ARCHITEKCI
GZOWSKI & GZOWSKI S.C.
80-178 Gdańsk, ul. Goplańska 38, tel./fax (58) 349-57-14
e-mail: biuro@architekci-gzowski.pl, www.architekci-gzowski.pl, NIP: 583-294-03-31, nr konta: MULTIBANK 73 1140 2017 0000 4102 0545 6993

BOAT MECH14

CMM/BO/345/A Fishing boat

Table of Contents

1. INTRODUCTION 3
B.1) DESCRIPTION OF THE COMPANY 3
B.2) APPLIED METHODOLOGY 4
B.2) SCANNING PROCESS 6
B.3) APPLIED EQUIPMENT 12
B.4) THE COURSE OF WORK 16
C) About the London Charter for the Computer-based Visualisation of Cultural Heritage, edited by Hugh Denard, King’s College London, 7 February 2009. 20
D) TECHNICAL DRAWINGS 39
D.1) VIEW FROM LEFT SIDE 39
D.2) VIEW FROM RIGHR SIDE 40
D.3) VIEW FROM BOW 41
D.4) VIEW FROM STERN 42
D.5) VIEW FROM THE TOP 43
D.6) VIEW FROM THE BOTTOM 44
D.7) ISOMETRIC VIEW 45
D.8) TOP VIEW WITH TRANSVERSE LONGITUDINAL STIFFENERS FISCHING BOAT MECH14 46
D.9) BOW CROSS SECTION FISHING BOATH MIECH14 48
D.10) MIDSHIP CROSS SECTION FISHING BOAT MECH14 51
D.11 STERN CROSS SECTION FISHING BOAT MECH14 54
D.12) BACKBONE FISHING BOAT MECH14 57
D.13) BACKOBONE DRAWNING WITH TRANSVERSE AND LONGITUDINAL STIFFENERS, WITHOUT PLANKS FISHING BOAT MECH14 58
E) CLOUD OF POINTS 59
E.1) ISOMETRIC VIEW 59
E.2) CROSS SECTION IN THE BOW SECTION 60
E.3) CROSS SECTION IN AMIDSHIPS 61
E.4) CROSS SECTION IN THE STERN SECTION 62
F) 3D MODEL 63
F.1) 3D model without textures based on the collected cloud of points(isometric view) 63
F.2) 3D model without textures based on the collected cloud of points (view from the left side) 64
F.3) 3D model without textures based on the collected cloud of points (view from the right side) 65
F.4) 3D model without textures based on the collected cloud of points (view from the top) 66
F.5) 3D model without textures based on the collected cloud of points (view from the bottom) 67

F.6) Full Plastic 3D model without textures (isometric view) 68
F.7) Full Plastic 3D model without textures (view from the left side) 69
F.8) Full Plastic 3D model without textures (view from the right side) 70
F.9) Full Plastic 3D model without textures (view from the top)..... 71
F.10) Full Plastic 3D model without textures (view from the bottom)..... 72
F.11) Full Plastic 3D model with textures (isometric view) 73
F.12) Full Plastic 3D model with textures (view from the left side) 74
F.13) Full Plastic 3D model with textures (view from the right side) 75
F.14) Full Plastic 3D model with textures (view from the top)..... 76
F.15) Full Plastic 3D model with textures (view from the bottom)..... 77
G) DIMENSIONING 78
G.1) MAIN DIMENSIONS..... 78
G.2) EXPLANTORY DRAWNING TOP VIEW 79
H) THEORETICAL CALCULATION..... 85

1. INTRODUCTION
B.1) DESCRIPTION OF THE COMPANY

Gzowski & Gzowski Architects Company sc was established in 2005 as a continuation of the research and design office - DART AGENCY acting since 1989. The growing interest of investors in transfiguring protected areas in new buildings became the basis for the formation of a new company profile. The laboratory is specialized in creating research and project documentation. The scope of activity is a 3D laser scanning of historic buildings (both museum exhibits and historic buildings), construction and restoration inventories, which are based on 3D scanning, projects of reconstruction of buildings and interior elements, ortophotogrammetry, multi-sector, building and implementing projects. The company also performs congeneric archaeological survey, architectural, conservation, congeneric programs of conservation work, the technical expertise of historic buildings with the analysis of declension (3D scanning) and architectural concepts in consultation with the Office of Conservation.

Substantive supervision over the calculative part:

Jan Młynarczyk PhD, an engineer of shipbuilding, specialized in small ships and yachts. A Technical Expert - Polish Register of Shipping (PRS), Department of Yachts and Boats, technical inspector, appraiser - Marine team. He is also the inspector (non-exclusive) of PRS supervision of yachts, the surveyor of International Measuring Formulas of marine yachts - RORC, IOR , IMS.

Ship Service: Ship Service Company was founded in 2009 in Gdansk. It is a design company specializing in small and medium-sized vessels, especially yachts, boats and fishing boats. It is one of the few companies on the market, which has experience in projecting wooden units. The company cooperates with shipyards, research institutes and design offices in the area of structures, equipment, installations and stability of vessels.

B.2) APPLIED METHODOLOGY

Ordering the inventory of historic boats, referred as "Making a digital inventory of historic folk boat team from the collections of the National Maritime Museum as a part of "Maritime Museum - Digital Maritime Museum (step 2)" project was realized in the period from 06.23.2014 to 30.09.2014. The aim of the task was to perform a complete digital documentation of 14 historic boats, located in Fishery Museum in Hel, by Gzowski & Gzowski Architects sc, Goplańska 38, Gdańsk.

The task specifies the equipment, which allowed for the proper performance of measurements and documenting the boat. The ground laser scanner Faro Focus model 120 was used. Scans were performed based on the capabilities and technologies offered by the above-mentioned device. When the contract with the National Maritime Museum was signed, the measurements started. The biggest threats to the proper execution of the order were: short delivery time, the scope of work, as well as weather conditions, having a key influence on the measurement.

It was the first documentation in the country made by laser scanning. For this reason, at the beginning of the work, a number of processing tests had to be performed, which resulted in a significant loss of time. On the other hand, these attempts made it possible to develop a suitable methodology of the work presented below.

The schedule is divided into three stages:

1) the stage of the measurement (laser scanning) in the Fishery Museum, Hel. The measurements of three boats were taken inside the building and the eleven boats were measured outside. The measurements are dependent on weather conditions.

2) the stage of processing the points. Processed, filtered and positioned data were analyzed, and after once accepted, the material was passed to the next stage of processing.

3) the stage of data processing of point cloud format. The entity responsible for the execution of 3D models is, in the first place, engaged in modeling airtight boats for the marine laboratory. On this basis, the laboratory began the calculations for individual units.

4) the stage of modeling full solids of boats to improve their condition. The final material was a boat in Mesch form together with textures. This operation was performed at the end of the task.

5) the equivalent of point 3 (drawings and calculations). After receiving the material in the form of airtight solids, 3D solids and drawings based on scans, the marine laboratory processed the material.

6) The final step: the analysis of 3D marine materials and execution of technical and narrative documentation.

The measurement works were based on the experience of our employees of Gzowski & Gzowski Architects sc in the field of scanning architectural monuments and archaeological buildings. The workshop conducted numerous innovative research, combining orthophotography, tachometric measurements, measurements with a laser scanner and traditional measurement methods. Thus, taking the measurements was possible, avoiding many obstacles posed by the scanning technique.

The main objectives of the project were the directives included in the specification of essential terms of the contract and the recommendations of the London Charter. The documentation of the boat made by the Norwegian studio was the comparative material and it was titled "DOKUMENTASJON AV AV FARTØY VED Hjelp LASERSCANNING", and obtained from a representative of the Central Maritime Museum, Martin Kłos MA. Based on the design of wooden oak boat and documented in the above-mentioned work, it was the only reference material for the preparation of the boat in Hel. It was considered that the visual effect should be similar to the result obtained in Norway. The progress was consulted on a regular basis with the representatives of the National Maritime Museum and the reports of each step were periodically sent out.

During the technical conference, which took place at the headquarters of the National Maritime Museum in Gdansk on 17.07.2014, the scope of work, expected results of measurements, Mesch visualizations, 3D views and drawings were

determined by the team. The result of this meeting was a note stating: "The direction and the material presented at the conference are suitable to accomplish this task."

B.2) SCANNING PROCESS

The majority of units was held outside the building due to the location of the boat. The area, on which a tripod scanner stood, was varied, gravel or granite paving stones. However, setting the scanner on a tripod made it possible to perform a reliable measurement.

The measurements were performed with a laser scanner after the preparation of the boat (cleaned of leaves, twigs, sand). In view of the material from which the boats were constructed and covering a few of the units thick layer of tar, the issue of possible reflections of the laser beam was discussed. T o avoid the error, which could significantly distort the scan, the measurements were held of completely drained units. The series of trial scans were performed to adjust the appropriate scan parameters.

The main recommendation of the National Maritime Museum was the information contained in the terms of the contract, which reads: "Scanning should be performed with the calibrated device to ensure the accuracy of its measurement 1 point per square millimeter (spatial resolution points). Permissible error shall not exceed 5mm (measurement uncertainty)"

Adopted scanner settings:

a) ¼ point horizontally and vertically;

b) scan size 1024x4267;

c) the resulting scan size in millions of points 43.7:

d) the distance of the point mm / 10m 6136;

e) resolution;

f) quality of 4x;

Scans were made in colour by using the photo-quality units 70Mpx (megapixels) integrated with the scanner. Total camera resolution is the result of a number of pictures taken by the scanner during a turn. On each boat, there were from 15 to 35 scans. The material obtained in the scanning process made it possible to accurately

reflect the plasticity and the geometry of each unit. After the registration of scans with scan filtration and removal of erroneous, individual data points, the density of the cloud of points from ~ 0.09 - 0.18mm was obtained.

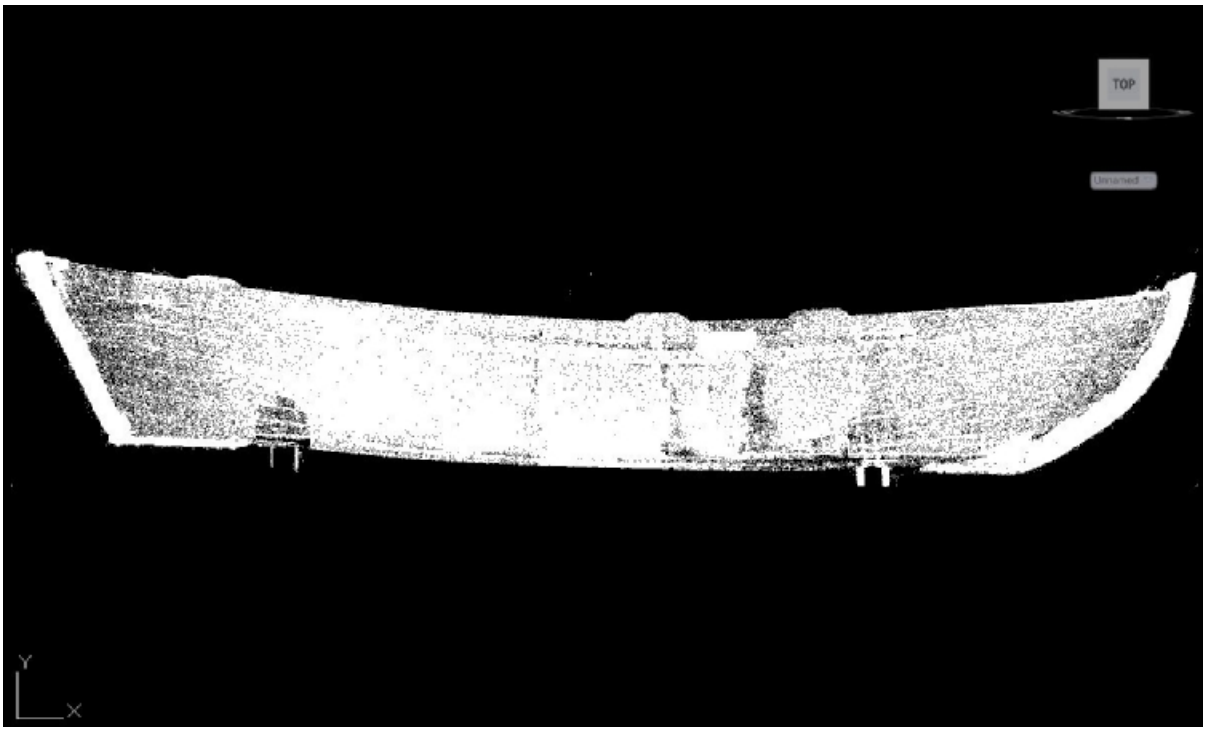


Figure 1.The density of the cloud of points of a sample boat.

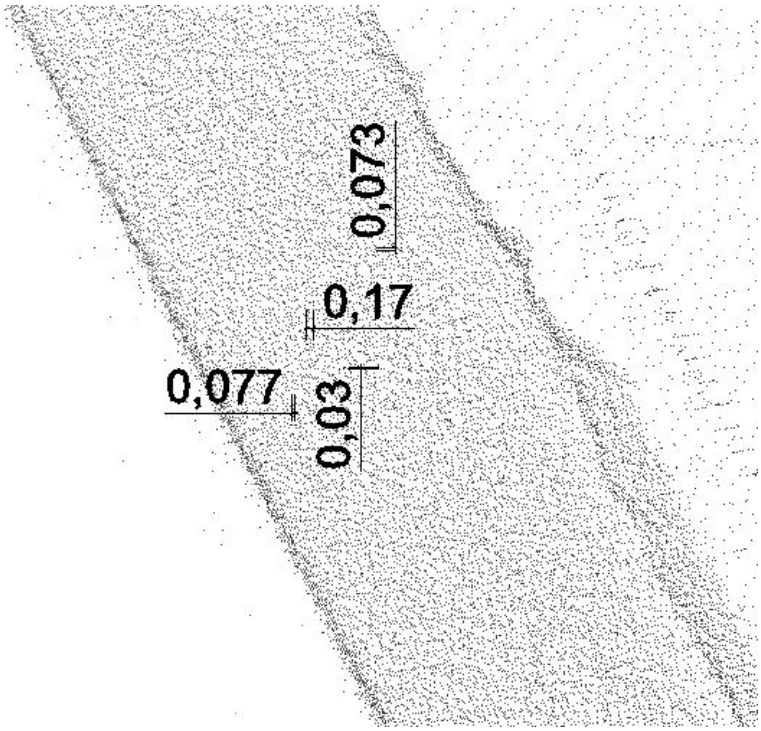


Figure 2. Distances (millimeters) of the recorded points during the measurement. Given the numerical value is the distance between neighboring points.

The next step was to analyze the collected data and the classification of each of the scans.

Figure 3. Selected part of the boat before the data filtration process.

Figure 4. Selected part of the boat after the data filtration process.

Chosen area scan, carrying the highest number of source points undisturbed and closest to each other. This resulted in the increased number of scanning points, but the result was a more effective and efficient amount of data. It was advisable to remove from the scans the measurements which were more than 450cm-600cm away. The scanner is able to register points to 80 meters. The data did not fall within the scope of the measured boat were removed. The simple elements of the boat (e.g. a board) were individual filtered since the large amount of data was unnecessary. This would result in a duplication of data and the increased volume of data to be processed. (Data analysis was carried out by a person engaged in scanning process and machining data after scanning.) Reducing the density of points on such surfaces allowed to reduce the volume of processing data and, consequently, the data that were made available in internet. This decision was dictated by the fact that the documentation of the wood surface structure was not of primary importance. It was more important to register the shape of the hull precisely.

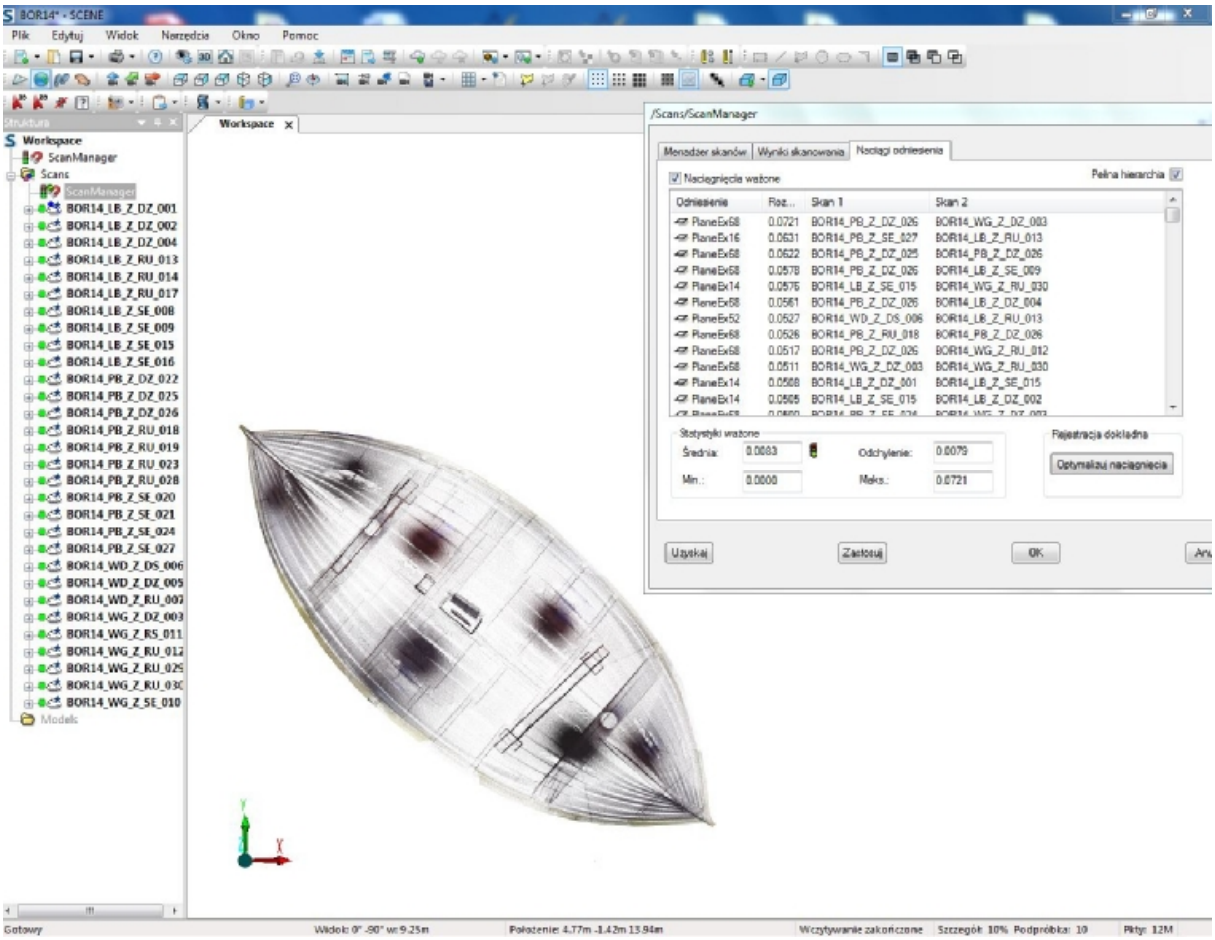


Figure 5. The filtration process and the registration of scans in Faro Scene software.

The material was an excellent starting base for the further process of surface modeling. The model was prepared based on the MESCHLAB software

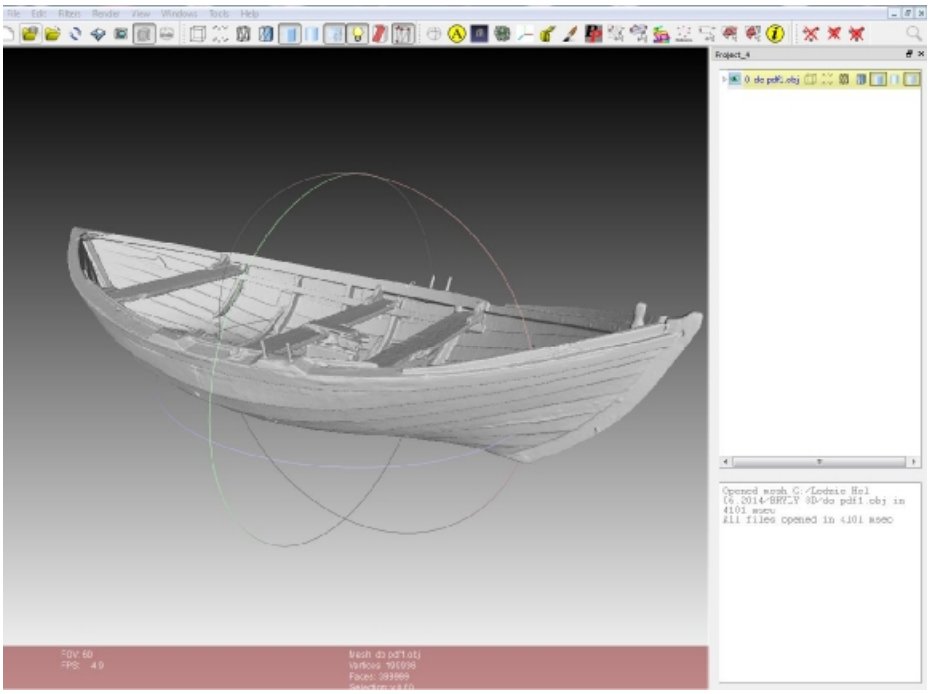


Figure 6. The process of creating a sample boat in the Meschlab software.

Raw points were exported in the Faro Scene, in PTX format. This format allows you to save the raw data along with texture. A single scan in the form of PTX reached the size from 200 megabyte to 1.2 gigabyte.

The scans in the form of PLY from Meschlab program were exported to Blender software for the analysis and they were again filtrated. Further process of submitting all scans together, creating a triangle mesh and UV mapping took place in the Meschlab program. This process is partly automated. When constructing a complex boat, the process took place manually. The final result was a Mesch solid of a boat with a texture, based on the cloud of points, obtained from the camera scanner.

The last step was to make tight solids (of complemented defects of the boats), which was performed in *Cinema 4D* program. This process was fully manual and made based on the model of the cloud of points, requiring the individual interpretation of the operator. The software used in the installation process is described fully in section B.3 APPLIED EQUIPMENT.

All in all, the method of laser scanning for measuring historic boats is faster and more efficient than the traditional forms of measurement and documentation. The material obtained from the measurement and treatment, gives a detailed picture of the boat, containing such information as colour (texture), size and structure of the object. Such accurate results would be difficult to obtain using the traditional forms of documentation.

B.3) APPLIED EQUIPMENT

The measurements of the boat were made with Faro Laser Scanner, Focus 3D model. Focus3D uses laser technology to produce detailed, three-dimensional images of complex environments and geometries. Scan result is made up of millions of colorful, three-dimensional measurement points and an exact digital reproduction of existing reality. The speed reaches 976,000 of measurement points per second.

Specifications:

Faro Focus 3D 120

The range of Faro Focus 3D 120 0.6 m - 120 m inside or outside the building in poor light and with the incident laser beam that perpendicularly reaches the surface and with the reflectance of 90%.

Speed measurement 122 000/244 000/488 000 / ~ 1 000 000 points / sec.

Distance measurement error +/- 2 mm

Photo module resolution up to 70 megapixels in colour. The function of dynamic colours. Automatic brightness adjustment.

Mirror Vertical field of view of 305°. Horizontal field of view of 360 °

Vertical resolution of 0.009 ° (40.960 pixels 3D 360 °)

Horizontal resolution of 0.009 ° (40.960 pixels 3D 360 °)

The maximum speed of vertical scanning 5,820 rpm. / Min or 97 Hz

Laser Laser power (continuous wave, Ø) 20 MW (laser of 3R class)

Wavelength 905 nm. Beam divergence of typical size of 0.16 mill radians (0.009 °)

Beam diameter at the output 3.8 mm (circular)

Operation and control of the scanner

Storage media: SD, SDHC ™, SDXC ™; with 32 gigabyte card included

Scanner control using touch screen

Date of last calibration 1/21/2013

The scanning process used markers and reference spheres of known radius. They are used for the registration of scans in order to connect with each other point clouds from different positions. The scans were gathered using the FARO SCENE and then processed in Blender, MESCHLAB and CINEMA 4D. FARO SCENE is the program to process the data of scanning and to manage them, using automatic object recognition, registration and positioning of the scans. Using SCENE software, you may also stain the scanned images. Cloud processing software generates data of high quality. After preparation of the data, they were also processed in Blender and MeshLab. MeshLab is an extensible, portable, multi-platform open Skurce system used for processing and editing of unstructured, three-dimensional mesh of tri / quad-mesh. The program includes implemented tools for processing typical models and clouds of points, resulting from 3D scanning. With the software, you may clean, repair, reconstruct and render a triangle mesh. The Cinema 4D allows you to create 2D and 3D animation. In the task, it was used to improve the physical quality of boats. Drawings calibrated as orthophotos were performed using Faro SCENE program, and then retouched in ADOBE PHOTOSHOP.

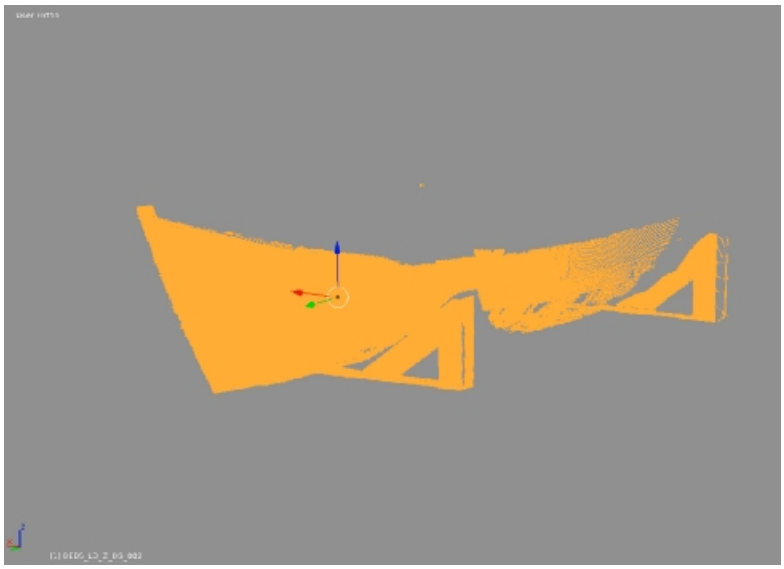


Figure 7. Processing data of boat portion in the software Blender.

(material data before filtering)

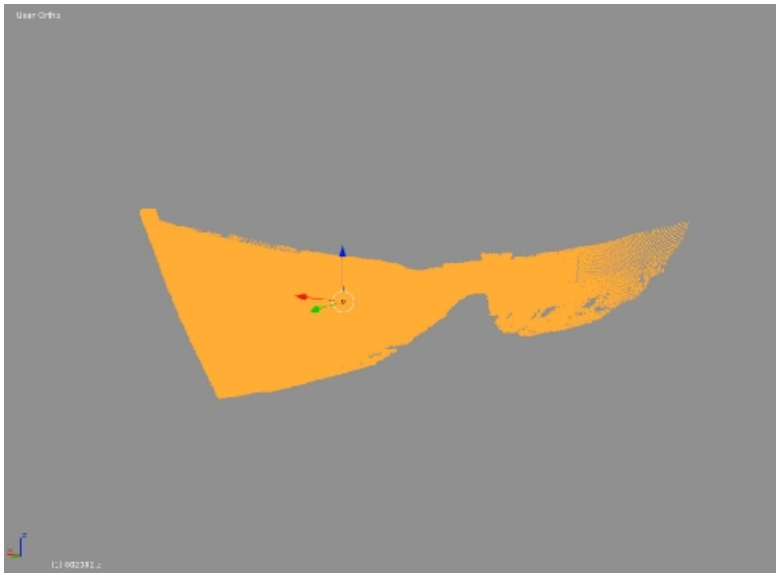


Figure 8. Processing data of boat portion in the software Blender.

(material data after filtering)

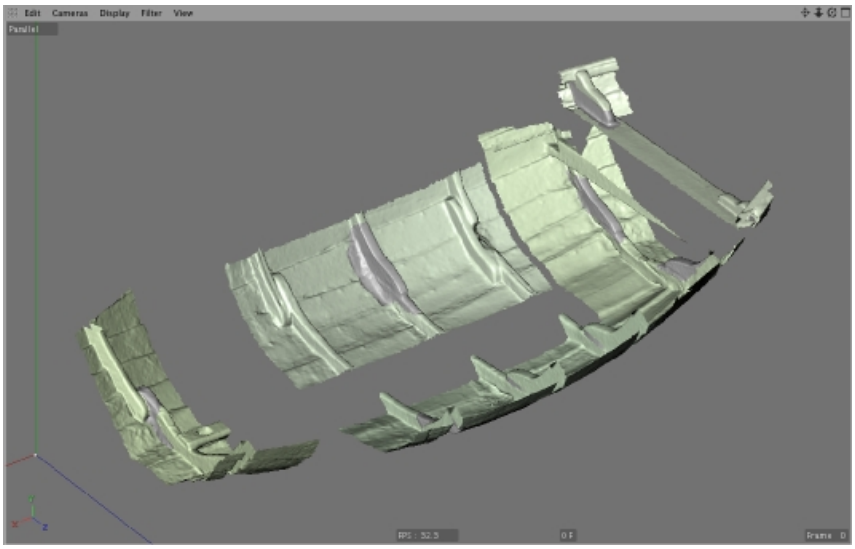


Figure 9. The process of formation of Full Plastic lumps supplemented with the missing data

B.4) THE COURSE OF WORK

DAILY REPORT LASER SCANNING

1.	Technician	MARCIN KULESZA				
2.	Scanner	FARO FOCUS 3D 120				
3.	Date of last calibration	21.01.2013				
4.	Precision	¼ the vertical and horizontal points ; Scan size Points 1024x4267 ; The resulting scan size in millions of points MPoints 43.7 ; distance of a point mm/10m 6.136 ; Resolution 1/4 ; Quality 4x ; Single scan time 09:06				
5.	The number of scans performed per day	25				
6.	The names of created files	MECH14_PB_Z_DZ_001; MECH14_WG_Z_SE_002; MECH14_WG_Z_RU_003; MECH14_WG_Z_RU_004; MECH14_WG_Z_RU_005; MECH14_WG_Z_SE_006; MECH14_WG_Z_SE_007; MECH14_WG_Z_DZ_008; MECH14_PB_Z_DZ_009; MECH14_PB_Z_DZ_010; MECH14_PB_Z_DZ_011; MECH14_PB_Z_SE_012; MECH14_PB_Z_SE_013; MECH14_PB_Z_DZ_014; MECH14_PB_Z_RU_015; MECH14_PB_Z_RU_016; MECH14_LB_Z_RU_017; MECH14_LB_Z_RS_018; MECH14_LB_Z_SE_019; MECH14_LB_Z_SE_020; MECH14_LB_Z_DZ_021; MECH14_LB_Z_SE_022; MECH14_WG_W_SE_023; MECH14_WG_W_RU_024; MECH14_WG_W_DZ_025				
7.	Scanned objects	11 **MECH14** – for (MECH-14) CMM/BO/345/A Fishing boat of the Puck Bay				
8.	Weather	sunny	without clouds	With some clouds	With a lot of clouds	rainy
9.	The average temperature in the hours of operation	20C				
10	Date	27.06.2014				

The boat was scanned with 25 positions of the scanner inside of the building. Scanning took one day

NOTES:

At the beginning the boat was dusted of numerous pollutants. The boat was secured during the measurement time. Boat was raised up to a height of ~ 70 cm using a hydraulic jack. The keel measurement was performed at a maximum lowered scanner

setting its head directly on the ground. Scans were performed outside and inside the unit. Overall dimensions of the scanner (the smallest in the class of ground scanners) allowed boat measurements in all available places. Boat, in order to better exposure, is mounted on a wooden support beams. Places that were obscured by support beams were not possible to be scanned. Dropouts was supplemented with 3D modeling and they are in the resources of complemented models.

Photo 1. View from the stern, right side.

Photo 2. View from the bow, left side.

Photo 3. View from the left side.

Photo 4. View of the top from the stern.

Photo 5. View from the bow, left side.

C) About the London Charter for the Computer-based Visualisation of Cultural Heritage, edited by Hugh Denard, King's College London, 7 February 2009.

The London Charter 2_1 proposes principles for creation of good practices in the field of digital visualisation of tangible heritage, with special emphasis on scientific methods and their evaluation in terms of projected aims and results. Moreover, it is an initiative which aims to promote mentioned good practices in cultural heritage sector and commercial sector. It does not cover visualization as used in modern art.

London Charter 2_1 describes six rules (as presented below in a shortened version):

1. Implementation (valid wherever computer-based visualisation is applied to the research or dissemination of cultural heritage);
   1.1. Development of a *London Charter Implementation Guidelines* by each community of professionals;
   1.2. Development of a *London Charter Implementation Strategy* for every computer-based visualisation of tangible heritage activity;
   1.3. Dissemination of knowledge about the *London Charter* and *Charter Implementation Guidelines* among activity participants who are involved in computer-based visualisation process;
   1.4. Calculation of costs of implementing scientific methods compliant with principles of the *London Charter* in relation to the added intellectual, educational or economic value of produced outputs;
2. Aims and methods (a computer-based visualisation method should normally be used only when it is the most appropriate available method for that purpose);
   2.1. Computer-based visualisation is not the most appropriate method for all cultural heritage research and dissemination of knowledge about tangible heritage;
   2.2. Decision about selecting a method should be proceeded by an assessment of all available methods which could be used to achieve established aims;

2.3. Decision about selecting a method should be based on an evaluation of the likely success of each approach in addressing each aim, especially when a development of a new method is taken to consideration;

3. Research Sources (scientific methods are based on relevant research sources and should be identified and evaluated in a structured and documented way);
   3.1. In the context of the *Charter*, research sources are defined as all information, considered during, or directly influencing, the creation of computer-based visualisation outcomes;
   3.2. Research sources should be used with reference to current understandings within communities of practice;
   3.3. Attention should be given to the influence of ideological, historical, social, religious and aesthetic factors;
4. Documentation (sufficient information about aims, methods and outcomes should be documented and disseminated);
   4.1. Enhancing practice – visualisation activity documented in designed order, so it might be used for enhancing methods and competences;
   4.2. Enhancing practice – documentation allows comparative analysis and outcome assessment, as well as detection of issues which have been revealed during the process of computer-based visualisation activity;
   4.3. Enhancing practice – documentation may assist in the management of Intellectual Property Rights or privileged information;
   4.4. Documentation of Knowledge Claims – Clearly indicated purpose of computer-based visualisation for example existing state, an evidence-based restoration, an hypothetical reconstruction, and information about the extent and nature of any factual uncertainty;
   4.5. Documentation of Research Sources – dissemination of research sources and their provenance;
   4.6. Documentation of Process (Paradata) – dissemination of documentation of all sorts of decisions made in course of computer-based visualisation in

such a way that the relationship between research sources, implicit knowledge, explicit reasoning and produced outcomes can be understood;

4.7. Documentation of Methods – dissemination of documentation containing the rationale for choosing particular computer-based visualisation method in such a way that it might be evaluated and provide conclusions for subsequent activities;

4.8. Documentation of Methods – dissemination of documentation containing detailed description of used method in case when it is likely that it will not be understood in relevant communities of practice;

4.9. Documentation of Methods – in case of interdisciplinary context, documentation should be undertaken in such a way that it identifies different research questions, methods, outcomes and lexica of participating members from diverse subject communities;

4.10. Documentation of Dependency Relationship – dissemination of computer-based visualisation outcomes in such a way that the nature and importance of significant, hypothetical dependency relationships between elements can be clearly identified by users and the reasoning underlying such hypotheses understood;

4.11. Documentation Formats and Standards – dissemination of documentation using adequate media, including graphical, textual, video, audio, numerical or combination of the above;

4.12. Documentation Formats and Standards – dissemination of documentation with reference to relevant standards and ontologies according to best practice in relevant communities of practice ;

5. Sustainability (planning and implementation of long-term sustainability);

5.1. Implementation of the most reliable and sustainable method of computer-based visualisation archiving;

5.2. Migration to different (new) formats and emulation of software applied to the use of computer-based visualisation data and documentation;

5.3. Where digital archiving is not possible or does not ensure the long-term survival of data, a two-dimensional record evoking as far as possible the scope and properties of the original output of a computer-based visualisation should be preferred;

5.4. Documentation strategies should be designed to be sustainable in relations to available resources and prevailing working practices;

6. Access (the creation and dissemination computer-based visualisation in such a way as to ensure that maximum possible benefits are achieved for the study, understanding, interpretation, preservation and management of cultural heritage);

6.1. The aims, methods and dissemination plans of computer-based visualisation should reflect consideration of how such work can enhance access to cultural heritage that is otherwise inaccessible due to health and safety, disability, economic, political, or environmental reasons, or because the object of the visualisation is lost, endangered, dispersed, or has been destroyed, restored or reconstructed;

6.2. Projects should take cognizance of the types and degrees of access that computer-based visualisation can uniquely provide to cultural heritage stakeholders, including the study of change over time, magnification, modification, manipulation of virtual objects, embedding of datasets, instantaneous global distribution.

Hereafter is described implementation of the London Charter (v. 2_1 PL) for computer-based visualisation of collection of traditional wooden boats from National Maritime Museum in Gdańsk within project “National Maritime Museum in Gdańsk – Digital Maritime Museum (Stage 2)”.

1. Implementation

Ad. 1.1. Development of a *London Charter Implementation Guidelines* by each community of professionals.

National Maritime Museum in Gdańsk is the leading museum in the field of digital documentation of maritime heritage in Poland. Museum's Professionals closely cooperate with National Institute For Museums And Public Collections and participate in numerous conferences which cover topics of computer-based visualisation for various scientific research.

A natural cooperation partner for museum is the Faculty of Ocean Engineering And Ship Technology of the Gdańsk University of Technology. Since 2011 mentioned cooperation intensified in the field of computer-based visualisations, mainly due to implementation of two projects ("Polish Maritime Museum – Digital Maritime Museum" stage 1 and 2) within Long-term Government Programme "Kultura+", priority digitization, funded by The Ministry of Culture and National Heritage and one (" Monography: Copper Ship – wreck of a medieval ship") within programme: "Cultural Heritage", priority: protection of archaeological objects, co-funded by The Ministry of Culture and National Heritage. Mentioned cooperation focuses on support in areas of technology and methodology (e.g. a born digital publication "Methodology of 3D arm" which is an outcome of the first of mentioned above projects, and is available online at Pomeranian Digital Library http://pbc.gda.pl/dlibra/docmetadata?id=23780&from=&dirids=1&ver_id=&lp=2&QI) or digital reconstruction based on preserved elements of the wreck.

Joint participation in projects with Gdańsk University of Technology and mutual understanding of the aims of the museum in the field of digital documentation (including computer-based visualizations) as well as of the spectrum of available technologies for industry and cultural heritage, significantly helped to define the technical parameters for this project.

Page 35 of the Terms of Reference contains a general description of work procedures:

2. Scanning

Scanning should be performed with a calibrated device that provides accuracy of a measurement of 1 point per mm^2 (spatial resolution points). Permissible error shall not exceed 5 mm (measurement uncertainty).

The whole object is to be scanned, that means from the outside and inside of the hull, which will determine, among other things, plating thickness at any point thereof.
Individual files with the output data in the form of point clouds collected during the scan, should be described in accordance with the guidelines set forth in Section 2.1. File Naming.
During work contractor must adhere strictly to the recommendations contained in the London Charter (see section 1.3 above).

Ad. 1.2. Development of a *London Charter Implementation Strategy* for every computer-based visualisation of tangible heritage activity.
The Product Specification (within Terms of References) contained detailed information about aims and manner of carrying out the documentation process, especially the method and the technology.
Pages 35-36 of the Terms of Reference contains description considering monitoring of the process:
2.1. Daily reports
Contractor is obliged to create reports from scanning containing paradata (technical metadata) describing the process of creation of computer-based visualisation.
Mentioned above paradata must cover at least:
1. Name of scanner operator
2. Name of scaner
3. Date of last calibration
4. Set measurement accuracy
5. Number of scans made during workday
6. List of file names (according to the names listed in point 2.2)
7. Scanned objects (according to the codes listed in point 2.2)
8. Weather conditions (e.g. sunny, cloudless, cloudy, mostly cloudy, rainy)
9. Average temperature during work of scaner.

Technical meetings and visits were an additional element of monitoring and implementation, and allowed to improve communication between contracting party and contractor.

Support in area of detailed technical knowledge was provided by the Faculty of Ocean Engineering And Ship Technology of the Gdańsk University of Technology, which cooperates with National Maritime Museum in Gdańsk for many years and which was a partner in the project „National Maritime Museum – Digitial Maritime Museum (stage 2)”.

Ad. 1.3. Dissemination of knowledge about the *London Charter* and *Charter Implementation Guidelines* among activity participants who are involved in computer-based visualisation process.

Dissemination of knowledge about the *London Charter* started on the stage of the public procurement as a description in the Terms of Reference, especially in the Product Specification.

Page 35 of the Terms of Reference contains a following description:

1.3. The London Charter

Published in Polish version in 2010 by the Instytut Historii Sztuki Uniwersytetu Wrocławskiego (Institute of History of Art, University of Wrocław) sets rules for computer-based visualisation methods for cultural heritage (originally: The London Charter for the Computer-based Visualisation of Cultural Heritage, edited by Hugh Denard, King's College London, 7 February 2009. Available at www.londoncharter.org). It describes crucial aspects, which must be taken into account while starting a computer-based visualisation project of cultural heritage. The document must be carefully studied by bidders during bidding process of public procurement, so they can assess if the offered method allows fulfilling aims described in this document. In case of winning the procurement and performing the contract, contractor must apply Charter rules, among other by keeping a detailed documentation of visualisation process.

The contractor has been informed about aims and rationale of created documentation and computer-based visualisation during the visit in the Fisheries Museum in Hel, where the boats are on an open air exhibition.

Next stage of dissemination of the knowledge has been a technical meeting with the contractor's engineering team.

Ad. 1.4. Calculation of costs of implementing scientific methods compliant with principles of the London Charter in relation to the added intellectual, educational or economic value of produced outputs.

Cost calculation and later implementation of the project showed no increase in the costs in relation to the implementation of the *London Charter*, because its goals and objectives were consistent with the objectives of the project, which from the very beginning assumed the creation of added value in the form of a complete technical documentation on the basis of scans and computer-based visualizations.

The technical documentation was carried out with scientific methods, which had been guaranteed in the Terms of Reference by requirement specifying that documentation must be prepared by a person possessing appropriate professional qualifications.

The outcome of the project in the form of documentation and computer-based visualization is available online for educational and scientific purpose.

Ad. 2.1. Computer-based visualisation is not the most appropriate method for all cultural heritage research and dissemination of knowledge about tangible heritage.

National Maritime Museum in Gdansk uses various methods of documentation from the 70s of the 20th century. Since 2009, the primary means of collections documentation is digital photography. It should be noted that in the case of boats exhibited in the museum, the results obtained using photographic methods are insufficient. The main difficulty is the spatial arrangement in which the boats are exhibited. This results in the problem of boats sizes in relation to the maximum distance from which a photograph can be performed. Moreover, in the case where it is possible to achieve an appropriate distance from the object, there is the effect of image

distortion or/as well as small scale of the object in the photograph. There is also no possibility of using commercially available rotary tables for photographing objects at a few degrees step of rotation, and then with use of software allowing to create 3D imitation from the set of a few dozen of pictures. Probably a shipyard infrastructure would be needed to perform that kind of documentation. Mentioned infrastructure, which by the way is inaccessible for museum, would among other allow to pivot boats and photographically document them from all sides.

A completely different method is the use of measurement documentation based on hand drawings and work with measuring instruments. Its disadvantages as time-consuming and significant human error (in terms of number of measuring points) cause that it cannot be taken into consideration in the context of the scale of the project and the time available for its implementation. In addition, financial calculations suggest the use of modern methods of measurement due to their speed and accuracy, and the possibility of using the generated output data in the future for various purposes, such as 3D prints.

There is an additional feature in favour of using the scanning method, namely, ability to document large object from a short distance as well as from long distance and joining the output data in one point cloud. This is a feature outperforming the other methods of documentation.

Ad. 2.2. Decision about selecting a method should be proceeded by an assessment of all available methods which could be used to achieve established aims.

Museum uses various methods of visual documentation and evaluates others, which were not used so far by it, with a substantive support of the Faculty of Ocean Engineering and Ship Technology Gdansk University of Technology. Gained experience in already applied methods and observation of global trends in cultural heritage documentation clearly confirmed that the chosen method is currently the most appropriate and the only which provides a projected outcome with use of scientific methods.

In addition, the currently emerging tools for 3D presentation online (e.g. SmithsonianX3D) indicate that the existing barriers to the dissemination of 3D objects online (including speed and traffic load and other factors affecting the user experience) are overcome.

Ad. 2.3. Decision about selecting a method should be based on an evaluation of the likely success of each approach in addressing each aim, especially when a development of a new method is taken to consideration.

The likelihood of achievement of the visualization objectives was defined as very large, bearing in mind two factors. Firstly, the chosen method is successfully used in the shipbuilding industry. Secondly, this method is used for the digital documentation of cultural heritage and has been applied successfully in the digital documentation of the branch of NMM – the Crane.

There was no need to develop or create a new method of computer-based visualization for purpose of this project.

Ad. 3.1. In the context of the *Charter*, research sources are defined as all information, considered during, or directly influencing, the creation of computer-based visualisation outcomes.

References (scientific material):

• photographic documentation

• publications

• spoken memories obtained from the fishermen living in Hel and remembering the use of the documented vessels

• output in the form of point clouds

In the case of technical documentation an applicable standards and regulations for the creation of this type of documentation were used.

Ad. 3.2. Research sources should be used with reference to current understandings within communities of practice.

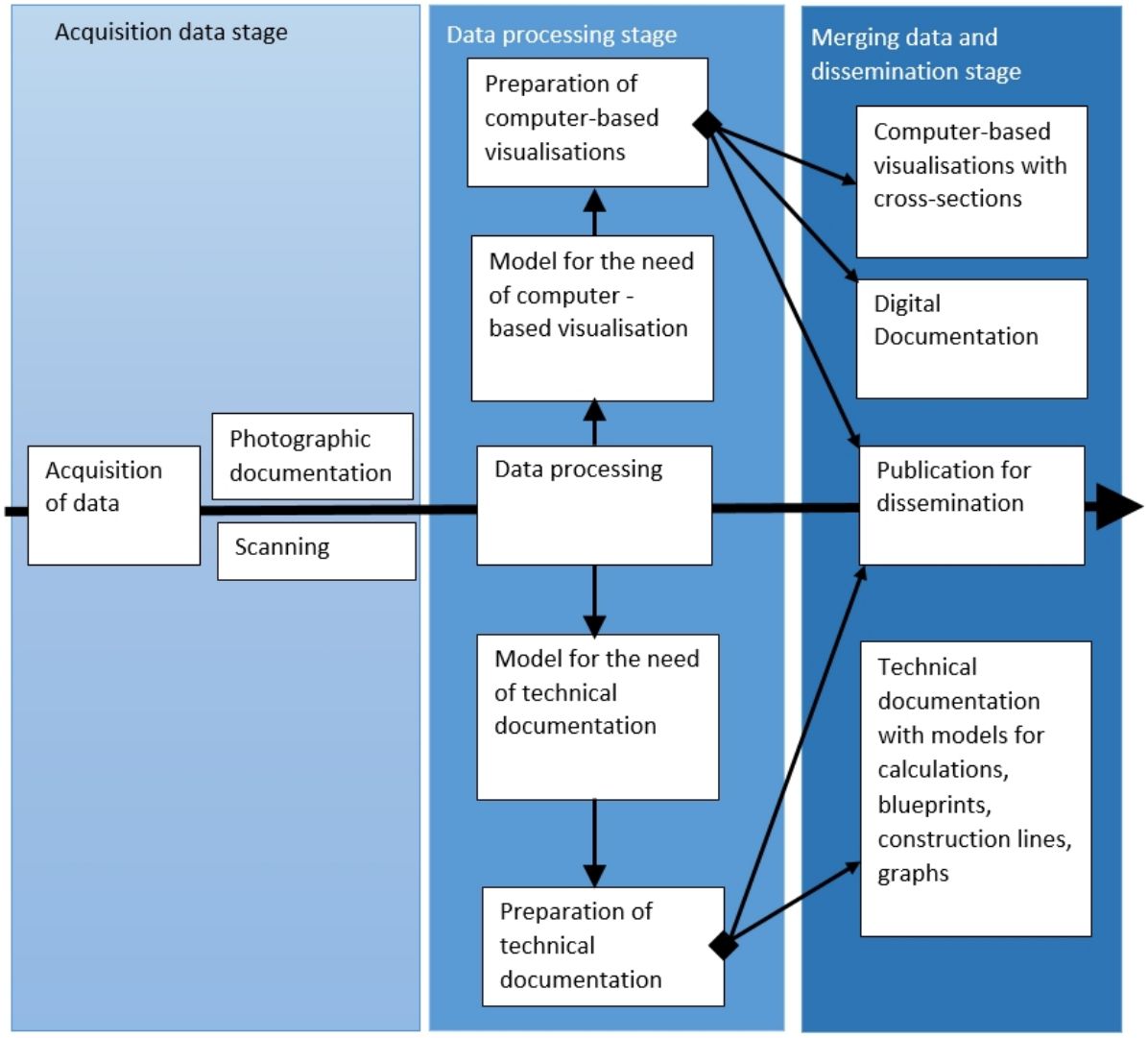
The source material has been used in accordance with the current state of knowledge in the professional environment both for the protection of cultural heritage sector as well as reverse engineering and hull design.

Ad. 3.3. Attention should be given to the influence of ideological, historical, social, religious and aesthetic factors.

During the process no ideological, historical, social, religious or aesthetic factors influenced the project outcome. Both museum and contractor strived to document actual state and tried to create computer-based visualisation of original appearance based on the output data.

Ad. 4.1. Enhancing Practice – visualisation activity documented in designed order, so it might be used for enhancing methods and competences.

Information about used methods with theirs descriptions is included in this study. Contractor photographically documented the process of data acquisition (point clouds). Museum did not require development and establishment of workflow by contractor. Simplified process is shown in the graph below.



Ad. 4.2. Enhancing Practice – documentation allows comparative analysis and outcome assessment, as well as detection of issues which have been revealed during the process of computer-based visualisation activity.

The whole documentation has been created in the same scale and with the use of the same methods, which will allow comparative analysis of documented vessels. The scope of the implementation of computer-based visualization and detection of problems in the process will be a subject of separate studies which will be presented at three conferences:

- “CAA-Norway” (in the group: Computer Applications and quantitive methods in Archeology) in Oslo in 2014

- “Condition.2015 Conservation and Digitization Conference” in Gdańsk in May 2015 – article from the conference will be published in the proceedings in three languages: Polish, English and Norwegian (proceedings will also be available online)
- XIII Conference of Polish Maritime and River Museology in 2016 - an article from the conference will be issued in the proceedings.

Ad. 4.4. Documentation of Knowledge Claims – Clearly indicated purpose of computer-based visualisation for example existing state, an evidence-based restoration, an hypothetical reconstruction, and information about the extent and nature of any factual uncertainty.

Page 35 of the Terms of Reference contains a following description specyfying established aims of the project:

1 Introduction

Digital documentation of collection of 14 boats in Fisheries Museum in Hel aims to create a complete technical documentation for these vessels for the purposes of:

a) conservation – i. e. on providing the fullest possible information on the physical parameters, and thus the preservation state of the vessels and providing data to any comparative work, maintenance, including reconstruction; obtained documentation is to ensure museum with the ability to make and exchange a single structural or planking element in the event of damage or irreversible degradation;

b) registration – i. e. on providing information about the physical and technical parameters of the vessels, for the purpose of inventory and scientific and research work;

c) sharing – i. e. use of the obtained data to disseminate knowledge about the vessels in society, including by publications in online catalogues, animations, augmented reality, re-use, etc.

The use of the term "inventory" in the title of the Terms of Reference is a deliberate action and is intended to indicate the status and purpose of performed digital

documentation, which must be made in a reliable manner, consistent with reality and best practices in this field, taking into account the parameters specified in the second paragraph.

Furthermore, on page 41 of the Terms of Reference it is indicated:

h.) Technical calculations

Calculations specifying among others hydrostatic data, will be performed on the basis of geometric data. Outcome will be presented in a graphical form (hydrostatic curves) and tabular. Technical calculations have to include at least:

- displacement (of hull form) in seawater,

- waterplane area,

- location of the centre of buoyancy,

- change in displacement per unit of immersion,

- curve of sectional areas

- the Bonjean scale

- hull coefficient,

- stability, including: metacentric height and the curve of righting moments.

Due to the fact that there is a lack of original documentation and blueprints for documented vessels (in the most cases they were built in accordance with the boat building tradition) some data will have to be adopted in theory by the Contractor for the need of calculations. Each time it should be clearly indicated in the documentation that such a parameter was adopted theoretically for the abovementioned needs.

Ad. 4.5. Documentation of Research Sources – dissemination of research sources and their provenance.

Documented boats are available for exploring on permanent exhibition at the Fisheries Museum in Hel (a branch of the National Maritime Museum in Gdańsk).

Publications on the topic of the traditional boats are available in bookshops and libraries. The most important are (given in order of publication):

1. Celarek A., *Rybackie łodzie żaglowe z wybrzeży Kaszub*, Gdańsk 1987.
2. Litwin J., *Polskie szkutnictwo ludowe XX wieku, Prace Centralnego Muzeum Morskiego w Gdańsku, Tom X*, Gdańsk 1995.
3. Celarek A., *Kaszubskie łodzie*, Gdańsk 2004.

The output material in the form of a raw point clouds will not be available for wide use in the nearest future.

Ad. 4.9. Documentation of Methods – in case of interdisciplinary context, documentation should be undertaken in such a way that it identifies different research questions, methods, outcomes and lexica of participating members from diverse subject communities.

Differences exist in accordance to the type and purpose of generated 3D models, especially between models required for computer-based visualizations of the current state of objects and models for the technical calculations associated with characteristics of hulls. Therefore, there are two types of models, which has been illustrated herein.

Both disciplines - reverse engineering and construction of hulls were conducted in parallel to each other and did not cause a collision or problems either in research or terminology.

Ad. 4.10. Documentation of Dependency Relationship – dissemination of computer-based visualisation outcomes in such a way that the nature and importance of significant, hypothetical dependency relationships between elements can be clearly identified by users and the reasoning underlying such hypotheses understood.

The documentation has been organized in such a way that it allows the understanding of the proposed hypotheses. Furthermore, areas where the interpretation was used, especially in computer-based visualizations, have been described or identified as containing an interpretation (e.g. filling of the exisitng gaps). Thus, the user can easily determine which element is a reflection of reality, and which has been enriched with generated date.

Page 37 of the the Terms of Reference contains the following statement clarifying areas of interpretation in the context of 3D modeling:

3. 3D Models

Models will be developed in the following variants (for each vessel):

a) model in the form of a point cloud, consisting of the output data obtained during scanning process;

b) full dimensional model without textures, based on the model indicated above (in step a);

c) simplified surface model, hermetic, serving as the basis for the calculation of hydrostatic; it is a model in which due to the need of "seal design" (with complemented defects in hull plating to constitute a complete form as close to the time of operation as possible) it is permissible to interpret and model output data in a way that differs from reality;

d) full dimensional model without textures, completed with missing elements (clearly marked with a different colour than the output data from the scan), in such a way that the hull forms as coherent whole as possible in compare to the period of operation; it is a model in which it is permissible to interpret and model output data in a way that differs from reality;

e) full dimensional model with textures (colour).

Ad. 4.11 i 4.12. Documentation Formats and Standards.

Project outputs will be available in two formats:

• In the case of computer-based visualization it will be published in PDF-3D, although if there is non-commercial or commercial online publishing tool for 3D, which will meet the requirements set by the museum, other formats will be published as well;

• In the case of geometrics (including isometric), drawings and cross-sections for point clouds, triangle meshes and 3D models with textures, as well as for technical calculations, this publication was created. It contains full documentation of the vessel

in Polish and English language in PDF format, and has been made available online. This type of publication was created for each of the 14 vessels. The Contracting party strictly defined content layout of publication in the Terms of Reference.

Ad. 5. Sustainability (planning and implementation of long-term sustainability).

All materials produced by the project, including all output data will be stored in the museum in raw and lossless formats.

Museum will endeavor to secure data in the future, including placing them in a national repository for digital collections at the time when such will be put into operation.

At present, it seems that the museum will not have sufficient resources in future to perform emulation of applications currently being used for viewing the computer-based visualizations and documentation. In this respect the museum has to rely on commercially available solutions.

PDF publications have been printed in several copies for each vessel in order to secure documentation in paper form. One copy of each publication is available in the museum’s library.

National Maritime Museum in Gdansk aims to share and disseminate documentation through Pomeranian Digital Library.

National Maritime Museum in Gdansk aims to share and disseminate information about documentation through Europeana.

Ad. 6. Access (the creation and dissemination computer-based visualisation in such a way as to ensure that maximum possible benefits are achieved for the study, understanding, interpretation, preservation and management of cultural heritage).

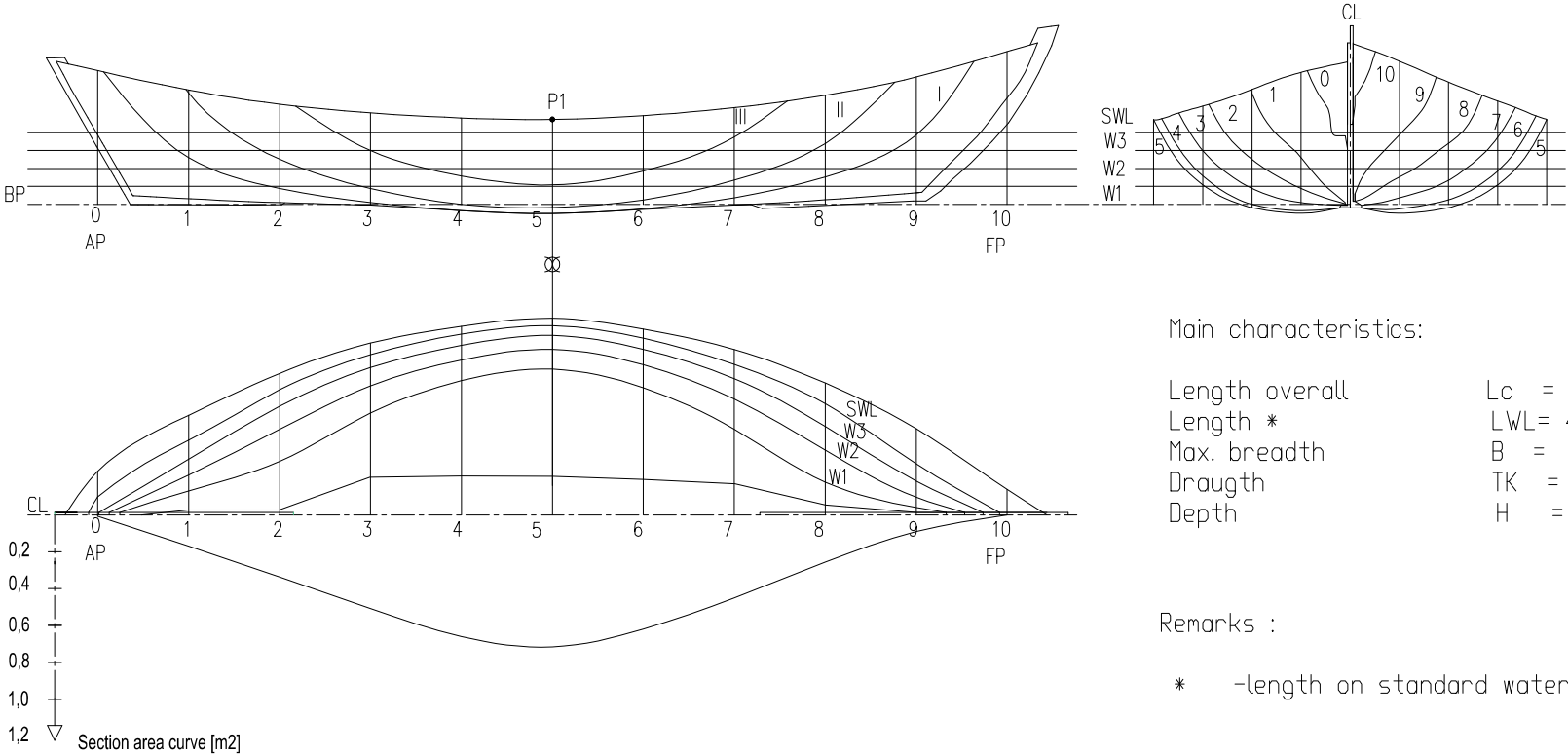
The purpose of sharing is to reach the largest audience in accordance with the museum's mission and with the objectives of the Long-term Government Program “Kultura+”. An important objective is to balance the differences in access to culture arising from the place of residence.

The generated documentation takes into account the cognitive benefits because it creates an opportunity to analyze changes in vessels over time (after re-scanning the boats in a few year time it will be possible to refer to the reference data from current project and to analyze undergone changes).

Documentation made available online will be available from all the places where there is access to the Internet. Entry of the key terms into metadata description of the webpage will increase search efficiency of the content, and preparation of the English version will facilitate the reception of it.

BODY PLAN

Fishing boat MECH14



Main characteristics:

Length overall	Lc = 5,46 m
Length *	LWL= 4,95 m
Max. breadth	B = 2,14 m
Draugth	TK = 0,39 m
Depth	H = 0,46 m

Remarks :

* -length on standard waterline on 0,85 D

SCALE 1:40

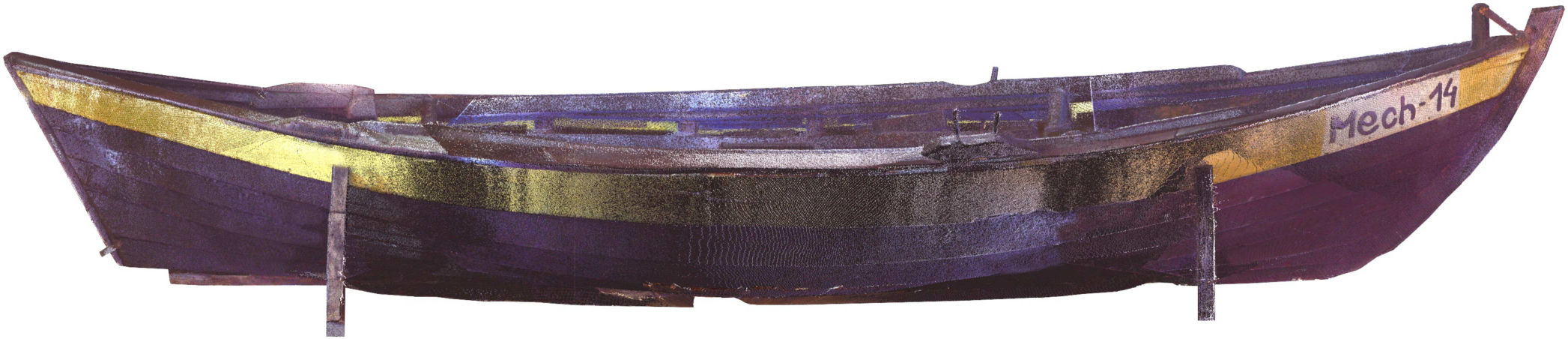
d.1)

PORT SIDE VIEW
FISHING BOAT MECH14

SCALE 1:20

d.2)

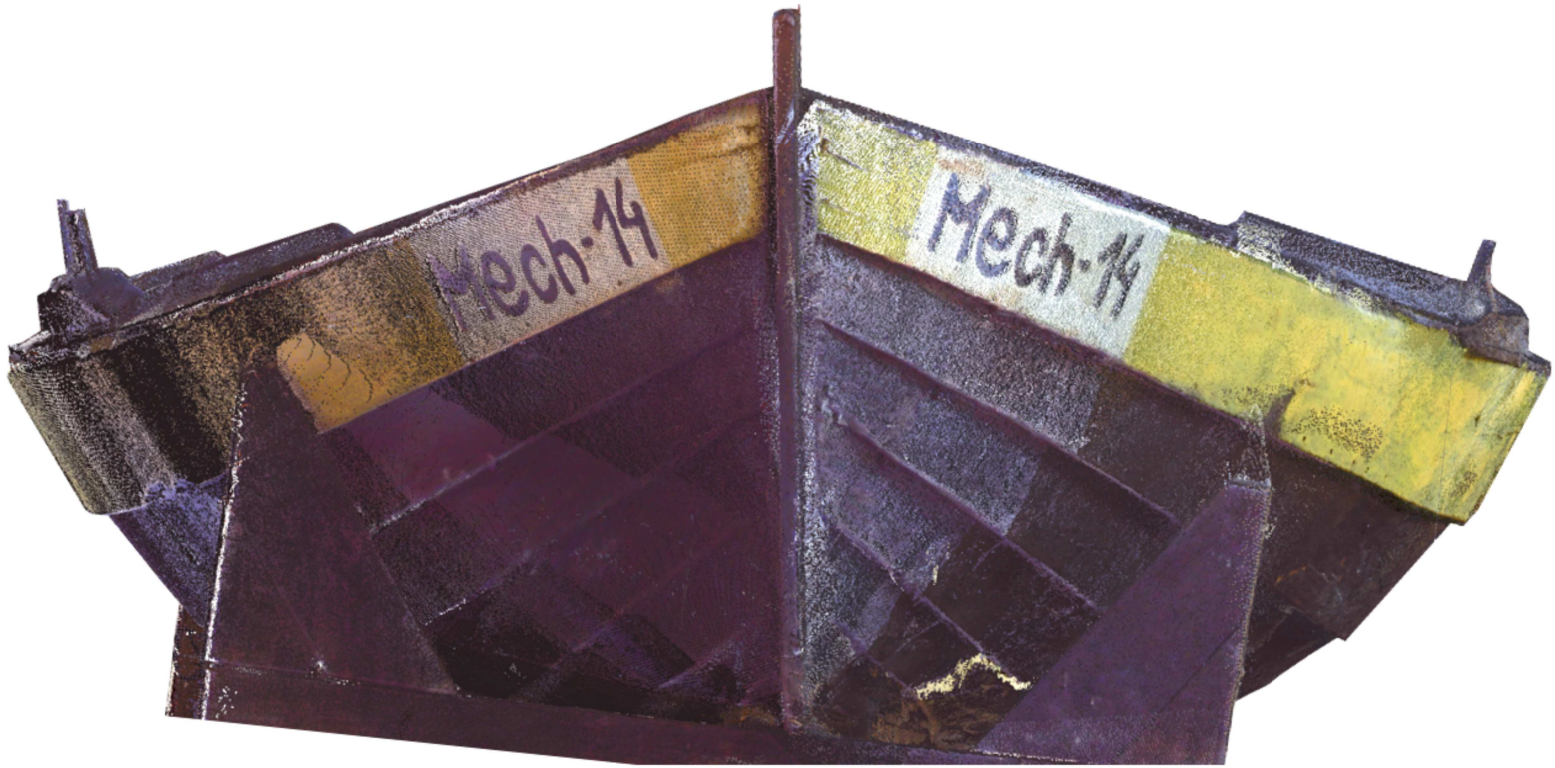
STARBOARD VIEW
FISHING BOAT MECH14



SCALE 1:20

d.3)

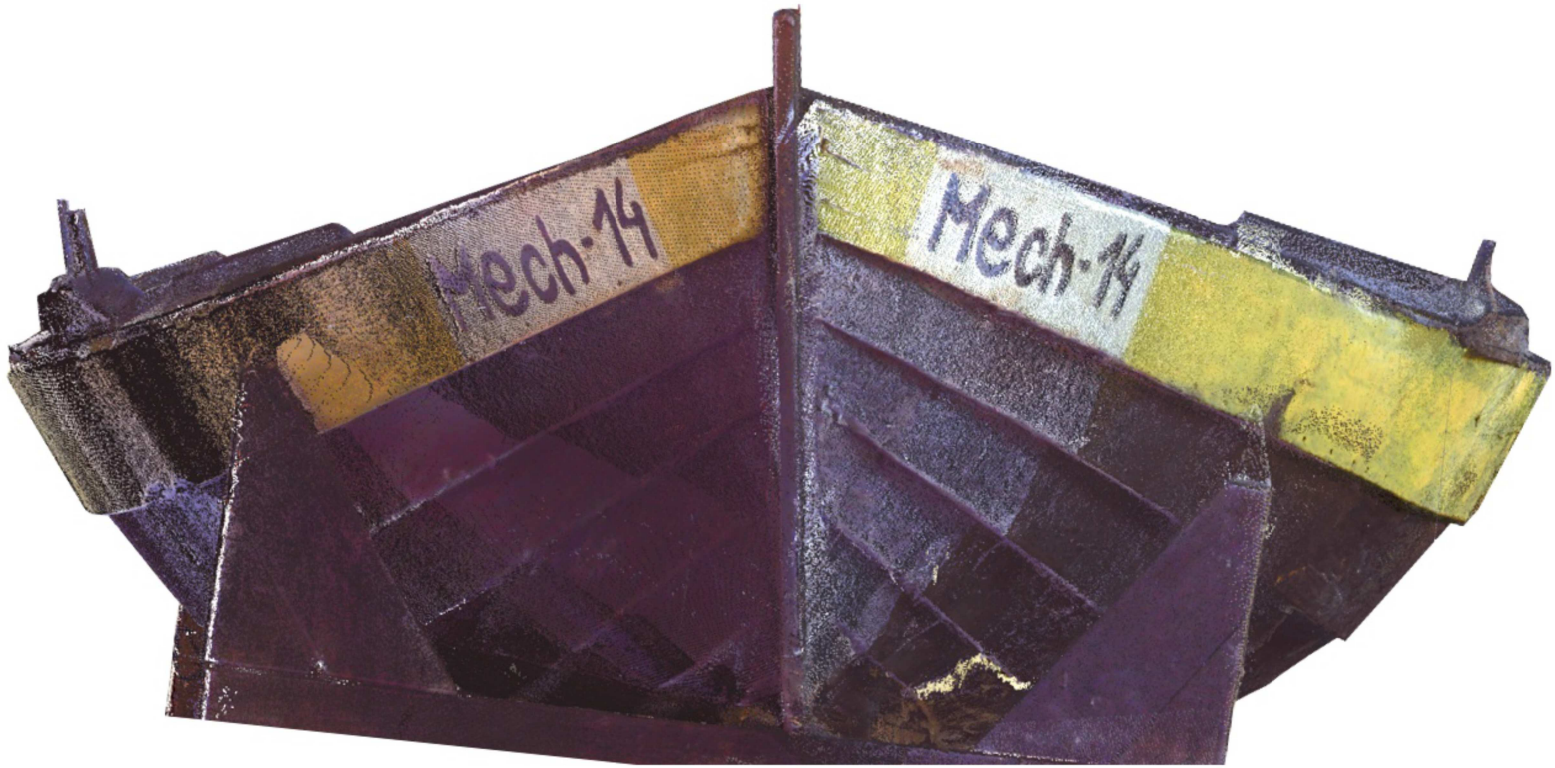
FRONT VIEW
FISHING BOAT MECH14



SCALE 1:10

d.4)

REAR VIEW
FISHING BOAT MECH14



SCALE 1:10

d.5)

TOP VIEW
FISHING BOAT MECH14

SCALE 1:20

d.6)

BOTTOM VIEW
FISHING BOAT MECH14

SCALE 1:20

d.7)

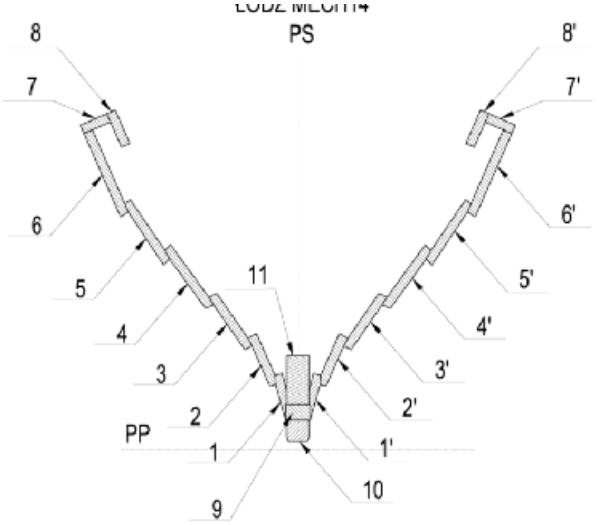
ISOMETRIC VIEW
FISHING BOAT MECH14

D.8) TOP VIEW WITH TRANSVERSE LONGITUDINAL STIFFENERS FISCHING BOAT MECH14

Top view				
No.	**Number on drawings**	**Part**	**Dimensions [m]**	
1	1	Transverse stiffener	height	0,055
			width	0,060
2	2	Longitudinal stiffener	height	0,050
			width	0,020
3	3	Transverse stiffener	height	0,055
			width	0,060
4	4	Transverse stiffener	height	0,055
			width	0,060

Top view				
No.	**Number on drawings**	**Part**	**Dimensions [m]**	
5	5	Transverse stiffener	height	0,055
			width	0,060
6	6	Transverse stiffener	height	0,055
			width	0,060
7	7	Floor	height	0,055
			width	0,060
8	8	Transverse stiffener	height	0,055
			width	0,060
9	9	Longitudinal stiffener	height	0,050
			width	0,020

D.9) BOW CROSS SECTION FISHING BOATH MIECH14

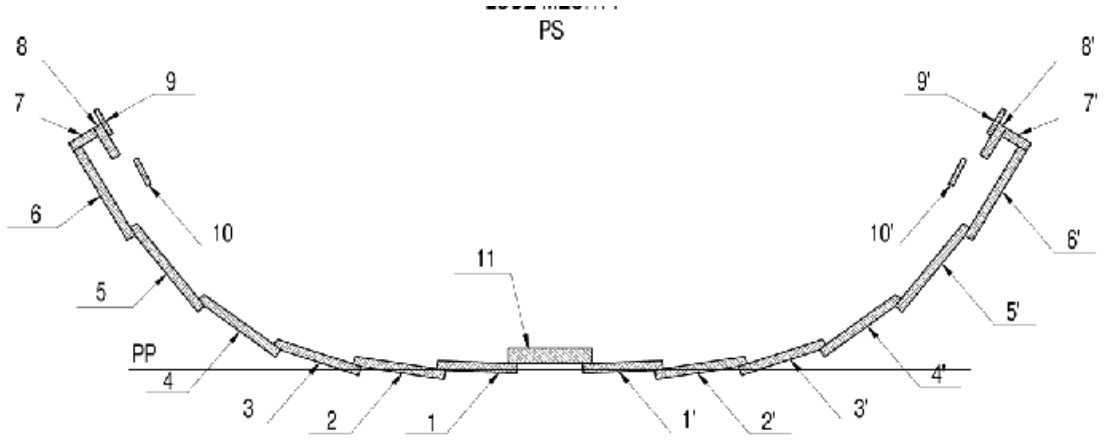


Bow cross section				
No.	**Number on drawings**	**Part**	**Dimensions [m]**	
1	9	Keel	height	0,033
			width	0,053
2	11	Bracket	height	0,107
			width	0,050
3	10	Keelson	height	0,047
			width	0,050
4	7	Sheer	height	0,020
			width	0,063
5	7’	Sheer	height	0,020
			width	0,063
6	8	Side reinforcement	height	0,080
			width	0,020

Bow cross section				
No.	**Number on drawings**	**Part**	**Dimensions [m]**	
7	8’	Side reinforcement	height	0,080
			width	0,020
8	1’	Plank	height	0,100
			width	0,020
9	2’	Plank	height	0,117
			width	0,020
10	3’	Plank	height	0,130
			width	0,020
11	4’	Plank	height	0,154
			width	0,020
12	5’	Plank	height	0,156
			width	0,020
13	6’	Plank	width	0,200
			width	0,020

Bow cross section				
No.	**Number on drawings**	**Part**	**Dimensions [m]**	
14	1	Plank	height	0,100
			width	0,020
15	2	Plank	height	0,117
			width	0,020
16	3	Plank	height	0,130
			width	0,020
17	4	Plank	height	0,154
			width	0,020
18	5	Plank	height	0,156
			width	0,020
19	6	Plank	height	0,200
			width	0,020

D.10) MIDSHIP CROSS SECTION FISHING BOAT MECH14

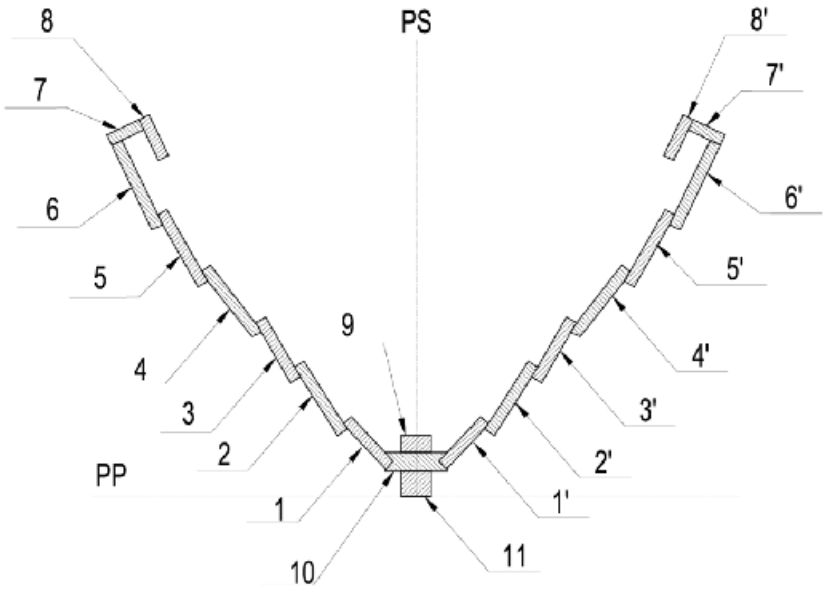


Midship cross section				
No.	**Number on drawings**	**Part**	**Dimensions [m]**	
1	11	Keel	height	0,033
			width	0,184
2	10	Longitudinal stiffener	height	0,064
			width	0,020
3	10’	Longitudinal stiffener	height	0,064
			width	0,020
4	9’	Side reinforcement	height	0,065
			width	0,010
5	9’	Side reinforcement	height	0,065
			width	0,010
6	8	Side girder	height	0,080
			width	0,020

Midship cross section				
No.	**Number on drawings**	**Part**	**Dimensions [m]**	
7	8’	Side girder	height	0,080
			width	0,020
8	7	Sheer	height	0,063
			width	0,020
9	7’	Sheer	height	0,063
			width	0,020
10	1’	Plank	height	0,175
			width	0,020
11	2’	Plank	height	0,200
			width	0,020
12	3’	Plank	height	0,200
			width	0,020
13	4’	Plank	height	0,208
			width	0,00
14	5’	Plank	height	0,235
			width	0,020
15	6’	Plank	height	0,228
			width	0,020

Midship cross section				
No.	**Number on drawings**	**Part**	**Dimensions [m]**	
16	1	Plank	height	0,175
			width	0,020
17	2	Plank	height	0,200
			width	0,020
18	3	Plank	height	0,200
			width	0,020
19	4	Plank	height	0,208
			width	0,00
20	5	Plank	height	0,235
			width	0,020
21	6	Plank	height	0,228
			width	0,020

D.11 STERN CROSS SECTION FISHING BOAT MECH14



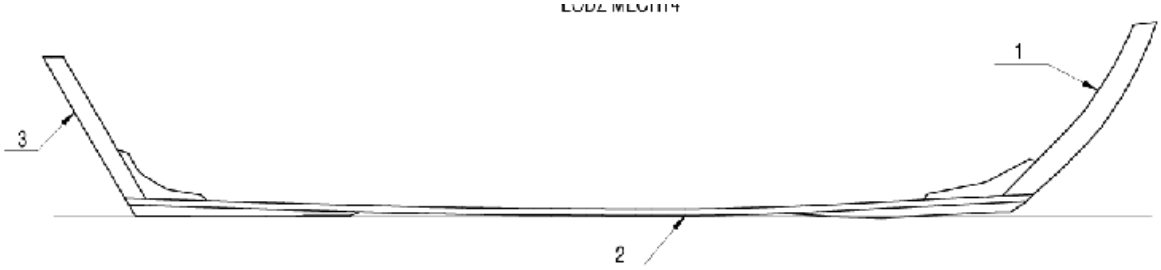
Stern cross section				
No.	**Number on drawings**	**Part**	**Dimensions [m]**	
1	10	Keel	height	0,033
			width	0,110
2	9	Bracket	height	0,030
			width	0,053
3	11	Keelson	height	0,046
			width	0,053
4	8	Side reinforcement	height	0,080
			width	0,020
5	8’	Side reinforcement	height	0,080
			width	0,020
6	7	Sheer	height	0,020

			width	0,063

Stern cross section				
No.	**Number on drawings**	**Part**	**Dimensions [m]**	
7	7’	Sheer	height	0,063
			width	0,020
8	1’	Plank	height	0,109
			width	0,020
9	2’	Plank	height	0,143
			width	0,020
10	3’	Plank	height	0,123
			width	0,020
11	4’	Plank	height	0,148
			width	0,020
12	5’	Plank	height	0,146
			width	0,020
13	6’	Plank	height	0,167
			width	0,020

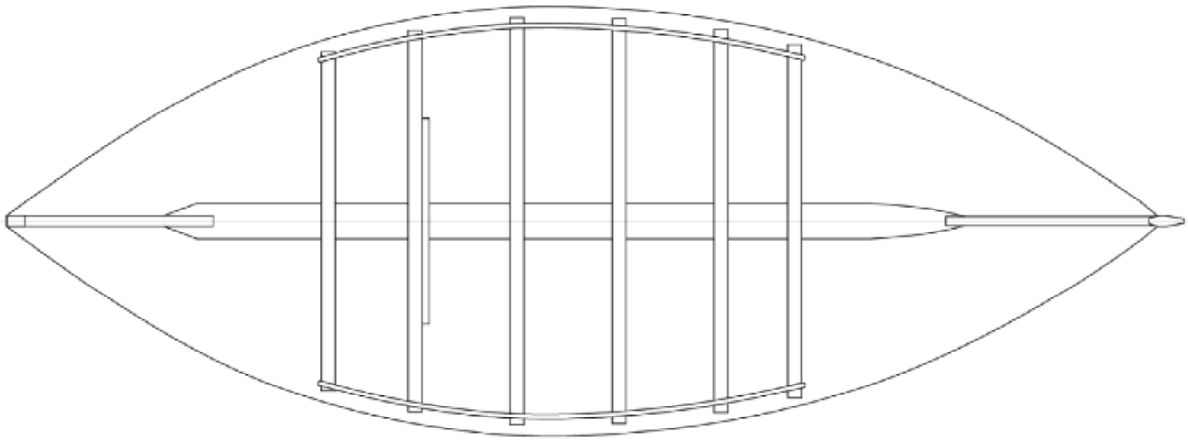
Stern cross section				
No.	**Number on drawings**	**Part**	**Dimensions [m]**	
14	1	Plank	height	0,109
			width	0,020
15	2	Plank	height	0,143
			width	0,020
16	3	Plank	height	0,123
			width	0,020
17	4	Plank	height	0,148
			width	0,020
18	5	Plank	height	0,146
			width	0,020
19	6	Plank	height	0,167
			width	0,020

D.12) BACKBONE FISHING BOAT MECH14



Backbone				
No.	**Number on drawings**	**Part**	**Dimensions [m]**	
1	1	Stem	height	0,116
			width	0,040
2	2	Keel	height	0,033
			width	0,184
3	3	Stern frame	height	0,090
			width	0,050

D.13) BACKOBONE DRAWNING WITH TRANSVERSE AND LONGITUDINAL STIFFENERS, WITHOUT PLANKS FISHING BOAT MECH14



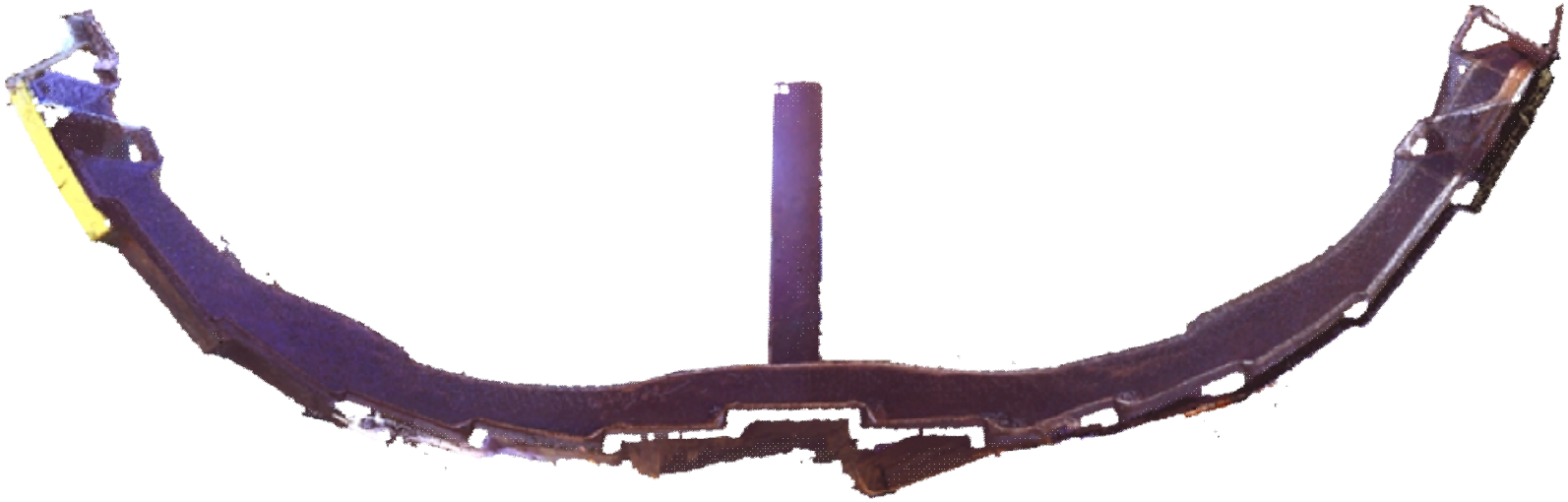
E) CLOUD OF POINTS

E.1) ISOMETRIC VIEW

E.2) CROSS SECTION IN THE BOW SECTION

Scale 1 : 10

E.3) CROSS SECTION IN AMIDSHIPS



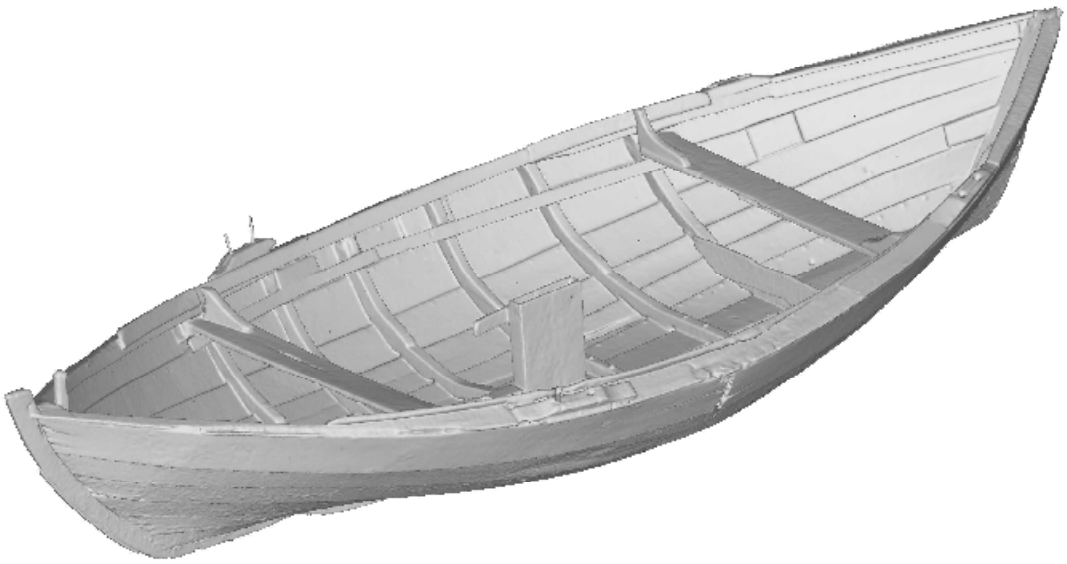
Scale 1 : 10

E.4) CROSS SECTION IN THE STERN SECTION

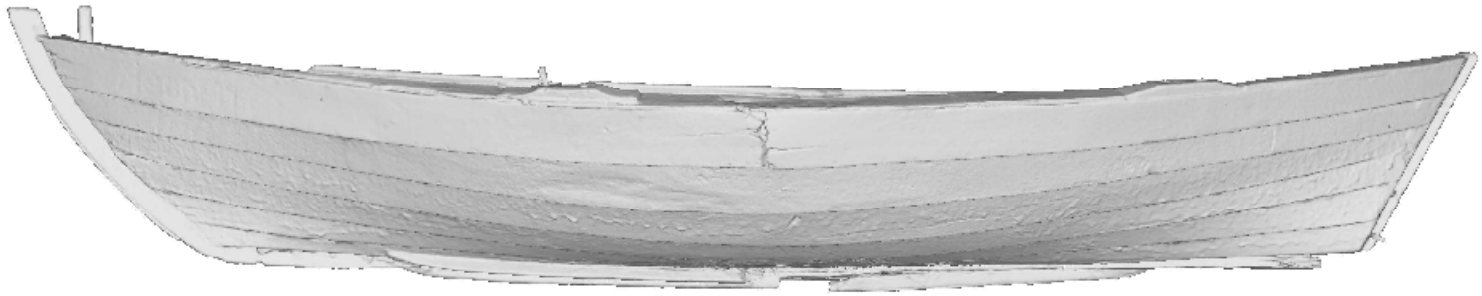
Scale 1 : 10

F) 3D MODEL

F.1) 3D model without textures based on the collected cloud of points(isometric view)



F.2) 3D model without textures based on the collected cloud of points (view from the left side)

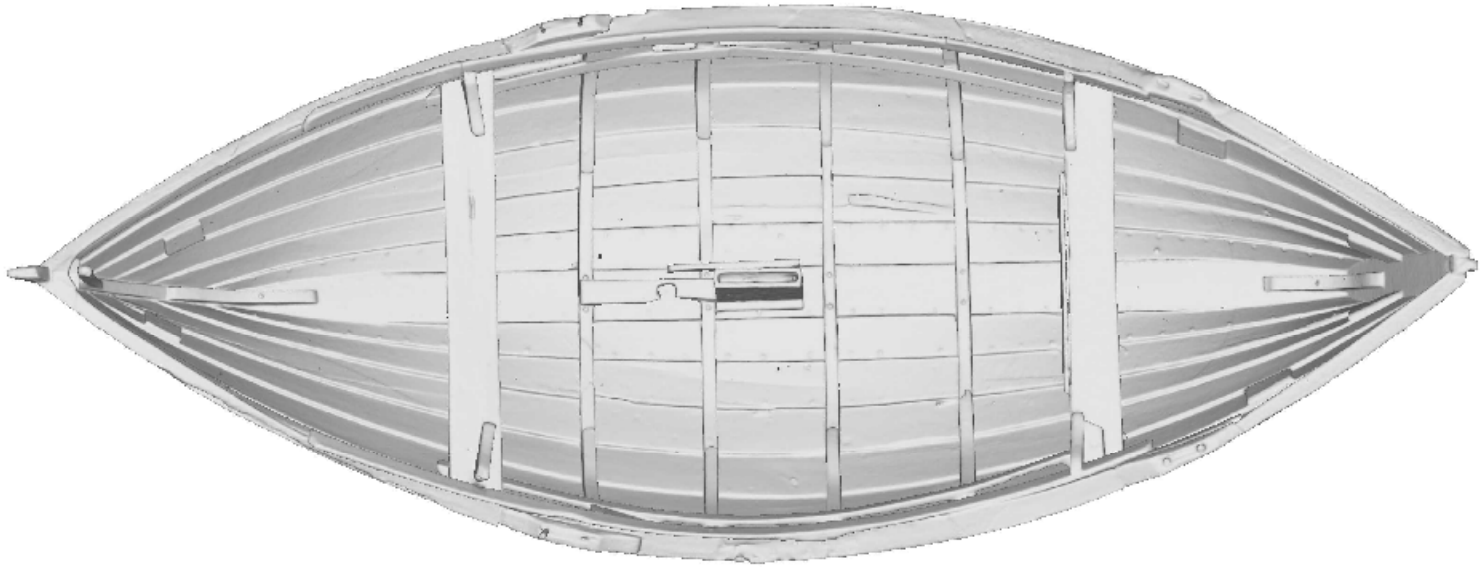


Scale 1 : 20

F.3) 3D model without textures based on the collected cloud of points (view from the right side)

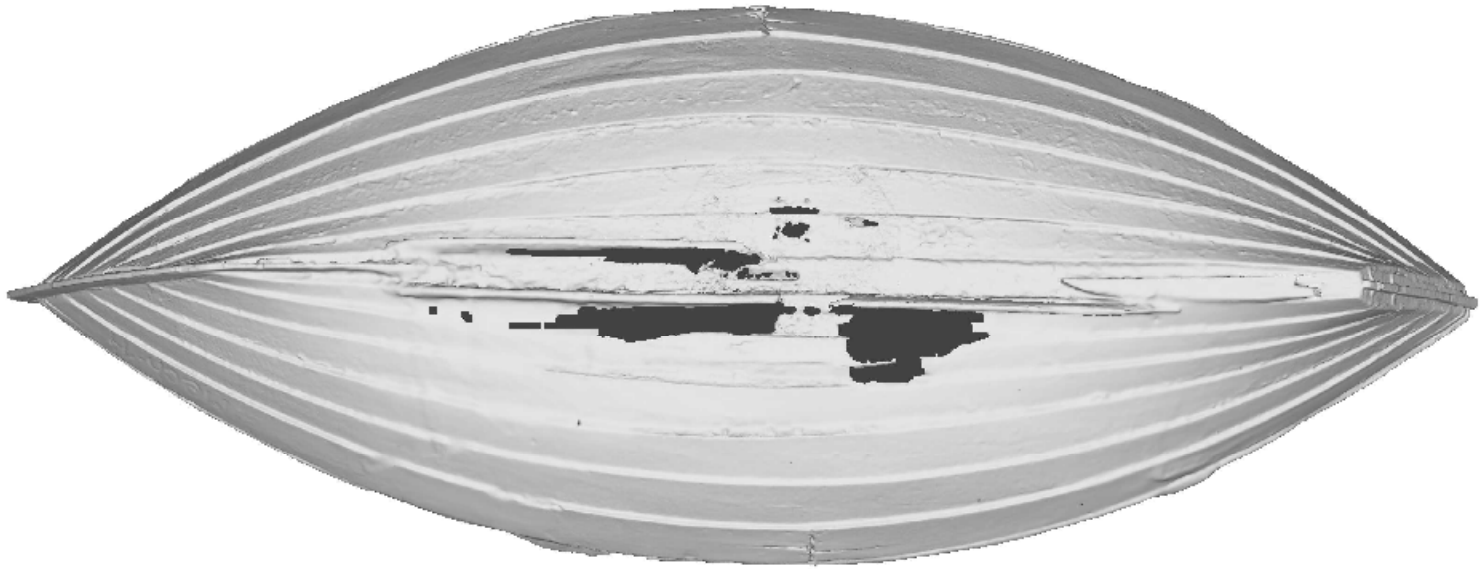
Scale 1 : 20

F.4) 3D model without textures based on the collected cloud of points (view from the top)



Scale 1 : 20

F.5) 3D model without textures based on the collected cloud of points (view from the bottom)

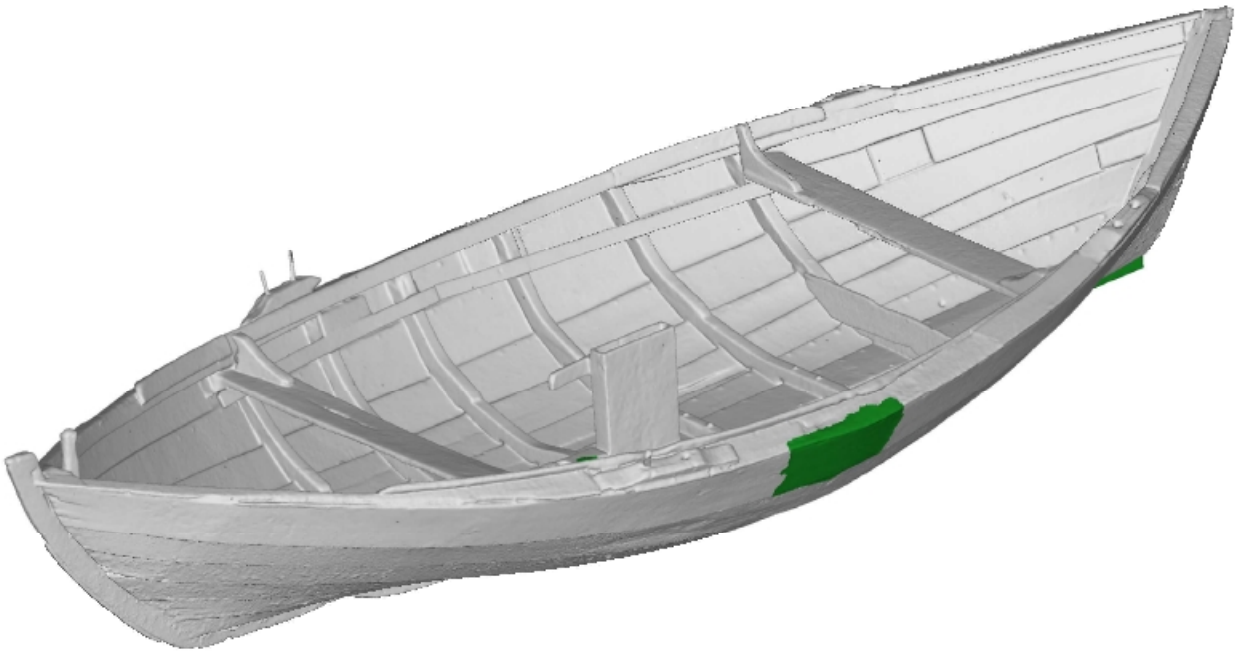


\\\

Scale 1 : 20

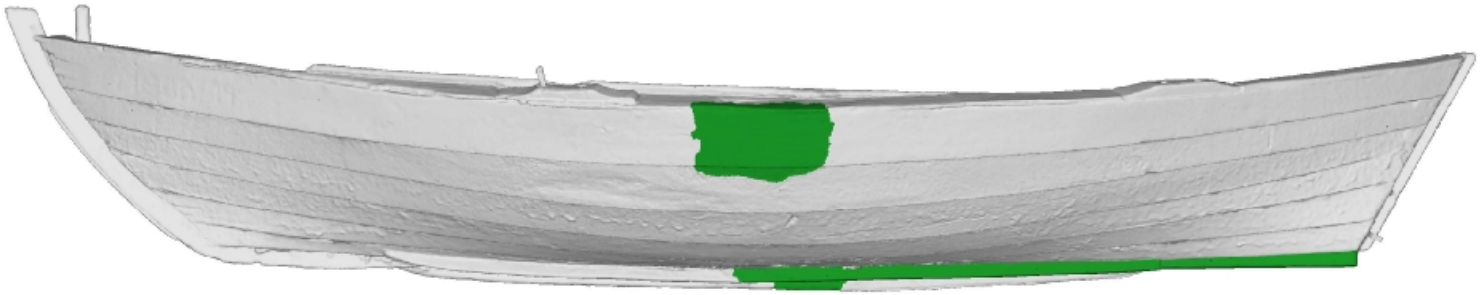
F.6) Full Plastic 3D model without textures (isometric view)

Places of additions shown in green.



F.7) Full Plastic 3D model without textures (view from the left side)

Places of additions shown in green.



Scale 1 : 20

F.8) Full Plastic 3D model without textures (view from the right side)

Places of additions shown in green.

Scale 1 : 20

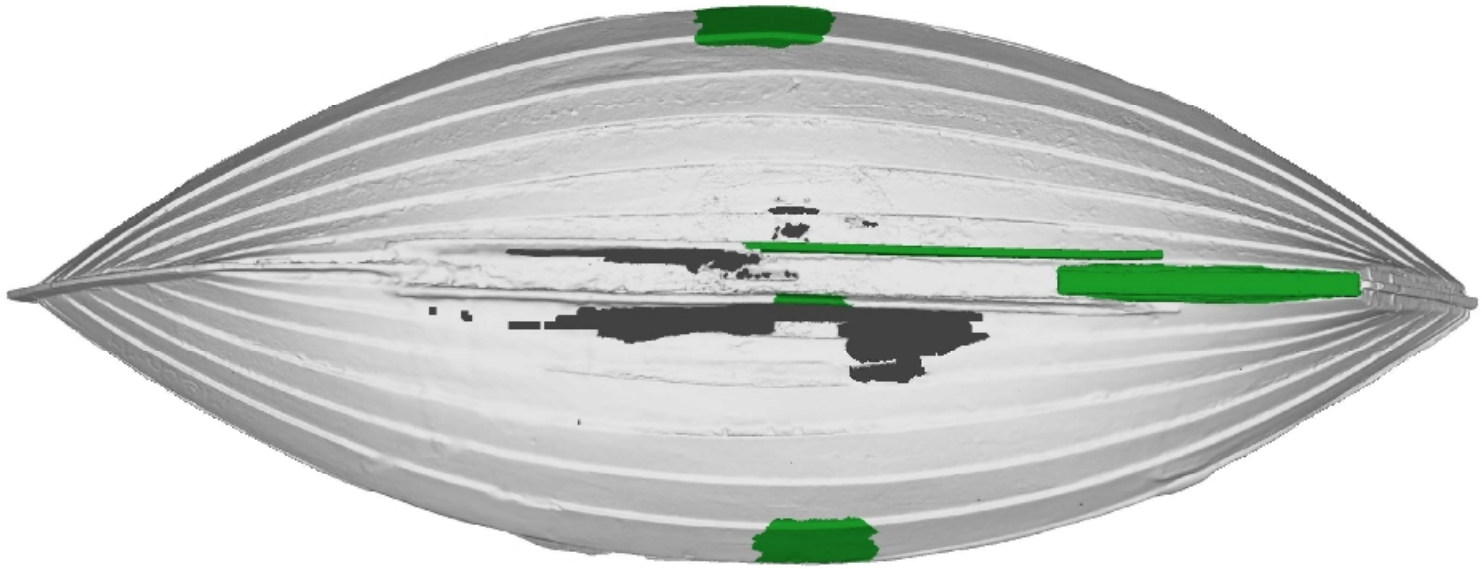
F.9) Full Plastic 3D model without textures (view from the top)

Places of additions shown in green

Scale 1 : 20

F.10) Full Plastic 3D model without textures (view from the bottom)

Places of additions shown in green



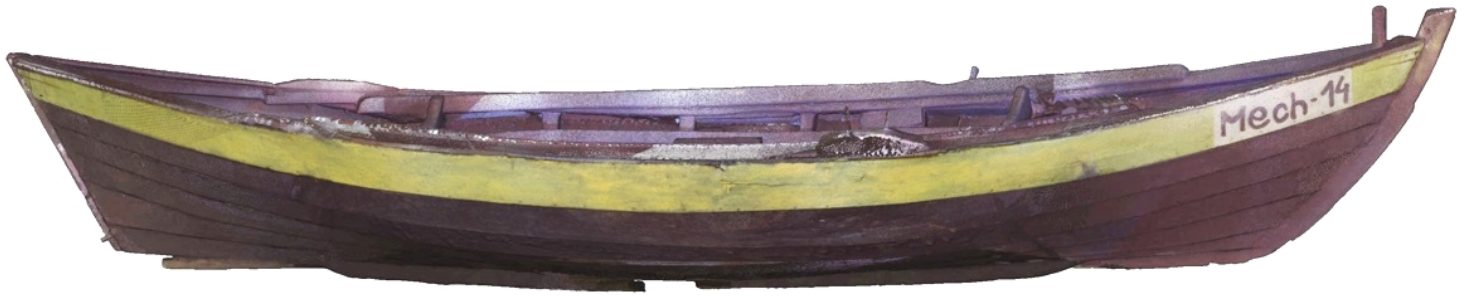
Scale 1 : 20

F.11) Full Plastic 3D model with textures (isometric view)

F.12) Full Plastic 3D model with textures (view from the left side)

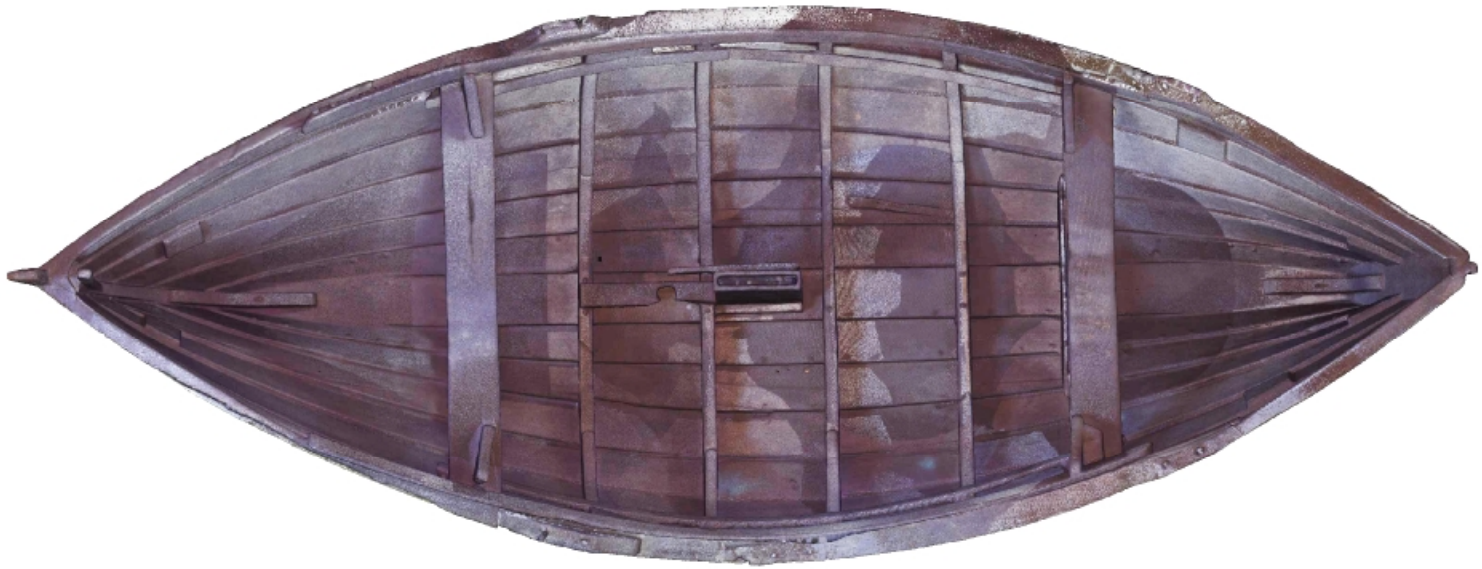
Scale 1 : 20

F.13) Full Plastic 3D model with textures (view from the right side)



Scale 1 : 20

F.14) Full Plastic 3D model with textures (view from the top)



Skala 1 : 20

F.15) Full Plastic 3D model with textures (view from the bottom)

Scale 1 : 20

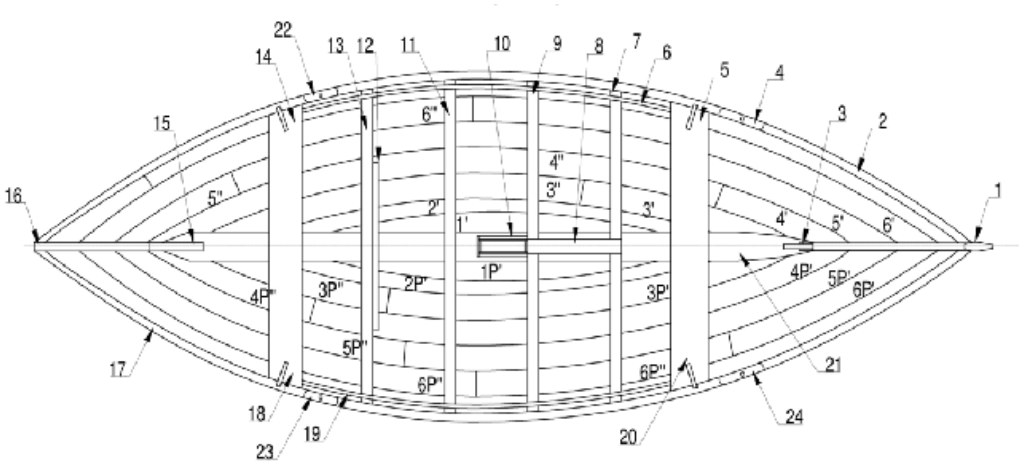
G) DIMENSIONING

G.1) MAIN DIMENSIONS

Length overall, width in 3 measuring points (include maximum), height in 3 measuring points (include maximum)

Wymiary podstawowe jednostki Mech-14		
Długość całkowita		
L.p.	Wartość[m]	Średnia[m]
1	5,500	5,500
Wysokość		
L.p.	Wartość[m]	Średnia[m]
1	0,460	0,740
2	0,970	
3	0,790	
Szerokość		
L.p.	Wartość[m]	Średnia[m]
1	2,140	3,130
2	2,000	
3	2,120	

G.2) EXPLANTORY DRAWNING TOP VIEW



Explanatory drawing					
No.	**Number on drawings**	**Name**	**Part**	**Dimensions [m]**	
1	1’	KP-1LB/1	First plank from bow first strake of plating port side	height	0,100
				width	0,020
2	2’	KP-2LB/1	First plank from bow second strake of plating port side	height	0,117
				width	0,020

Explanatory drawing					
No.	**Number on drawings**	**Name**	**Part**	**Dimensions [m]**	
3	3’	KP-3LB/1	First plank from bow third strake of plating port side	height	0,130
				width	0,020
4	3’’	KP-3LB/2	Second plank from bow third strake of plating port side	height	0,200
				width	0,020

5	4’	KP-4LB/1	First plank from bow fourth strake of plating port side	height	0,154
				width	0,020
6	4’’	KP-4LB/2	Second plank from bow fourth strake of plating port side	height	0,154
				width	0,020
7	5’	KP-5LB/1	First plank from bow fifth strake of plating port side	height	0,156
				width	0,020
8	5’’	KP-5LB/2	Second plank from bow fifth strake of plating port side	height	0,235
				width	0,020
9	6’	KP-6LB/1	First plank from bow sixth strake of plating port side	height	0,200
				width	0,020

Explanatory drawing					
No.	**Number on drawings**	**Name**	**Part**	**Dimensions [m]**	
10	6’’	KP-6LB/2	Second plank from bow sixth strake of plating port side	height	0,228
				width	0,020
11	1P’	KP-1PB/1	First plank from bow first strake of plating starboard	height	0,100
				width	0,020
12	2P’	KP-2PB/1	First plank from bow second strake of plating starboard	height	0,117
				width	0,020
13	3P’	KP-3LB/1	First plank from bow third strake of	height	0,130

			plating starboard	width	0,020
14	3P’’	KP-3PB/2	Second plank from bow third strake of plating starboard	height	0,200
				width	0,020
15	4P’	KP-4PB/1	First plank from bow fourth strake of plating starboard	height	0,154
				width	0,020
16	4P’’	KP-4PB/2	Second plank from bow fourth strake of plating starboard	height	0,208
				width	0,020
17	5P’	KP-5PB/1	First plank from bow fifth strake of plating starboard	height	0,156
				width	0,020
18	5P’’	KP-5PB/2	Second plank from bow fifth strake of plating starboard	height	0,235
				width	0,020

Explanatory drawing					
No.	**Number on drawings**	**Name**	**Part**	**Dimensions [m]**	
19	6P’	KP-6PB/1	First plank from bow sixth strake of plating starboard	height	0,200
				width	0,020
20	6P’’	KP-6PB/2	Second plank from bow sixth strake of plating starboard	height	0,228
				width	0,020
21	6P’’	KP-6PB/3	Thirdplank from bow sixth strake of plating starboard	height	0,167
				width	0,20

22	1	Sd	Stem	height	0,116
				width	0,040
23	2	M	Sheer	height	0,020
				width	0,063
24	3	W	Bracket	height	0,030
				width	0,053
25	4	Dw-LB	Oarlock on port side	height	0,045
				width	0,180
26	5	Wr-1	First frame from bow	height	0,055
				width	0,060
27	6	Wz-LB	Longitudinal stiffener on port side	height	0,050
				width	0,020

Explanatory drawing					
No.	**Number on drawings**	**Name**	**Part**	**Dimensions [m]**	
28	7	Wr-2	Second frame from bow	height	0,060
				width	0,055
29	8	W	Bracket	height	0,030
				width	0,053
30	9	Wr-3	Third frame from	height	0,060

			bow		
				width	0,055
31	10	S	Centreboard box	height	0,110
				width	0,265
32	11	Wr-4	Fourth frame from bow on port side	height	0,060
				width	0,055
33	12	D-1	First floor from bow	height	0,060
				width	0,055
34	13	Wr-5	Fifth frame from bow	height	0,060
				width	0,055
35	14	Wr-6	Sixsth frame from bow	height	0,060
				width	0,055
36	15	W	Bracket	height	0,030
				width	0,053
37	16	Sr	Stern frame	height	0,090
				width	0,050

Explanatory drawing					
No.	**Number on drawings**	**Name**	**Part**	**Dimensions [m]**	
38	17	M	Sheer	height	0,020
				width	0,063
39	18	Ł-1	Bench	height	0,005
				width	0,170
40	19	Wz-PB	Longitudinal stiffener on starboard	height	0,050
				width	0,020
41	20	Ł-2	Bench	height	0,005
				width	0,200
42	21	St	Keel	height	0,033
				width	0,184
43	22	Dw-LB	Oarlock on port side	height	0,180
				width	0,045
44	23	Dw-PB	Oarlock on starboard	height	0,045
				width	0,178
45	24	Dw-PB	Oarlock on starboard	height	0,045
				width	0,178

H) THEORETICAL CALCULATION

The purpose of the theoretical calculations is to determine hydrostatic characteristics of boats dependent on its geometric shapes and determine the stability of the boat for established loading conditions marked mass of the boat and vertical position of the center of mass.

For the task created a calculation model includes:

1. Establishing a clear nomenclature, the coordinate system, the calculation assumptions.
2. Presentation of geometric shape of boat hull in the implementation of a professional marine computer program.
3. Determination of mass of boats and vertical coordinates of the center of mass for establishing loading conditions.
4. The choice of a computer program, calculations and their graphics and digital presentation.

Ad 1.

Symbols and names adopted by the Code of Safety for Fishermen and Fishing Vessels, IMO, London 1969 (CSF&FV) and ITTC (International Towing Tank Conference) dictionary. Points and the reference plane adopted in accordance with Fig. TC -1 as for a boats made of wood. Fishing boats are not designed waterline in terms of shipbuilding, therefore adopted the standard water lines according to (CSF & FV), which corresponds to the maximum loading condition of the boat. The calculations were performed for the water of the Baltic Sea in the Polish coastal zone where the salinity of the water corresponds to the specific mass **r** =1.0065 t/m3.

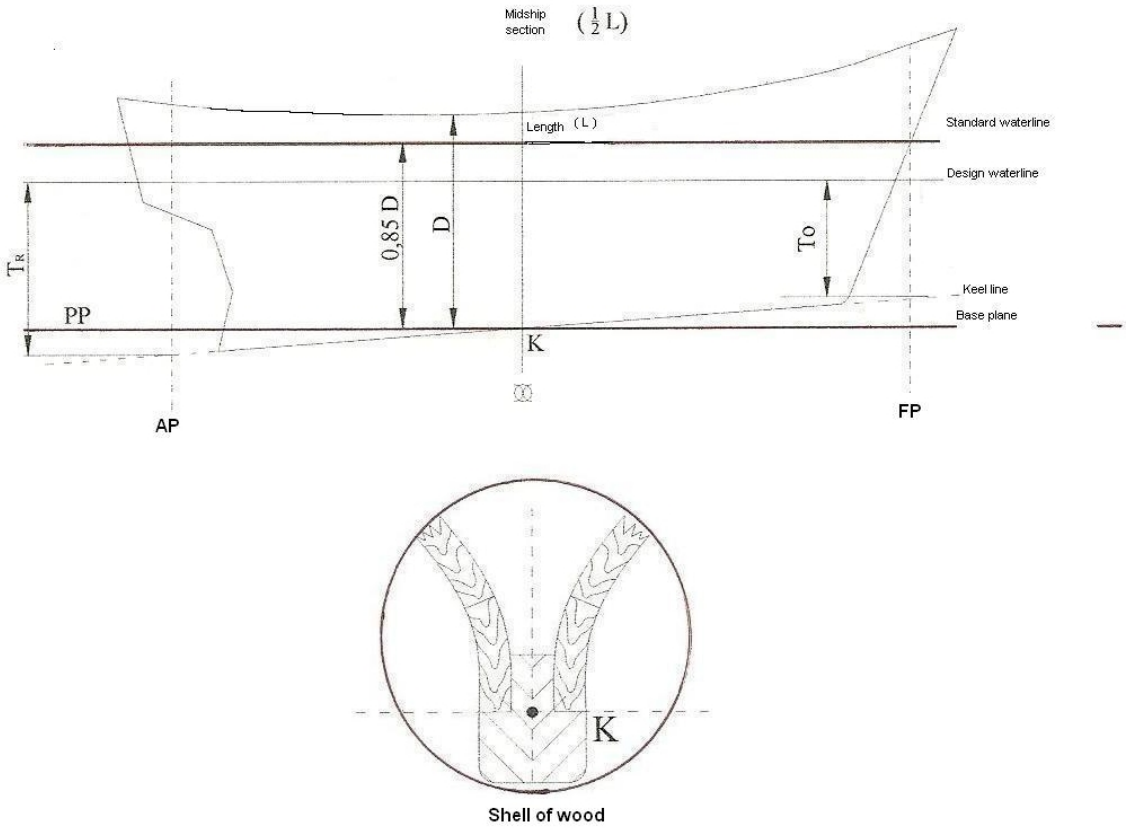


Fig . TC – 1

Ad 2.

For the calculation in the implementation of PC generated relevant to the method the lines drawing that for hull of wood are envelope of external measuring points as shown in Fig.TC-2. In a ship calculations shall be marine shell factor k_P dependent on the material of the hull. For boats with clinker planking the factor $k_P = 0{,}98$. Calculated value of the corrected specific mass of salt water

$\rho = \rho_{ws} \times k_P = 0{,}986.$

Point K is the center of the adopted coordinate system XYZ and provides a reference for the calculation of the stability of the boat. After failings the boat shapes, generated computational lines drawing were used for calculation of hydrostatic and to stability.

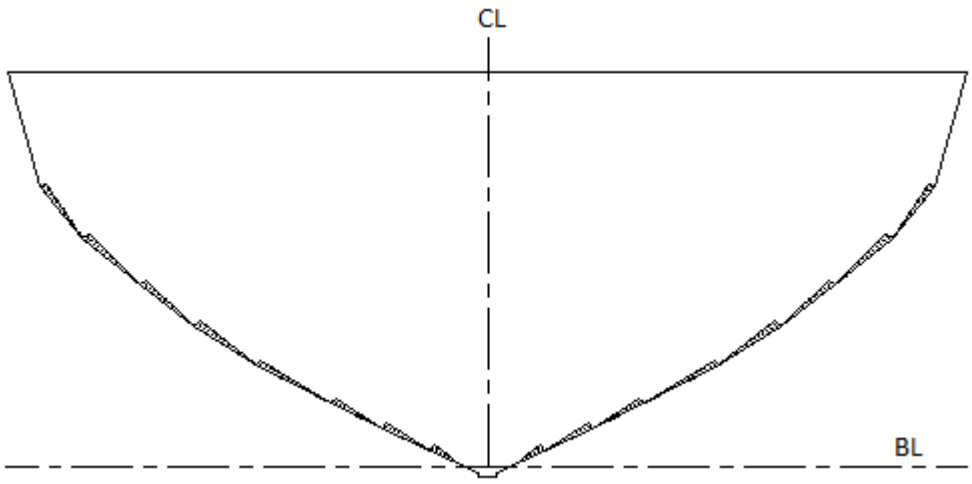


Fig. OT - 2

Ad 3.

For the stability calculations must determine the mass and center of mass of the empty boat. These values are standard defined based on the results of the inclining test. Due to the technical conditions of the boat these values determined theoretically. For the boat MECH14 created a 3D surface model of the outer and inner side. Shell model presents material of wooden construction of the hull and allows the calculation of the mass and center of mass. For the material of the hull with oak wood adopted a density **r** = 700 kg/m3.

For boat MECH14:

Mass of the light vessel = 325 kg

Vertical coordinate of center of mass from base plane ZG = 0,18 m

Ad4.

Theoretical Calculations carried out by a computer program CHGK commonly used for small vessels in classification and certification.

The stability calculations were performed for two loading conditions of the boat.

1. Stability of the boat when leaving the port - a dry net , crew - 2 persons , provision.

2 . Stability of the boat at return to port - a wet net, crew – 2 persons, caught fish.

The following assumption has been adopted:

- Crew - 2 persons
- Network and caught fish are located on the floor of the boat
- Wet net mass + maximum mass of caught fish m_{Nw-f} = 500 kg
- Dry net mass m_{Nd} = 100 kg
- Mass of one person - 75 kg, the center of mass of a man standing -1.0 m above the floor of the boat
- Mass of provision m_p = 5 kg /person

Scope of calculation:

1. **Hydrostatic curves –** define the following values depending on the draft of the boat:
   - Area of the waterplane A_W (m2)
   - Coordinate X of the center of area of waterline from midship section xF, (“”– “ towards the stern)
   - Transverse moment of inertia of waterplane IT (m4)
   - Longitudinal moment of inertia of waterplane IL (m4)
   - Volume displacement V (m3)
   - Mass displacement D (t)
   - Longitudinal coordinate X of center buoyancy from midship section xV (LCB), (“- “ towards the stern) (m)
   - Vertical coordinate Z of center buoyancy from base plane BP (m)
   - Transverse metacentric radius r0 (BM) (m)
   - Metacentric height KM (m)
   - Longitudinal metacentric radius R0 (BM_L) (m)
   - Increase of buoyancy per unit immersion dD (t/mc)
   - Unit trimming moment Mj (tm/cm)
   - Block coefficient CB
   - Midship section coefficient CM
   - Waterplane coefficient CW
   - Prismatic coefficient CP

   where:

$$C_B = \frac{V}{L \cdot B \cdot T},\ C_p = \frac{V}{A_{\otimes} \cdot L},\ C_M = \frac{A_{\otimes}}{B \cdot T},\ C_W = \frac{A_w}{L \cdot B}$$

   L, B, T , V– length, breath , draft of boat and displacement

$A_{\otimes}$ – area of midship section

A_w – area of waterplane.

2. **Bonjean scale** - given sections area and their moment of inertia depending on a draft of the boat. It allows you to find the position of the center of the waterplane, the center of buoyancy and displacement of the trimmed boat.

3. **Cross curves of stability** - determine the righting lever depending on the shape of hull in relation to displacement and angle of heel of the boat.

4. **Curve of flooding angle** - determines the angle at which boat will be flooded with outboard water, in relation to displacement of the boat (loading condition).

5. **Curve of static and dynamic stability:**

- Curve of static stability shows the arm of the static righting moment $\mathbf{M_P}$ at the angle of heel **fi** , $\mathbf{l_s = M_P / D}$.
- Curve of dynamic stability expresses the work L_P needed to heel the boat to the dynamic angle of heel **fi** , $\mathbf{l_d = L_P / D}$.

The range of the righting arms curves of static and dynamic stability is valid to the flooding heel angle of $\mathbf{fi_{zl}}$ at which the boat is flooded with water and loses stability.

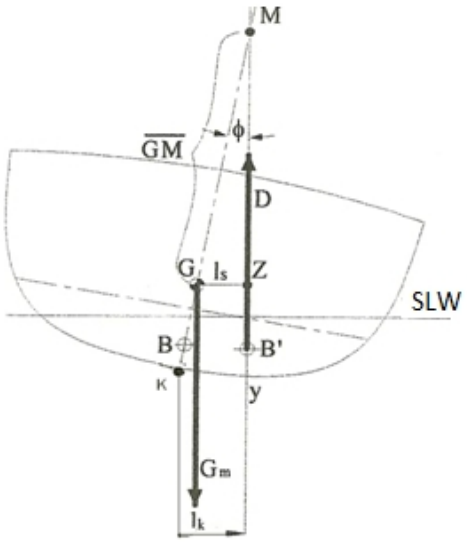
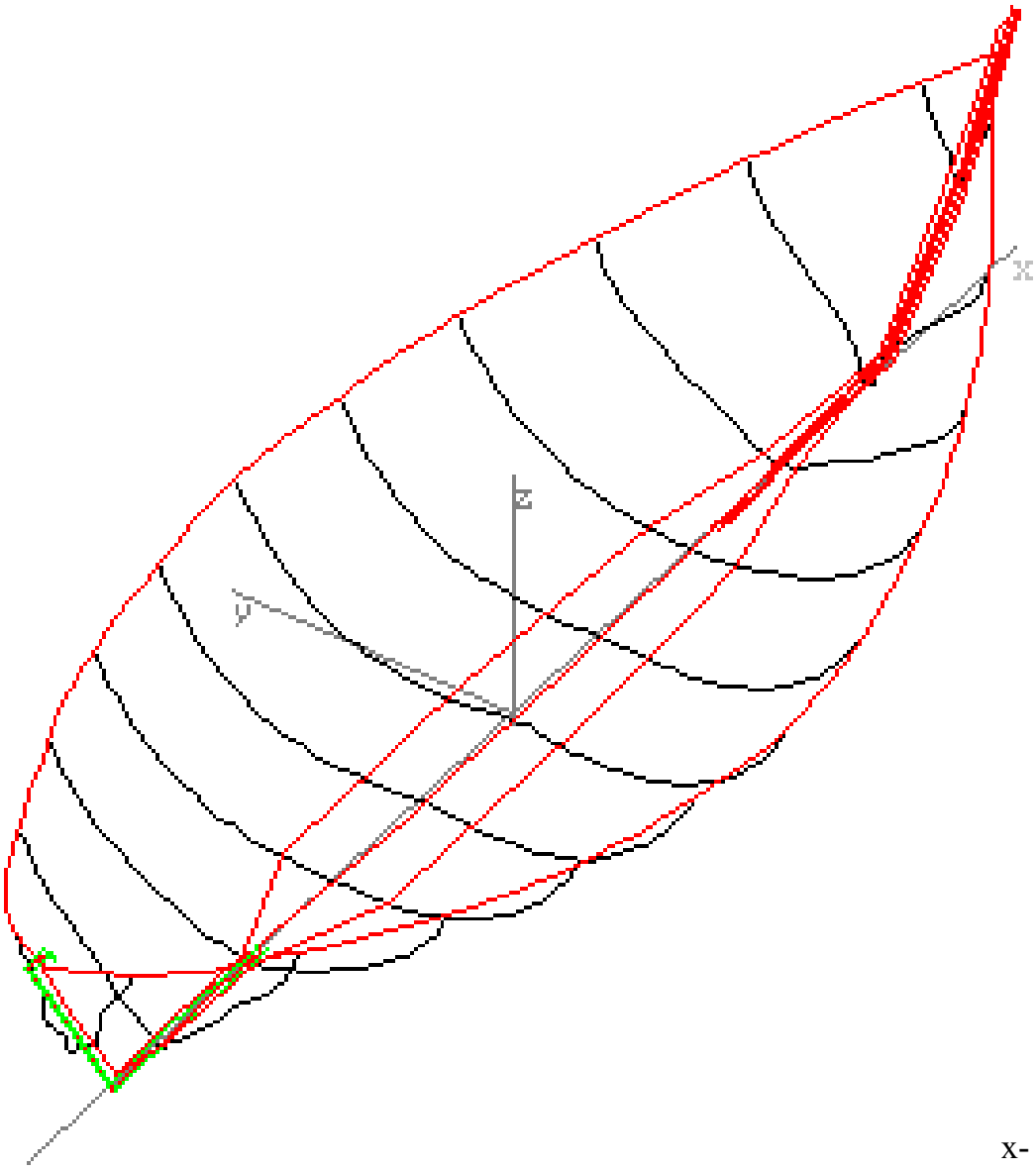


Fig. TC-3

THE RESULTS OF THEORETICAL CALCULATIONS

Fishing boat MECH14

THE COORDINATES SYSTEM



x- „+” bow

y – „+” right sight

z – „+” to

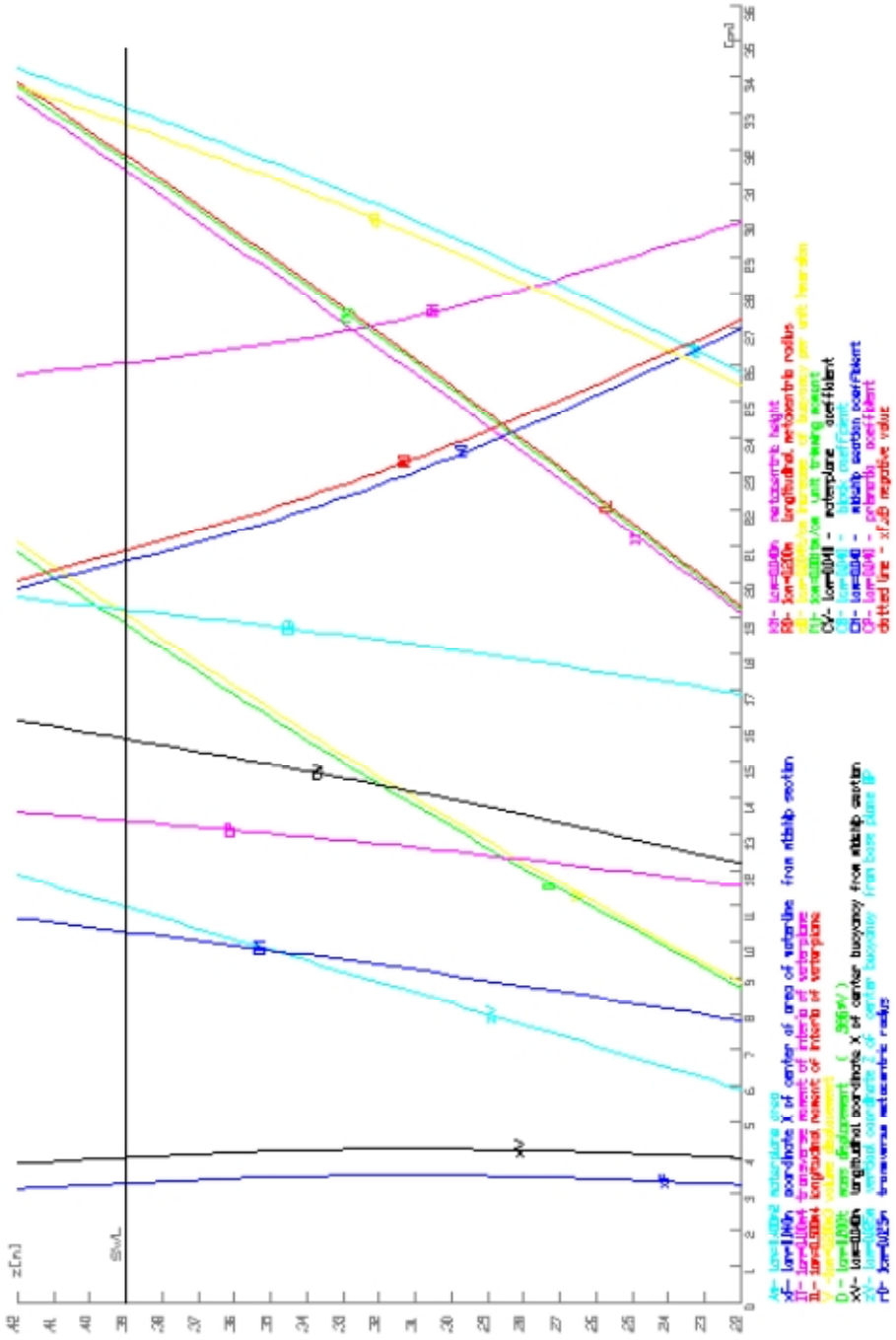
HYDROSTATIC CURVES

Fishing boat MECH14

z[m]	Aw[m2]	xF[m]	IT[m4]	IL[m4]	DD[t/cm]	Mj[tm/cm]	CW[-]	CM[-]
0,170	4,661	-0,093	0,769	4,037	0,046	0,008	0,440	0,638
0,180	4,765	-0,091	0,807	4,203	0,047	0,008	0,450	0,646
0,190	4,868	-0,089	0,844	4,366	0,048	0,009	0,460	0,654
0,200	4,969	-0,087	0,882	4,526	0,049	0,009	0,469	0,661
0,210	5,068	-0,084	0,920	4,681	0,050	0,009	0,478	0,669
0,220	5,163	-0,082	0,957	4,829	0,051	0,010	0,487	0,676
0,230	5,253	-0,079	0,995	4,969	0,052	0,010	0,496	0,683
0,240	5,341	-0,076	1,032	5,108	0,053	0,010	0,504	0,689
0,250	5,427	-0,074	1,069	5,254	0,054	0,010	0,512	0,696
0,260	5,516	-0,072	1,106	5,415	0,054	0,011	0,521	0,702
0,270	5,607	-0,073	1,142	5,598	0,055	0,011	0,529	0,708
0,280	5,702	-0,075	1,179	5,809	0,056	0,012	0,538	0,714
0,290	5,800	-0,079	1,215	6,038	0,057	0,012	0,548	0,720
0,300	5,899	-0,083	1,252	6,275	0,058	0,012	0,557	0,725
0,310	5,995	-0,086	1,288	6,508	0,059	0,013	0,566	0,731
0,320	6,087	-0,088	1,324	6,725	0,060	0,013	0,575	0,736
0,330	6,173	-0,088	1,360	6,917	0,061	0,014	0,583	0,741
0,340	6,253	-0,087	1,396	7,090	0,062	0,014	0,590	0,746
0,350	6,330	-0,085	1,431	7,250	0,062	0,014	0,598	0,751
0,360	6,404	-0,082	1,467	7,406	0,063	0,015	0,605	0,756
0,370	6,477	-0,080	1,502	7,564	0,064	0,015	0,611	0,760
0,380	6,550	-0,078	1,537	7,732	0,065	0,015	0,618	0,765
0,390	6,624	-0,078	1,571	7,907	0,065	0,016	0,625	0,769
0,400	6,698	-0,078	1,605	8,089	0,066	0,016	0,632	0,774
0,410	6,772	-0,078	1,639	8,275	0,067	0,016	0,639	0,778
0,420	6,846	-0,079	1,673	8,464	0,068	0,017	0,646	0,782

z[m]	V[m3]	D[t]	xV[m]	zV[m]	r0[m]	KM[m]	R0[m]	CB[-]	CP[-]
0,170	0,640	0,631	-0,105	0,089	1,202	1,290	6,310	0,278	0,435
0,180	0,688	0,679	-0,104	0,095	1,176	1,270	6,130	0,285	0,441
0,190	0,737	0,727	-0,103	0,100	1,151	1,251	5,953	0,292	0,447
0,200	0,786	0,775	-0,103	0,106	1,126	1,232	5,779	0,299	0,452
0,210	0,836	0,824	-0,102	0,112	1,102	1,215	5,610	0,306	0,457
0,220	0,886	0,874	-0,100	0,118	1,080	1,198	5,449	0,313	0,463
0,230	0,938	0,925	-0,099	0,124	1,060	1,184	5,297	0,319	0,467
0,240	0,990	0,976	-0,097	0,130	1,040	1,171	5,157	0,325	0,472
0,250	1,044	1,030	-0,096	0,136	1,022	1,158	5,033	0,331	0,476
0,260	1,100	1,084	-0,095	0,142	1,005	1,147	4,926	0,338	0,481
0,270	1,157	1,140	-0,096	0,148	0,988	1,136	4,840	0,344	0,486
0,280	1,215	1,198	-0,097	0,154	0,971	1,125	4,777	0,350	0,490
0,290	1,275	1,257	-0,100	0,160	0,954	1,114	4,731	0,356	0,495
0,300	1,336	1,317	-0,102	0,166	0,938	1,103	4,692	0,363	0,500
0,310	1,397	1,378	-0,105	0,172	0,922	1,094	4,654	0,369	0,505
0,320	1,459	1,439	-0,106	0,178	0,907	1,085	4,609	0,375	0,509
0,330	1,521	1,500	-0,106	0,184	0,894	1,077	4,550	0,380	0,513
0,340	1,584	1,561	-0,106	0,190	0,881	1,071	4,482	0,386	0,517
0,350	1,646	1,623	-0,104	0,196	0,869	1,064	4,408	0,391	0,521
0,360	1,710	1,686	-0,103	0,201	0,858	1,059	4,333	0,396	0,524
0,370	1,774	1,750	-0,101	0,207	0,846	1,054	4,263	0,401	0,528
0,380	1,840	1,814	-0,099	0,213	0,836	1,049	4,201	0,406	0,531
0,390	1,907	1,880	-0,098	0,219	0,825	1,044	4,147	0,411	0,534
0,400	1,974	1,946	-0,098	0,225	0,814	1,039	4,099	0,416	0,538
0,410	2,042	2,013	-0,097	0,231	0,804	1,035	4,054	0,421	0,541
0,420	2,110	2,080	-0,096	0,237	0,793	1,030	4,012	0,426	0,544

HYDROSTATIC CURVES
Fishing boat MECH14



BONJEAN SCALE

Fishing boat MECH14

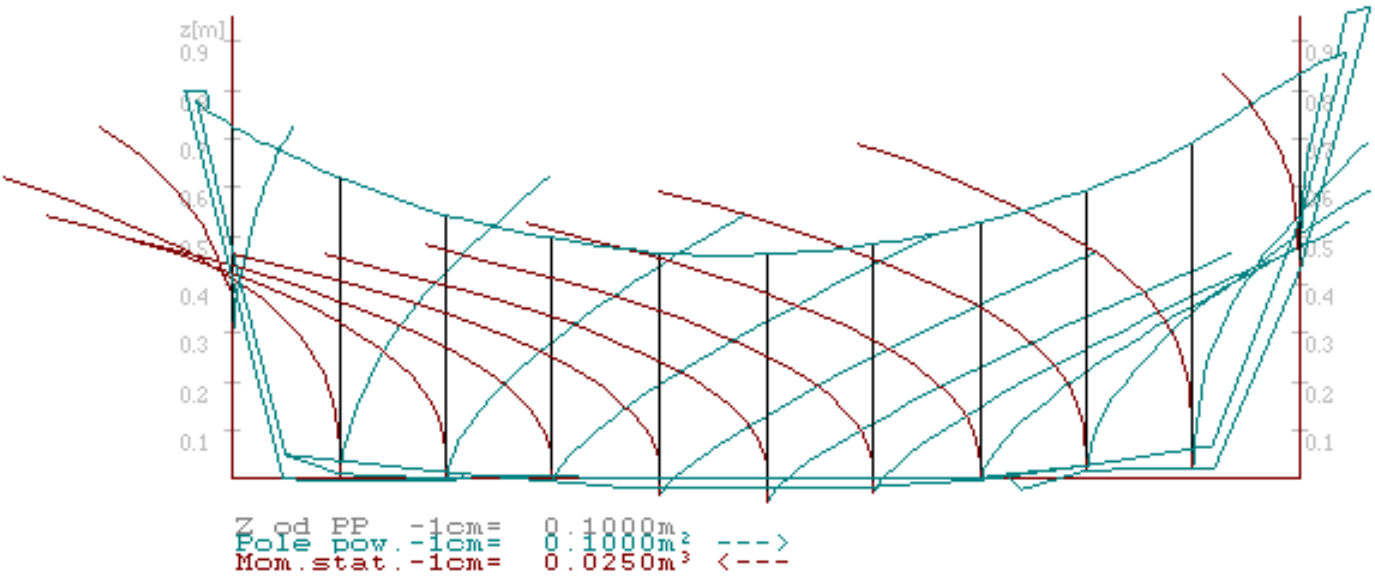
wręg 1	x =	-2,47	wręg 2	x =	-1,976	wręg 3	x =	-1,482
z[m]	As[m2]	Msy[m3]	z[m]	As[m2]	Msy[m3]	z[m]	As[m2]	Msy[m3]
0,304	0,0000	0,0000	-0,002	0,0000	0,0000	-0,003	0,0000	0,0000
0,346	0,0015	0,0005	0,060	0,0064	0,0002	0,052	0,0110	0,0004
0,388	0,0056	0,0020	0,123	0,0219	0,0017	0,106	0,0383	0,0026
0,431	0,0143	0,0056	0,185	0,0449	0,0053	0,161	0,0779	0,0079
0,473	0,0233	0,0097	0,248	0,0744	0,0117	0,216	0,1276	0,0173
0,515	0,0329	0,0144	0,310	0,1106	0,0218	0,271	0,1857	0,0315
0,557	0,0438	0,0203	0,372	0,1551	0,0370	0,325	0,2509	0,0509
0,599	0,0573	0,0280	0,435	0,2074	0,0582	0,380	0,3220	0,0760
0,642	0,0729	0,0377	0,497	0,2655	0,0853	0,435	0,3977	0,1069
0,684	0,0902	0,0492	0,560	0,3279	0,1183	0,489	0,4771	0,1436
0,726	0,1092	0,0626	0,622	0,3938	0,1572	0,544	0,5596	0,1862

wręg 4	x =	-0,9910	wręg 5	x =	-0,4940	wręg 6	x =	0,0000
z[m]	As[m2]	Msy[m3]	z[m]	As[m2]	Msy[m3]	z[m]	As[m2]	Msy[m3]
-0,004	0,0000	0,0000	-0,034	0,0000	0,0000	-0,048	0,0000	0,0000
0,046	0,0311	0,0008	0,016	0,0439	-0,0002	0,003	0,0426	-0,0007
0,096	0,0808	0,0044	0,066	0,1073	0,0024	0,054	0,1105	0,0013
0,146	0,1404	0,0116	0,116	0,1791	0,0090	0,105	0,1880	0,0075
0,196	0,2076	0,0232	0,166	0,2574	0,0200	0,156	0,2725	0,0185
0,247	0,2810	0,0394	0,216	0,3409	0,0360	0,207	0,3627	0,0349
0,297	0,3593	0,0607	0,265	0,4290	0,0572	0,258	0,4574	0,0569
0,347	0,4418	0,0873	0,315	0,5208	0,0838	0,308	0,5559	0,0848
0,397	0,5279	0,1193	0,365	0,6158	0,1162	0,359	0,6577	0,1188
0,447	0,6170	0,1569	0,415	0,7139	0,1545	0,410	0,7623	0,1591
0,497	0,7090	0,2003	0,465	0,8147	0,1988	0,461	0,8696	0,2058

wręg 7	x =	0,4940	wręg 8	x =	0,9910	wręg 9	x =	1,4820
z[m]	As[m2]	Msy[m3]	z[m]	As[m2]	Msy[m3]	z[m]	As[m2]	Msy[m3]
-0,028	0,0000	0,0000	-0,004	0,0000	0,0000	0,017	0,0000	0,0000
0,023	0,0388	0,0001	0,049	0,0222	0,0006	0,075	0,0109	0,0006
0,074	0,0995	0,0031	0,102	0,0647	0,0039	0,132	0,0325	0,0028
0,125	0,1700	0,0101	0,155	0,1206	0,0111	0,190	0,0660	0,0083
0,176	0,2478	0,0218	0,208	0,1853	0,0229	0,247	0,1106	0,0181
0,227	0,3314	0,0386	0,261	0,2572	0,0398	0,305	0,1637	0,0328
0,277	0,4198	0,0609	0,314	0,3352	0,0622	0,363	0,2256	0,0535
0,328	0,5121	0,0889	0,367	0,4181	0,0905	0,420	0,2953	0,0808
0,379	0,6078	0,1228	0,420	0,5050	0,1247	0,478	0,3700	0,1144
0,430	0,7064	0,1627	0,473	0,5954	0,1651	0,535	0,4483	0,1541
0,481	0,8078	0,2089	0,526	0,6891	0,2119	0,593	0,5295	0,1999

wręg 10	x =	1,9760	wręg 11	x =	2,4700
z[m]	As[m2]	Msy[m3]	z[m]	As[m2]	Msy[m3]
0,019	0,0000	0,0000	0,435	0,0000	0,0000
0,086	0,0037	0,0002	0,475	0,0011	0,0005
0,154	0,0106	0,0011	0,514	0,0027	0,0013
0,221	0,0230	0,0034	0,553	0,0046	0,0023
0,288	0,0430	0,0086	0,593	0,0066	0,0035
0,356	0,0717	0,0178	0,632	0,0101	0,0056
0,423	0,1091	0,0324	0,672	0,0156	0,0092
0,490	0,1553	0,0536	0,711	0,0226	0,0140
0,557	0,2086	0,0815	0,751	0,0309	0,0201
0,625	0,2666	0,1158	0,790	0,0402	0,0273
0,692	0,3280	0,1563	0,830	0,0506	0,0357

BONJEAN SCALE
Fishing boat MECH



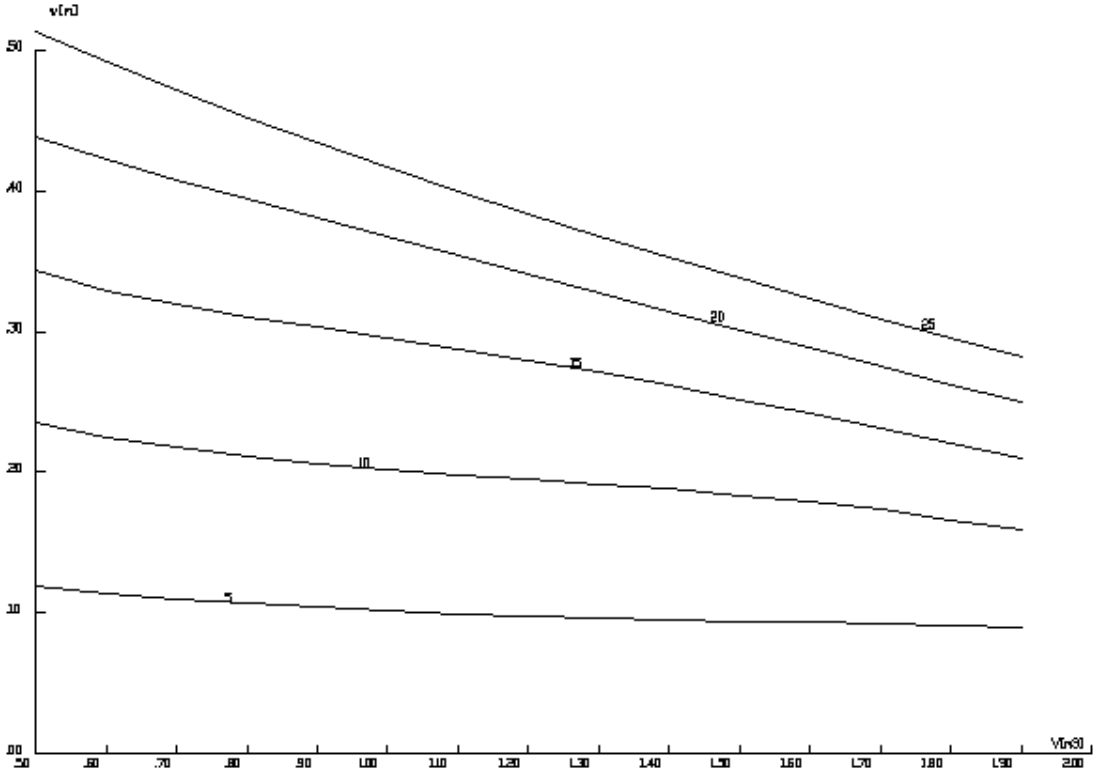
CROSS CURVES OF STABILITY

Fishing boat MECH14

Fi =	5	10	15	20	25
V[m3]			w[m]		
0,5	0,120	0,235	0,343	0,438	0,513
0,6	0,114	0,225	0,329	0,423	0,491
0,7	0,110	0,217	0,319	0,408	0,471
0,8	0,107	0,211	0,311	0,394	0,452
0,9	0,104	0,206	0,303	0,381	0,434
1,0	0,102	0,202	0,296	0,367	0,417
1,1	0,100	0,198	0,288	0,354	0,400
1,2	0,098	0,195	0,280	0,341	0,384
1,3	0,097	0,192	0,271	0,327	0,368
1,4	0,095	0,188	0,262	0,314	0,353
1,5	0,094	0,184	0,252	0,301	0,338
1,6	0,093	0,179	0,242	0,288	0,323
1,7	0,092	0,174	0,231	0,275	0,309
1,8	0,091	0,167	0,221	0,262	0,295
1,9	0,090	0,160	0,210	0,250	0,282

CROSS CURVES OF STABILITY

Fishing boat MECH14



CURVES OF FLOODING ANGLES

Fishing boat MECH14

Współrzędne punktu zalewania (od owręża) :

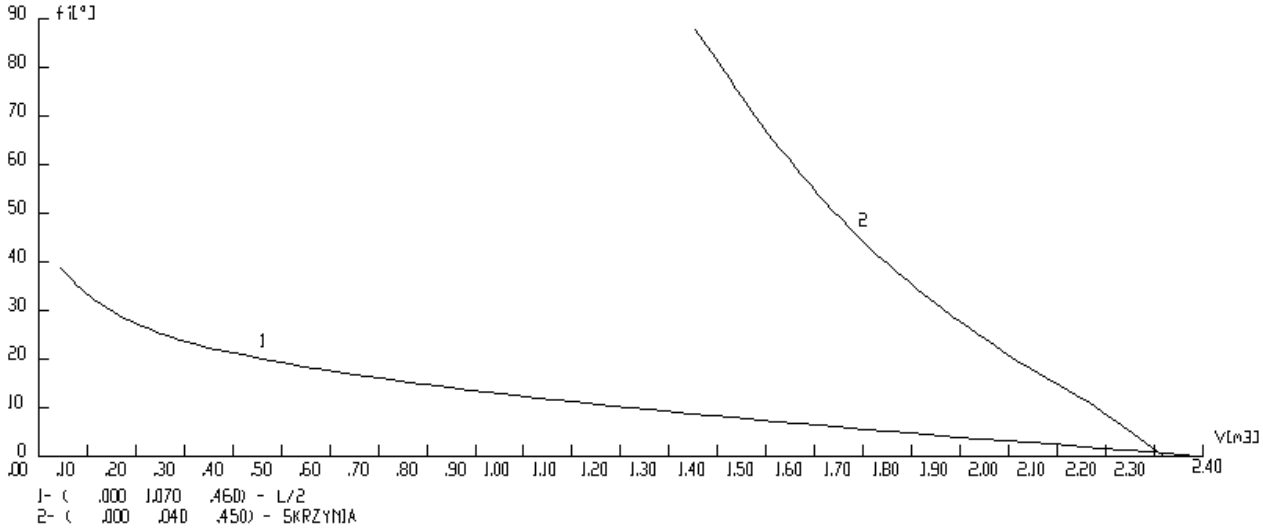
1 (x,y,z) = 0,00 1,07 0,46 - burta

2 (x,y,z) = 0,00 0,04 0,45 - skrzynia mieczowa

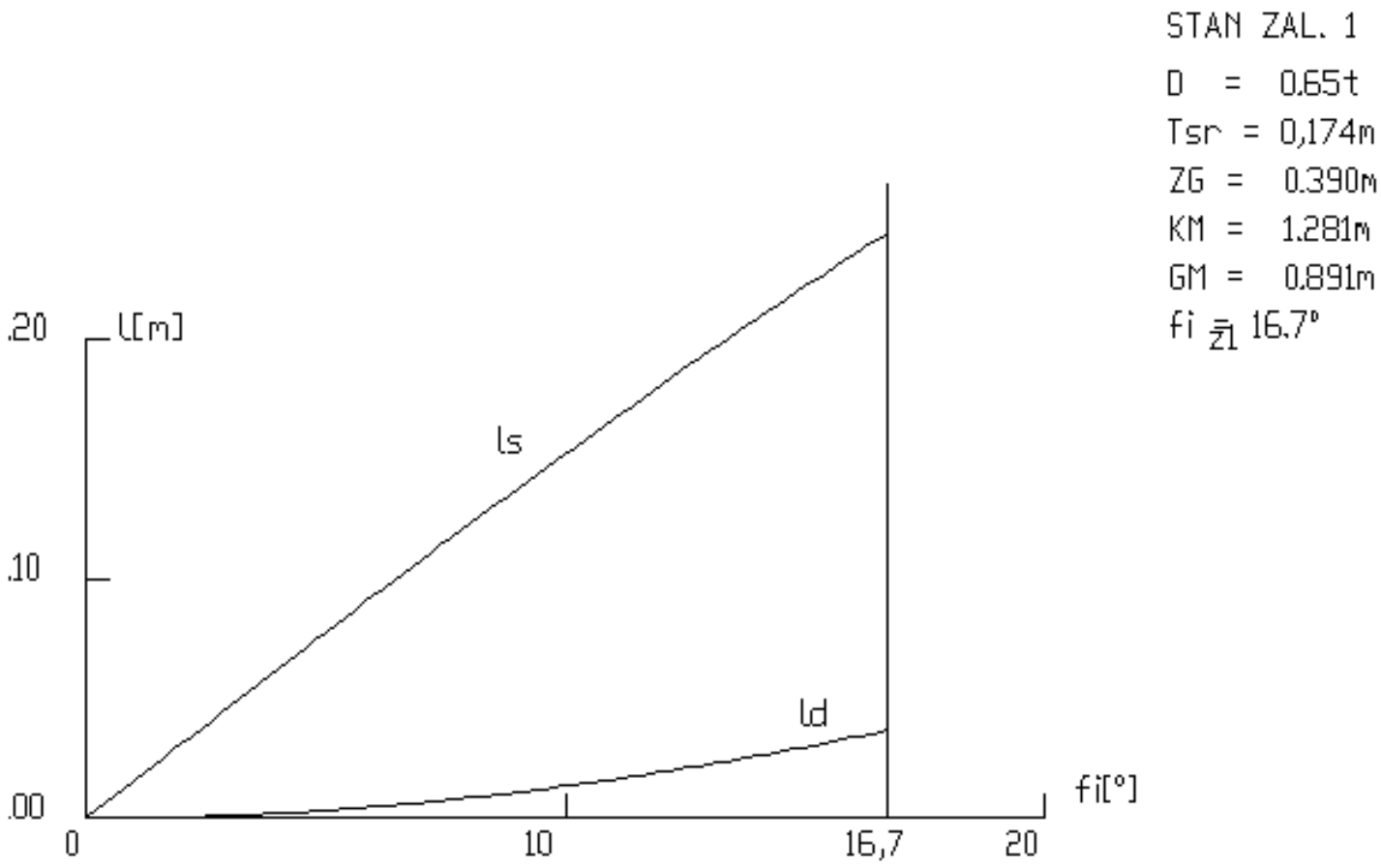
fi[st]	V[m3]	V[m3]
	1	2
0	2,39	2,32
10	1,22	2,18
20	0,46	2,01
30	0,15	1,87
40	0,04	1,75
50	0,00	1,64
60	0,00	1,56
70	0,00	1,48
80	0,00	1,41
90	0,00	1,34

CROSS CURVES OF STABILITY

Fishing boat MECH14



STABILITY OF THE BOAT WHEN LEAVING THE PORT
Fishing boat MECH14
LOADING CONDITION 1

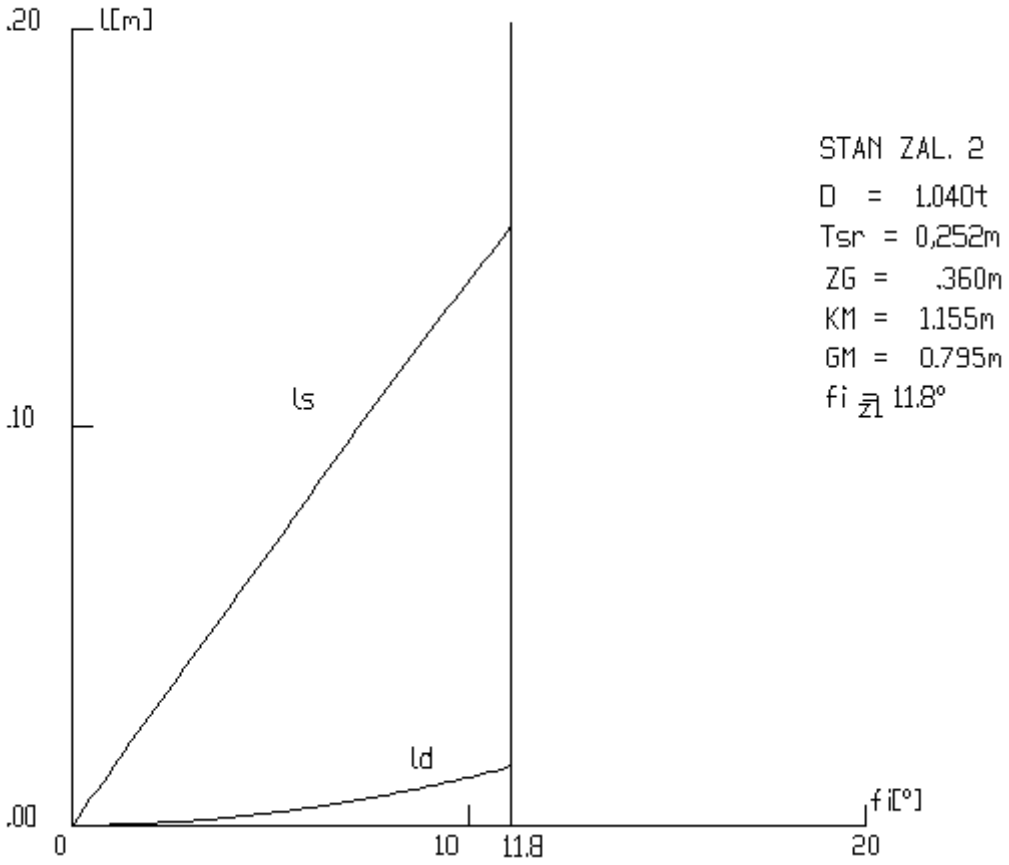


STABILITY OF THE BOAT WHEN LEAVING PORT
Fishing boat MECH14
LOADING CONDITION 1

Td = 0,174 [m]
Tr = 0,174 [m]
D = 0,650 [t]
XV = -0,104 [m]
ZV = 0,091 [m]
KM = 1,281 [m]
ZG = 0,390 [m]
GM = 0,891 [m]

fi[st]	w[m]	ls[m]	ld[m]
5	0,111	0,077	0,003
10	0,220	0,152	0,013
15	0,323	0,222	0,030
20	0,414	0,280	0,052

STABILITY OF THE BOAT AT RETURN TO PORT
Fishing boat MECH14
LOADING CONDITION 2



STABILITY OF THE BOAT AT RETURN TO PORT
Fishing boat PUC16
LOADING CONDITION 2

Td = 0,252 [m]
Tr = 0,252 [m]
D = 1,040 [t]
XV = -0,097 [m]
ZV = 0,137 [m]
KM = 1,155 [m]
ZG = 0,360 [m]

fi[st]	w[m]	ls[m]	ld[m]
5	0,101	0,069	0,003
10	0,199	0,137	0,012
15	0,292	0,198	0,027