) *Kirkeskibe og kirkeskibsfester*. København, Høst & Søn.
- Holck, O.P. (1939) *Den historiske modelsamling paa Holmen*. Unknown.
- Holck, P. (1934) *Cort Adeler*. Copenhagen.
- Hoving, A. (2005) *William Rex: a model of a 17th-century warship*. Waanders.
- Hoving, A.J. & Wildeman, D. (2012) *Nicolaes Witsen and Shipbuilding in the Dutch Golden Age*. Texas A&M University Press.
- Jakobsson, K. (1999) The Warship in Swedish Seventeenth-Century Society? A Cultural Construction? *Scandinavian Journal of History*, 24 (3-4), pp.225–243.
- Jespersen, K.J.V., Feldbæk, O., Due-Nielsen, C. & Petersen, N. (2006) *Revanche og neutralitet : 1648-1814*. Danmarks Nationalleksikon.
- Johnsrud, E.H. (1996) *Norske kirkeskip*. Norsk Sjøfartsmuseum.
- Johnston, S.A. (1994) *Making Mathematical Practice: Gentlemen, Practitioners and Artisans in Elizabethan England*. University of Cambridge.
- Jordening, B.W. (1896) *Katalog over den historiske modelsamling på orlogsværftet*. København, Thiele.
- Judichær, O. & Jersin, J. (1684) *Pseudokrisis Sensuum & Anankaiochrēsism sive, Disputatio mathematico physica prior ostendens fallaciam sensuum in judicando et Hypothesium necessitatem atque utilitatem*. Hafniæ, literis Joh. Phil. Bockenhoffer ...
- Kenchington, T. (1993) The Structures of English Wooden Ships: William Sutherland's Ship, circa 1710. *The Northern Mariner / le Marin du Nord*, 3 (1), pp.1–43.
- Ketting, H. (1981) *Prins Willem: ein Ostindienfahrer des 17. Jahrhunderts*. Hinstorff.
- Köster, A. (1926) *Ship models of the seventeenth to the nineteenth centuries*. E. Weyhe.

- Kroman, J. (1993) Skibsmodeller I danske kirker. *Handels- og Søfartsmuseet på Kronborgs rådgivning om kirkeskibe.*
- Lavery, B. (1992) Introduction. In: R. Gardinier ed. *The line of battle: The sailing warship, 1650-1850.* London, Conway Maritime Press, pp.7–10.
- Lavery, B. (1984) *The Ship of the Line: Design, construction and fittings.* Conway Maritime Press.
- Lavery, B. & Stephens, S. (1995) *Ship Models: Their Purpose and Development from 1650 to the Present.* 1st Edition. Philip Wilson Publishers Ltd.
- Lemée, C.P.P. (2006) *The Renaissance Shipwrecks from Christianshavn: An Archaeological and Architectural Study of Large Carvel Vessels in Danish Water, 1580-1640.* Viking Ship Museum, Roskilde.
- Lemineur, J.-C. & Coulomb, F. (2007) *Le François, vaisseau de 5e rang: manuscrit de François Coulomb, Toulon 1683.* Nice, A.N.C.R.E.
- Lind, H.D. (1896) *Kong Frederik Den Tredjes Somagt.* Miloske.
- Lind, H.D. (1917) Om Nogle danske Orlogsskibe paa Kong Christian den Femtes tid. *Tidsskrift for Søværnen.*
- Lockhart, P.D. (2004) *Sweden in the Seventeenth Century.* Palgrave.
- Maarleveld, T.J. (1996) *Archaeology and early modern merchant ships. Building sequence and consequences. An introductory review.* Alphen a/d Rijn, Dept. of Underwater Archaeology.
- Maarleveld, T.J. (2013) Early Modern Merchant Ships, Nicolaes Witsen and a Dutch-Flush Index. *IJNA International Journal of Nautical Archaeology*, 42 (2), pp.348–357.
- Mazer, A. (2011) *The Ellipse: A Historical and Mathematical Journey.* John Wiley & Sons.
- Nielsen, E. Major Danish Warships Built at the Holmen Shipyard [Internet]. Available from: <[http://www.milhist.dk/vaaben/vands/holmen\\_ships/holmen\\_ships.htm](http://www.milhist.dk/vaaben/vands/holmen_ships/holmen_ships.htm)>.
- Nitz, H.J. (1993) *The Early Modern World-System in Geographical Perspective.* Coronet Books.
- ODS (1919) Ordbog over det danske Sprog [Internet]. Available from: <[http://ordnet.dk/ods\\_en/dictionary-1?query=Afrids&set\\_language=en&aselect=afride](http://ordnet.dk/ods_en/dictionary-1?query=Afrids&set_language=en&aselect=afride)>.

- Olesen, C.R. (2009) Dannebrog 1692-1710, Forlis, arkæologiske undersøgelser og byggeprincipper. *Maritim Kontakt*, XXXII, pp.55–93.
- Ollivier, B. (1992) *18th century shipbuilding: remarks on the navies of the English & the Dutch from observations made at their dockyards in 1737*. Rotherfield, East Sussex, Engl., By Jean Boudriot Publications.
- Orlogsmuseet: Privatarkiv Holck Konstruktionsbog.
- Owen, N.C. (1991) Hazardous 1990–1991 interim report. *International Journal of Nautical Archaeology*, 20 (4), pp.325–334.
- Owen, N.C. (1988) HMS Hazardous wrecked 1706. Pre-disturbance survey report 1987. *International Journal of Nautical Archaeology*, 17 (4), pp.285–293.
- Perrin, W.G. (1919) Navy Board Letter of 4th June, 1716, to the Master Shipwrights at the Various Yards About Models. *The Mariner's Mirror*, 5 (2), pp.56–56.
- Pevny, T. (2011) Historic Naval Architecture Practices as a Guide to Shipwreck Reconstruction: The La Belle Example. In: B. Ford, D. L. Hamilton, & A. Catsambis eds. *The Oxford Handbook of Maritime Archaeology*. Oxford University Press. Available from: <<http://www.oxfordhandbooks.com/view/10.1093/oxfordhb/9780195375176.001.0001/oxfordhb-9780195375176-e-12>> [Accessed 7 January 2014].
- Polak, J. (1976) *Bibliographie maritime française: depuis les temps les plus reculés jusqu'à 1914*. Grenoble, Editions des 4 Seigneurs.
- Probst, N. (1993) Nordeuropæisk spanteopslagning i 1500- og 1600-tallet: Belyst ud fra danske kilder. *Maritim Kontakt*, XVI, pp.7–42.
- Probst, N.M. (1996) *Christian 4.s flåde*. Gyldendal.
- Probst, N.M. (2005) *Niels Juel: vor største flådefører*. Kbh., Statens Forsvarshistoriske Museum.
- Proia, L.M. & Menghini, M. (1984) Conic Sections in the Sky and on the Earth. *Educational Studies in Mathematics*, 15 (2), pp.191–210.
- Remondino, F. (2011) Heritage Recording and 3D Modeling with Photogrammetry and 3D Scanning. *Remote Sensing*, 3 (12), pp.1104–1138.
- Roach, A. (2008) Model Boats in the Context of Maritime History and Archaeology. *International Journal of Nautical Archaeology*, 37 (2), pp.313–334.

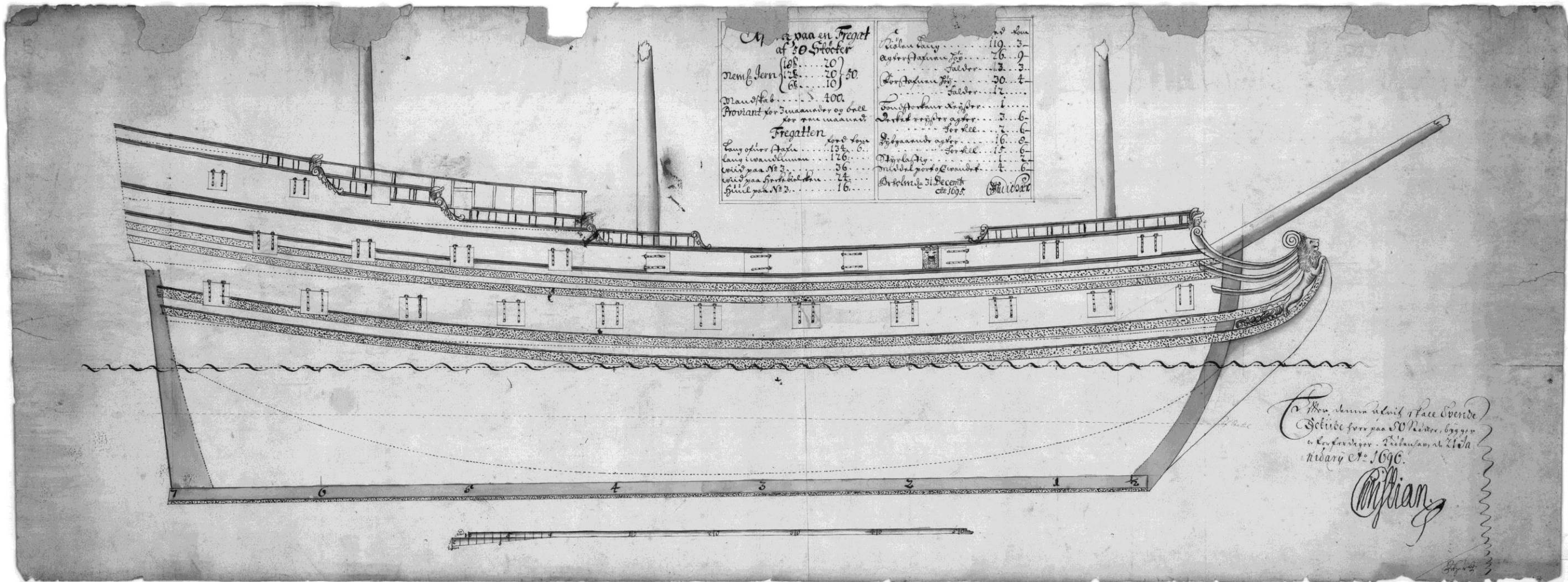
- Salisbury, W. (1954) The Framing of Models. *Mariner's Mirror*, 40, pp.156–157.
- Seerup, J. (2001) *Søkadetakademiet i oplysningstiden*. Gullanders Bogtrykkeri, Skjern.
- Skarlatos, D. & Kiparissi, S. (2012) Comparison of laser scanning, photogrammetry and sfm-mvs pipeline applied in structures and artificial surfaces. *ISPRS Annals of Photogrammetry, Remote Sensing and Spatial Information Sciences*, I-3, pp.299–304.
- Smeed, V.E. (1979) *Model Ships*. Bison Books.
- Steensen, R.S. (1974) *Flåden: Flåden gennem 475 år*. Martins forl.
- Steensen, R.S. (1961) *Orlogsmuseet*. Marinehistorisk selskab.
- Steffy, J.R. (2012) *Wooden ship building and the interpretation of shipwrecks*. College Station, Texas A & M University Press.
- Sutherland, W. (1711) *The ship-builders assistant: or, Some essays towards compleating the art of marine architecture*. London, Printed for A. Bell at the Cross-keys and Bible, and R. Smith under the Royal Exchange, Cornhill.
- Thalund, H. (1989) *Fynske kirkeskibe*.
- Topsøe-Jensen, T.A. & Marquard, E. (1925) *Officerer i Den Dansk-Norske Søetat 1660-1814 Og Den Danske Søetat 1814-1932*. Kopenhagen.
- Tuxen, A.P., Hansen, A.L. & With-Seidelin, C.L. (1903) *Felttoget i Skaane, 1709-1710. Udarbejdet ... Af Oberstløjtnant A.P. Tuxen, Kommandør C.L. With, Kaptajn A.L. Hansen. [With Nine Plans.]*
- Tybjerg, K. ed. (2011) *Ole Rømer*. Aarhus, Aarhus Universitetsforlag.
- Uricchio, W. (2011) The algorithmic turn: photosynth, augmented reality and the changing implications of the image. *Visual Studies*, 26 (1), pp.25–35.
- Vérin, H. (2008) La mise en œuvre de la méthode de Renau d'Élissagaray. *Documents pour l'histoire des techniques. Nouvelle série*, (16), pp.187–197.
- Wassell, J. (1979) The Framing of Navy Board Models. *Mariner's Mirror*, 65 (3), pp.253–254.
- Winfield, R. (1997) *The 50-gun ship*. Chatham Pub.
- Winter, H. (1991) *Der holländische Zweidecker von 1660/1670*. N.-A. Delius Klasing Vlg GmbH.

- Winthrop Pratt, J. (1949) The Model of an English Fourth-Rate Ship-of-the-Line ca. 1719-30. *Bulletin of the Museum of Fine Arts*, 47 (269), pp.59–62.
- Yilmaz, H.M., Yakar, M., Gulec, S.A. & Dulgerler, O.N. (2007) Importance of digital close-range photogrammetry in documentation of cultural heritage. *Journal of Cultural Heritage*, 8 (4), pp.428–433.
- Van Yk, C. (1697) *De nederlandsche scheepsbouwkunst open gestelt*. A. Voorstad.

## Appendix I

Sheer plan of *Prinz Carl/Prinz Wilhelm*, with the length between posts of *Prinz Carl*.

RA: Søetaten kort- og tegningssamling: A9



*En paa en Fregat af 30 Stuecker*

Nemf Jern (108) . . . . . 20	108	20
(10) . . . . . 10	10	10
Mandskab . . . . . 400	400	
Proviant for 3 Maanedes og Bræd for om maaned		
<b>Fregatten</b>		
Lang eller Stude . . . . . 136	136	6
Lang i vandlinum . . . . . 126	126	6
Lang paa No 2 . . . . . 56	56	6
Lang paa No 3 . . . . . 24	24	6
Quil paa No 3 . . . . . 16	16	6

108	20	108	20
10	10	10	10
400		400	
136	6	136	6
126	6	126	6
56	6	56	6
24	6	24	6
16	6	16	6

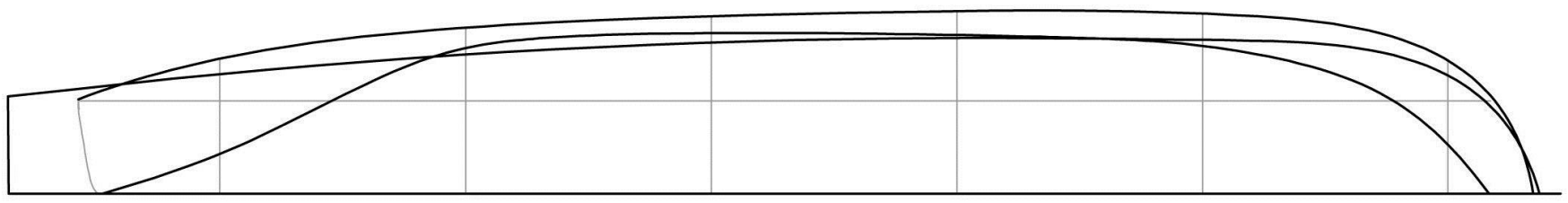
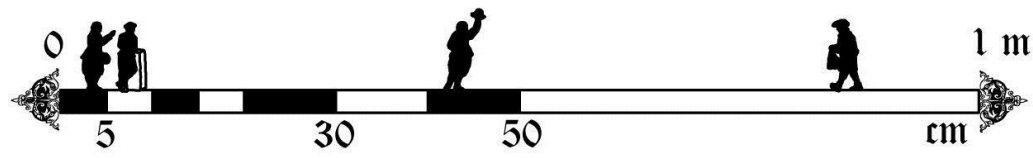
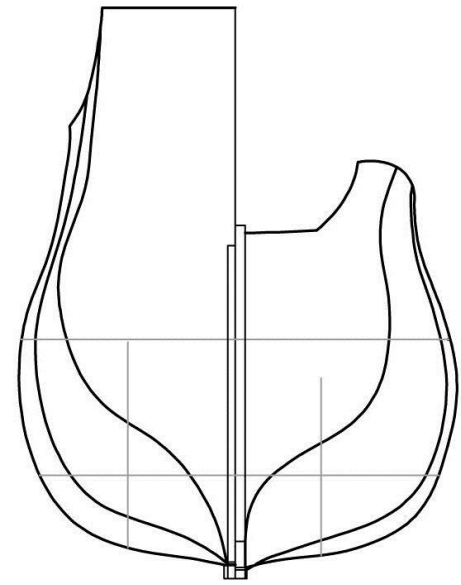
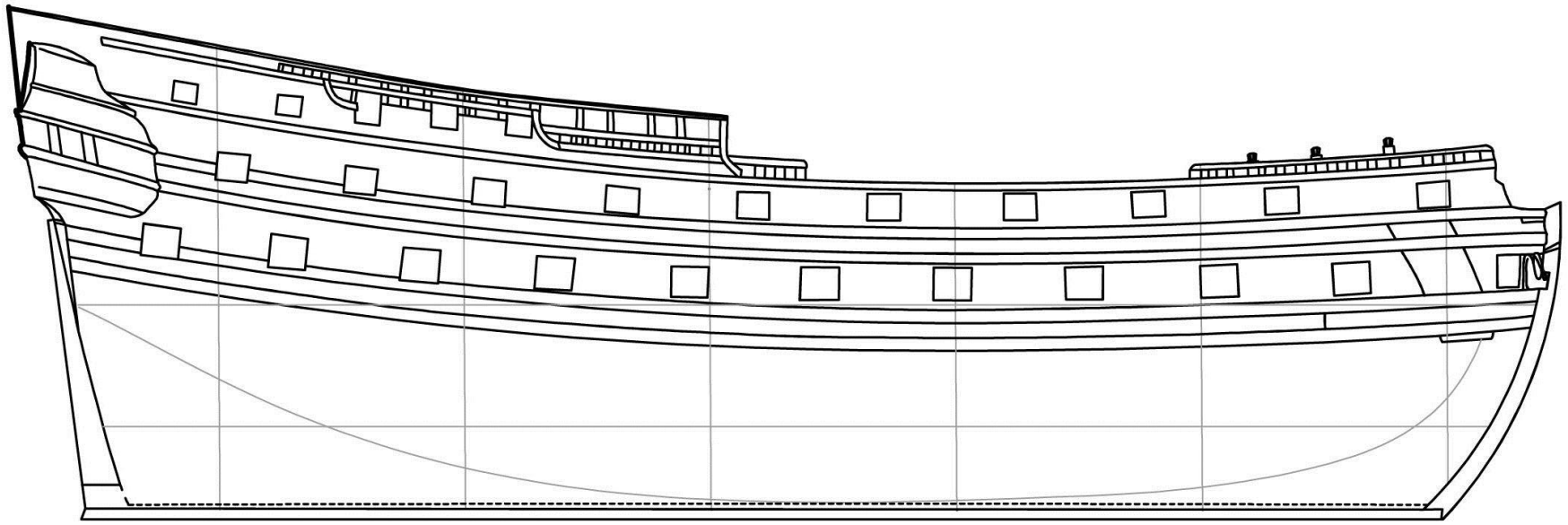
Brislen 31 Decemb 1696. *M. L. S.*

*En paa en Fregat af 30 Stuecker, bygget i Kjøbenhavn. Tidspunktet er 1696.*  
*Christian*

## Appendix II

Lines Plan of the model of *Prinz Wilhelm*.

Author  
Massimiliano Ditta



54-guns <i>Prinz Wilhelm</i>
Scale of the model 1/24
Length between the posts: 139' 3" - 43.72 m
Moulded breadth: 36' - 11.30 m

## Appendix III

### *Glossary*

**Bilge:** The area of the hull's bottom on which it would rest if grounded.

**Filling frame:** A frame composed of a single row of timbers.

**Floortimber:** The centre piece of a composed frame, spanning the bottom of the vessel across the keel.

**Frame:** A transverse element which can be made up by multiple timbers; the planking strakes and ceiling planks are fastened to it.

**Futtock:** A framing timber spanning the side of a vessel. If the sides are spanned by multiple futtocks, then the top one is called a top-timber.

**Keel:** The central element of a vessel, also known as the backbone of a vessel.

**Midship:** The broadest part of the hull.

**Narrowing line:** On the halfbreadth plan, the curve designating the maximum breadth or ends of the floor timbers.

**Rabbet:** A groove or cut made in a piece of timber in such a way that the edges of another piece could be fit into it to make a tighy joint.

**Ribbands:** Long, flexible strips of wood most commonly used as temporary keepers by nailing them across the outside of standing frames while the vessel was being built.

**Rising line:** On the sheer plan, the curve of the outer ends of the floor timbers or the height of maximum breadth.

**Scarf:** An overlapping joint used to connect two timbers or planks without increasing their dimensions.

**Sheer:** The longitudinal sweep of a vessel's sides or decks.

**Sheer line:** Specifically, the line of the upper or main deck where it meets the side, but the term is often used to describe the sweep of the bulwarks or weather rail.

**Stempost:** A vertical or upward curving timber or assembly of timbers, scarfed to the keel or central plank at its lower end, into which the two sides of the bow were joined.

**Sternpost:** Identical function as the stempost, except that the two sides of the stern joined into it.

**Strake:** A row of planks running from the vessel's bow to the stern.

**Taffrail:** The upper part of the stern or the rail on top of the stern.

**Wale:** A thick strake of planking, or a belt of thick planking strakes, located along the side of a vessel for the purpose of girding and stiffening the outer hull.