University of Lisbon
Instituto Superior Técnico

Shipyard Technology

First Work
Block’s Preparation

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SUMMARY

1. Introduction

The project presents an analysis of shipbuilding and outfitting procedures using the latest and most established technologies in shipyards.
The work involves the study of a block obtained by dividing a midship section into three parts.
The object of study in question is the section between the upper intersection of the ship's side and the deck with its junction to the hatch of the hold of an Ore Carrier.
The production of a workpiece blank presupposes the study of the project for the geometric definition, dimensioning, nesting, marking and manufacture of the components of the blank. Through the following production processes: preparation of cutting, cutting and forming of sheets and parts, welding, painting and transport of the block.

The main study objectives of the work are as follows:

1. Interpretation of block drawing. Characterization of the main dimensions of the block.
2. Evaluation of the materials needed for manufacturing (nesting).
3. Calculate the quantity of consumables needed for cutting and welding of the structure.
4. Establishment of work's sequence. Timetable of activities.
5. Calculate the total weight of the structure and the position of the centre of gravity.
6. Study of the lifting system.
7. Brief work on painting, including sequence on manufacturing.
8. Graphical modelling of the structure.
9. Indication of the critical aspects related to quality control (dimensional control, welding quality and inspection, etc.).

2. Block definition

The block under analysis is that of an Ore carrier ship consisting of a double bottom and double sides in which a ballast tank divides the two ends.
Ore carrier ships have this type of structure because they are designed for the following purpose: is a type of bulk cargo vessel. An ore carrier is a single deck vessel with the engine compartment in the stern and two length wise bulkheads amidships, between which are cargo holds. The below deck areas between the lengthwise bulkheads and the sides and under the second bottom are used for taking on water ballast and can be adapted to transport liq uid cargoes. A higher double bottom
increases the strength of the vessel and increases maneuverability.
The new types of Ore carriers are being developed to become vessels suitable for transporting mineral products as before and then in the past ballast tanks are filled and designed to transport petroleum products. These ships take the name OBO (Ore-bulk-oil carrier).
In our case we will analyse the production sequence of an Ore carrier.

Fig.1 Ore Carrier in navigation

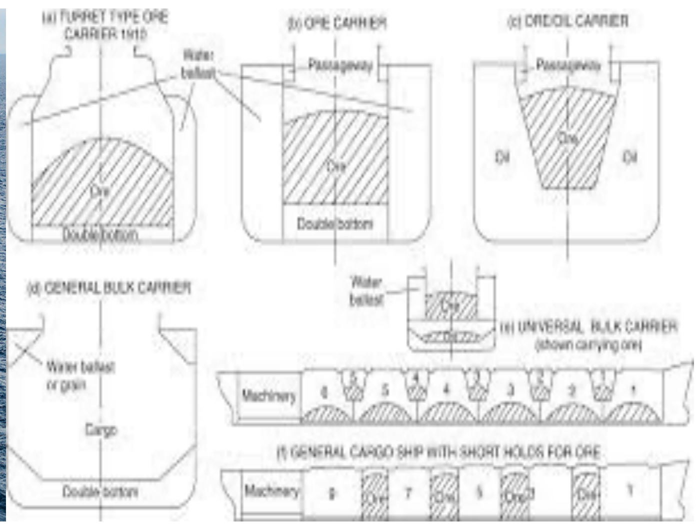


Fig.2 Main subdivision of the holds in a capacity plan of an Ore Carrier

In order to better understand the structure of the main section, we are going to work on the geometry of the main dimensional aspects of the block: mainly relating to the subdivision of the type of components and their assembly.

In the study of ship strength, the main section, or midship section, is the typical strongest section of the ship. It contains all the structural elements useful to understand how the hull is made in the central area, and therefore a large part of the ship's beam, such as transversal subdivision of the spaces, structural geometry (transversal and longitudinal continuous development), dimensions of the planking, ordinary reinforcements and reinforced beams.

To do this, we will break down all the components by analysing the main functions and their structural contributions:

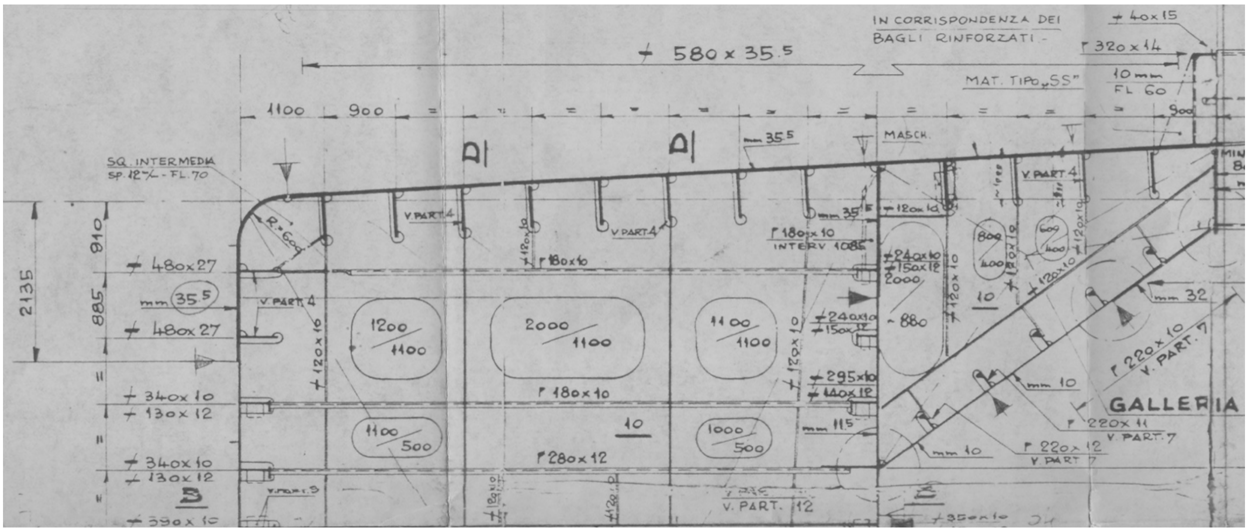


Fig.3 Modelling block area

Distance between frames	Block length	Block width	Block height
1.085 m	4.340 m	12.800 m	6.500 m

Table.1 Main dimensions of the Block

From the analysis of the block we can deduce that the naval structure is mainly reinforced longitudinally, which means that the main reinforcements that will contribute most to the overall strength concept of the section will be those developed in a direction coplanar to the length of the ship.

The transversal reinforcements present are for connection between the main beams, which is also shown by the fact that the depth of development (120/180 mm) does not contribute to the complete distribution of shear and bending stresses in the beam system.

Looking at the cross-section in broad terms, we note the presence of a flat sloping plate which defines the bolzon, which is thicker up to the intersection with the head of the hatch. The marked variation in the thickness (35.5 mm) of the plate can also be seen at the intersection between the side of the section and the beam line, which identifies a structure without sharp edges but formed by a constant radius of curvature which allows for greater stress relief due to the load on the structure and the hydrostatic head in critical conditions, as these are the most stressed points, due to the fact that the distance from the neutral axis is maximum.

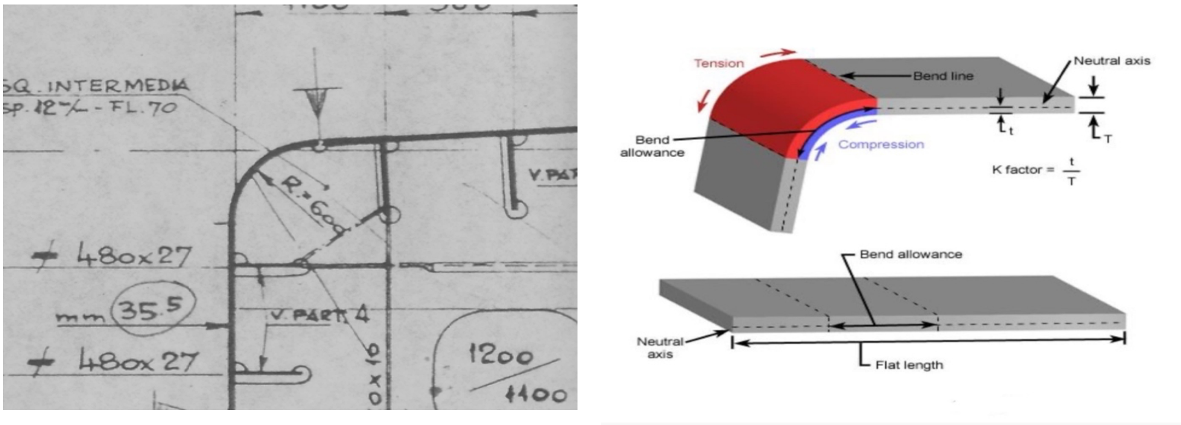


Fig.4 intersection between flank and camber

The intersection is further reinforced by the presence of a 12 mm thick flanged bracket with a 70 mm flange.

Continuing the analysis from a global point of view, it is important to note the presence of an inclined bulkhead connected to the anchorage of the hatchway head, because depending on the type of ship, besides strengthening the already known intersection between the side and deck, it has a usefulness in relation to the type of cargo used in Ore Carrier ships: being bulk ships, the main purpose is to allow the bulk cargo inside to self-support downwards in relation to the fact that the centre of gravity, which moves vertically with respect to the z-axis, remains as low as possible in order to avoid dangerous situations for the stability and consequent physical integrity of the ship.

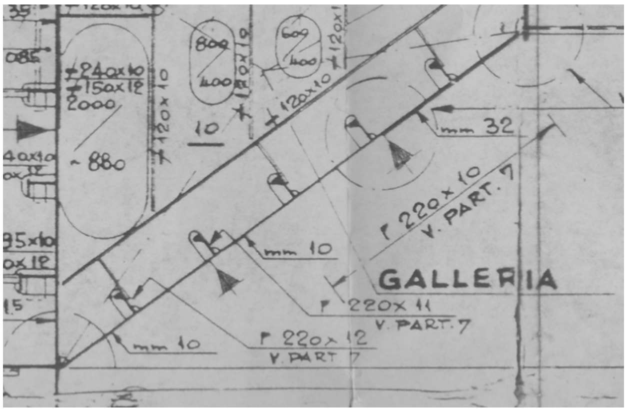


Fig.5 Inclined bulkhead

In addition, the presence of pass-through holes and piping/plumbing holes of considerable size makes it possible to indicate and underline the considerable ductility of the structures surrounding the main hold.

Proceeding inside the superstructure, it is possible to analyse the subdivision of the main longitudinal reinforcements, which contribute to the shear, bending and torsion resistance, under the aspect of a global beam-ship system and successively the secondary connection reinforcements, arranged transversely to the section.

We note the presence of flat iron girders arranged on the bridge deck following the direction of the camber and the intersection with the side of the block.
This choice is aimed at eliminating the so-called "shelf" effect, in which the beams with 90° connections between the deck and the core would overload the structure, leading to instability and problems of raising the centre of gravity.

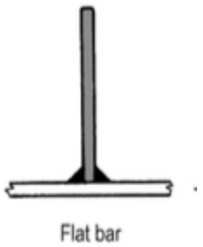


Fig.6 Layout and characteristics of the flat beam: orthogonal to the inclination of the bolzon, length 580mm and thickness 35.5mm

Continuing clockwise, in the sloping part of the bulkhead it is possible to note the presence of longitudinal bulbous stiffeners, which have the best inherent characteristics for the distribution of shear and bending stresses, since the particular shape and distance from the neutral axis creates optimal resistance to stress.

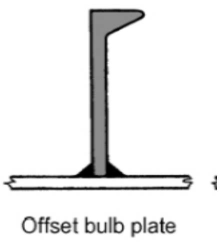
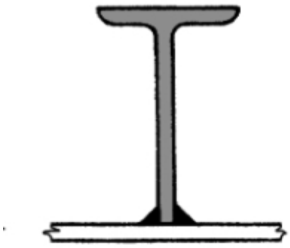


Fig.7 Layout and characteristics of the bulbous stiffener: orthogonal to the inclined bulkhead, length 220mm and thickness increasing of 1 mm proceeding to the lower part

The last remaining main longitudinal reinforcements turn out to be anti-symmetrical T-beams, arranged on the vertical part of the structure and decisive in the connection with the respective vertically arranged bulbous beams in order to increase the global resistance of the structure.
Most probably the anti-symmetrical geometry of the beam was given by the manufacturer with the intention of optimising an L-beam and leaving the correct and effective millimetres for a good weld.



Tee bar

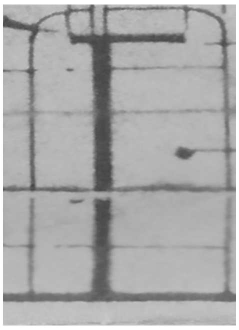
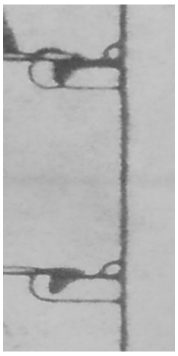


Fig.8 Layout and characteristics of a “T” bar: orthogonal to the inner plate of the ship's side plating, fixed core length for the right side reinforcements 340mm and fixed deck length for the same at 130mm. Thicknesses 10 and 12 mm respectively.
For the right side core length increased sliding towards the intersection of the deck 240/295 mm. Flat bar length fixed at 150 mm and thicknesses fixed at 10 and 12 mm respectively.

To conclude the part on reinforcements, let us briefly analyse the secondary reinforcements designed to redistribute the loads due to the primary stresses: they are divided into transversal and vertical reinforcements, mainly the horizontal reinforcements are composed of bulbous beams of 180 mm depth and 10 mm thickness. From a dimensional point of view, we can see that the structure supported by these reinforcements is more stressed, and for this reason the dimensioning is done in order to relieve the stress in the form of load.



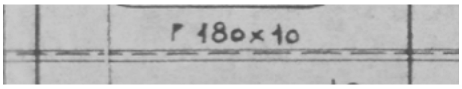


Fig.9 representation of horizontal secondary reinforcement with respective D-D section

As regards the vertical reinforcements of the structure, they have a thickness of not more than 10mm and a depth of 120mm, constituting marginal resistance against the bottom sheet of the structure with which they are bonded.

To conclude, the discussion concerning the execution of lightening and welding holes, called cut-out holes, is very important. These holes are drilled into the beam or plate at the points where the stresses are lowest, for the passage of secondary systems or reinforcements within the primary ones.

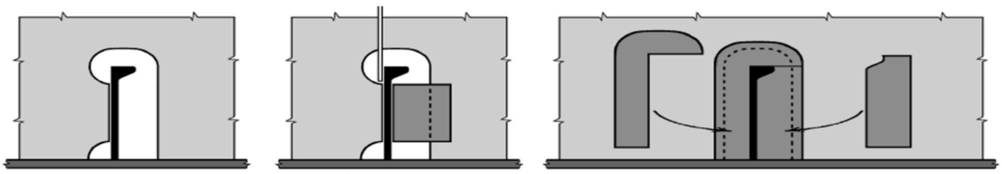


Fig.10 Cut-out holes and application of masks

Finally, the presence of brackets and connecting elements within the block is of relative importance for the distribution of peak stresses: these are secondary elements of the ship's structure, useful for continuity between beams and for distributing isostatic lines. The brackets may be placed at the intersection of elements of the same order (end brackets), or between elements of a different order (web brackets). In the latter case they reinforce the respective cores and have an anti-buckling effect. The web brackets cannot be inclined excessively (too much like a right angle), because in bending they would create too high a concentration of stresses at the foot of the bracket.

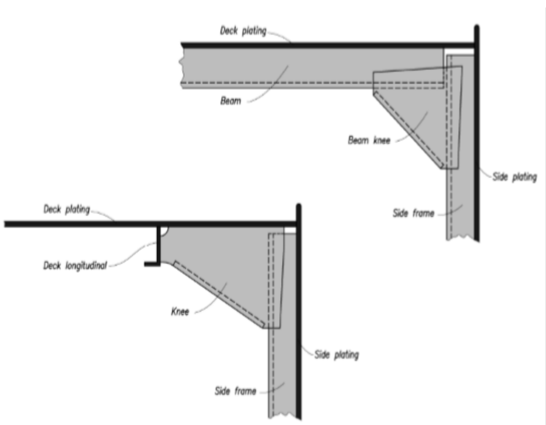


Fig.11 Fittings on top of the hold

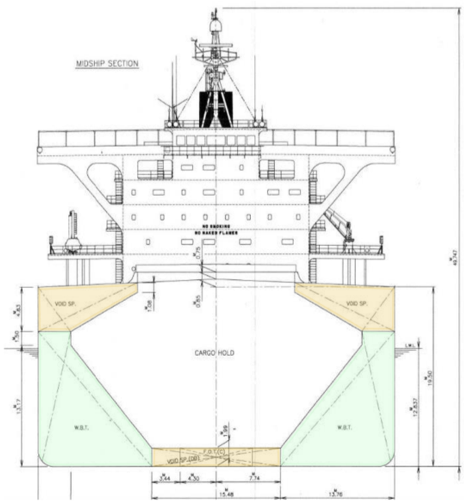


Fig.12 generic structure of a hold in an ore carrier ship

3. Nesting

In manufacturing assiduity, “nesting” refers to the process of laying out cutting patterns to minimize the raw material waste. Exemplifications include manufacturing corridor from flat raw material similar as distance essence. Similar sweats can also be applied to cumulative manufacturing, similar as 3D printing. Then the advantages sought can include minimizing tool movement that isn't producing product or maximizing how numerous pieces can be fabricated in one figure session.
To minimize the quantum of scrap raw material produced during slice, is typical to use a software. In this case, “nest&cut” software was used in order to maximize operability and produce a process finalization report. The software analyses the geometry and area of the disassembled components and creates a corresponding layout in order to reduce material usage and thus the production cost of the process.
An important consideration in shape nesting is to corroborate that the software in question actually performs true profile nesting and not just block nesting. In block nesting an imaginary cube is drawn around the shape and also the blocks are laid lateral-by side which actually isn't outline nesting.
In our case we used a reference and cutting plate with dimensions 20000x100000mm, in which it is entirely possible to derive the breakdown of parts for a block. If we consider the total assembly then we have to multiply the plate by 4 units and we get the exact amount of material to make the whole structure.
A full description is given in the following table:

Thickness [mm]	N°	Area occupied	Area avaible	% optimization
10	76	85.567 m^2	122.86 m^2	70%
12	32	90.746 m^2	122.86 m^2	75%
14	4	97.988 m^2	122.86 m^2	78%
15	4	98.281 m^2	122.86 m^2	76%
22	4	96.181 m^2	122.86 m^2	78%
27	8	88.756 m^2	122.86 m^2	73%
32	4	98.456 m^2	122.86 m^2	80%
35.5	64	104.652 m^2	122.86 m^2	85%
Total nesting		95.130 m^2	122.86 m^2	77.43%

4. Cutting and Welding

4.1Cutting

Once you have thought about the nesting of the components of the block, you will need to cut all the plates indicated in the yard. Cutting on site can be done in at least the following ways:
- Water jet (very slow)
- Laser (used especially for thin sheets due to its precision)
- Oxicut (most used process in the Naval industry)
- Plasma (faster way and can cut up to 5cm thickness)

There are different cutting equipment, manual or automatic, that can be applied in the manufacturing of the block pieces. Since the block will be manufactured in a workshop, we will only consider automatic equipment such as oxyfuel, plasma, laser and waterjet. The most used equipments in shipbuilding are oxyfuel and plasma.
In a first step, plasma, laser and waterjet cutting equipments will be compared. The following table shows the characteristics of the equipment of oxyfuel.

Plate Thickness (mm)	Pressure O2 (Kg/cm2)	Acetilene Consumption (l/m)	O2 consumption (l/m)	V (m/h)
3	1,5	10	55	22
5	2,5	12	75	20
10	3	17	120	18
20	3,5	25	225	15
30	4	40	350	12
40	5	50	450	10
50	5,5	60	600	8

Plasma cutting is a process that cuts electrically conductive materials through a rapid jet of hot plasma. The materials most commonly cut by this process are steel, stainless steel, aluminum and others. Due to its speed and high precision, plasma cutting seems to be the best option for cutting using CNC (computing numerical control). Because of all this, it seemed to be the best way of cutting to use in this case, since we have relatively small thicknesses and because it has a good cost/speed ratio, which is quite important for large ships.
However beyond the plasma there is another equipment quite economical, the oxyfuel. The oxyfuel is an equipment where the cut is performed by heat transfer through the combustion of a flame and the chemical reaction of iron oxireduction by the application of a jet of oxygen.

Oxyfuel cutting compared to plasma has a lower acquisition cost (The basics of oxy fuel cutting, 2018). For this reason, our choice will be the oxyfuel cutting system.

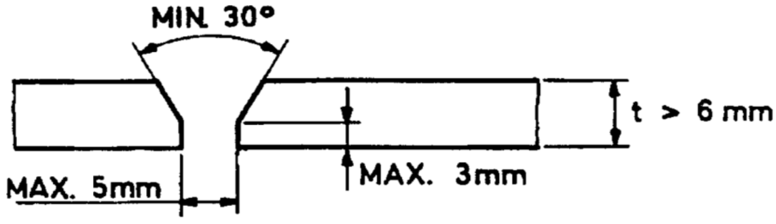
The important thing in the cutting analysis is to understand how many hours will be spent to perform the cutting of all the pieces, and also, for the plasma case, to know how much nitrogen will be used.
To calculate these parameters, we first had to obtain the perimeter of all the pieces to be cut.
The relation between the velocity, the consumption of Acetylene, O2 and the thickness of the material can be considered linear, and it is possible to calculate the specific velocity and consumption for each thickness. Then, considering the distance to cut for each part we can calculate a good approximation of the consumption and time needed to cut all parts.

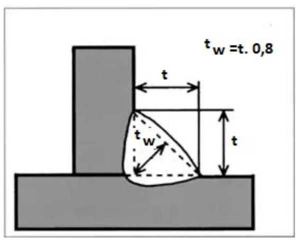
Thickness [mm]	Length to cut [m]	Acetilene [l/m]	O2 [l/m]	V [m/s]	Acetilene consumption	O2 Consumption	Time (h)
10	108,819	3	120	18	1160,457	66580,28	2,2
12	70,7	3,1	140	17,4	240,87	20878	5,5
14	26,27	3,25	170	16,5	105,3775	4465,9	1,6
15	30,644	3,3	180	16,2	84,6252	4615,92	1,6
22	120,87	3,55	237,5	14,7	145,6885	3056,625	0,9
27	60,14	3,8	300	13,2	195,532	17542	1,9
32	150,593	4	350	12	162,372	5457,55	1,3
35.5	80,924	4,8	430	10,4	182,0352	16307,32	3,6
Total	585,927				1933,46175	104618,305	17,2

4.2Welding

Welding, like cutting, is a process whose selection of the equipment to be used depends on several variables and its choice can have a big impact on the total costs of the block construction.
The welding processes selected for joining the parts of this block were submerged arc welding (SAS or SAW Submerged arc welding) and flux-cored arc welding (FCAW Flux-cored arc welding), these being the most usual processes in shipbuilding. The application of other processes is still relatively limited, mainly by small shipyards
Submerged arc welding is a fusion process where an electric arc is formed between the workpiece and the consumable (continuous solid wire or flux), where both are covered by a solid layer of granulated flux, the arc is submerged. Part of the flux is melted generating a protective layer over the weld fusion bath.

The remaining unmelted material is collected for reuse.
Due to its high metal deposition rate, it is a process particularly suitable for long straight good quality joints in the vertical position. It will therefore be applied to butt joints in the horizontal position.
Flux cored welding, like the previous process, is a fusion process where an electric arc is formed between the work piece and the tip of the wire. However, the fusion bath and the electric arc are protected by the flux contained inside the wire (in the case of self-protected flux-cored wires) or by an external gaseous source.
Given that the joining of the parts of the block will be carried out in a workshop, welding by flux-cored wires with gas protection is the most suitable. This process will be applied where the relative position of the components allows for the automated process and in the rest of the joints it will be done manually in all the joints except those mentioned above.
The type of welding to be applied, the length, area and volume in each joint of the block pieces and the welding sequence were defined. For the area of butt joints, the spacing was ignored, a 45° angle was assumed throughout the sheet thickness, according to DNV (Det Norske Veritas) rules and a factor of 1.05 was placed for the final welding volume (figure 13). In the areas of the T-joints, the weld throats were assumed to have a depth of $tw = t.\ 0.8$





Top joint T joint

T joints are predominant on this block and will be done by both welding technologies. It was assumed that $t_w = 0.8\ mm$ therefore A=$100mm^2$

1 – better / high 6 – worst / low	Manual SMAW	FCAW	Gravity	Submersed arc (SAW)	Electro gas Electro slag	MIG	TIG
Deposition speed of material	5	4	3	2	1	6	7
Equipament Cost	6	3	5	2	1	3	4
Mechanical properties (Resiliência)	3	2	4	5	6	2	1
Position	All	All	Down	Down	Vertical	All	All
Cost (relative value)	1-2	4	2	3-40	4-60	4	2-20
General opinion	Versatile	Good	No special training	High speed & production	No edge preparation. Affected by wind. (electrogás)	Easy to initiate arc. Affected by wind.	

SAW
Submerged arc welding is an automatized process destined to weld long straight and uniform joins, the solid flux shields the electrode from atmospheric gases and melts. The quality of the join is very good considering the deposition velocity but this process is limited to an horizontal position and to one degree of freedom, therefore, not all joins can be done with it.

FCAW
Flux Cored Arc Welding produces a high-quality weld and is very versatile it can be used in all directions and with all degrees of freedom. The equipment is semi-automatic, and the deposition velocity is decent. Although the consumable price is very high it is a good option as there won't be a need to redo any work.

	SAW	FCAW
Velocity [m/h]	5,42	4,71
Ropes per meter	3	4
Equipment Cost	29000	4000
Anulat maintenance cost	870	120
Equipment durability	10	10
Shield Gas consumption[Kg/m]	[ ]	0,34
Electrode Consumption [Kg/m]	2,69	3,91
Electrode Consumption effieciency	0,9	0,9
Flux Consumption [Kg/m]	[ ]	0,94

Process	SAW	FCAW	TOTAL
Distance of welding [m]	180	3645	3825
n° components	570	17490	18060
Gas consumption [kg]		7060	7060
Electrode consumption [kg]	598	4457	5055
Time of welding [h]	34	873	907

5. Establishment of working sequence

In a modern shipyard, construction is done in prefabrication. The basic stages are: the start of work, when the first sheet of metal is cut; laying, when the keel is laid on the dock or slipway; launching, when the ship leaves the dock or slipway; and delivery with final outfitting. A distinction can be made between hull work, which involves carpentry and structural aspects, and outfitting work, completion of plant engineering and furnishings.

MANUFACTURING PROCESS

5.1 Introduction

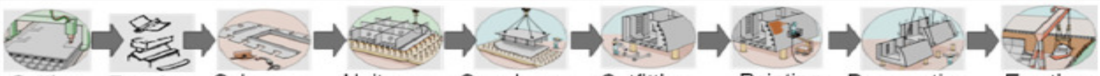
The shipbuilding industry has over the years developed the construction of ships with hulls and structures in steel.

For some decades now other construction materials, such as metal alloys, have been introduced. Aluminium alloys have been widely used in the construction of light, small-sized vessels, while special metals such as titanium have been used in particular cases. These are not currently used on an industrial scale and are therefore not included in this study.

5.2 The manufacturing process

The manufacturing process for steel or aluminium vessels is similar and therefore one description is given for both processes. The greatest differences are those inherent in the difference in vessel size: aluminium vessels have a much smaller volume than steel vessels. The sheet metal used is therefore thinner and can be cut, bent and soldered more easily than that used in the construction of large steel ships.

Apart from requiring great skill in metal-working techniques, the construction of a ship also calls for professionalism and knowledge of numerous technical sectors, such as erection of scaffolding for constructing the hull and plating, electrical wiring, raising and moving operations, sandblasting, cleaning and painting and all the details of fitting-out.



		Indoor					Outdoor			
Shipbuilding process		Cutting	Forming	Sub assy.	Unit assy.	Grand assy.	Outfitting	Painting	Pre-erection	Erection
Area capacity		Indoor area					Outdoor area			Dry dock
		Stock area (Plate&Part)	Stock area (Plate&Part)	Assembly zone (cell) / Assembly line			(Outfitting zone)	(Painting zone)	PE zone	
Facility	Main	Cutting mc.	Press mc.	Welding facilities (considered as a critical resource only when the line type)			Nothing special (Capa. Is mainly dependent on the area.)			
	Sub	Overhead crane (Weight capacity is dependent on the block weight)					Jib crane, Tower crane		Jib crane, Goliath crane	
	MHS	Transporter, Folk-lift								

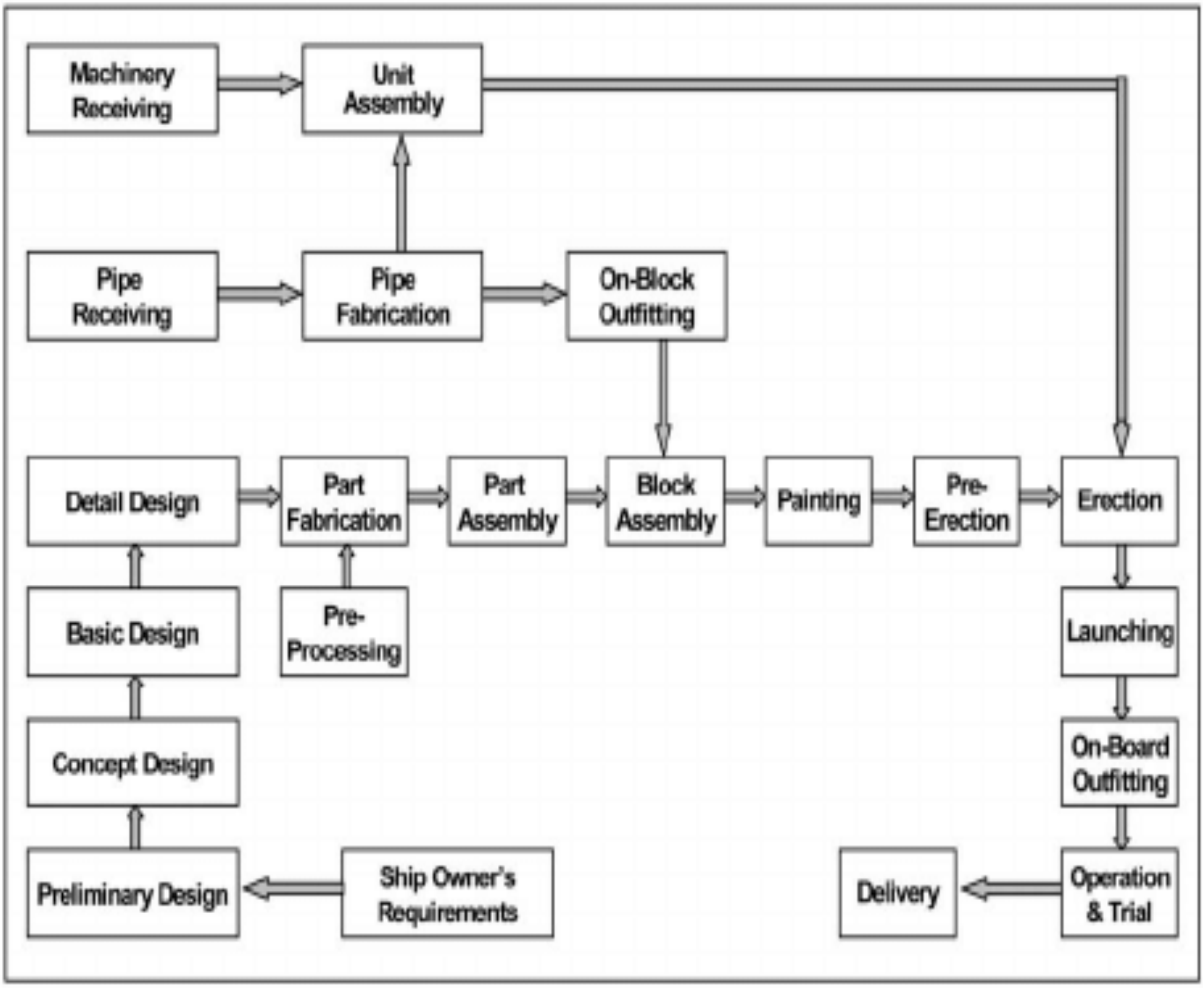


Fig.13 - The manufacturing cycle in metalworking shipyards

5.3 Materials

The variety of manufactured products which go to make up a fitted-out vessel is enormous and entails a wide range of different materials; these include semi-worked products such as metal sheeting and sections, finished products such as engines and items for fitting-out which vary according to the type of ship, be it a petrol or dangerous substance carrier, a passenger ship or a cruise ship.

The following in particular are required: joinery and insulation materials, products for sandblasting, cleaning and painting, gas and electrodes for soldering and welding and oils for tool machines.

On arrival material is offloaded from the relevant means of transport (transport is by sea or land depending on the size of the material), checked and then stored in a warehouse.

This study refers primarily to the construction of a vessel which has a supporting structure made in steel. Where this differs from construction using other metal alloys, the difference is noted.

5.4 Movement of materials

Movements depend on how the shipyard is laid out.

Materials are divided between the various departments on the basis of the work cycle. In the first place the sheet metal and sections are delivered to the naval workshop and then the rest of the material is delivered to the relevant departments. Large shipyards have a general warehouse which houses materials of general use.

Sheet metal and other bulky goods are moved using:

- Gantry cranes on rails,
- Cranes on wheels,
- Fork lift trucks,
- Wheeled trucks.

5.5 Naval workshop

The naval workshop can be considered the starting point in the manufacturing cycle. Here the sheet metal and sections that will be used in constructing the hull, the plating, and internal and external structures are laid out, cut and formed.

Cutting operations are always preceded by tracings, and are carried out in different ways depending on the material used, the size of the steel plate and the shape that is to be cut. Mechanical cutting is carried out by machine tools and is followed by cleaning of the sheet metal to remove any off-cuts. Oxygen cutting, whether using oxy-propane, oxy-acetylene or plasma is carried out by specialised operatives either with the help of a pantograph or by hand using a simple etcher. Each type of cut requires particular machinery and tools along with appropriate systems for moving the piece (small cranes, hoists etc.) towards the machine.

After each cutting operation the work area must be cleaned of off-cuts and waste. Prefabrication of non-heavy rough pieces is begun in the naval workshop and sheet metal and sections are put together here.

Finishing operations carried out in the naval workshop include the moulding of semi-worked products which are then delivered to the various departments. These pieces may be used for new assembly of both small and large pre-fabrications as well as directly on the stocks.

5.6 Mechanical workshop

The mechanical workshop features in many manufacturing cycles as it produces all the elements for installing machinery on board, such as supports, joints, anti-vibration couplings, pipe work, valves and pumps.

Numerous operations are carried out here, such as cutting, moulding, welding, and cleaning and sandblasting of the metal parts which form part of the machinery on board.

The mechanical workshop also carries out maintenance work of on-site machinery, lifting mechanisms and operating machinery.

In large shipyards the mechanical workshop has specified departments for working pipes and for welding easily-transportable pieces.

5.7 Pre-fabrication

Small pre-fabrication involves the assembly, where necessary by welding, of sheet metal and pipe work to form small-sized pieces such as walkways etc. The welding is either done electrically or using gas in inert atmospheres.

The main aim of large-scale pre-fabrication, which can be done both in parallel or in series with small pre-fabrication, is the construction of semi-worked items which make up elements in the base structure and plating. When assembled with the appropriate walls of insulation and sound-proofing this type of pre-fabrication can produce almost complete “blocks” which are then used to construct the ship.

Interiors are made of wood which comes from the ship-yard carpenters and from other materials which are previously worked in the appropriate department. The materials used must retain their characteristics in a marine environment.

Different blocks of the ship are then constructed contemporaneously in different “islands”, thus providing for better work organisation, and most importantly reducing the overall construction time.

Work from the ground is carried out using safety platforms, parapets, scaffolding, elevator platforms and cranes, all of which are essential for working at high level on the blocks. As work progresses it becomes necessary to work in restricted spaces, particularly when carrying out interior work on small cabins carved out of the block.

5.8 Sandblasting and painting

After assembly, which is once more accomplished by welding, the parts are then sanded, using jets of sand directed at the metal surfaces. This simultaneously cleans and primes. The cleaned surface is then covered with a protective paint, or primer, which preserves it against the oxidising effect of damp air and other aggressive agents. These operations are carried out in a different place to that where the item was constructed, and it is therefore necessary to move the blocks on trolleys or cranes to the sheds which are specially equipped for such operations.

5.9 Construction on the stocks

The completed blocks are then assembled on the stocks with the help of a bridge crane. The stocks may consist either of two large slipways or by a dock with an opening towards the sea. The various blocks are fixed together and then welded, thus creating the vessel.

In addition to assembly, during this phase many of the other operations which render the vessel operative are carried out.

During the phase of on the stocks construction all the internal and external finishing operations are carried out on the hull in order to guarantee that the vessel will float and to complete the parts that will be under water following the launch.

Tests are carried out on the hydraulics, the electrical wiring system, and, under pressure, on the pipework and tanks, particularly for those ships which are to be used for the transport of pressurised liquids.

5.10 Cleaning and painting

The final operations prior to launch are those of cleaning and painting of the hull. It should be pointed out that all the construction operations described above, such as welding during the assembly of the blocks and cleaning and painting, involve the use of platforms and scaffolding for the workers and hoists for the machine tools used.

5.11 Launch

Launching operations depend on the type of stocks used. In practice, when the vessel is mounted on a slip-way the stops are removed and the ship is left to slide into the sea. When the vessel has been assembled in dry-dock, the dock is filled with water.

5.12 Fitting-out

Operations of loading and installing machinery and fitting-out can be carried out both on solid ground (on the stocks) and after launching. In general it is better to carry out these operations on solid ground, particularly for work which must be done in limited space or where communication hatches leading to adjacent areas are restricted. These works include finishing operations and all other auxiliary services carried out with the aim of making the ship fit for navigation. Some of the most important of these are the services for dealing with situations of flood or fire, those intended for the crew or passengers (bunks, kitchens etc), navigational services, such as command and route-finding equipment, and services connected to the distribution of electricity produced by the auxiliary generator which runs on engine or turbines.

During fitting-out plant and machinery are completed and tested. The cabins are painted and the last finishing operations are finalised.

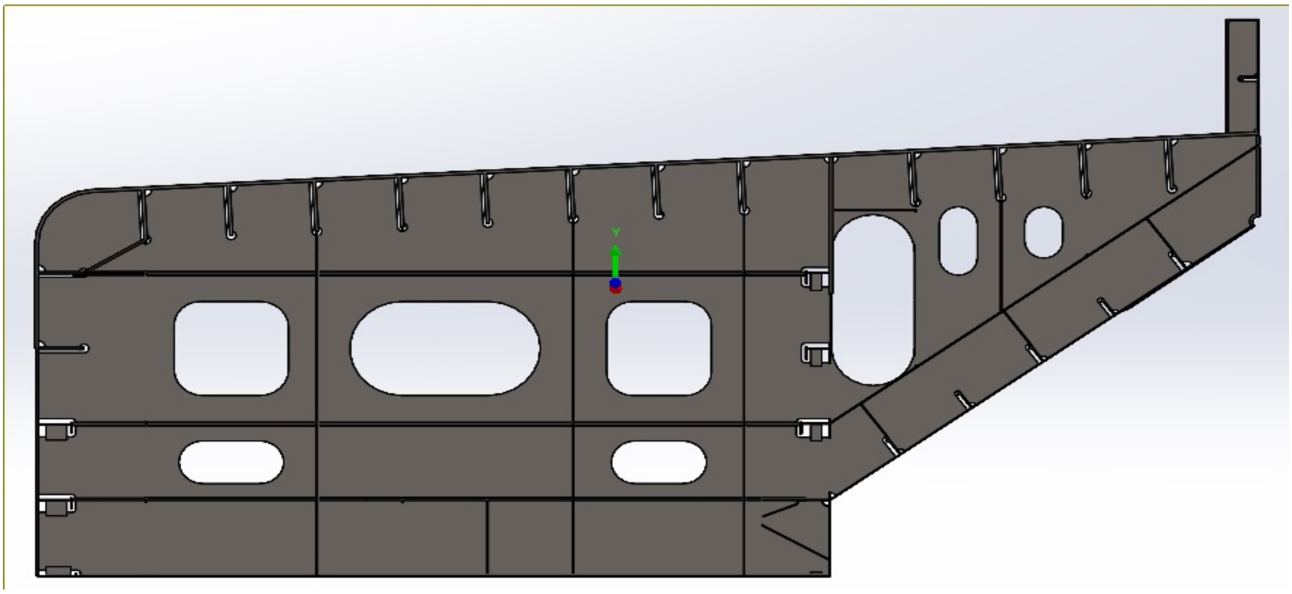
5.13 Sea trials and delivery

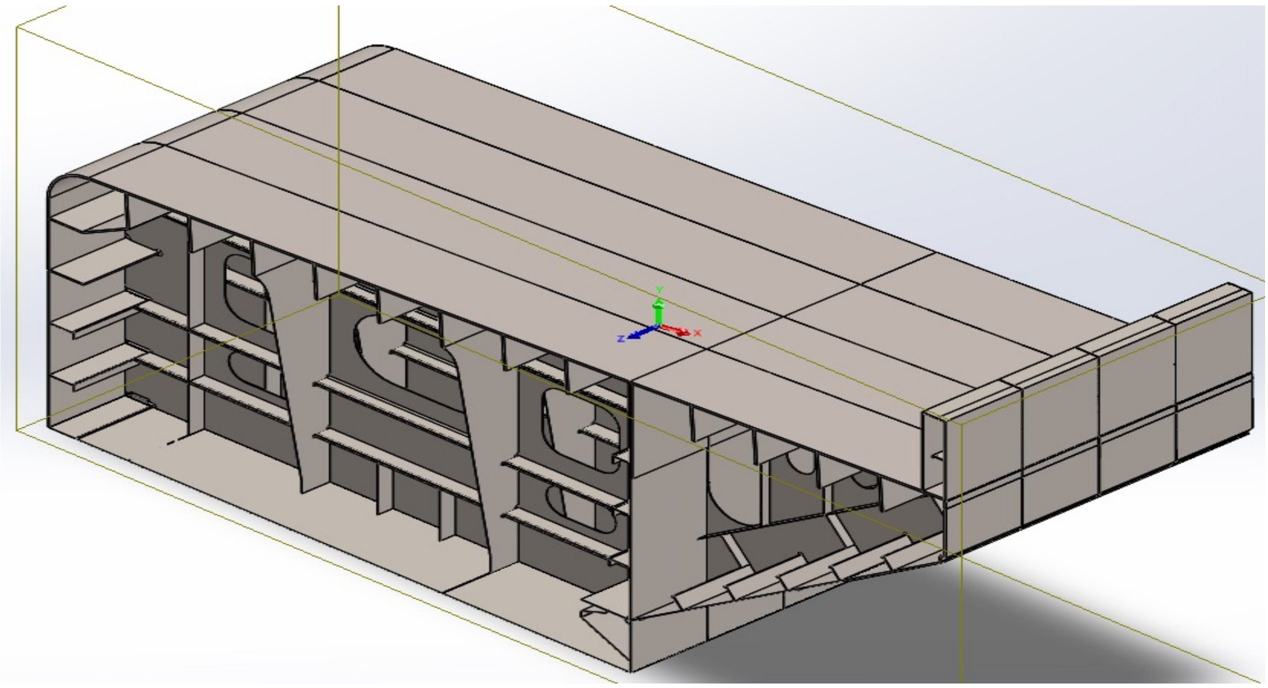
The last phases of the “manufacturing cycle” are sea trials, which are essential for testing the propulsion system, operability, and control equipment and safety systems for navigation, both for crew and passengers. In general a preliminary trial is carried out prior to the official one.

Before delivery the on-board equipment is loaded.

6. Total weight of the structure and centre of gravity

Then the physical characteristics of the final block including weight and centre of gravity will be explained.
AISI 316 naval steel was used in the construction of the block and was used to calculate the density and centre of mass of the block.
The main characteristics are shown below





Mass properties of FINALASSEMBLY MODELLING STRUCTURE DAVIDE MELOZZI
Configuration: Default
Coordinate system: -- default --

Mass = 81285768.34 grams

Volume = 10160720873.63 cubic millimeters

Surface area = 1221860741.23 square millimeters

Center of mass: (millimeters)
X = 6056.28
Y = 3421.42
Z = 1701.96

Principal axes of inertia and principal moments of inertia: (grams * square millimeters)
Taken at the center of mass.

Ix = (0.99, 0.17, 0.01)	Px = 329070251933622.44
Iy = (-0.16, 0.97, 0.19)	Py = 1462176206330426.50
Iz = (0.02, -0.19, 0.98)	Pz = 1509755219533012.25

Moments of inertia: (grams * square millimeters)
Taken at the center of mass and aligned with the output coordinate system.

Lxx = 360511255050260.63	Lxy = 186006978019479.47	Lxz = 8396360211185.04
Lyx = 186006978019479.47	Lyy = 1432578570347254.75	Lyz = 10517667447510.84
Lzx = 8396360211185.04	Lzy = 10517667447510.84	Lzz = 1507911852399550.00

Moments of inertia: (grams * square millimeters)
Taken at the output coordinate system.

Ixx = 1547507757728660.25	Ixy = 1870334699447280.00	Ixz = 846252919780272.50
Iyx = 1870334699447280.00	Iyy = 4649480070871791.00	Iyz = 483853767358169.69
Izx = 846252919780272.50	Izy = 483853767358169.69	Izz = 5440894663569894.00

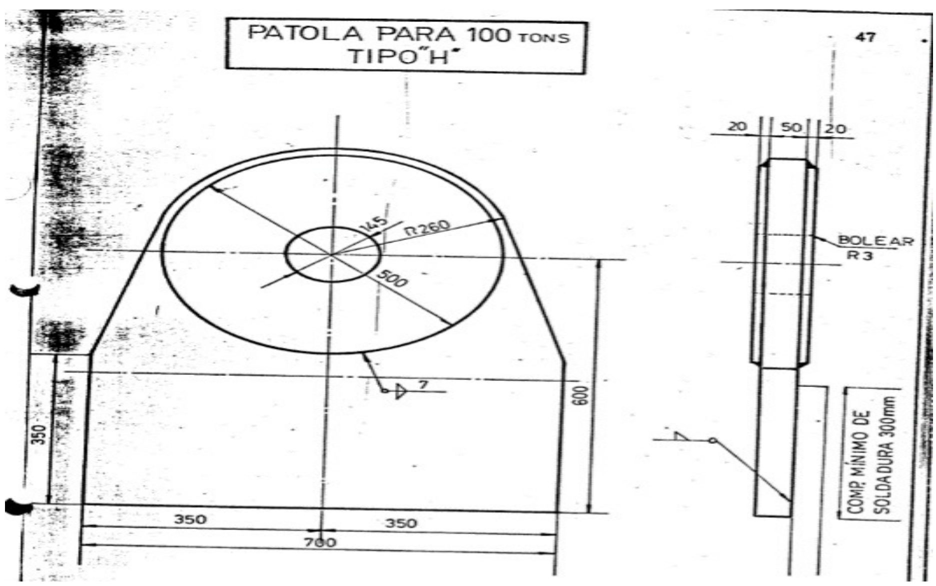
7. Trasportation of a block

For the conveyor system, first of all, you have to take into account its capacity limits so that safety is ensured.
For this block, since it will be welded with the deck facing down, it will need to be rotated 180 degrees to be joined with the rest of the ship's blocks. To do this you need to take into account the weight of the block and therefore the pads to be used. It is also important to understand the tensions to be applied on the cables carrying the block. This is essential so that there are no accidents with the cables or weakening of the block.

The feet must be placed in the most reinforced places possible, preferably on reinforcements or beacons. Since the block has a weight that not exceeds 100 tonnes but does not reach 200 tonnes, then it was decided to use springs that can hold 100 tonnes each, so that when only two are being used, there is safety.

Four "H" type springs were used and it was decided to place them at both ends of each center plate of the first and fourth goal. The geometry of these springs is shown in the following picture.
For the transportation system, first of all, it has to take into account its capacity limits so that safety is ensured.

The selection of the lifting means for suspension, rotation and movement of the block depends on the existing means on site. For this case it was considered the use of two gantry cranes with a capacity to support the weight of the block, one inside the workshop for moving the block to the transport vehicle for the construction line and a second one for lifting and moving to the ship structure. Due to the 21 metre width of the block a stabilizer bar must be used so that the force is correctly distributed by the cables



8. Painting

Painting is a process that represents 9-12% of the total construction costs of a vessel. The importance of the paintwork to be applied is due to the fact that it provides essential protection to maintain structural integrity, good hydrodynamics and longevity in the ship's life

Painting the structure is important in for aesthetical reasons but also to protect it against corrosion which is why not only the hull must be painted but also the ballast and cargo tank walls.

Normally there are 2 layers applied to the tanks and 3 to the hull, the first two are for corrosion protection while the second is to ensure a good coating between the first and the third. The third layer gives the colour and is only applied to the hull.

The painting of the bolster parts can be started after cutting and forming, if necessary, this process must be carried out simultaneously with the other processes in order to reduce costs and optimise construction

The application of the paint scheme is divided into several phases: preparation for painting (according to the manufacturer's technical specification and ISO8501), painting, inspection and repair if the need is identified during the inspection. During the whole process, the temperature, humidity and other parameters recommended by the manufacturer and classification society must be taken into account.

Table 3.1 Maintenance coating

Allocation	*Coating type*	*Total average DFT micron*	*Number of coats minimum*
Ballast tanks and hull internals	Epoxy based, "surface tolerant", "high tech", "mastic", etc., preferably light coloured	300 - 350	1 - 2

Table 2.5 Hull coating systems and allocation

Allocation	*Coating type*	*Total average DFT microns*	*Number of coats*
External hull, under water including boot-top* area * between loaded and ballasted water line	Epoxy or Epoxy coal tar + Anti-fouling paint	300-350 250-350	2-3 2-3

Table 2.4 Coatings for miscellaneous areas

Allocation	*Surface preparation*	*Coating type*	*Nominal DFT microns*	*Number of coats minimum*
Fresh water tanks	Sa 2,5	Epoxy	200	2
Product tanks	Sa 3	Epoxy Phenolic Epoxy Zinc silicate	300-350 300-350 75-100	2 - 3 2 - 3 1
Accom-modation and Engine rooms	Sa 2 - St 3	Alkyd, etc.	100-150	2
Reefers, underneath thermal insulation on tank top or inner bottom plate	Sa 2,5	Epoxy	300	2

Paint	Area [m^2]	Thickness [mm]	Density [kg/m^3]	Layer	Volume [m^3]	Weight [kg]	Liters [l]	Healing [days]	Time [h]
Zinc epoxy BS 17360	1286,5	0.06	3214	1	0.063	193.6	63.8	6	144.16
Epoxy BS 17634	1286.5	0.2	1863	2	0.387	890.3	387	6	145.30
Polyurethane BS 55610	1286.5	0.06	1357	1	0.063	178.4	63.8	6	144.16
Total	3859.5				0.513	1262.3	514.6	18	433.62

9.Quality Control

Quality control is very important in the construction/repair of a block and consequently in the construction/repair of the ship. This is usually done by classification societies, but throughout the manufacturing process it is necessary to constantly check the quality of the process carried out so that no problems occur in the end.

The first quality control problem is the size of the components of the block. The biggest problem linked to the size of the components is in the cutting process. All the equipment must be calibrated beforehand, but there will always be a millimetre tolerance. There can also be problems with material shortages which can lead to problems during final assembly, which is one of the reasons why nesting is an important part of the manufacturing process.
Also with regard to cutting, it is necessary to control the edges after cutting, so that there are no problems, such as warping, due to exposure to high temperatures.
When welding, it is also very important to have a quality control, since a bad quality welding can damage the whole block, and consequently the integrity of the ship.

There are several methods to ensure that the weld is well done once it is complete. Normally the tests focus on the quality and resistance of the weld, but they can also refer to technological actions to confirm the position, location and extension of the weld. These methods are divided into destructive testing and non-destructive testing. In this case, only non-destructive testing can be applied, for obvious reasons. These tests are more visual tests and are conducted by an inspector who will use equipment or his own vision.

The most commonly used non-destructive tests are:

X-Ray: This method uses penetrating radiation and analyses the internal structure of materials. This test can be performed by a technician with X-ray based images or videos.

Ultrasonic Waves: This test is based on the propagation of ultrasonic waves in materials, detecting internal damage that materials may have. This test is normally used for Steel.

Liquid Penetrant: It is a widely used test due to its low cost and detects defects on the surface of materials in non-porous materials such as metals. It is widely used to detect surface defects such as fatigue cracks, surface porosity and leaks in new products. It is also used to detect corrosion.

Magnetic Particle: Used to detect discontinuities on the surface of ferromagnetic materials such as steel. The process creates a magnetic field on the part and being tested magnetises the part.

10.CONCLUSIONS

From the overall analysis of this project we can deduce the following considerations:

Elaborating the 3D drawing was essential for the construction study of the block, it allowed to visualise and size each part to be manufactured, facilitating nesting and calculating cutting, welding and painting times and consumables.

The nesting was carried out using software in order to optimize the process and reduce material waste, obtaining an 77% utilization of the plates to be cut.

It was verified that there are several solutions to perform the cutting and that the choice of the process to be adopted depends on several factors, with emphasis on the acquisition cost, the quality, the cutting speed and the thickness of the sheet to be cut.

The welding process is extremely important in the manufacture of the block, because if the welding fails the whole structure will fail.

There are several options for lifting, rotating and moving weights and the selection of which means to use depends on the shape of the object to be transported. This choice should primarily take into account safety and man-hour costs.

The selection of the paint scheme to be applied and its proper application are of extreme importance for the integrity of the material and consequently of the vessel.

Also quality control is fundamental in order to guarantee the response of the platform and, by the way, the safety of the people on board. Beyond these extreme situations, quality control guarantees a construction in accordance with the expectations of the client, preventing the occurrence of failures and additional costs.

As we have seen, building just one block is a time-consuming and costly process in itself processes and their simultaneous progression is essential to reduce the delivery time of the ship to the client and at a lower cost.