Ship Launching in Small Shipyards

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ABSTRACT

The most important process in the shipbuilding industry is a ship launching. The launching process takes various forms in shipyards, especially in proximity of rivers or canals where water level can change any time and where shipping traffic is extensive.

The object of my study is a shipyard with the following limitations:

- No slipway,
- Very limited area for building ship sections and a ship hull,
- No floating cranes,
- No economical possibilities to rent a floating deck,
- No permission from the Port Authority to perform a ship launching because of restricted zone of shipping traffic.

I propose the launching solution for all types of ships, which can be applied in a small shipyard with the above-mentioned limitations. I have done research regarding experiences of several shipyards, methods of launching ships and other floating structures.

The most important part of this study is a development of the ship launching methodology and a proposal to use the original launching device, supported by the numerical analysis referring to the launching process.

The proposed methodology and designed device can be widely applied in other launching processes.

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NOMENCLATURE

$\beta \;\; = Slope\ of\ \ slipway\ track$

$D_p \;\; = Weight\ of\ displacement\ of\ pontoon\ (tn)$

$L_p \;\; = Lenght\ of\ pontoon(m)$

$B_p \;\; = Breadth\ of\ pontoon(m)$

$T_p \;\; = Draft\ of\ pontoon(m)$

$J_{G_p} \;\; = Moment\ of\ inertia\ of\ mass\ of\ potoon\ relative\ to$

$central\ axis\ passing\ through\ center\ of\ gravity\ (tn.m.s^2)$

$l_{G_p} \;\; = Distance\ of\ transfer\ of\ moment\ of\ inertia\ of\ mass\ of\ potoon$

$relative\ to\ axis\ O_2x\ (m)$

$\xi\eta_{G_p} = Separation\ of\ center\ of\ gravity\ of\ pontoon\ to\ axis\ O_2\ (m)$

$a_p \;\; = Elevation\ of\ center\ of\ gravity\ of\ pontoon\ over\ his\ center\ of\ buoyancy$

$in\ initial\ position\ (m)$

$SG_p \;\; =$
$Distance\ from\ the\ point\ O_2\ to\ the\ perpendicular\ lowered\ on\ slip\ plane\ (m)$

$z_{G_p} \;\; = Ordinate\ of\ center\ of\ gravity\ of\ the\ potoon\ (m)$

$H_{2p} \;\; = Length\ of\ the\ perpendicular\ lowered\ from\ the\ center\ of\ gravity\ of$

$the\ pontoon\ over\ the\ slip\ plane\ (m)$

$\sum_{n=1}^{m} X_X \;\; = Sum\ of\ \ the\ moments\ of\ inertia\ of\ the\ free\ surface\ area\ relative$

$to\ the\ central\ axis, perpendicular\ to\ the\ slip\ plane\ (m^4)$

$l_A \;\; = Separation\ of\ hull\ of\ pontoon\ from\ axis\ of\ coast\ abutments\ (m)$

$e \;\; = Separation\ of\ axis\ of\ coast\ abutments\ to\ wall\ (m)$

$H_5 = Height\ on\ side\ of\ pontoon\ from\ the\ bottom\ up\ to\ the\ threshold\ (m)$

$l_b \;\; = Distance\ of\ tranfer\ of\ moment\ of\ inertia\ of\ mass\ of\ pontoon$

$relative\ to\ axis\ O_4x\ (m)$

$\gamma = Specific\ weight\ of\ water\ (m)$

$\xi_0 =\ Distance\ from\ the\ axis\ of\ coast\ abutments\ to\ the\ water\ horizon\ (m)$

$D_c\ = Weight\ of\ ship\ in\ launching\ \ (tn)$

$f_a\ = Coefficient\ of\ dynamic\ friction$

$H_2\ \ = Elevation\ ot\ the\ center\ of\ gravity\ over\ axis\ \text{¨}s\text{¨}\ in\ second\ period\ (m)$

$H\ \ = (hk) Elevation\ ot\ the\ center\ of\ gravity\ over\ slip\ plane\ (m)$

$s = way, made\ for\ ship\ in\ the\ first\ step\ of\ launch$

$\dot{s} = velocity\ of\ ship\ in\ the\ first\ step\ of\ launch$

$\ddot{s} = aceleration\ of\ ship\ in\ the\ first\ step\ of\ launch$

$y, z = coodinate\ of\ center\ of\ gravity\ of\ ship$

$\dot{y}, \dot{z}$
$= proyection\ of\ total\ velocity\ of\ center\ of\ gravity\ of\ ship\ in\ the\ axis\ Oy\ andOz$

$\ddot{y}, \ddot{z}$
$= proyection\ of\ total\ aceleration\ of\ center\ of\ gravity\ of\ ship\ in\ the\ axis\ Oy\ andOz$

$\theta = angle\ of\ inclination\ of\ ship$

$\dot{\theta} = angular\ velocity\ of\ ship$

$\ddot{\theta} = angular\ aceleration\ of\ ship$

$\delta = angle\ of\ skate$

$\dot{\delta} = angular\ velocity\ of\ skate$

$\ddot{\delta} = angular\ aceleration\ of\ skate$

$t = time$

$Jz; Jx$
$= Inertia\ moment\ of\ ship\ \ and\ relative\ walkway\ to\ axis, in\ the\ center\ of\ gravity$

CHAPTER I

1. INTRODUCTION

We know the launch of a ship is the transference of the ship from the place of construction to water. Typically the ship is launched end on, where the stern gets into water first. For shipyards located in narrow rivers (small shipyards), the launch is sideways.

For small shipyards, it is common to use the transversal launching or others, where different devices are used for this process. The construction of one longitudinal slipway is reserved for big shipyards where it is possible the construction of big ships.

1.1.Objective

The more import requirement in this project is to know the type of ship launching and their characteristics for small ship yards. Also to know how important is that process in the spiral of design.

1.2.Main idea

The principal idea is analyzing all possibilities for making the process of ship launching in one small shipyard and present the possible solutions for development of this process.

2. DESCRIPTION OF SHIPYARD

The shipyard is one industrial complex which has structures equipment (Workshop, slips, etc.), necessary for shipbuilding and assembly of the ship equipment. Also has workshops for preparing ship machinery, workshop for different auxiliary mechanics and additional details.

The distribution of one shipyard is presented in fig.1

The capacity of the shipyard will depend of cranes capacity. The methods of production and applications of new technologies and standards of quality is important for shipyards [2].

Shipyards can build all types of ships but only shipyards with experience in military ships can build that type of ships.

It is possible to divide the material of construction in a shipyard (steel, fiber glass, wood, aluminum). Most of these shipyards are for small ships.

For small shipyards it is recommended the use of floating dry docks for launch of ships, but this method is necessary to make pumping plans and to develop procedures for drydocking difficult or unusual vessels

Usually small shipyards use 1,000 ton capacity floating dock

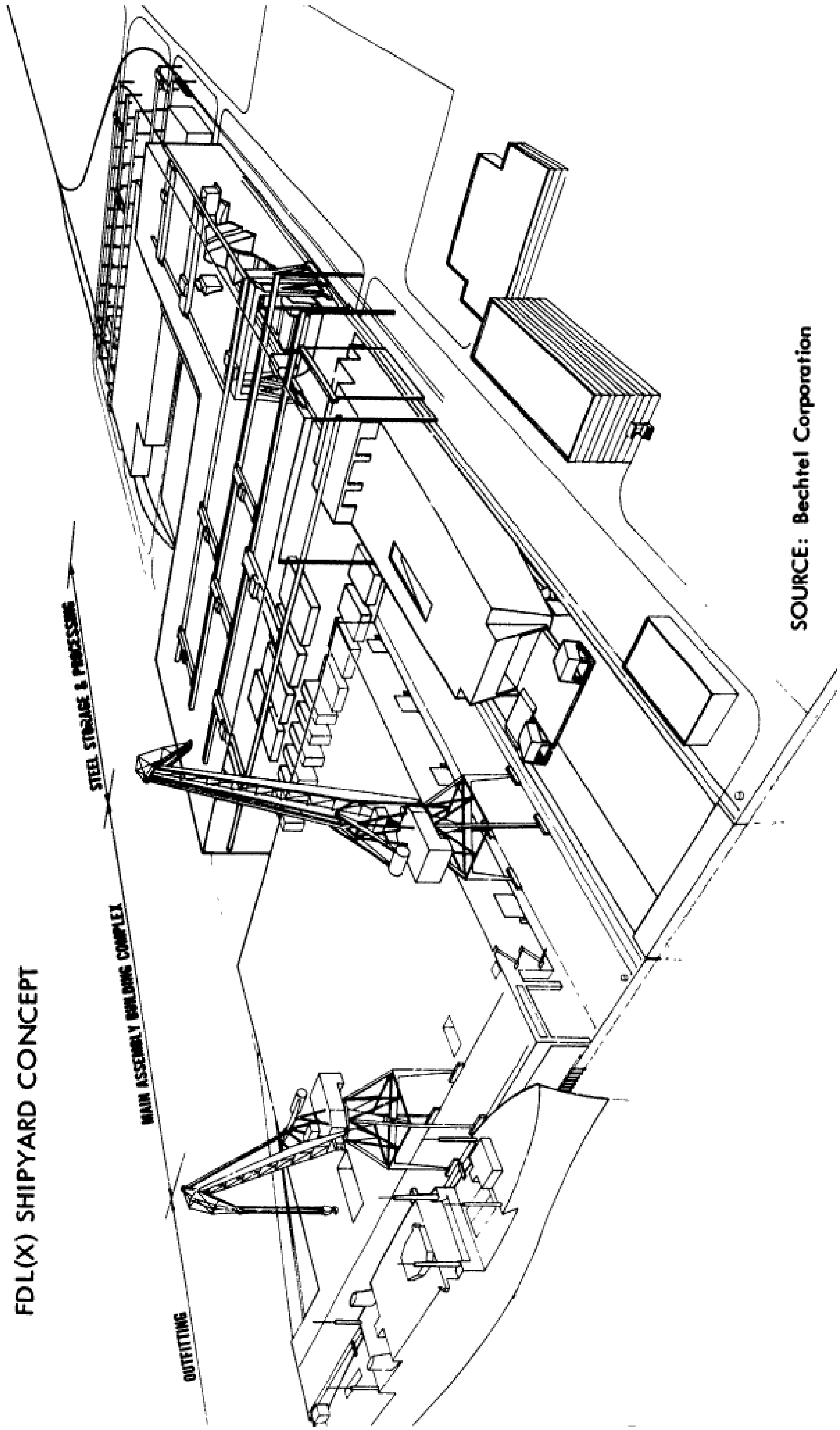

Fig.1. Shipyard Layout [1]

3. ACTUAL SITUATION OF SHIPYARD INDUSTRY

The politics of business had a very close relation with oil prices, and the effects of the petroleum crisis can affect the economic planning for a shipyard.

The favorable economic situation has the Asian shipyards, specially Japan, Korea and China, with almost all orders for tankers and containers in the world

In the same period of time all countries in Europe will decrease its naval industry, except Holland which has good possibilities.

The biggest increase is in Asia to 2019, in particular Hong Kong. [3]

The shortage of orders will affect shipyards, and force them to be more competitive in their pricing for news projects. [4]

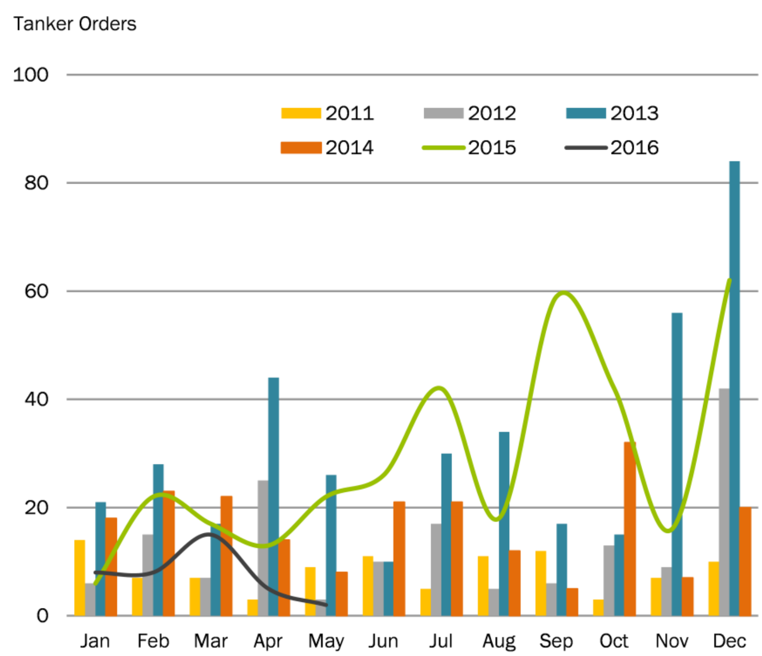

Fig.2.Order for construction of tankers [5]

At this moment the Korean shipyards are in a serious economic situation, because of the decreased participation in the shipbuilding market.

In Europe, the big France shipyard in Saint Naizare, which has experience in the construction of offshore platform and supply vessels, at this moment has plans for construction of liner cruises until 2021.

¨This project is a join work between the Italian shipbuilding Fincateri Company and the German Papenburg company¨[6]

The German shipbuilding companies think quality then quantity at this moment of crisis

In Germany the change started in 2011 and has the opportunities for improving the environmental requirements.

It is the reason why the price of construction of big ships is being depressed. Also, a lot of ship yard should be changing the orientation of their services for different clients at this moment.

The shipyard should use new type of infrastructure and planning operation, new type of monitoring and identification of process where necessary.

But, that information is relevant for construction of new types of big projects. For medium and small ships, the construction advances. Also in ship remount it is necessary anew type of shipyard policy.

In this analysis we do not present information of navy ships, but for different political problem in the world, a lot of countries start new military projects.

4. LAUNCHING OF SHIPS

The launching of a ship is a significant event in the life of the ship and the everyday work of shipbuilders.

This process has two circumstances.

The first of these is that at the time of launching the ship moves from one medium to another, getting in their native medium, in this case the water.

The second circumstance is the launching of the ship, is the only time in the process of its construction, which has a clear synchronization.

Indeed, in the process of construction of ship no one knows when the ship starts building but the completion of construction is clearly defined.

But the fact is, at in this moment, the ship is not yet "built". Obvious deficiencies and latent defects are not uncommon in the practice of shipbuilding. In this case, these defects are removed after putting the ship into operation.

For ship launching this time is in used various ways and various structures.

Also is in important to know, when the ship launching occurs, that the construction in the ship in not finished, and afterwards, when the ship is floating we can continue the construction.

In the next table 1, we show this information [7].

Type of Ship	Type of Launch	% of preparation
Big Ships	Slipway/Dry Dock	55-70
Medium Ships	Horizontal place	75-90
Small Ships	Mechanical	95-98

Table1.Information of % of ship construction

5. METHODS FOR SHIP LAUNCHING

Ship launching begins in the period of preparation and ends in the construction period.

Modern technology provides maximum readiness of ships before their launching.

The moment of ship launching is chosen depending on the technology adopted for construction, manufacturing conditions, shipyard or construction plant and time of year.

Before ship launching different compulsory works should be completed: assembly and welding to ensure tightness and structural strength of the ship; painting the underwater hull and show of the draft marks; installation and testing of seawater valves; installation of device of stern tube of axis ; installation of rudders, propeller shafts and propellers, rotary nozzles; installing the necessary components of the mooring devices and rescue equipment; fixing of mechanisms and cargo submitted to the ship.

There are several ways of launch of ship:

- Free - In an inclined plane under the action of gravity;
- Surfacing - when raising the water level in the launching facilities;
- Forced - mechanized.

5.1.Ship launching under gravity

The ship launching by gravity (longitudinal and transverse) is one of the most complex process in the shipbuilding industry. The period of launch is very small, and the time of preparatory work is long. For this form of launch use the slipway, it is near of shipyard.

5.1.1. Longitudinal ship launching

The longitudinal ship launching is performed in an inclined longitudinal slipway with 100 to 350 m length and it is perpendicular or an angle to the coastline.

The slipway is a complex engineering structure having a reinforced concrete base to accommodate trigger tracks. It consists of a surface and underwater part.

Fig.3.Tipical longitudinal ship launching [8]

5.1.2. Transversal ship launching

The transversal ship launching is usually used for launching of ships of small and medium tonnage in shipyards located on rivers.

Constructions consisting of a horizontal slip (before launch position) and incline launch track, in perpendicular direction to the axis-slip are used for transversal launch.

The slope of the slip track is much greater than for longitudinal launching.

The slip track is placed on the ground or on a reinforced concrete base and deepened in the water at 1.5m or is not deepened.

Fig.4.Transversal ship launching in canals [9]

As a last resort, is also possible to launch ships using special airbags.

Fig.5. Ship launching in airbags [10]

5.2.Ship launching by surfacing

The ship launching by surfacing is realized in a dry dock, which chamber is filled with water by means of pumping stations.

The docks are filled with water to a level to achieve sufficient separation under the bottom of the refloated ship for removal of the keel blocks.

5.2.1. DryDock

In this case, the objective is filling the dry dock where the ship was built to water level. Afterwards. the ship is pushed using tugs in from the harbor.

Fig.6. Ship launching by dry dock [11]

5.2.2. Floating dock

Is one rectangular pontoon divided in tanks which work by action of pompons and valves.

There are different types: box, pontoon dock, sectional dock.

The total capacity of the floating dock depends on its buoyancy capacity.

It is possible to use the floating dock for small and big ships. More owners prefer the floating dock than the dry dock, because it is more flexible

The floating dock has rules of classification, and it is necessary to perform structural inspections in the tanks and pompons because, ¨A *40% loss of metal thickness drastically reduces the allowable buckling stress of the deck panels*¨.[12]

For security it is necessary to know the measures of waterline deflection and multiple types of deflection on a floating dry dock.

In the launching of dock, at the place of construction, the launch is possible when the level of water is the same of the ocean .Afterwards one tug will transport to the coast.

Fig.7.Ship launching by floating dock [13]

5.3.Forced mechanized ship launching

Forced mechanized ship launching is carried out through the following installations: transverse and longitudinal slips, vertical ship lifts, cranes and floating docks.

This method of launch is most often used by shipyards in the construction of small and some medium-sized ships.

5.3.1. Launching by Cranes

This process in not different from lifting and lowering of big loads. When the construction of the ship is finished, girths are prepared at the bottom of ship and in the deck spacer for safety of the ship hull. The ship launch is possible with one or two coast or floating cranes.

Fig.8.Ship launching by crane [14]

5.3.2. Travel lifting

For small ships, it is possible to make the launching with special equipment.

In this case, the ship is lifted completely from a dry dock by a travel lift and transferred to the ocean.

Fig.9. Ship launching by Travel lift [15]

5.3.3. Ship-lift system

The synchrolift o syncrolift is a cargo platform. Its movement is up-and-descenders for repairing or maintenance of ship. It is installed between two pile piers, and it is equipped with rail tracks and sliding trolleys, and lifting gear to both sides. According to the principle of action this system is divided into electromechanical, hydraulic, pontoon and combined. It also serves to lift out of the water and launching floating equipment, concrete caisson and caisson gate for dry docking activities.

The synchrolift has weight capacity ranges from 3,000 tons to tens of thousands of tons. The vertical movement of the platform with ship is possible due to the lifting equipment. The ship is transported by rail tracks with sling trolleys from the lift platform to the workplace in the shipyard. [16]

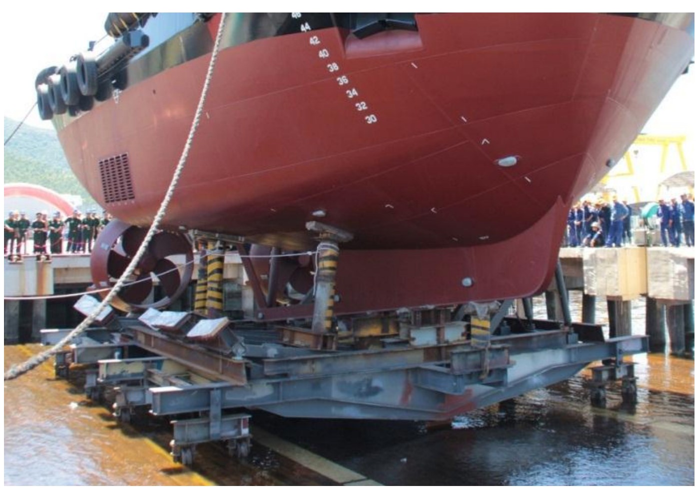

Fig.10. Rolls-Royce Syncrolift® [17]

5.3.4. Launching of offshore structures

Floating pontoons are commonly used for launching structures (Jacket), in the offshore industry

The structure is slipped from place of construction to pontoon, by reels, afterwards it is transported to the launch position. Two rocker arms are installed at the stern of pontoon, which rotate when the structure is in the process of launch that is necessary for supporting the reactions in the pontoon and jacket structure during launching process. [18]

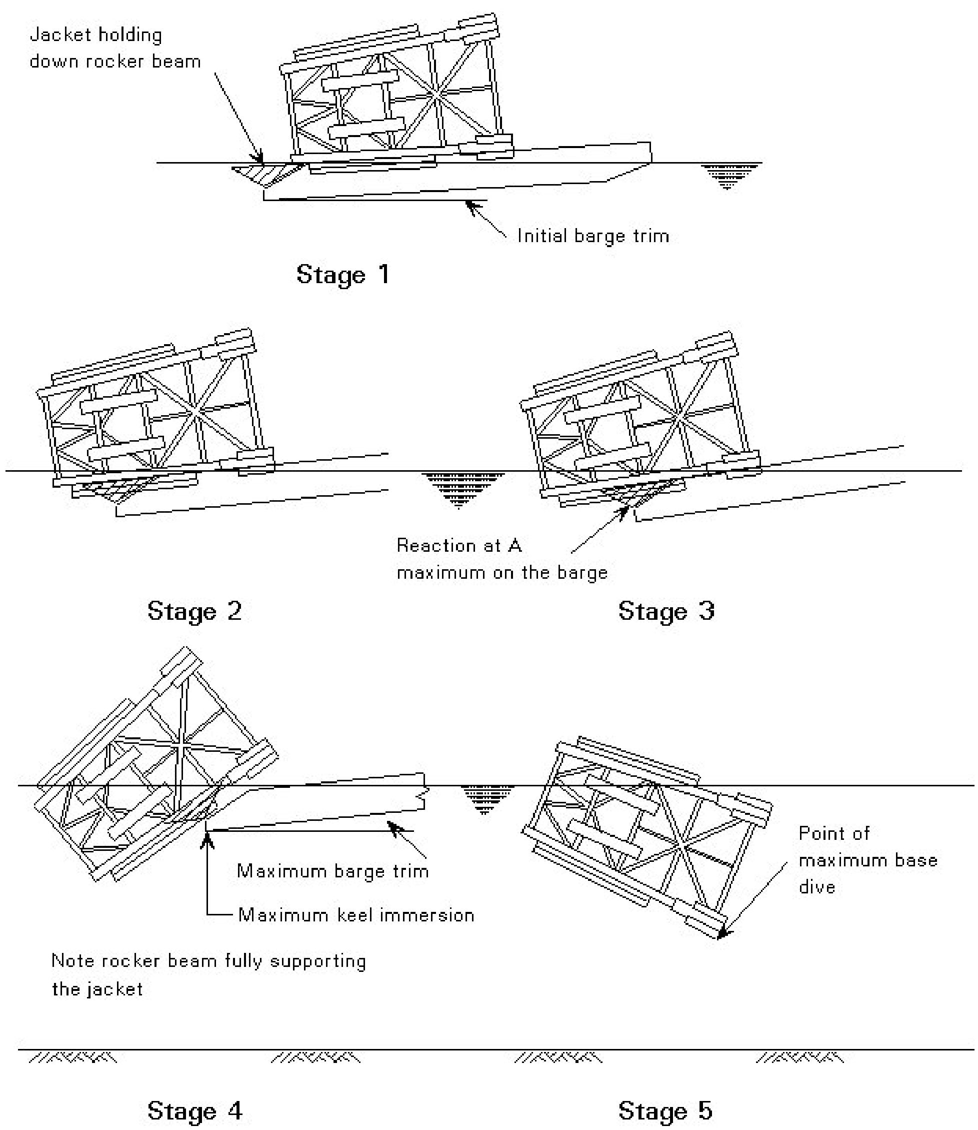

Fig.11. Launch of jacket. [19]

Afterwards, the stern part of pontoon is inclined by pompons. That is controlled to insure stability of pontoon. That process gives the possibility to install the jacket in vertical position.

It is necessary to understand that after launch process the pontoons have amplitude roll, amplitude pitch, period of roll or pitch and heave acceleration.[18]

Other type of ship launching is the process of construction in blocks. After which the sections are launched to the water the floating sections will be coupled.(Fig.12)

That process has the next characteristics.

- The coupled of ships afloat is made for a long time.
- Caissons or various proprietary sealing devices are used for welding the abutting parts of the ship.
- In addition to welding to connect the parts it is possible to use mechanical connection devices, such as those used for coupling the barge-tug convoys.

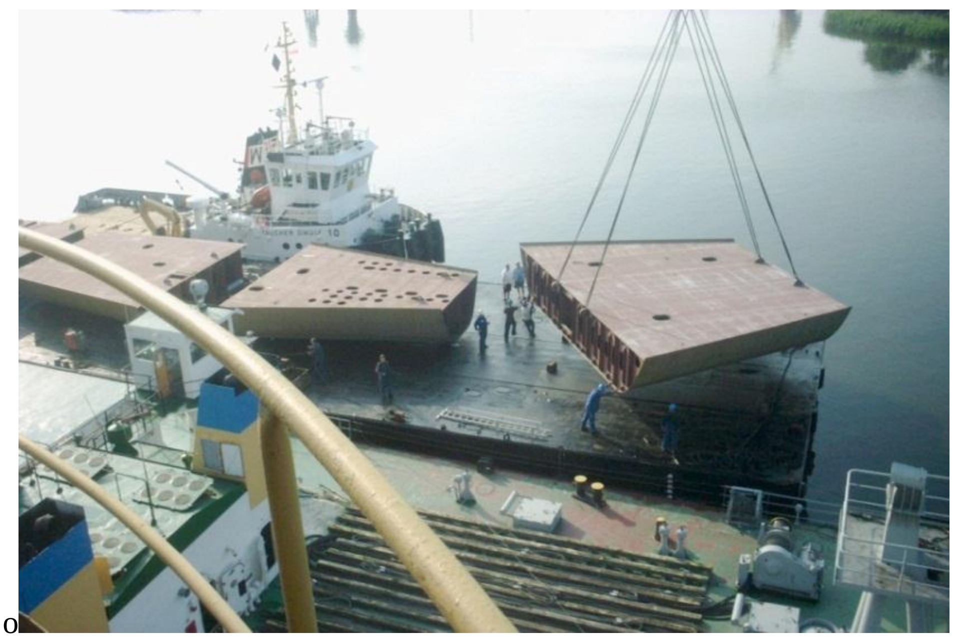

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Fig.12.Transport of block by pontoon [14]

In the future, this method is obvious and means for coupled ships afloat can be improved.

This will limit ship displacement and dimensions for launching and for economically reasonable limits.

Such structures allow launching large ships to water and components of large ships

6. TRANSVERSAL FREE SHIP LAUNCHING IN SMALL SHIPYARDS

The transversal launch of ship is used for small and medium ships. The main idea of this type of launch is the same for longitudinal movement of big boy one inclined plane.

6.1. Basic principle of transversal ship launching

The basic principle of transversal free ship launching along an inclined plane is the movement under the action of its own weight.

Construction of launching devices with this method is much easier and slip track is shorter than the longitudinal slipway.

Reduction of the length of the tracks contributes to a big slope and the use of specific types of transversal launching: normal launch, leap launch, throw launch.

Depending on the location of slipway places a transversal launch can be carried out in several schemes.

The ship launching directly from the construction place (slipway) is done by launching devices, consisting of multiple rotary beams (balancing tables) which are simultaneously supporting surface of building slipway.

6.2. Types of slipway for Transversal ship launching

In the shipbuilding industry it is possible to realize the process of ship launching in different form.

The election will be depend of type of ship, type of slipway or occupancy of shipyard.

But the launches by slipway and launch device have big differences.

1- The construction of ship is made in the place of work, after finish the construction; the ship is transported by slipway and afterwards the ship launch is performed (Fig.13a).
2- The ship is transported to the slip car for the pre-launch position, where in the horizontal slip under hull of ship, slip trucks are installed. The ship with car is

transferred to slip truck in the launch position. Afterwards the launching is realized, by lubricated slip truck. (Fig.13b).

3- The ship for launch is transported to car for pre-launch position, where it is transferred to launching car. In this position the ship is transferred to slip truck and then ship is launched.(Fig.13c)
4- The ship for launch is transported to pre-launch position with balancing table and slip trucks. The balancing table with the use of hydraulic pumps rotates to connect with incline slip truck. Afterwards the ship is moved to launch position, and it is possible to make the launch.(Fig.13d)

6.3. Types of transversal ship launching

There are three different types of transversal launch: normal launch, leap launch and throw launch (Fig.15).

The normal launch is made by immersion of ship. For this form of launch it is necessary that the height between keel and launch be 0.3-0.4m.(Fig.15a)

The leap launch is made to limit of coast. The ship rotates and falls to water with an angle between 50-60 grades.(Fig.15b)

In the throw launch, the position of the slipway is above the level of water by 1,5-2.5m. The ship moves by slipway with device launch in the little part of slipway and falls to water with one angle of 90 grades.

The transversal launch is for use in shipyards for ship weights between 1500-2000 tn. In this type of launch, less the economical spending, and have the possibility to make different type of launch.

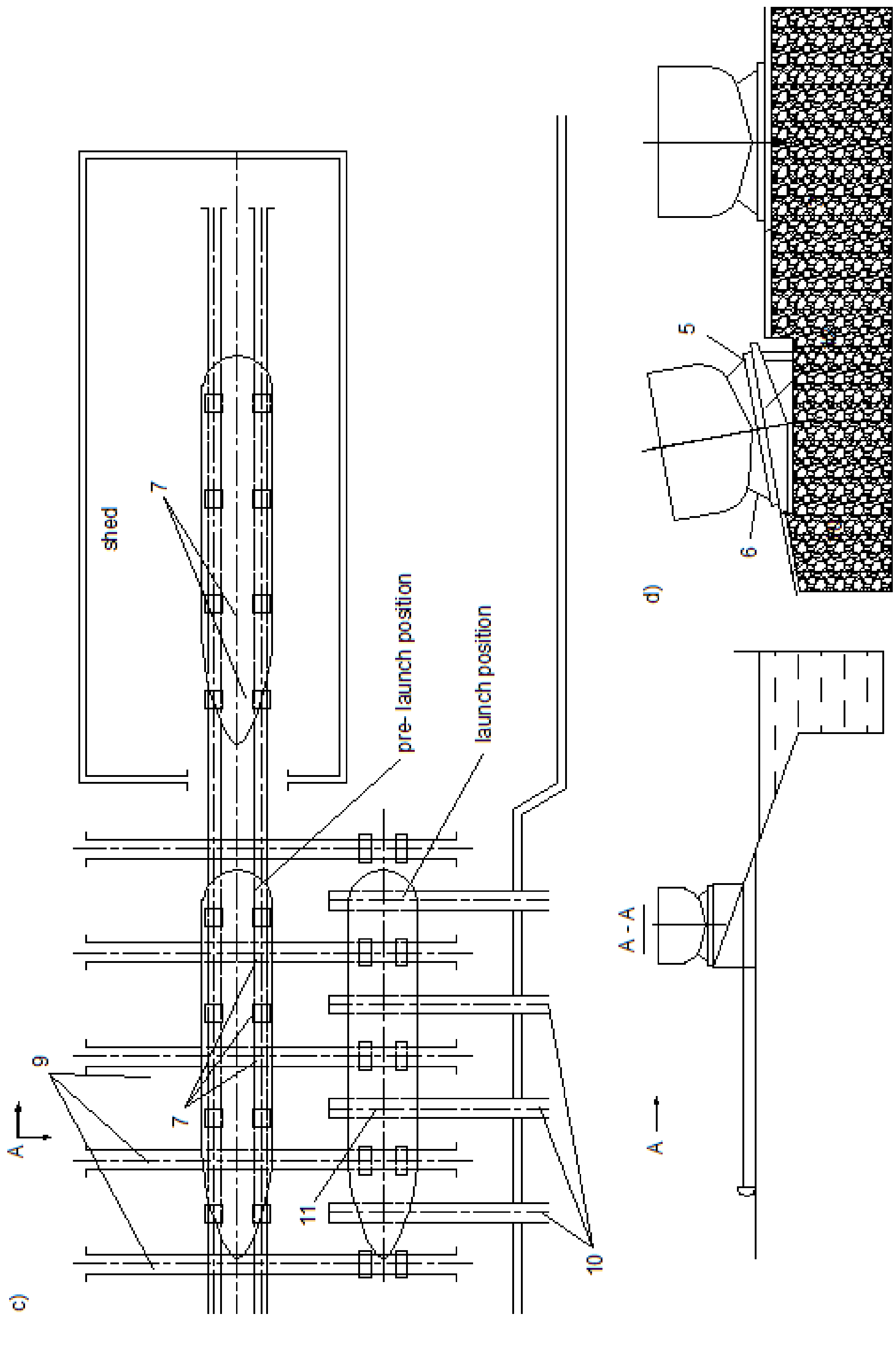


Fig. 13 Transversal ship launch a - first type; b - second type; c - thre type; d - four type

1 - ship ; 2 - shoals ; 3 - horizontal slipway ; 4 - indinate slipway ; 5 - slipway track ;
6 - ship cradle ; 7 - slipway car ; 8 - winch ; 9 - transversal slipway track ; 10 - tracks ; 11 - keel track ; 12 - balancing table

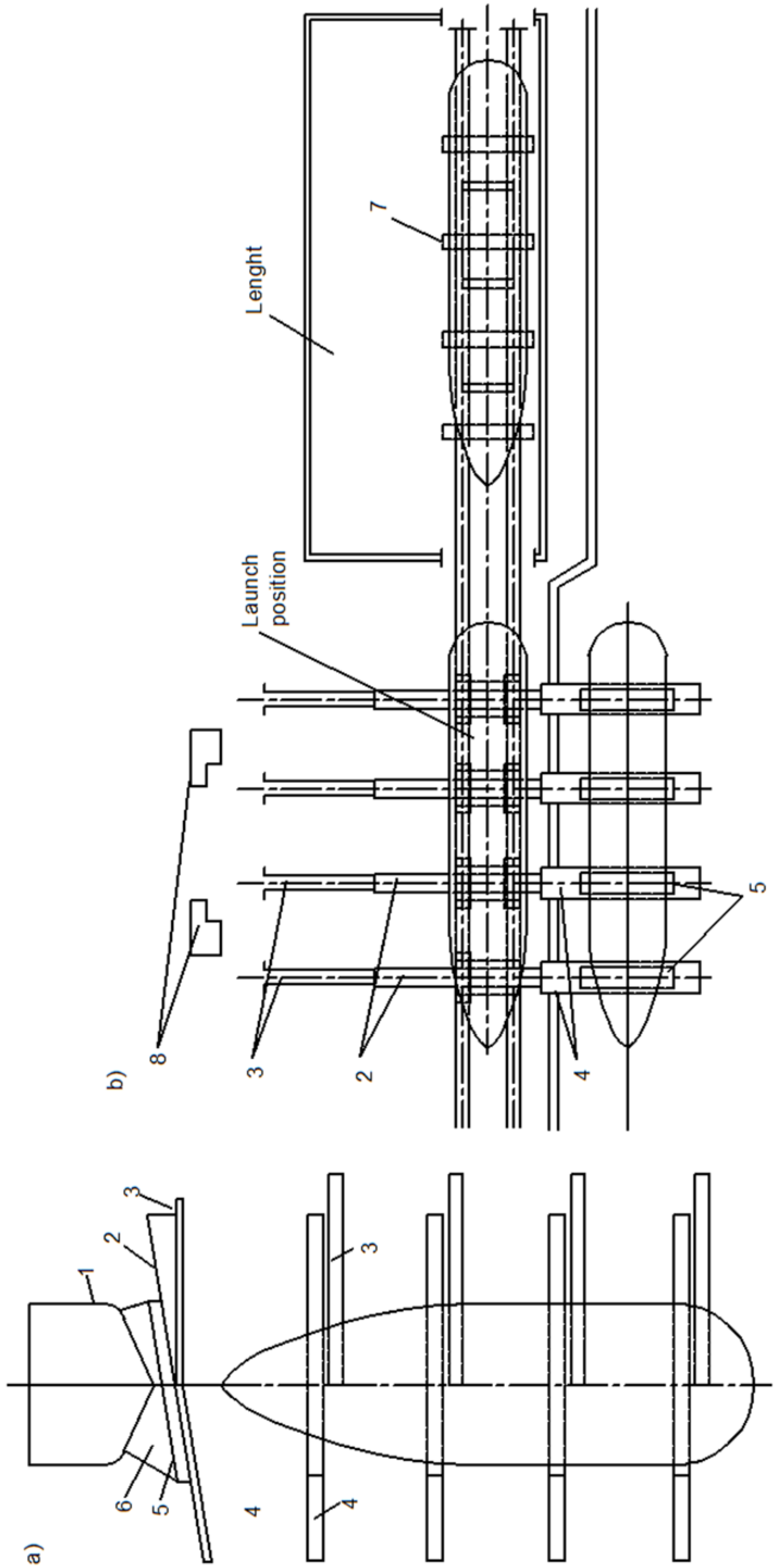

a)
1
2
3
4
5
6
b)
Lenght
Launch position
7
8

Fig.14.Transversal launching in slipway [9]

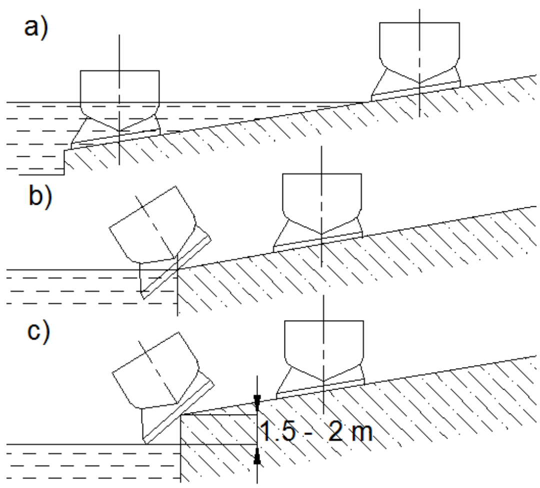


Fig. 15 Types of transversal ship launch
a - normal launch; b - leap launch; c - throw launch

Fig.16.Normal ship launching from slipway of river shipyard [9]

Fig. 17.Leap Launch of ship, in close water way (Canal) [9]

Fig.18.Throw launch of ship [9]

6.4. Steps for transversal ship launching

Transversal ship launching involves many steps: preparing of slipway and launching device; elaboration for schedules of ship launching and distribution of workers involved in the ship launching;

- Inspection of underwater slipway tracks by divers;
- Drying of tracks and rails, application of lubricant grease;
- Translation to ship launching position using a special winch;
- Positioning and fixation of slips below of ship;
- Lift of ship with hydraulic jacks and final installation of slips in regular places with mounted of keel blocks;
- Fixing of slip track and installation of special pieces;
- Transfer of ship to the launching device using hydraulic jacks and transport trolleys rolling out from under the ship.
- All along the slipway on the ship is secured with special ropes.
- After the ship translation the trolley is stopped.
- The ship is towed to the quay, where the trigger device parts are dismantled.
- After the launching of the ship, a special team, which arrived with a tug, makes a thorough inspection of compartments of re-floated ship and eliminates the defects. The ship is transferred to the pier for completion of construction and testing.
- Perhaps there will be new ways of launching ship in the future.

The processes of transversal ship launching, and the most important steps, before and after the process are shown in Fig. 19.

PROCESS OF TRANSVERSAL SHIP LAUNCHIG

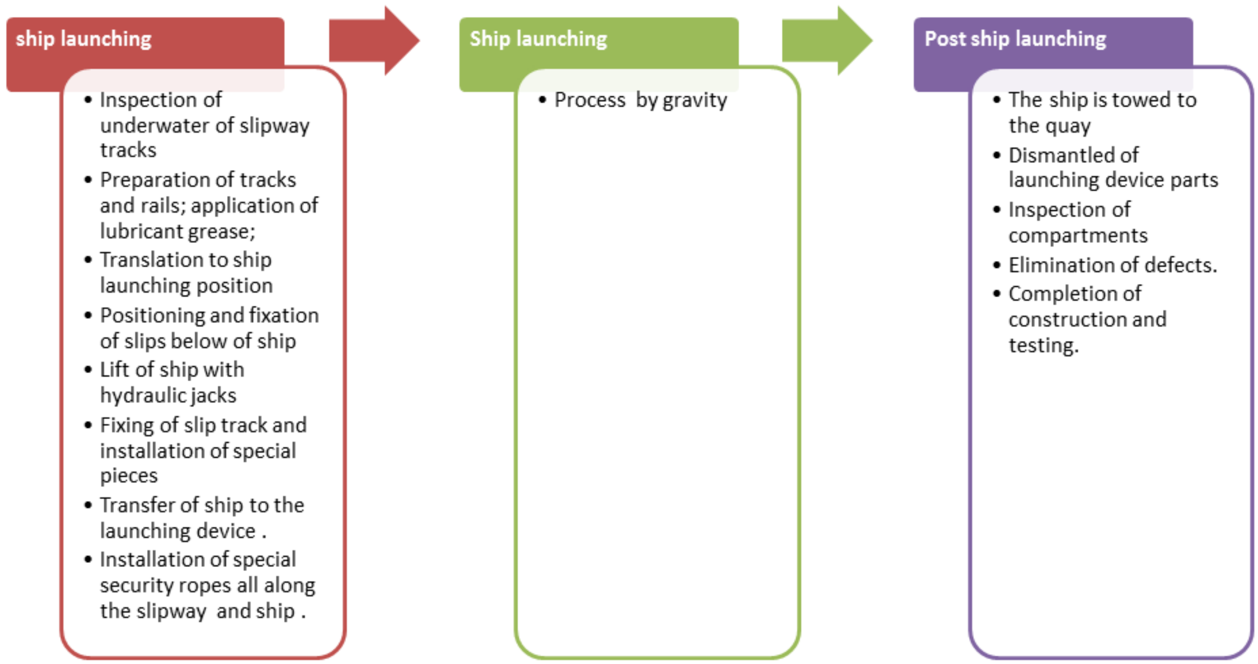


Fig.19.Process of transversal ship launching

7. CASE STUDY

In the shipping industry there are different types of shipyards, and each type has individual problems. In this project we will take one real ship yard from the industry, which has a problem in ship launching.

Launching problems can have negative consequences in economical and contracting terms.

After identifying the problems and limitations of this shipyard we will present one engineering solution. That solution should be economically sound and possible to implement in the shipyard.

7.1.Description of Finomar Company

Finomar Company is a private company, which makes projects in shipbuilding and civil structures. The shipyard is near the river Oder, in Szczecin, Poland.

In this moment the shipyard does not have a slipway, for launching ships, but that situation is no disadvantage for development new projects of ships.

Finomar Company uses different launching methods, because the capacity of cranes is not powerful and the cost of rent one floating deck is excessive for these small projects.

The company uses floating cranes and pontoons for transporting ships in blocks.

Fig.20.Transport of ship block, by floating crane [14]

To realize the ship launching, for a complete ship, Finomar Company also uses one barge for transport to a close crane in other company and make the launch.

Fig.21.Ship launching by crane is shipyard [14]

But the principal problem is that for every launch it is necessary the certification by the maritime authorities. This is necessary, because the shipyard is in a very transited place of the river Oder, and the major disadvantage is the nearness of Szczecin terminal.[22]

This problem is common in other shipyard. The ship launching can be the cause of the problems, for example the close of roadways. If the shipyard is close to river or canal, that problem has directly relationship with economical and tariff ranges.

Fig.22 interruption of transit caused by the waves made for the launch process [9].

Those disadvantages make the launch of ship use a lot of time, and are a costly process, because it becomes necessary to engage the service of other companies or organizations.

The analysis of the situation of this company found one possible solution.

8. CHARACTERISTIC OF TRANSVERSAL SHIP LAUNCHING

The process of transversal launching has different steps, and in every step use different mechanical devices.

In this part we will describe the more important parts of these mechanical pieces.

The analysis of work and the mechanical pieces used in the process of ship launching is the most important part for designing any solution for the ship launching, because after that we will have a possible idea on how to develop the process of ship launching.

8.1.Ship position in the slipway

The position of ship relative to slipway is important, because it makes possible the development of the future process for make the ship launching.

It is necessary to use the general requirements for the height between the bottom of hull ship and slipway (next): it is possible to use 700 – 800 mm from bottom of ship to slipway reel. This present 1000-1200 mm to slipway base and 1200 - 1500 between reels.(Fig.23)

But, in the shipbuilding experience is possible; find other measures for this description, for example between 350- 700mm distance from the bottom to slipway reel

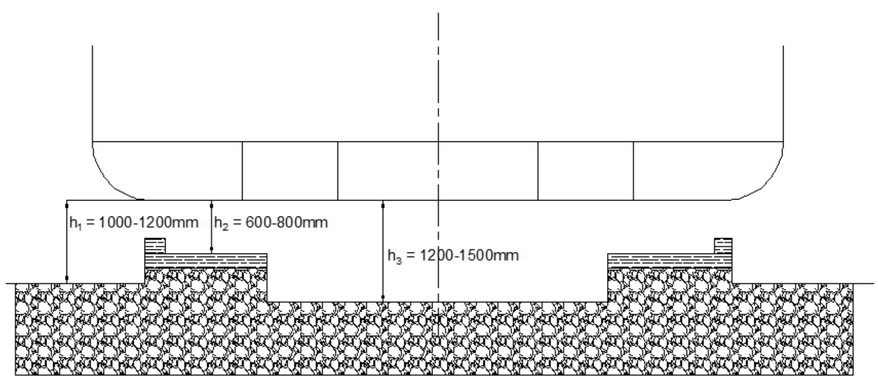


Fig. 23 Hight of ship bottom to slipway

8.2.Retention device equipment.

This device is used for the retention of ship in the slipway at the moment of transference of ship in the slipway to launching moment.

The retention device should be resistant and safe for work.

8.2.1. Mechanical retention device

This device has simple construction, low weight and dimension, but climate temperature affects it.

There are fixed in couple, in every side of slip .The steps for operation of the device are shown next:

The retention piece is one curve cam. This piece has the possibility to rotate out of the structure and support the mobile piece of slip track with a special unbalanced lever.

In the inferior part the device has a cord to a command point or other special place of slipway.

When the cord is cut, the lever falls and the curve cam set free to slip track and initiate the movement.

The retention device has between 200 to 600 tn of retention force. The ship is detained with big force by some couple retention device.

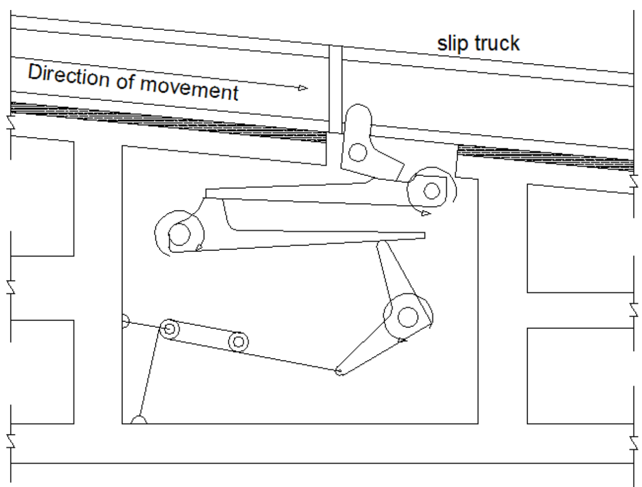


Fig. 24 Hammer trigger

Fig.25.Trigger device in pre preparing launching [23]

Fig.26. Open Trigger device. It is possible to show the retention structure in the slip truck [23]

8.3.Slip truck in rollers

The launch is possible when the slipway is static launch way, so in this case it is a metallic canal .The dimensions of canal is determined by launch weight of the ship. The canal is welded to a piece of sheetmetal, and the width of the canal is less than the width of the rollers. In this case it is possible to use a width of 300mm.

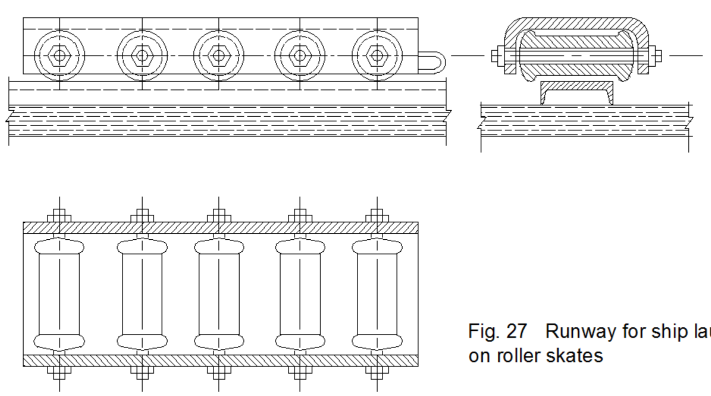


Fig. 27 Runway for ship launch on roller skates

It is possible to install one ship cradle in each runway and between cradle and the hull of the ship to have wooden beams to distribute stresses.

The ship cradle is installing en every side of the ship and they are connected with one girder. This type of runway is used for small and medium ships, but it is also possible to use in big ships.

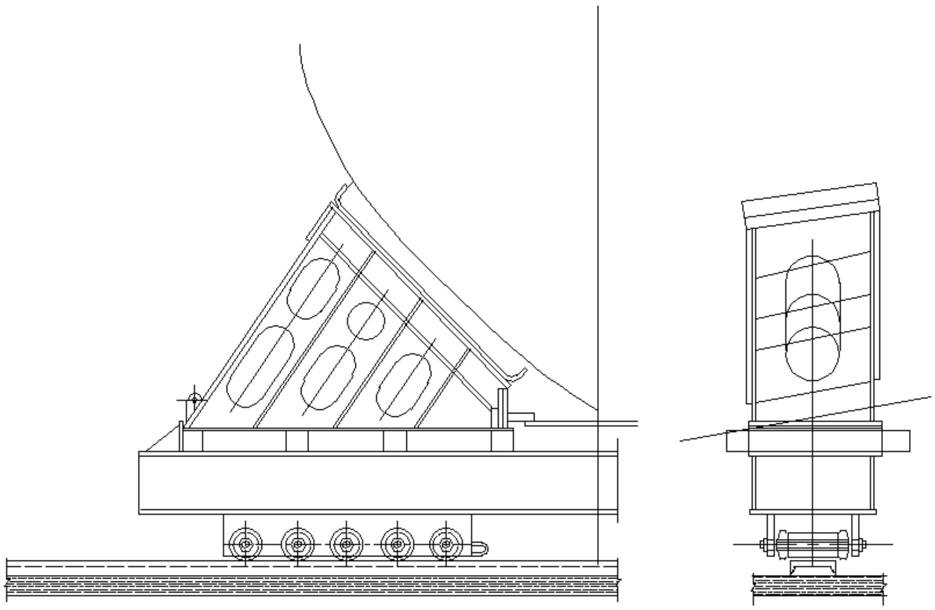


Fig. 28 Ship cradle in wheels

8.4.Slipway track.

The numbers of slipway tracks depend on the slipway type and launch device. Typically, 4 or 5 slip trucks are used for ships up to 1000tn.But for big ships it is possible to use up to 20 trucks.

Fig.28 shows 2 piece-slipway used for one small ship.

The slipways should be parallel and have the same inclination. The length can be up to 20-50m. The truck does not have submerged part for leap launch and throw launch.

The inclination of the truck is 7 degrees to 10 degrees. The finished part of the slip truck should be at the same level as the water.

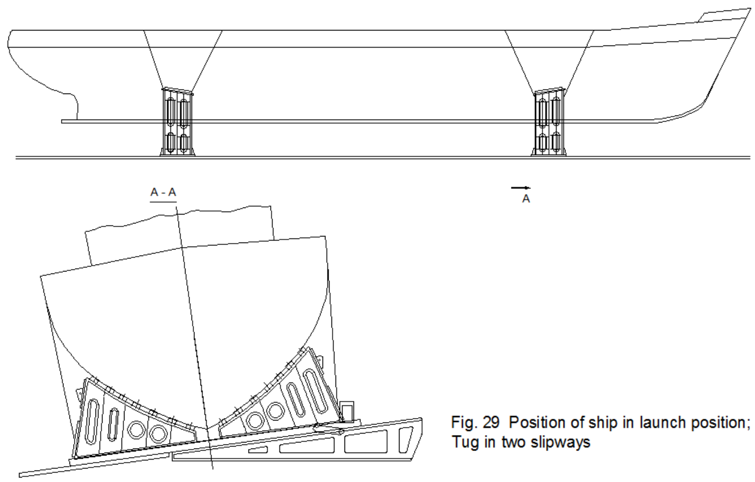


Fig. 29 Position of ship in launch position; Tug in two slipways

8.5.Characteristics of Slip Track

For transversal ship launching metal and wood are used. Metallic slip truck (fig 30), is used in a T-Beam form, installed and welded in the structure. It is possible to install also pieces of wood in the slip track. Finally, it is possible to use plastic plate and use that with any lubricant.[24]

The length of slip truck has relation with the breadth of ship. It is possible to use a slip truck from 0.8 to 1.5m more than the dimension of ship breadth.

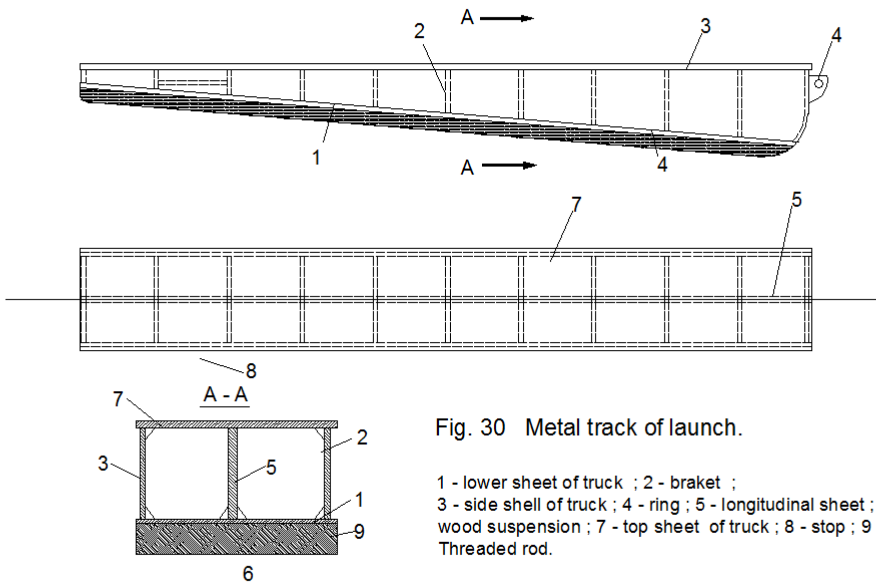


Fig. 30 Metal track of launch.

1 - lower sheet of truck ; 2 - braket ; 3 - side shell of truck ; 4 - ring ; 5 - longitudinal sheet ; 6 - wood suspension ; 7 - top sheet of truck ; 8 - stop ; 9 - Threaded rod.

The breadth of the slip truck is the same of slipway and cradle.

The work pressure in the slip truck is around 2-3.5 kg/cm2 and has direct relation with the inclination of slip truck

The slip truck device for transversal launch has the following parts: slip truck, slip keel blocks, girths, wedges, weight blocks, and retention device.

The construction of other parts and slip truck, has relationship with type and dimensions of ship and characteristics of slipway.(See fig. 30 and fig.31).

For ship launching in series it is very common that the material of slip truck is metal. In the slip truck have girths (if is necessary) between their wedges. In the girths keel blocks are installed, and they have the cradle functions.

The metal keel block is fabricated with the form of the surface of hull ship and is installed in the slip trucks.

Fig31.Slip truck device in job position [25]

8.6. Launch cradle

With a launch cradle (fig.32) it is possible to transfer all ship weight to slip truck, after transporting to keel block. The ship cradle is made of metal or wood.

In a metallic cradle, pieces of wood are installed and fixed in the top part. The top part of ship cradle is fabricated with the form of the hull of ship.

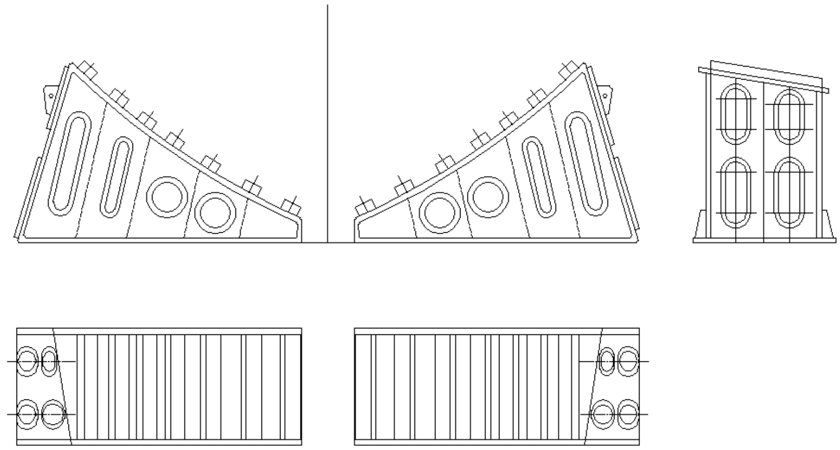


Fig. 32 Ship cradle

8.7.Girths and wedges

The girths are made of metal. They are the foundation for the wedges and ship cradle. In the bottom part the girths have place for wedges, and in top part of him surface welded protectors or holes for bolts for fixing the ship cradles.

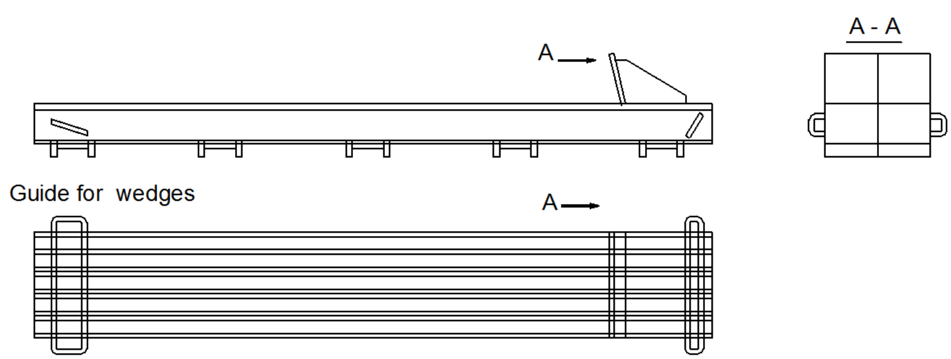


Fig. 33 Metalic girths

To avoid uncontrollable movement of girths defenses are installed in the slip truck. The breadth of girths and the slip truck is the same, and the length of girths depends of length of keel blocks.

For transversal launch, use the same wedges than longitudinal ship launch. The angle of wedges is not more than 3 degrees.

8.8.Lashing

This device is use to join the launch device to the hull of ship. The material is metal or fiber plastic. The lashing use turnbuckles for fixation. The type of fixing depends of the form of cradles and slip trucks.

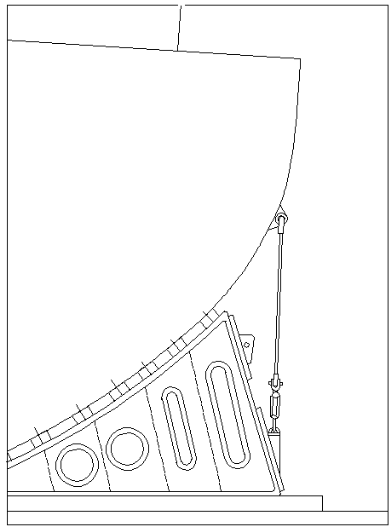


Fig.34. Position of security lashing

The ship is moved in the cart only to the inclined part of the slipway, then the ship launching is made after transfer to the multi roller car. The transfer of the ship to the multi roller cart is made with metallic frames (Fig.36), and the finished part of incline slipway. The transfer is possible in 2 steps:

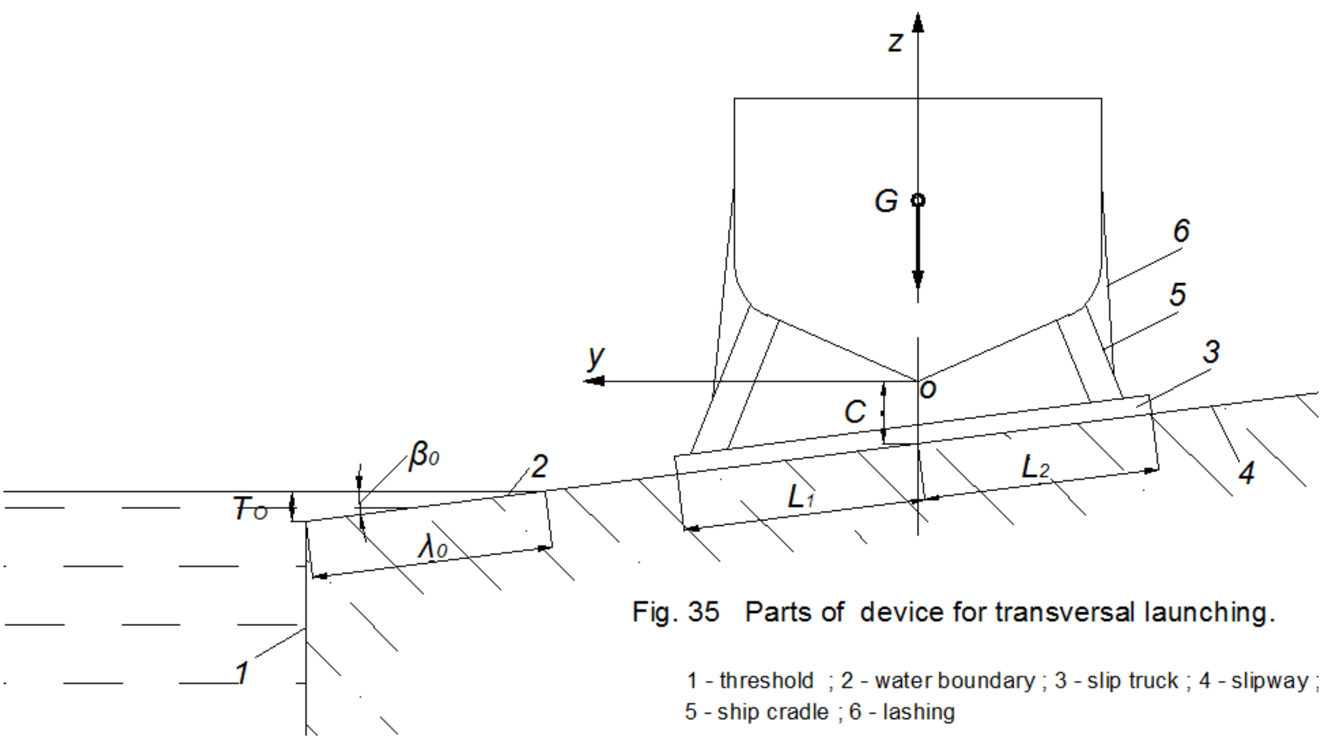


Fig. 35 Parts of device for transversal launching.

1 - threshold ; 2 - water boundary ; 3 - slip truck ; 4 - slipway ;
5 - ship cradle ; 6 - lashing

The ship is transported on metallic frames to prevent the possibility of cross under bottom. After transfer all the structures with the ship, installing in the launching position and transfer to multi roller cart, the ship is launched.

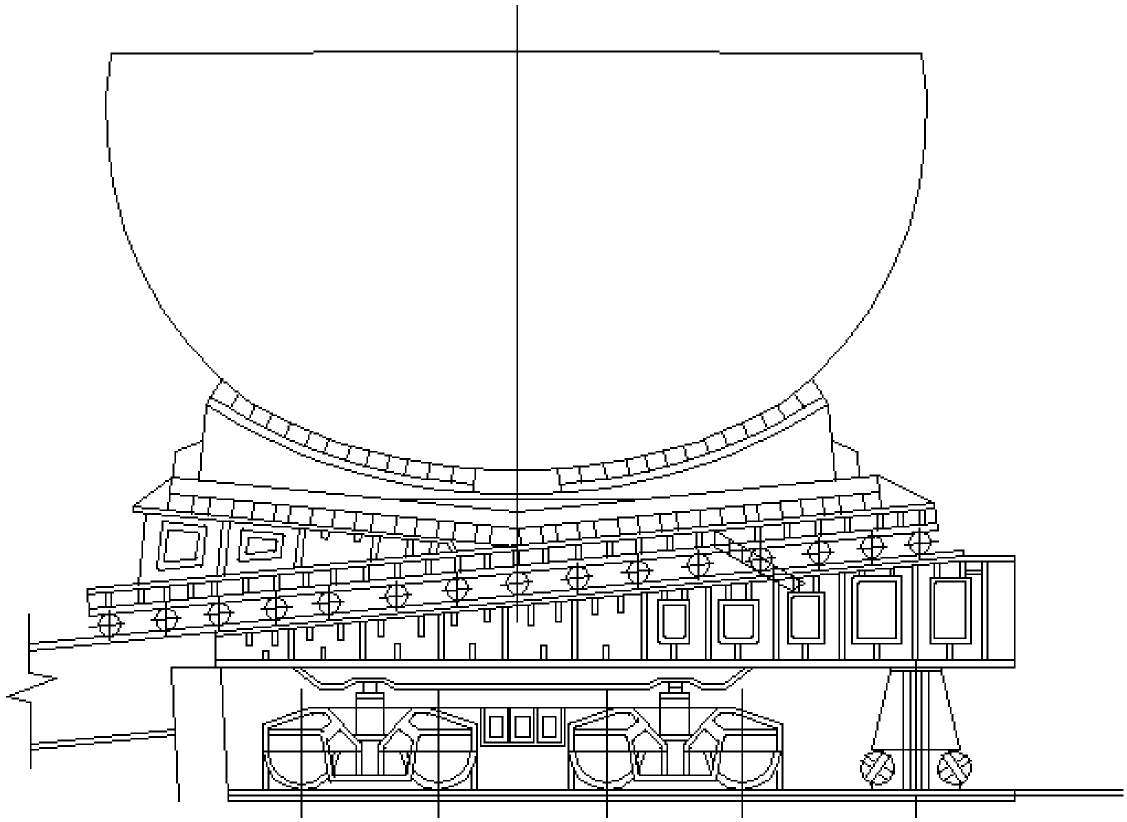


Fig. 36 Metallic reels and multiple cart

8.9.Process of ship launching by slipway

In the transversal ship launching ,the most important characteristic is the inclination of the ship relative of inclination of slipway and height of the ship in the plane of slipway.The position of sliptruck of slipway has the same position of the frames or bulkhead of ship.

The process of ship launching in the inclined slipway can be divided in four periods:

1. Period from initial movement to aproximation to threshold of ship
2. Period from aproximation to threshold to moment of contactoof hull of the ship with the water.
3. Period from contact of hull of the ship with the water to moment when the final part of sliptruck has contacted with the threshold.
4. Free movement of ship by inertia to final stop.

The ship launching is realized in the launch device. Transversal launch is less dificult than longitudinal launch,but it is necessary to think, from the moment of iniciation movement of ship that process is not controlled. The most dangerous moment is no initial synchronization movement in every truck. That problem can sag the ship.

In the initiation of ship launching, is activation of the force of gravity of ship and sliptruck device, in perpendicular direction to slipway and ship movement, and frictional force between the slip device and slipway.

Static and dinamic frictional coeficient have the same dimension than the longitudinal launch.

In the moment contact sliptruck with water,will initiate appear the resistence force,in the direction of movement of ship,and in the vertical direction ,will appear the boyancy force,wich will increase ,when appear the inmertion of ship.

The ship debelovment one complicated movement , movement of center of gravity and rotational relative to his axis in the center of gravity.When the ship it sinks and the ship weigt and boyancy force is the same the ship have the normal floating.

CHAPTER II

9. PROCESS OF PROJECTING SOLUTIONS FOR SHIP LAUNCHING

In the process of design, we will use the information of ship yard, their technical limitations and other problems creating limits to the process of ship launching.

After that we will decide the next step for the solution of the problem.

It is necessary to understand the principal requirements of the ship launching process and the basic requirements of shipyard for designing and developing one possible solution for ship launching.

The limitations and requirement of shipyard are presented here:

1. Impossibility to make any construction in the ship yard
2. It is necessary to make the launching in other place, far from restricted areas of port.
3. It is necessary to find one solution for the difference in level of shipyard relative to deck of pontoon
4. The possibilities make one ship launching, and not use floating cranes or floating decks
5. Process should work for any ship size, small and medium ship
6. The process should be economic and require a short amount of time
7. The solution should be easy or not require to make contract with specialized professional

For these requirements one solution will be presented, also that solution will be practical in his application in the shipyard.

10. ANALYSIS OF PROBLEM

From this requirement, we understand, it will be necessary to use one transport to make the ship launching, because it is not possible to make any launch maneuver near port.

The company has experience in the transport ships and block in pontoons. The problem is to determine the correct level between shipyard and pontoon for transfer of the ship.

Other important thing is we can not use any floating crane or floating dock. This restriction gave us the idea to design one device for the realizing the ship launching.

In this case, we will study the possibility to make launch of the ship from one pontoon. For that, we will design the appropriate slipway which will be installed in the deck of pontoon.

After, we will analyze the dynamic process of launch of ship from one pontoon and one structural analysis for the new type of slipway.

10.1. Ship launching from floating pontoon

After understand the main idea of all problems for development the ship launching, it is decided to make the ship launching from one pontoon.

In the offshore industry, the floating pontoon is used for launch different types of structures, but this launching is in type longitudinal and for very big structures, also it needs special pompoms and other equipment.

In this project we will use one typical pontoon, which will not need to make any inclination for ship launching. The process of ship launching will be by gravity force and transversal type.

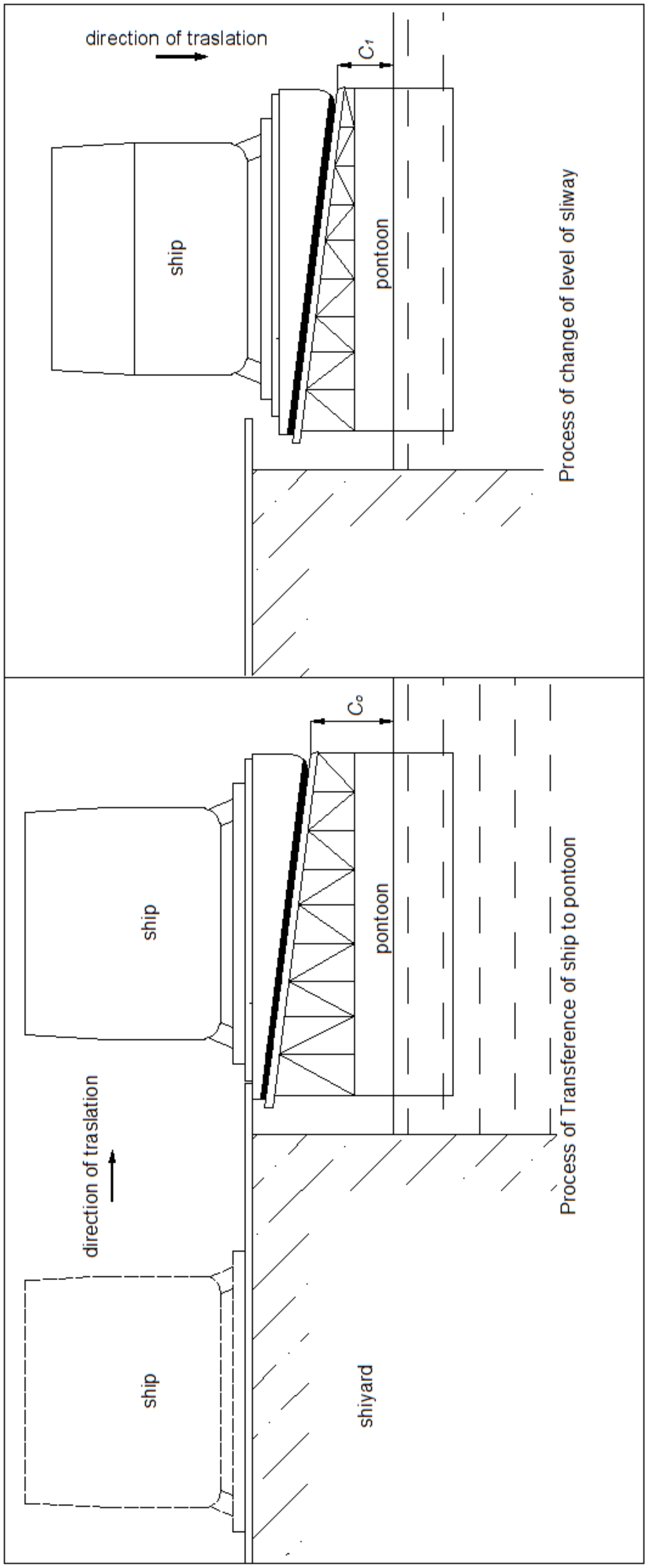
The position of the ship will be above the necessary number of portable slipways. That slipway is installed in the deck of pontoon and those can be used afterwards for other ship.

The portal slipway will be easy in construction, installation and repairing, and have the possibilities to change its height to be used in ships of different positions levels in the shipyard.

10.2. Process of transfer the ship

The transfer from shipyard to pontoons will be possible with reels and rolls cart. That process is actually in development for ship launching. Different shipyards have experience in this process. That idea we will combine with initial requirement for solving the problem of level between the shipyard and pontoon.

But we need to understand, we don't have any possibility to make any ship launch near the shipyard. Fig.37 presents the proposal of transversal launch from pontoon for this project


direction of traslation
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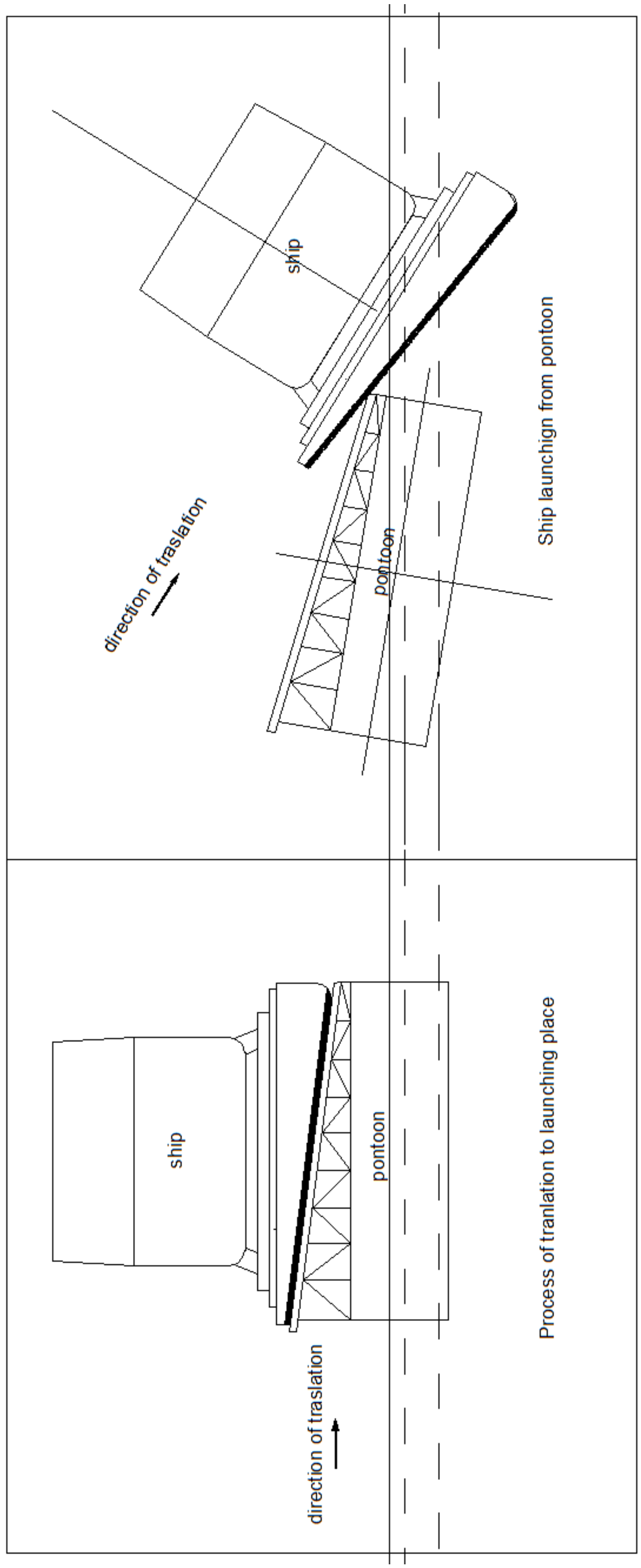

Fig.37.Preliminary design of ship launching

11.EQUIPMENT FOR TRANSVERSAL LAUNCHING FROM PONTOON.

For this project it is necessary different types of devices, which will be in all the processes.

One principal idea is the possibility to use those devices for launching different types of ships.

11.1. Pontoon

The pontoon is one of the principal pieces of equipment of this project. For the maneuver of ship launch it is necessary to perform different preparation steps in the deck of the pontoon (fix the support of slipway, preparation of launching).

The position of pontoon should be static at the moment of ship launching. It is possible also to use one tug for movement in different directions of the ship, and also can use one tug for the ship launching in different direction then pontoon.

Also it is possible to use more safety tugs, with can help in the ship launch. One tug can the control of launch for the ship, and in pontoon side can realized the same auxiliary work.

Type ship	LxB	Weight(Tn)
Service ship	80x20	2000
Container ship	106x15	1350
Container ship	103x17	1400
Purse Seiner Trawler	64x13,8	800
Fishering	70x12	775
Fishering	70x15	1000

Table. 2. Types of ship which are make in one small shipyard

From table 2, we decide use one pontoon LxBxT=65x18x3.8, because with this dimension it is possible to make ship launching of more of the small and medium ships from this table.

For example the company Finomar has experience in transfer of ship from shipyard to pontoon, and for that process uses reels and cradles.

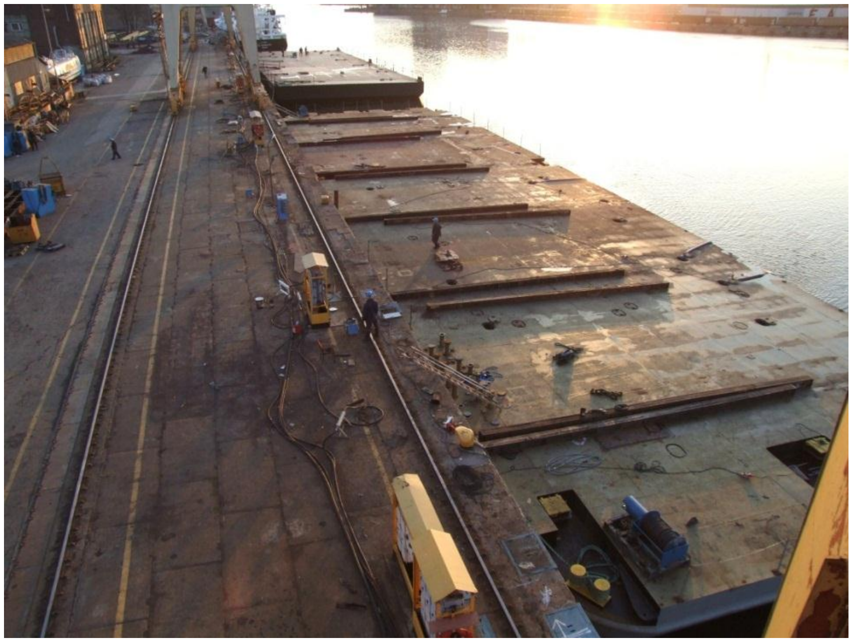

Fig.38. Pontoon in statically position for making the transfer of ship [14]

11.2. Reels

The reels are structures used for transporting the ship from shipyard to pontoon (Fig.39). They have holes where is possible install hydraulics pompoms, which work in coordination for ship transfer.

The ships have supports or cradle in the canal formed by working with reels.

Between reels and ship supporting, we also will use one lubricant with good frictional coefficient.

In the Fig.40, the process of transfer of ship to pontoon is presented.

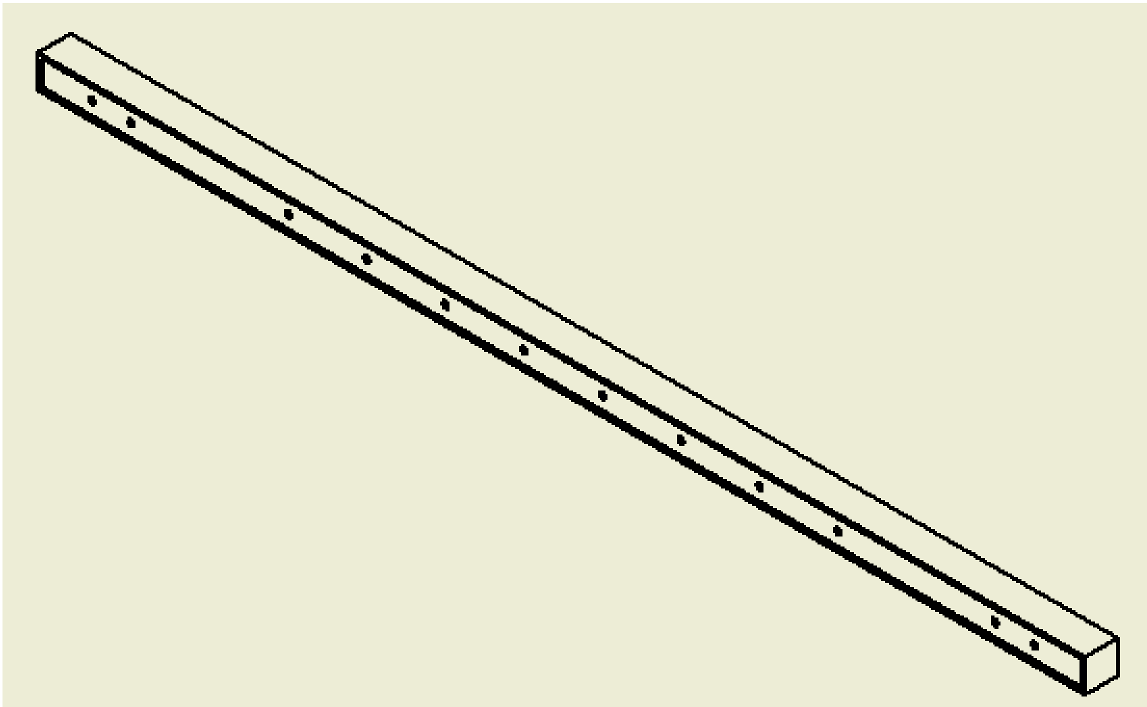

Fig.39. Typical reels for transportation of ship to pontoon

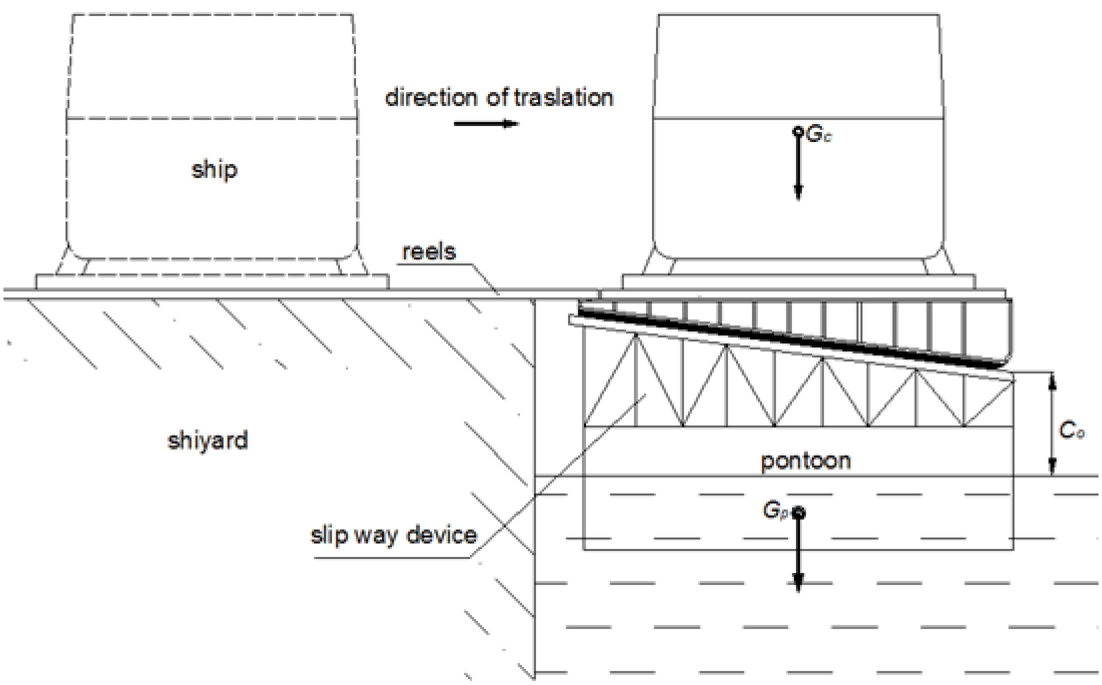

Fig.40. Transference of ship to pontoon

11.3. Slip device

In this project, we developed the design parameters for this new type of slipway device.

This slipway device is a new type of slip truck that solves the process of transversal launch.

This slip truck is a type structure with outline specification for mechanical/hydraulically equipment for a 1,000 ton capacity.

This solution gives us the possibilities to solve the problem of level difference between shipyard and pontoon. We will use the necessary jacks in the sliptruck

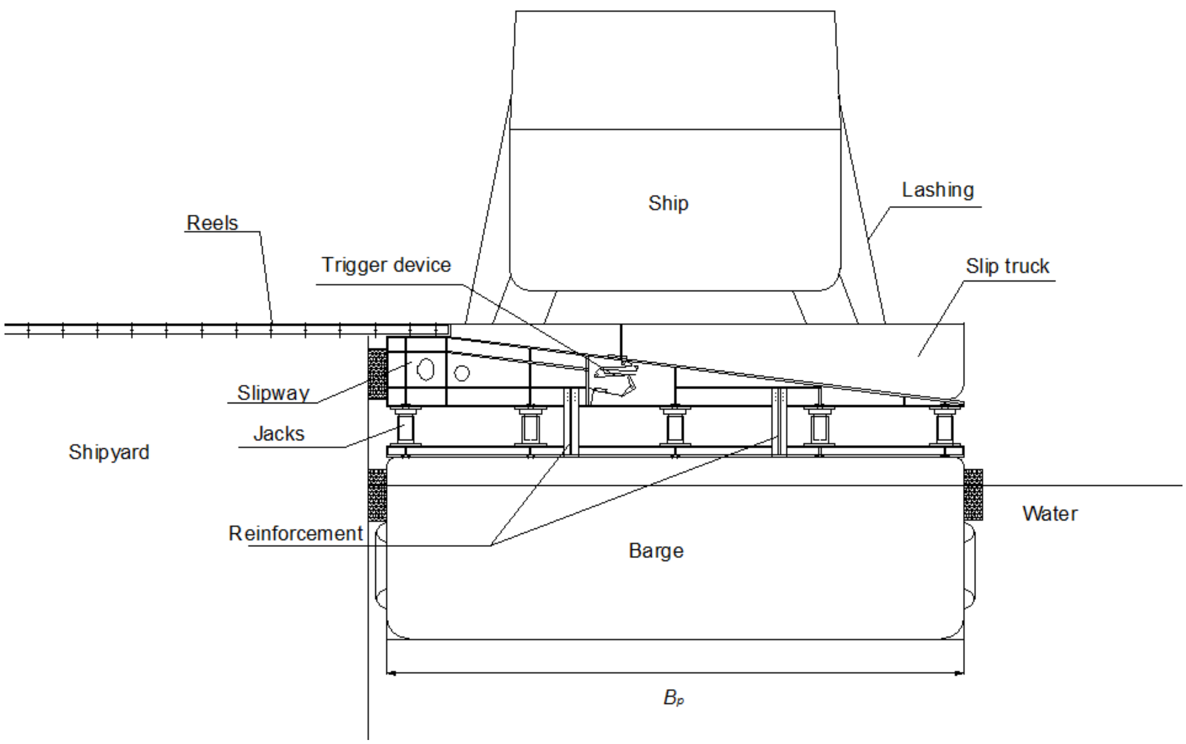

Fig.41. Preliminary portable slip truck and slipway

The process of ship launching is shown in the next graphic. This instance has different step, so what is necessary is a high accuracy.

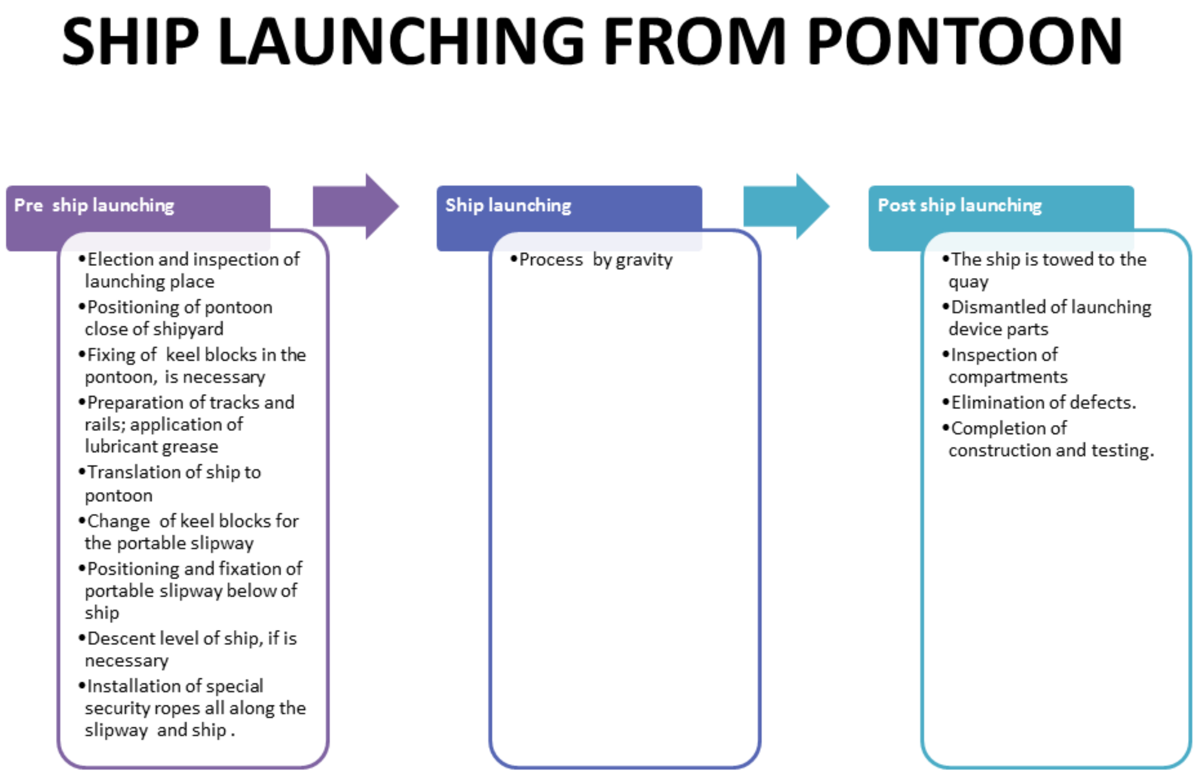

Fig.42. Ship launching process from pontoon

12.DESCRIPTION OF PORTABLE SLIPTRACK

The new slipway can be used in the pontoons. The number of slipways, depends on the weight of ship. For example for one ship of 1000tn it is approximately necessary 5 units.

The transversal launch, which is supported in one pontoon, has some characteristics.

The dimension of slip track depends on the dimensions of pontoon and the weight and dimensions of small and medium ship. In table 1, we present the possibilities of ship examples for use this slip track.

The time of work of this slip track is no more than 7 seconds.

Also it is necessary the use of an adequate lubricant between the ship cradle and slip truck. The frictional coefficient should be between 0.17 to 0.2, for more safety during ship launching.

In analogy of others slip ways for transversal launching, used in the ship building industry, in this project the cradle and slip track are modeled in one structure.

That model give us the possibility to make a more portable structure, for use in the deck of pontoon. Also with that model it is possible to use by different models of ship, because every cradle has different positions in hull of ship.

Fig. 43 shows the one slipway for transversal launching

Fig.43.Slipway with different slip tracks [26]

In the fig.43, shows a proposal of slip track. In this design, we change the slip track and use it at the same time as the cradle.

We decide to join the cradle and slip track, to make easy the launching and for recuperation after the ship launching

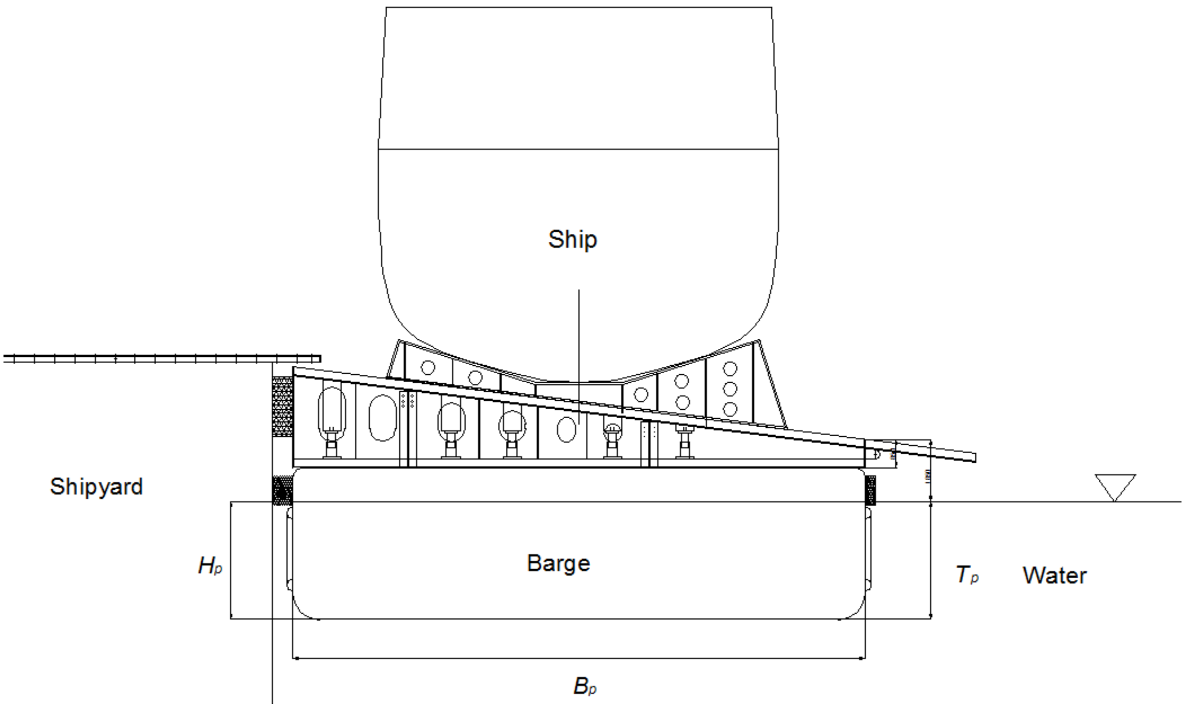

Fig.44.Slip truck in the positions of transfer the ship

12.1. Characteristics of portable slip truck

This portable slip track has 3 principal parts. All parts are made of steel.

Fig.45. the positions of slip truck depend on the length of the ship [27]

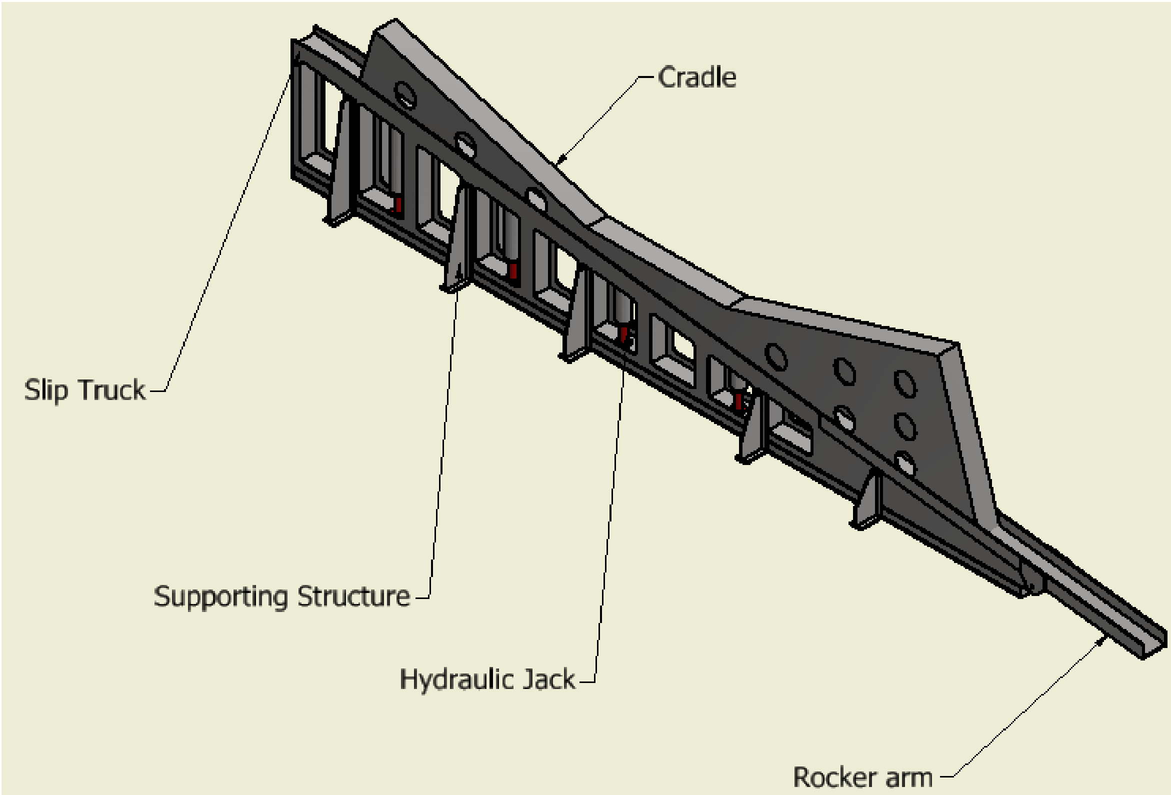

Fig.46. Portable slip way

12.2. Slip track

The connection is in form of a canal for assembling with the ship cradle. That situation gives the possibilities for the correct movement of ship to water, and can avoid the possible rotation or other movement of ship and pontoon, at the moment of ship launching (Fig.47).

Also it has one rotating part, in this case one rocker arm, with rotate at the final part of launching (Fig.48).

That element avoids collisions between cradle and slip track, and lessens the concentration of stress in the slip track and cradle.(Fig.49)

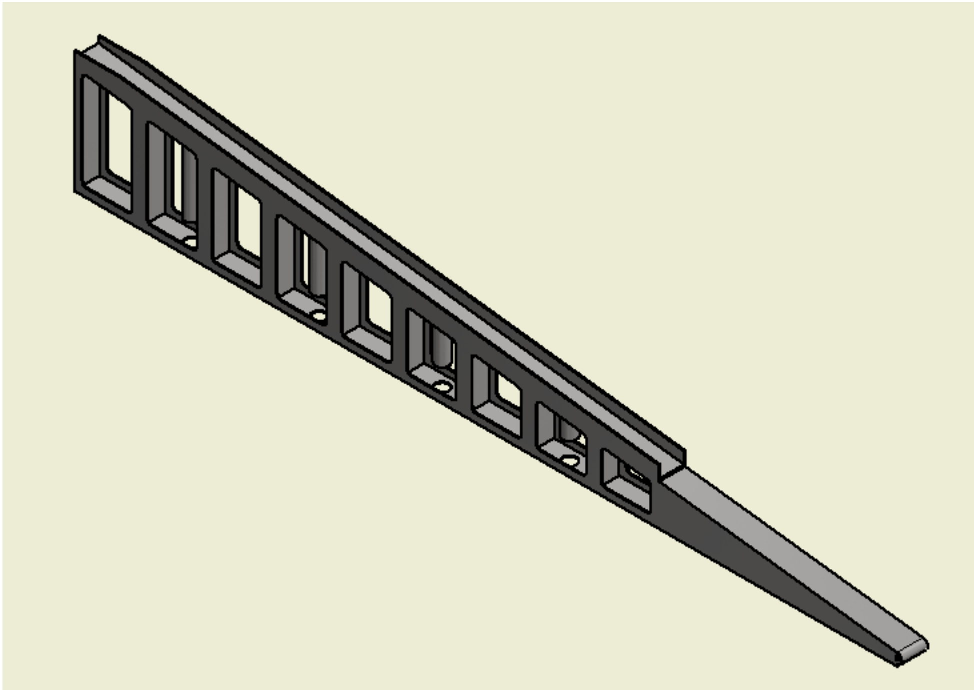

Fig.47. Slip truck

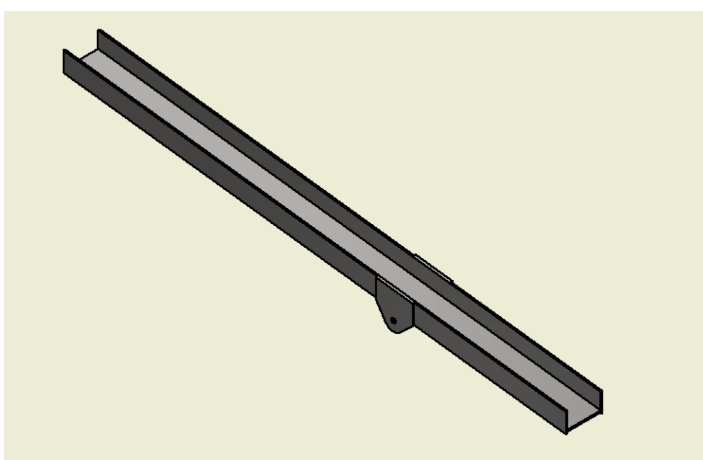

Fig.48. Rocker arm

Fig.49.Slip way witch rocker arm [28]

12.3. Slip cradle

This part has a connection with the ship at all time and is removed after the launch. That part is one construction with internal reinforcement, because is supporting all the weight of the ship.

In the slip cradle we install the security trigger. It is necessary one in every side of slip cradle.

Those triggers should be mechanical-electric, because it is necessary they work in the same time.

At the initial moment of the ship launching, all triggers should be open.

The process of shoring of ship is made with ship cradles in different position of ship. Their position was determined previously. This is necessary because the launching of the ship is a dangerous moment in the construction of ship(Fig.50)

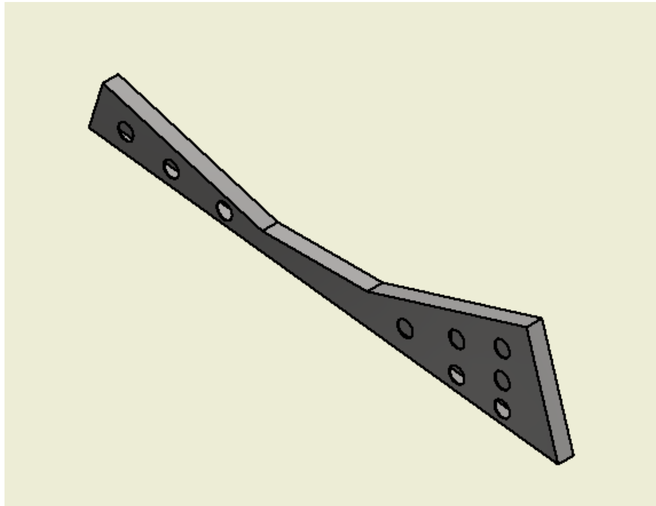

Fig.50. Cradle for medium part of ship

12.4. Supporting structure

That part supports and connects the structure of slipway and pontoon (Fig.51). In the process of ship transfer to pontoon, this part should be installed and also the jacks should be in the correct position for the descent of the ship.

The union between supporting and slip track is possible with necessary bolts in every side of the slipway.

The connection with pontoon is possible with fix supporting in the deck of pontoon.

The capacities of hydraulic jacks depend of weight of ship. We need to design the hydraulic system for the largest capacity. It is recommend to use more than 20 tn for every jack.

The structure of slip way is possible to be made in steel (Fig.52). In this case the project uses one typical pontoon, and one ship of 1000 TN. It is also possible to design a bigger model of slipway to make launch for different types of bigger ships. It is only necessary to define the height of launch for other big model of slipway.

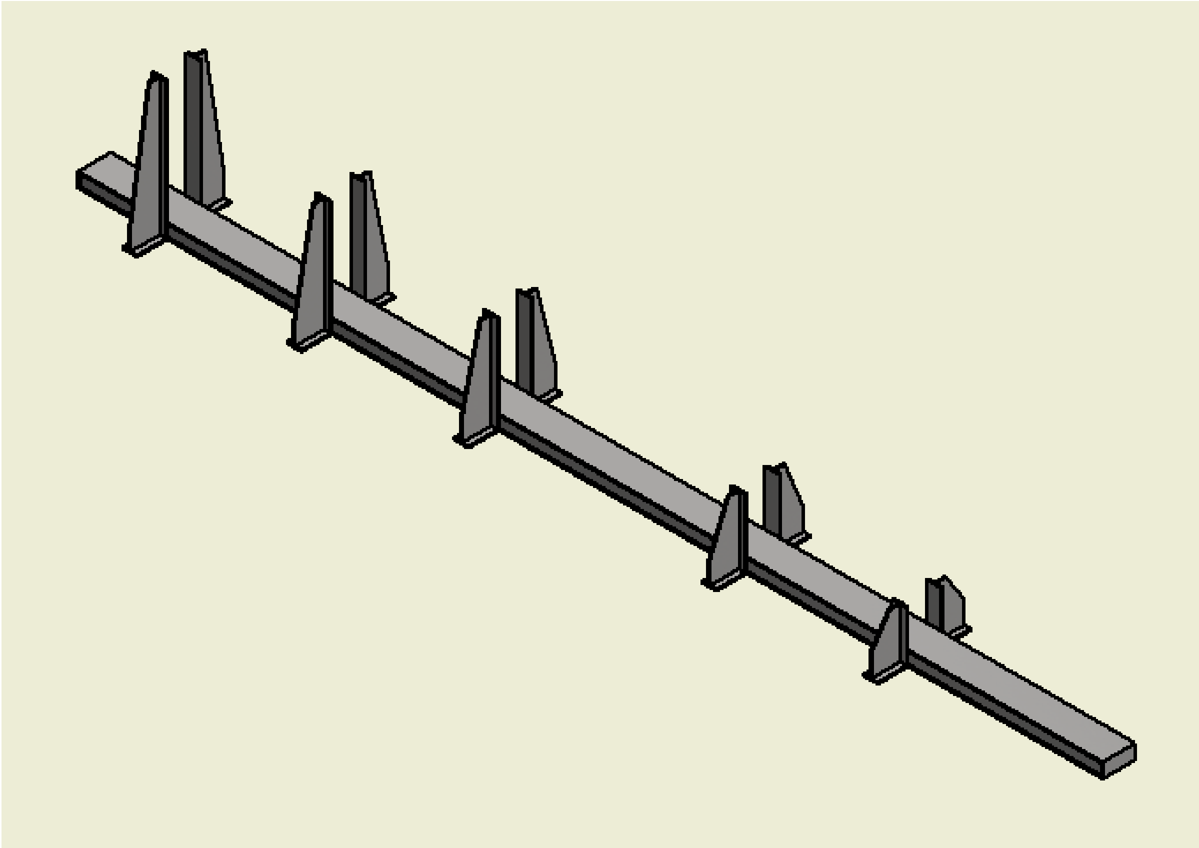

Fig.51. Supporting structure

After finish the design of portable slipway, it is possible determinate the weight for every part and other physical characteristics (Table3).

It is necessary to know those structures were designed with 25mm of thickness. We take that value because it has the maximum capacity for supporting the weight of ship and ship launching. In the following structural analysis it will be possible to change the thickness of any part to reduce the weight of the portable slipway structure.

	Area(m2)	Weight(Tn)	Volumen(m3)
Cradle	119.80	11.80	1.50
Slip track	119.15	16.65	2.12
rocker arm	18.69	1.85	0.24
Reforcement	79.12	7.67	0.97
Total Assemble	341.35	38.43	4.88

Table.3.Physical characteristics of portable slipway

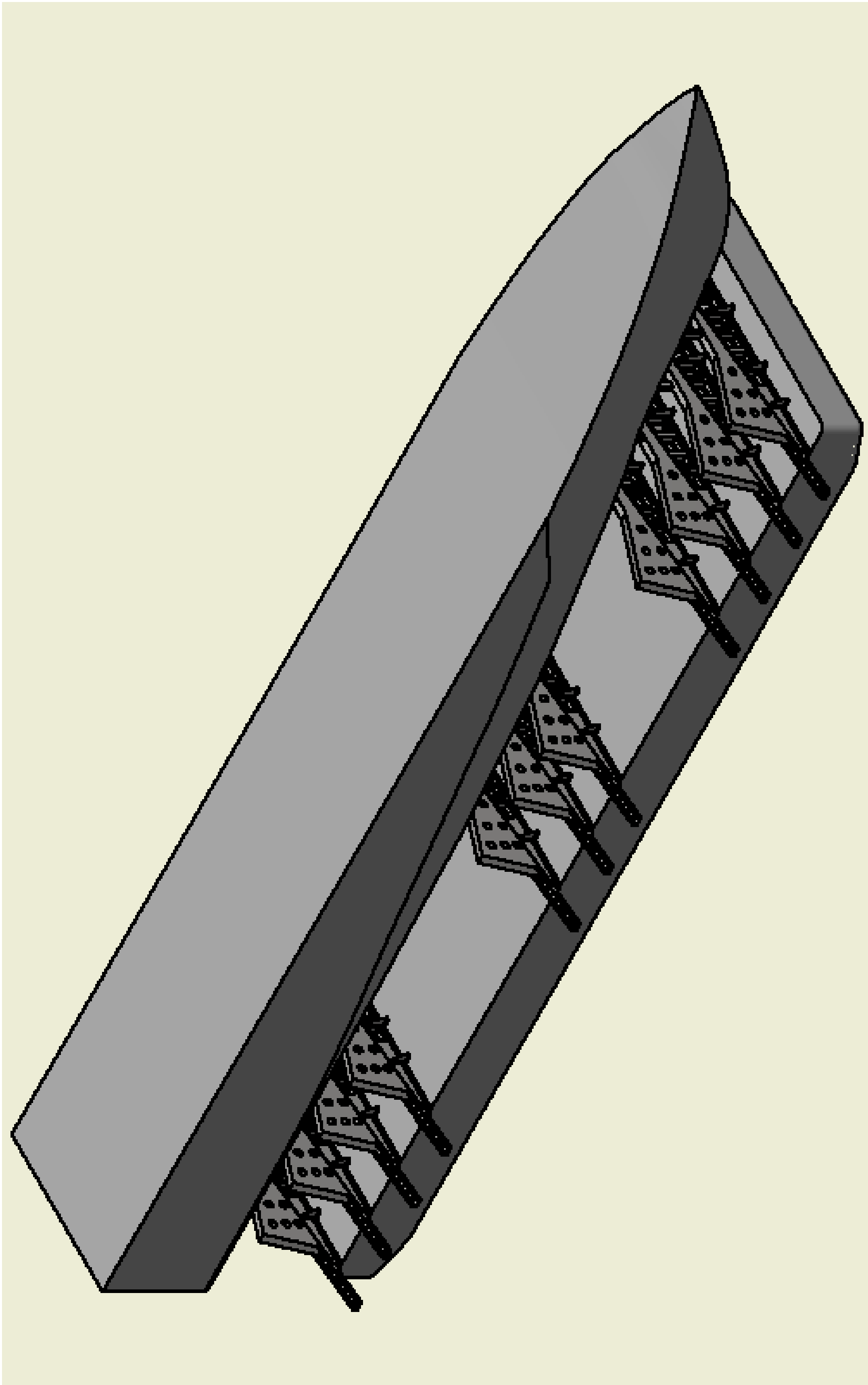

Fig.52. Portable slipway in position of launch

13. MODELING OF TRANSVERSAL SHIP LAUNCHING

We will use the stability theory for the barge and ship at the moment of launch.

In this case we will model the translation of the ship from the middle position in the pontoon to the moment when the ship has contact with water.

For this analysis we will use the methodology for transversal ship launching, present in the book ¨ Ship launching; A.A.Kurdyumov; 1966¨

But in this project we have the condition from one floating pontoon, which does not have a connection with any supporting

13.1. Process of ship launching

In this type of ship launch, the slipway is perpendicular to diametric plane of ship.

For this launch, also we take the same nomenclature as the longitudinal ship launch.

The transversal launch has different steps

When the ship initiates the movement, it makes complex translational and rotational movements, relative to an axis at the center of gravity.

After the opening of the security hammer, the movement is from the force of gravity, but it is necessary to implement the next condition.

$$D_0\ Sin\beta > F \qquad (II.1)$$

$Where$

$F = Static\ Frictional\ Force$

$$F = f_s\ N \qquad (II.2)$$

Where

$N = Normal\ reaction\ of\ slipway$

We will project of force in the plane perpendicular to the direction of movement.

Then

$$N - D_0\ cos\beta \qquad (II.3)$$

The angle of slipway is little, then for the future estimation the take

$sin\beta \approx \beta$ and $cos\beta \approx 1$

Then, condition for the independent movement of ship is

$$\beta > f_s \qquad (II.4)$$

Therefore, for initial movement of ship, is necessary, that inclination of slipway was more them statically frictional coefficient of slip truck.

Then in the process of ship movement

$$F = f_d\, N \qquad (II.5)$$

For transversal launch in the initial translation to threshold f_d is between 0.15 and 0.2 .That value takes for the third period in the ship launching

The differential equation of movement of ship in the axis s

$$-\frac{D_0}{g}\ddot{s} + D_0\, Sin\beta - F = 0 \qquad (II.6)$$

From relation $F = f_d D_0\, Cos\beta$ and $sin\beta \approx \beta$ and $cos\beta \approx 1$

The result is

$$s = g(\beta - f_d) \qquad (II.7)$$

After apply integral in the II.7, and assuming what $initial\ velocity\ (\dot{s})\ and\ initial\ way(s_o)$ is neglected, the result is

$$\dot{s} = g(\beta - f_d)t \qquad (II.8)$$

$$\ddot{s} = g(\beta - f_d)\frac{t^2}{2} \qquad (II.9)$$

The time is excluding from in the last formulation and take length slipway of initial position of diametric plane of ship to threshold is s_1 , and we find formulation for ship velocity in the moment of translation of ship to pontoon

$$\dot{s_1} = \sqrt{2g(\beta - f_d)s_1} \qquad (II.10)$$

The information above is for typical transversal launching, but in this project it is possible use that criteria.

13.2. Calculation of transversal ship launching from pontoon

Transversal ship launching from pontoon has different typical characteristics

We will present the calculation of positions of ship at the moment of ship launching.

The transversal ship launch from pontoon has seven periods

13.3. **Period of transference of ship**

In this period the ship transfers by reels from the ship yard to pontoon, when the ship has the safest position in the pontoon. In this case the ship movement is horizontal and the pontoon is static.

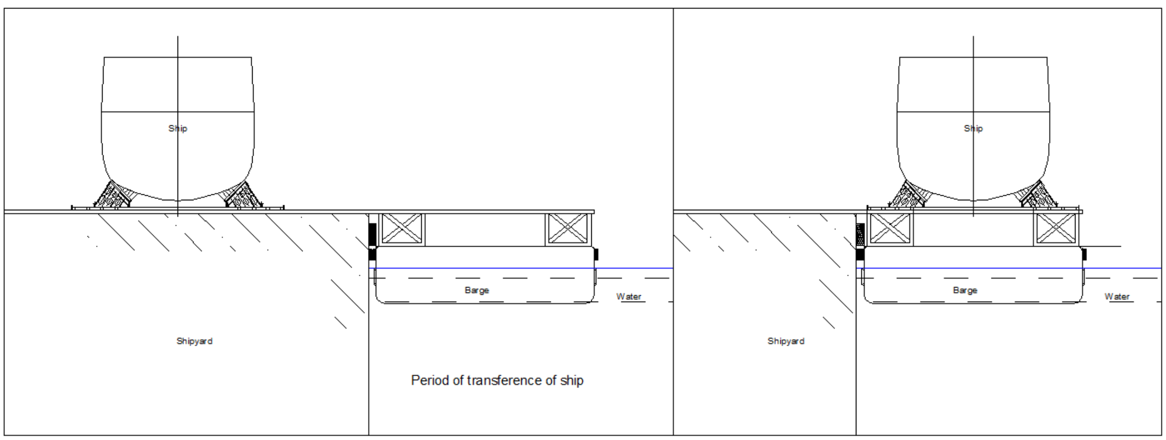

Fig.53.Period of transference of ship

13.3.1. **First Period**

First period starts when the ship is in the pontoon, near the ship yard. In this period the original support of transfer of ship changes. The new slip track is a montage under bottom of ship. In the process of design of ship launching, we will determinate the number of pieces of slip trucks, because the number depends on the weight of ship.

After that, also in this period it is possible to change the level of the ship relative to water line, in this case the finish part of slip truck, should be less 2.5 mt from the water line.

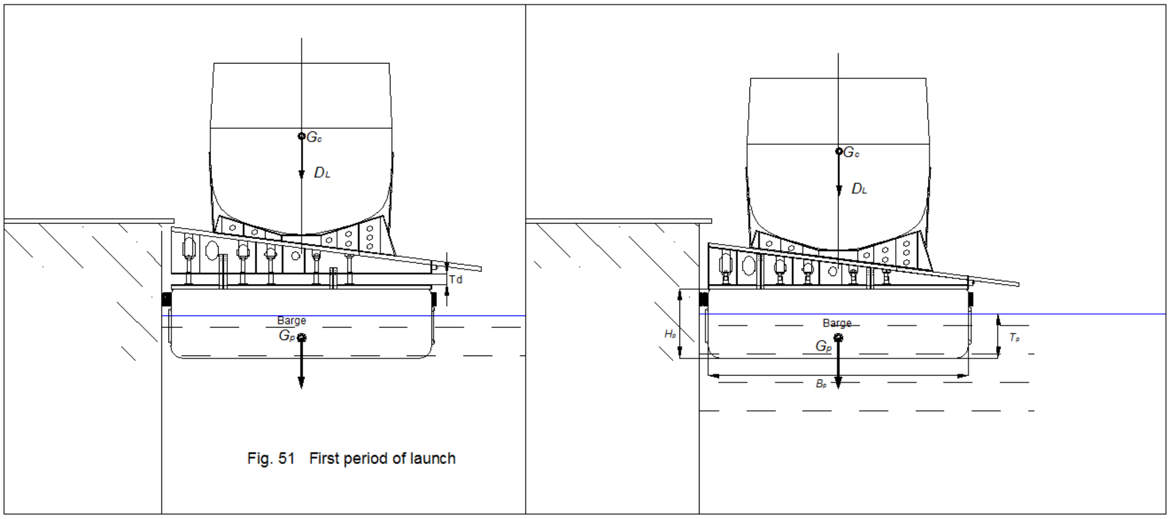

Fig.54.First Period

13.3.2. Second period

In this period the ship and pontoon are preparing for ship launching. There can be transporting to other place, when it is safest to make that maneuver

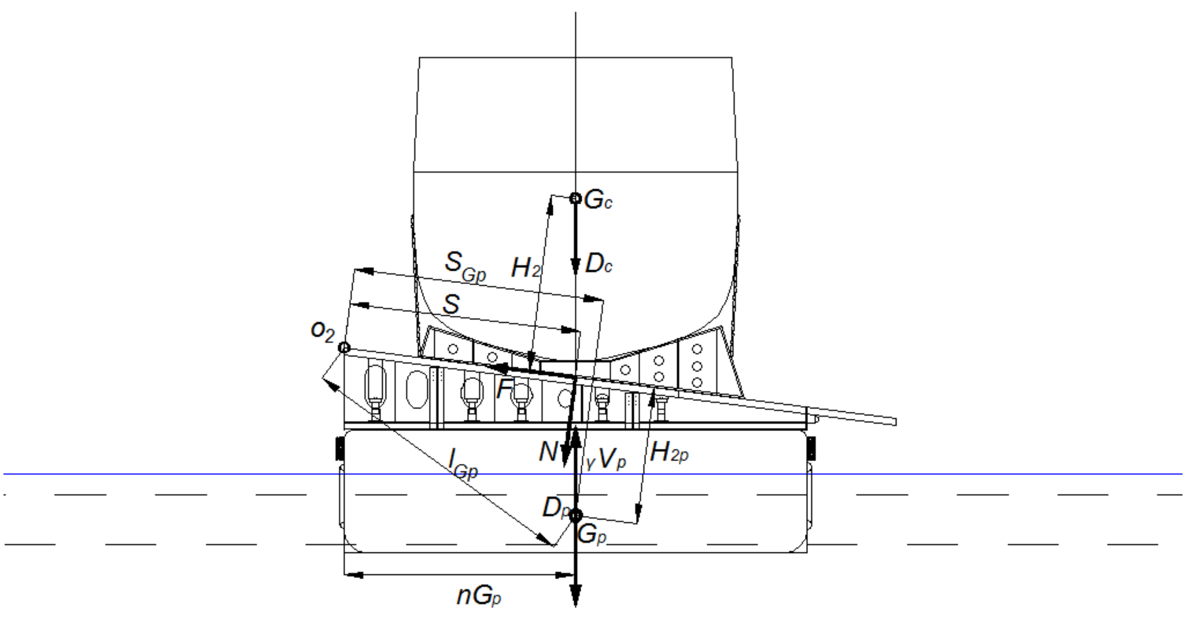

Fig.55.Second period of launch

13.3.3. Third period

In this period, the ship initiates the movement of ship launching .The ship star realizes one horizontal movement and its center of gravity rotates relative to its axis.

The movement of ship and pontoon is the result of gravity force. It is not necessary to make any other maneuver.

Also it is not necessary to make any inclination in the pontoon

The finish of this period is when the ship initiates contact with the water.

The system ship-pontoon makes a very complex horizontal and rotational movement relative to their center of gravity.

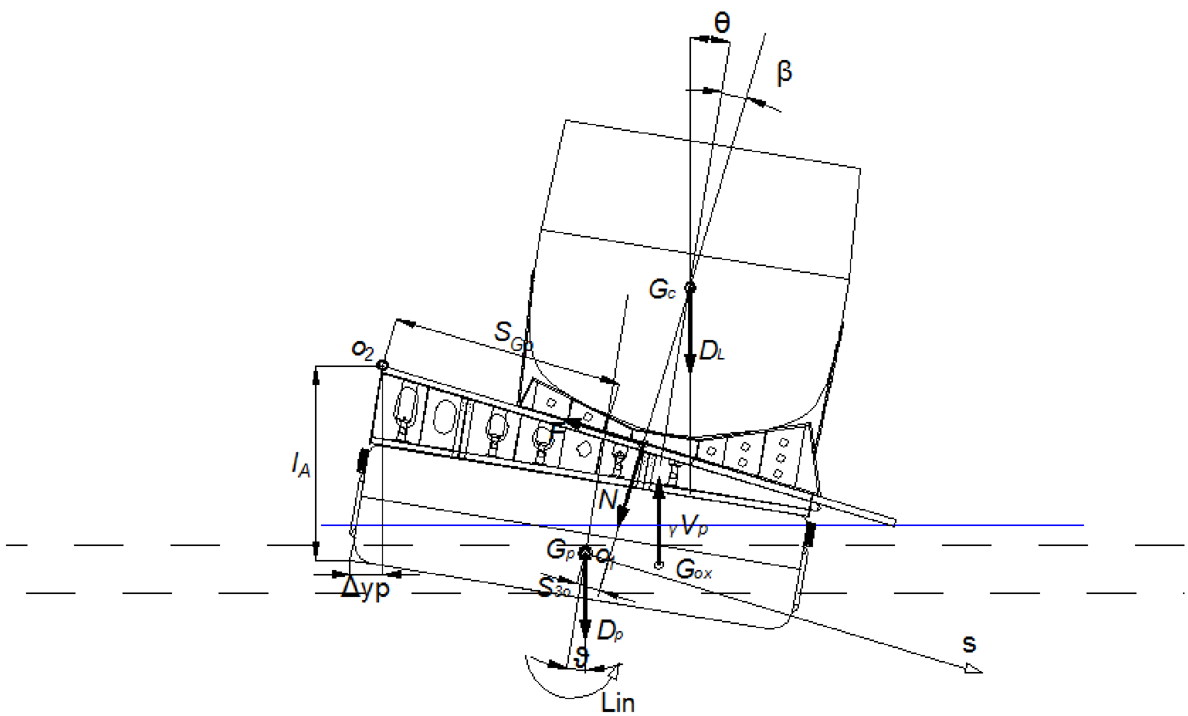

Fig.56.Thrid period of launch

13.3.4. Fourth period

Movement of ship initiates from contact of hull ship with the water to moment when the ship cradle initiates separation of slip truck by the rotation of ship.

The ship realizes one plane-parallel movement relative to pontoon, and the pontoon realizes one rotational movement.

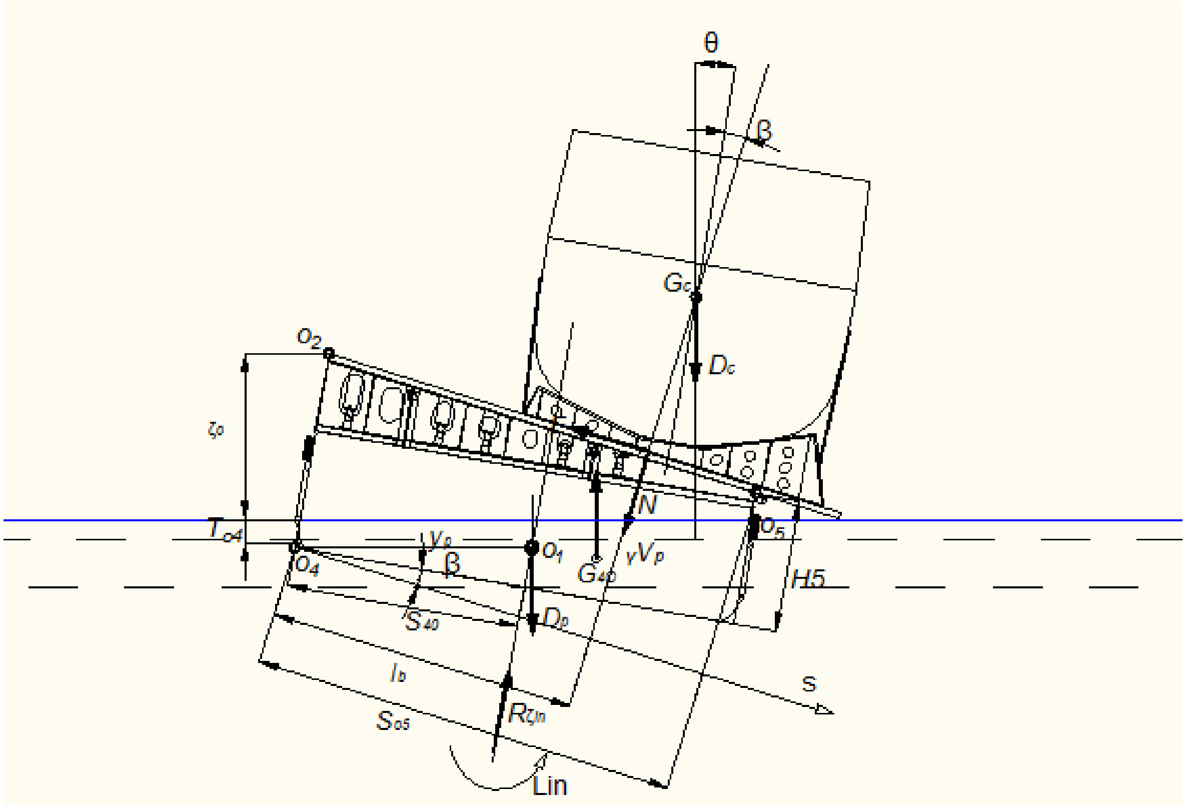

Fig.57. Fourth period of launch

13.3.5. Fifth period

This period initiates from separation of ship cradle of slip truck to moment when the hull ship has contact with water.

The ship realize one complex movement of transfer and rotation, relative point O_2

The pontoon also realizes rotational movement relative to point O_2.

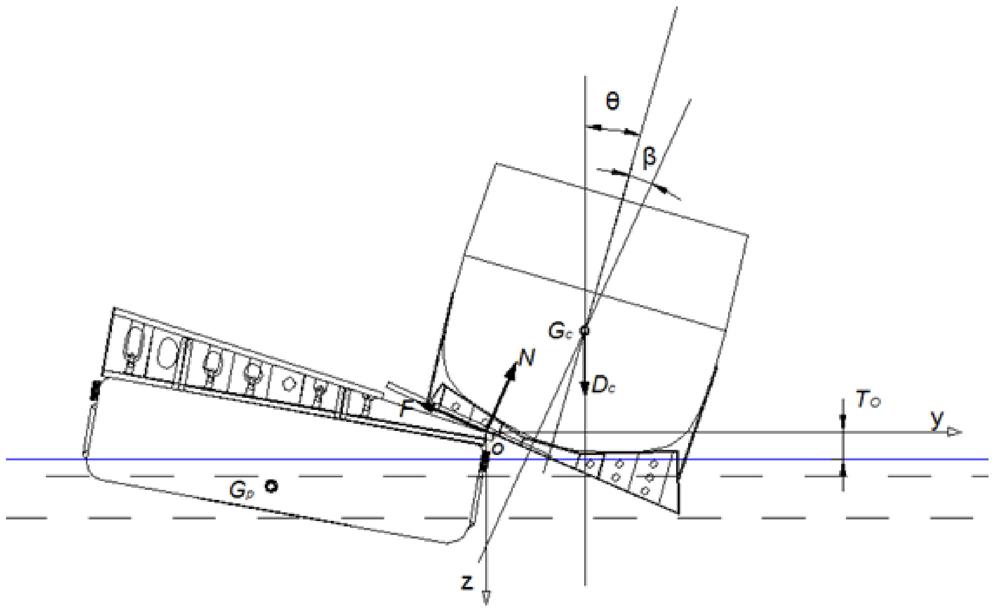

Fig.58.Fith period of launch

13.3.6. Sixth period

This period initiates when hull ship contacts with water and ends when finish part of ship cradle is separated from the slip truck.

The ship has movement in the water, a movement is the same type of five period.

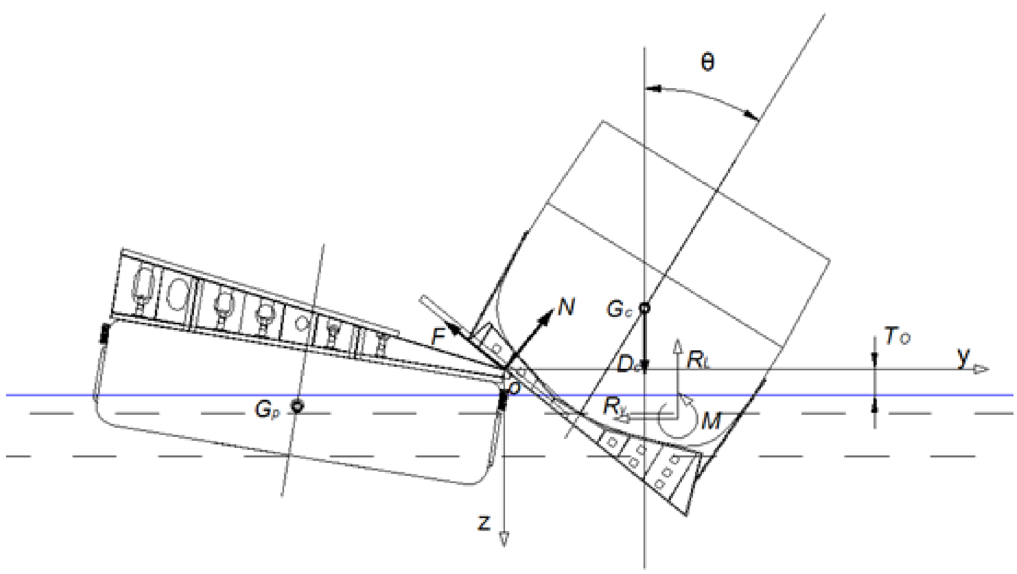

Fig.59.Sixth period of launch

13.3.7. Seventh period

Free inertial movement of ship to water from initial angular and lineal velocity to total stopped.

The ship makes plane-parallel movement

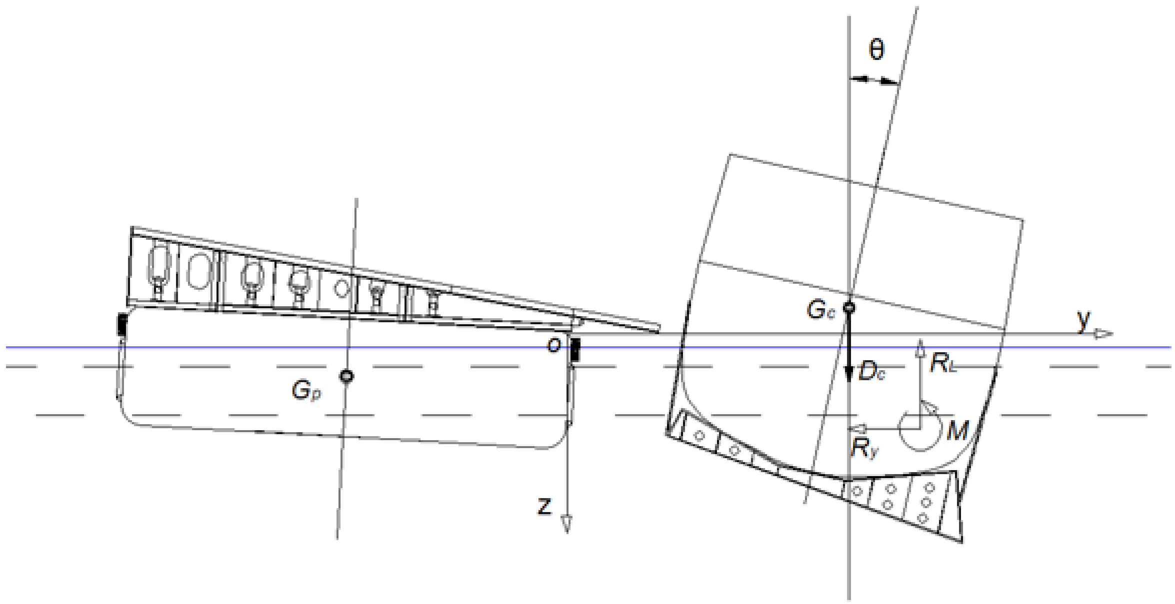

Fig.60.Seventh period of launch

14.DYNAMIC THEORETICAL ANALYSIS

To verify the possibility of realizing the ship launching a modeling of this process will be made, considering a ship, a pontoon and a respective portable slipway.

With this equipment, we will model the dynamics of ship launching, obtaining the most important characteristics for this process.

After that, also, it is possible to make a structural analysis of the portable slipway, from where we will obtain the regions where there is the highest concentration of stress

Gravity force, frictional force and normal reaction in the slip truck appear in the ship and pontoon in the all periods of ship launching.(the frictional force and normal reaction finish disappear at the start of the seventh period). Also, the ship resistance force and sustentation force appear in the pontoon on the third period. The buoyancy force and ship resistance force also appear on the sixth and seventh period.

It is possible to show an exact formulation movement system pontoon-ship in polar coordinate $s\ ,\vartheta\ ,r\ and\ \theta$ for Lagrange method, taking into account all forces:

For third and fourth period of ship launching:

$$a_2\ddot{s} + a_1\dot{\vartheta} = a_0$$

$$b_2\ddot{s} + b_1\dot{\vartheta} = b_0$$

For fifth and sixth period of ship launching:

$$a_3^{\prime}\dot{\vartheta} + a_2^{\prime}r + a_1^{\prime}\theta = a_0^{\prime}$$

$$b_3^{\prime}\dot{\vartheta} + b_2^{\prime}r + b_1^{\prime}\theta = a_0^{\prime}$$

$$c_3^{\prime}\dot{\vartheta} + c_2^{\prime}r + c_1^{\prime}\theta = a_0^{\prime}$$

For seventh period of ship launching:

$$\ddot{y} + a_2^{\prime\prime}r + A = 0$$

$$\ddot{z} + b_2^{\prime\prime}r + B = 0$$

$$\ddot{\theta} + a_2^{\prime\prime}y + b_2^{\prime\prime}z + C = 0$$

In this formulation, it is possible to determine the relationship between coordinates, velocity and parameters, for calculating buoyancy force, stability and ship resistance of ship and pontoon in the process of ship launching.

In this project we will present one approximate solution

This approximate solution is possible for next condition:

- Inertial force and moment of ship to pontoon is neglected. Ship is calculated as one material point, which appear in the pontoon with force equal reaction in the slip truck.
- The movement of the pontoon, is the same movement of body in constant slope
- Force and moment from ship resistance is neglected.
- Horizontal force from ship resistance is also neglected.
- It is assumed that the rotation of pontoon in the third period is in the axis across the center of gravity, also vertical sinking of pontoon is neglected.
- The sinking of pontoon in the third and fourth periods is constant. The inclination of pontoon in the third and fourth period is the same volume.
- The pontoon in the fifth and sixth period launching is immobilized and height of threshold is the same as at the finish of the fourth period.

In the second period, fig.55 shows the force in the system, which rotate relative to axis O_2x. The formulation for rotation equation of movement of the pontoon relative to axis O_2x, is show

$$J_{po2}\dot{\vartheta} = M_{kr} - M_{pod} - M_{in} \qquad (II.11)$$

Where

J_{PO_2} $- Inertial\ Moment\ Mass\ of\ pontoon$

M_{kp} $- Moment\ of\ angle\ of\ list\ of\ pontoon$

$M_{kpod} - Moment\ of\ Sustentation\ Force$

$M_{in} -\ Moment\ of\ Inertial\ Force, appear\ in\ the\ pontoon$

$\dot{\vartheta} - Angular\ Velocity\ of\ Pontoon$

Then, by inertial moment mass theorem relative parallel axis

$$J_{po2}\vartheta = J_{Gp} - \frac{D_P}{g} l_{gp}^2 \qquad (II.12)$$

Where

$D_p \quad = Weight\ of\ displacement\ of\ pontoon\ (tn)$

$J_{G_p} \quad = Moment\ of\ inertia\ of\ mass\ of\ pontoon\ relative\ to$

$central\ axis\ passing\ through\ center\ of\ gravity\ (tn.m.s^2)$

$l_{G_p} \quad = Distance\ of\ transfer\ of\ moment\ of\ inertia\ of\ mass\ of\ pontoon$

$relative\ to\ axis\ O_2x\ (m)$

The axis ¨s¨ in the initiation in the point O_2 in the deck of pontoon

Moment of angle of list of pontoon is

$$M_{kp} \approx Ns \qquad (II.13)$$

Where

$s - Cordinate\ of\ center\ of\ gravity\ of\ ship, from\ O_2\ in\ direction\ s$

$N - Normal\ force\ , equal\ presion\ in\ the\ pontoon$

$$N = D_0 cos\beta$$

For small slip truck slope β, then $cos\beta \approx 1$

$$N = D_0 \qquad (II.14)$$

Then, with all requirements

$$s = g(\beta - f_d)\frac{t^2}{g2} + \dot{s}_{2_0}t + s_{2_0} \qquad (II.15)$$

$\dot{s}_{2_0} - \ Velocity\ of\ center\ of\ gravity\ os\ ship\ in\ the\ initiation\ of\ secodn\ period$

We know also

$$\dot{s}_{2_0} = \sqrt{2(\beta - f_d)s_1} \qquad (II.16)$$

Where

$s_1 - Lenght\ of\ part\ of\ cost\ in\ the\ slipway. In\ this\ proyect\ we\ will\ neglect$

$\dot{s}_{2_0} -$
$Position\ of\ center\ of\ gravity\ of\ ship, relative\ to\ pontoon\ \ in\ the\ star\ \ secod\ period$

$$s_{2_0} = -H_2 sin\beta \approx -H_2\beta \qquad (II.17)$$

$H_2 \;= Elevation\ ot\ the\ center\ of\ gravity\ over\ axis\ ¨s¨\ in\ second\ period\ (m)$

From relationship *II.17* to *II.15*, and *II.15* to *II.13* and change N by D_0, we will obtain the next relation

$$M_{kp} = D_0\left[g(\beta - f_d)\frac{t^2}{g2} + \dot{s}_{2_0}t - H_2\beta\right] \qquad (II.18)$$

In the initial position

$$D_P = \gamma V_P$$

And

$$V_P = L_P B_P T_P$$

Where

$L_p = Lenght\ of\ pontoon\ (m)$

$B_p = Breadth\ of\ pontoon\ (m)$

$H_p = Draft\ of\ pontoon\ (m)$

Elevation of center of gravity of pontoon from center of buoyancy in the initial position

$$a_p \quad = z_{G_p} - z_{O_p}$$

Where coordinate $z_{G_p}\ \ and\ z_{G_p}$ is measured from base line of pontoon.

In the inclination of pontoon relative axis $O_2x\ forces\ D_p\ and\ \gamma V_p$ will create one negative buoyancy moment, and additional sinking in the pontoon, in this case positive buoyancy moment.

Then

$$M_{pod} = M_d + \Delta M_p \qquad (II.19)$$

Where

$$M_p = -\gamma V_p a_p \vartheta \qquad (II.20)$$

$$\Delta M_p = -\gamma \Delta V_p y_k \qquad (II.21)$$

$\vartheta -$ *angle of hell of pontoon*

$y_k - Distance\ of\ boyancy\ force\ of\ aditional\ sinking\ volume$

$of\ pontoon\ \Delta V_P\ relative\ axis O_2 x$

From fig.56

$$\Delta V_P \approx L_p B_p\ \eta_{G_p} \vartheta \qquad (II.22)$$

Where

$\eta_{G_p} - Coordinate\ of\ center\ of\ gravity\ of\ pontoon\ in\ the\ axis\ \ \eta O_2 \zeta$

The center of buoyancy of volume ΔV_P is in the center of gravity in the trapeze fig.56 .Is possible take y_k is equal distance of center of gravity of OBC to point O.

$$y_k \approx \frac{2}{3}\left(\eta_{G_P} + \frac{B_P}{2}\right) \qquad (II.23)$$

If equations II.23 and II.22 to II.21, the result is

$$\Delta M_P \approx \gamma L_P B_P \eta_{G_P} \frac{2}{3}\left(\eta_{G_P} + \frac{B_P}{2}\right)\vartheta$$

Designate

$$k_{V_P} \approx \gamma L_P B_P \eta_{G_P} \frac{2}{3}\left(\eta_{G_P} + \frac{B_P}{2}\right) \qquad (II.24)$$

Receive

$$\Delta M_p \approx k_{V_P} \vartheta \qquad (II.25)$$

The necessary landing of pontoon before ship launching is possible after take water in ballast. The free surface ballast in tanks less the restoring moment in the measure equal the next add.

$$\Delta M_p = [\gamma \textstyle\sum_{n=1}^{m} i_{xn}]\vartheta \qquad (II.26)$$

Where

$i_{xn} - Inertial\ moment\ of\ plane\ in\ the\ free\ surface\ of\ water\ in\ the\ \ n -$
$i\ \ tank\ of\ pontoon\ relativ\ the\ central\ axis, perpendicular\ inclinate\ plane$

The equation II.20, II25 and II.26 in II.19 and change γV_p and D_p we will receive

$$M_{pod} = \left(k_{V_P} - D_P a_P - \gamma \textstyle\sum_{n=1}^{m} i_{xn}\right)\vartheta \qquad (II.27)$$

Moment of inertial force of water resistance, applied in the pontoon in the axis O_2x

$$M_{in} = R_\zeta^{in}\eta_{G_P} + L_{in} \qquad (II.28)$$

$R_\zeta^{in} = Projection\ of\ inertial\ force\ of\ water\ resitance\ in\ the\ O_2\zeta$

$L_{in} =\ Moment\ inertial\ force\ of\ resistance\ of\ water, relative\ \ axis,$

$with\ pass\ by\ center\ of\ gravity\ pontoon$

$Expressing\ R_\zeta^{in}\ and\ L_{in}\ in\ \ adding\ mass, is\ posible\ show$

$$R_\zeta^{in} \approx\ \lambda_\zeta^0\dot{\zeta} \approx \lambda_\zeta\eta_{G_P}\vartheta \qquad (II.29)$$

$$L_{in} \approx \lambda_\omega^0\dot{\vartheta} \qquad (II.30)$$

Adding mass $\lambda_\zeta^0\ \ and\ \lambda_\omega^0$, for vertical and lateral pitching of pontoon, it is possible to take equal approximation

$$\lambda_\zeta^0 \approx \frac{\pi}{8}\frac{\gamma}{g}L_P B_P^2 \qquad (II.31)$$

$$\lambda_\omega^0\dot{\vartheta} \approx \frac{1}{81.5}\frac{\gamma}{g}L_P B_P^4 \qquad (II.32)$$

If the equation II.29 and II.30 in II.28, the solution is

$$M_{in} = \left(\lambda_\zeta^0\eta_{G_P} - \lambda_\omega^0\right)\dot{\vartheta} \qquad (II.33)$$

In the relation II.18 and II.27 and II.33 in the initial equation II.11, after the accommodation, the solution is

$$\vartheta + k\vartheta = at - bt + c \qquad (II.34)$$

where

$$a = \frac{D_0 g(\beta - f_d)}{2J} \qquad (II.35)$$

$$b = \frac{D_0 s_{2_0}}{J} \qquad (II.36)$$

$$c = -\frac{D_0 H_2 \beta}{J} \qquad (II.37)$$

$$k^2 = \frac{k - D_P H_P - \gamma \sum_{n=1}^{m} i_{xn}}{J} \qquad (II.38)$$

$$J = J_{po2} - \lambda_\zeta^0 \eta^2{}_{G_P} + \lambda_\omega^0 \qquad (II.39)$$

The equation II.34 .is lineal differential equation of second degree is constant coefficient. Their solution is the sum of two equations

$$\vartheta = \vartheta_{ov} + \vartheta_{ch}$$

The generally solution of equations is

$$\vartheta_{ov} = C_1 coskt + C_2 sinkt$$

This is particular solution

$$\vartheta_{ch} = B_0 + B_1 t + B_2 t^2$$

For find the coefficient B_0, B_1, B_2 we will use the next relation

$$k^2 \vartheta_{ch} = k^2 B_0 \ ; \ k^2 B_1 t = k^2 B_2 t^2 \ ; \ \vartheta_{ch} = 2B_2$$

That equation in II.34, we get

$$k^2 B_0 + 2B_2 + k^2 B_1 t + k^2 B_2 t^2 = c + bt - at^2$$

$$k^2 B_0 + 2B_2 = c$$

$$k^2 B_1 = b$$

$$k^2 B_2 = a$$

From those relations, we get

$$B_2 = \frac{a}{k^2}$$

$$B_1 = \frac{b}{k^2}$$

$$B_0 = \frac{c}{k^2} - \frac{2a}{k^4} \qquad (II.40)$$

From those relations we get the angle of inclinations of pontoon

$$\vartheta - C_1 coskt + C_2 sinkt = B_0 + B_1 t + B_2 t^2 \qquad (II.41)$$

The angular velocity of pontoon is from derivative of equation II.41

$$\dot{\vartheta} = -kC_1 sinkt + kC_2 coskt + B_1 + 2B_2 t \qquad (II.42)$$

The constant C_1, C_2 is get from equations II.41 and II.42, which define the initial situation of movement

In the initial of second period for $t = 0; \vartheta = 0 ; \dot{\vartheta} = 0$,this conditions in equation II.41 and II.42,we get

$$C_1 = -B_0$$

$$C_2 = \frac{B_1}{k} \qquad (II.43)$$

At the finish of second period, the cradle begins the separation of slip truck. Here we neglect inertial force in the ship and pontoon, also inertial force from water resistance, applicant to pontoon; we will take, which this separation begins when:

$$M_{kp} = M_{pod}$$

And

$$D_0 = \gamma \Delta V_{pod}$$

If equation II.18 and II.27 is equal and change D_0 in the equation II.22, after we get

$$t^2 + pt + q = 0 \qquad (II.44)$$

Where p and q are coefficient

$$p = \frac{2s_{2_0}}{g(\beta - f_d)} \qquad (II.45)$$

$$q = \frac{2}{g(\beta - f_d)}\left(H_0\beta + \frac{k_{V_P} - D_P a_P - \gamma \sum_{n=1}^{m} i_{xn}}{\gamma L_P B_P \eta_{G_P}}\right) \qquad (II.46)$$

From the positive result, we get

$$t = -\frac{p}{2} + \sqrt{\left(\frac{p}{2}\right)^2 - q} \qquad (II.47)$$

Which determines the end of the second period.

In the third period, the pontoon by the force of gravity rotates relative to axis $G_p x$, passing by center of gravity of pontoon. The same which the second period, the differential equation of rotate movement of ship is:

$$J_{G_P}\dot{\vartheta} = M_{kp} - M_{pod} - M_{in} \qquad (II.48)$$

In the beginning axis s in the third period, take in the center of gravity of pontoon. The moment of inclinations of pontoon, relative axis $G_p x$

$$M_{kp} \approx Ns \qquad (II.49)$$

Where

$$N = D_0 cos\varphi \qquad (II.50)$$

$$\varphi = \beta + \vartheta_2 \qquad (II.51)$$

The coordinate of center of gravity of ship

$$s = g(sin\varphi - f_d cos\varphi)\frac{t^2}{2} + \dot{s}_{3_0}t + s_{3_0} \qquad (II.52)$$

Where

$\dot{s}_{3_0} - Velocity\ of\ center\ of\ gravity\ in\ the\ beginning\ of\ third\ period$

$s_{3_0} -$
$Position\ of\ center\ of\ gravity\ relative\ to\ pontoon\ in\ the\ beginning\ of\ third\ period$

After differentiating the equation II.15, we get

$$\dot{s}_{3_0} - \dot{s}_2 = g(\beta - f_d)t_2 + \dot{s}_{2_0} \qquad (II.53)$$

That information in the fig.57

$$s_{3_0} = s_2 + s_{G_P} \qquad (II.54)$$

Where

$s_{G_P} - Distance\ from\ O_2 to\ perpendicular,$

$from\ center\ of\ gravity\ of\ pontoon\ to\ slip\ plane$

The equation II.50 and II.52 to II.49, we get

$$M_{kp} = D_0 cos\varphi \left[g(sin\varphi - f_d cos\varphi) \frac{t^2}{g2} + \dot{s}_{3_0} t + s_{3_0} \right] \qquad (II.55)$$

Inertial moment of sustentation of pontoon relative axis $G_p x$ is possible to determine by metacenter equation. With the consideration of free surface of water in the ballast tanks of pontoon.

$$M_{pod} = \gamma \left(V_{P_2} h - \sum_{n=1}^{m} i_{xn} \right) \vartheta \qquad (II.56)$$

Where

$V_{P_2} - Volmen\ of\ displacemnt\ pontoon\ in\ the\ finish\ second\ period$

$$V_{P_2} = V_P + \Delta V_{P_2} \qquad (II.57)$$

$$\Delta V_{P_2} = L_P B_P \eta_{G_P} \vartheta_2 \qquad (II.58)$$

$h - Metacenter\ height\ of\ pontton$

$$h = r - z_{G_P} + z_{C_P} \qquad (II.59)$$

Where

$r - Transversal\ metacentral\ radius$

$z_{G_P} -\ z\ ordinate\ of\ center\ of\ gravity\ of\ pontoon$

$z_{C_P} -\ z\ ordinate\ of\ center\ of\ gravity\ of\ pontoon$

For box pontoon

$$r = \frac{L_P {B^3}_P}{12 V_{P_2}} \qquad (II.60)$$

$$z_{C_P} = \frac{T_{P_2}}{2} \qquad (II.61)$$

In this case T_{P_2} is measure in the diametric plane of pontoon.

$$T_{P_2} = \frac{V_{P_2}}{L_P B_P} \qquad (II.62)$$

Equation II.62 to II.61,and II.61 and II.60 to II.59,we get

$$M_{pod} = \gamma \left[V_{P_2} \left(\frac{L_P B^3{}_P}{12 V_{P_2}} + \frac{V_{P_2}}{2 L_P B_P} - z_{G_P} \right) - \sum_{n=1}^{m} i_{xn} \right] \vartheta \qquad (II.63)$$

The inertial moment force of water resistance

$$M_{in} - L_{in} \approx \lambda_\omega^0 \, \vartheta \qquad (II.64)$$

Adding the mas λ_ω^0 and take the second grade

The equations II.55 and II.63 and II.64 to equation II.48, we get

$$\dot{\vartheta} + k^2 \vartheta = a t^2 + b t + c \qquad (II.65)$$

Where

$$a = \frac{D_0 g cos\varphi (sin\varphi - f_d cos\varphi)}{2J} \qquad (II.66)$$

$$b = \frac{D_0 cos\varphi \dot{s}_{3_0}}{J} \qquad (II.67)$$

$$c = \frac{D_0 cos\varphi s_{3_0}}{J} \qquad (II.68)$$

$$k^2 = \frac{\gamma \left[V_{P_2} \left(\frac{L_P B^3{}_P}{12 V_{P_2}} + \frac{V_{P_2}}{2 L_P B_P} - z_{G_P} \right) - \sum_{n=1}^{m} i_{xn} \right]}{J} \qquad (II.69)$$

$$J = J_{G_P} + \lambda_\omega^0 \, \vartheta \qquad (II.70)$$

In The equation II.65 by analogy in the second period (II.34). It is possible to make the solution

It is necessary to find the constant C_1 and C_2.

In the beggining of third period $t-0$; $\vartheta - \vartheta_2$; $\dot{\vartheta} - \dot{\vartheta}_2$; that information in the equation II.41 and II.42.then

$$C_1 = \vartheta_2 + B_0 \qquad (II.71)$$

$$C_2 = \frac{J_G - B_1}{k} \qquad (II.72)$$

At the finish of third period, the point A and the center of gravity moveΔy_p, in opposite direction of the ship. That movement is the result from two forces; Force N – the pressure of ship to pontoon and buoyancy force of sinking volume of pontoon, in the second period. The pontoon is pushed by the last force from water.

The equation of horizontal move of center of gravity of ship is

$$\frac{D_p}{g}\ddot{y}_p = N sin\varphi + \gamma \Delta V_P sin\varphi cos\varphi \qquad (II.73)$$

In the position N, we change by equation II.50, then

$$y_p = D \qquad (II.74)$$

Where

$\ddot{y}_p =$
$Aceleration\ of\ center\ of\ gravity\ of\ pontoon\ in\ the\ static\ coordinate\ axis\ yO_2z$

$$D = \frac{g}{2D_p} sin2\varphi\left(D_0 + \gamma \Delta V_{P_2}\right) \qquad (II.75)$$

On integral equation II.74, then

$$\dot{y}_p = -C - Dt \qquad (II.76)$$

$$y_p = -C_2 - C_1 t - D\frac{t^2}{2} \qquad (II.77)$$

For find C_2 and C_2 used the initial condition for $t - 0$

$$y_P = y_{P_2} \ \ , \ \dot{y}_P = \dot{y}_{P_2} = z_{P_2}\vartheta \qquad (II.78)$$

Where

$\dot{y}_p = Velocity\ of\ center\ of\ gravity\ of\ pontoon\ in\ the\ static\ coordinate\ axis\ yO_2z$

$z_{p_2} = Cordinate\ of\ center\ of\ gravity\ of\ pontoon\ in\ the\ finish\ of\ second\ period$

Is fig.56,

$$z_{P_2} \ = s_{G_P} sin\varphi + \ H_{2P} cos\varphi \qquad (II.79)$$

$H_{2P} - Lenght\ of\ perpendicular, from\ center\ of\ gravity\ of\ pontoon\ to\ O_2s$

From initial condition to equation II.76 and II.77

$$C_1 = z_{P_2}\dot{\vartheta} \qquad (II.80)$$

$$C_2 = y_{P_2} \qquad (II.81)$$

Then

$$y_p = y_{P_2} \ \ - \dot{y}_{P_2} t - D\frac{t^2}{2} \qquad (II.82)$$

For $y_{P_2} - \ y_p = \Delta y_P$, we get

$$t^2 - pt + q = 0 \qquad (II.83)$$

Where

$$p = \frac{2\dot{y}_{P_2}}{D} \qquad (II.84)$$

$$q = \frac{-2\Delta y_P}{D} \qquad (II.85)$$

With the positive solutions we can find time and final moment of finish of the third period.

For find Δy_P ,

$$\Delta y_P = \ l_A cos\left[arccos\left(\frac{\eta_{G_P} t-\frac{B_P}{2}}{l_A}\right)+\vartheta_2\right]-e \qquad (II.86)$$

Where

$l_A - Distance\ from\ A\ to O_2$

$e - Distance\ from\ cost\ to\ potonn$

In the fourth period (fig 57), rate in axis O_4x ,passing by pontoon

The equation of rotate movement is

$$J_{PO_4}\dot{\vartheta} = M_{kp} - M_{pod} - M_{in} \qquad (II.87)$$

Coordinate s in the four period is relative from O_4

Inertial moment of mass relative axis O_4x

$$J_{PO_4} = J_{G_P} + \frac{D}{g} l_P^2 \qquad (II.88)$$

Where

$l_P - Distance\ of\ transfer\ inertial\ moment\ \ relative\ axis\ O_4x$

Moment of inclinations, which appear in the pontoon relative axis (fig.57)

$$M_{kp} = Ns + D_P y_P \qquad (II.89)$$

Where

$$N = D_0 cos\varphi \qquad (II.90)$$

$$\varphi = \beta + \vartheta_3 \qquad (II.91)$$

$y_P - Distance\ weight\ force\ of\ pontoon\ relativ\ O_4x$

The distance tale constant, and is the same as the finish of third period

From fig.57, show

$$y_P = \frac{B_P}{2} cos\vartheta_3 - z_{G_P}\ sin\vartheta_3 \qquad (II.92)$$

If angle $\vartheta_3 \leq 10°\ to\ 15°\ , and\ \cos\vartheta_3\ \approx 1; \sin\vartheta_3\ \approx 0$

Then

$$y_P = \frac{B_P}{2} - z_{G_P}\,\vartheta_3 \qquad (II.93)$$

Coordinate of center of gravity of ship

$$s = g(sin\varphi - f_d cos\varphi)\frac{t^2}{2} + \dot{s}_{4_0}t - s_{4_0} \qquad (II.94)$$

Where

$\dot{s}_{4_0} - Velocity\ of\ center\ of\ gravity\ of\ ship\ in\ begining\ of\ four\ period$

$s_{4_0} -\ Position\ of\ center\ of\ gravity\ of\ ship,$

$relative\ pontoon\ in\ the\ beginning\ of\ four\ period$

After differentiating II.52, we get

$$\dot{s}_{3_0} - \dot{s}_3 = g(sin\varphi - f_d cos\varphi)t_3 - s_{3_0} \qquad (II.95)$$

Is fig.57,show

$$s_{1_0} = \frac{B_P}{2} - z_{G_P}\beta -\ s_3 \qquad (II.96)$$

The equation II.90 and II.94 to equation II.89, then

$$M_{kp} = D_0 cos\varphi\left[g(sin\varphi - f_d cos\varphi)\frac{t^2}{2} + \dot{s}_{4_0}t - s_{4_0}\right] + D_P y_P \qquad (II.97)$$

The moment of force sustentation of pontoon relative axis O_4x , with free surface of water in the ballast tanks

$$M_{pod} = \gamma V_{p_2} y_{V_{P_2}} - \gamma[\sum_{n=1}^{m} i_{xn}]\vartheta \qquad (II.98)$$

Where

$y_{V_{P_2}} -\ Distance\ of\ force\ sustentation\ \ \gamma V_{p_2}\ relative\ axis\ O_4x$

The expression for the distance $y_{V_{P_2}}$ is:

$$y_{V_{P_2}} = y_p + h\vartheta \qquad (II.99)$$

Where

$h - Metacentric\ height\ of\ pontoon$

It is possible to find the metacentric height h of the same steps than in third period. Then after the transformations we get

$$M_{pod} = \gamma V_{p_2} y_P - \gamma \left[V_{P_2} \left(\frac{L_P B^3{}_P}{12 V_{P_2}} + \frac{V_{P_2}}{2 L_P B_P} - z_{G_P} \right) - \sum_{n=1}^{m} i_{xn} \right] \vartheta \qquad (II.100)$$

Inertial moment of force of water resistance (fig.57)

$$M_{in} = R_\zeta^{in} \frac{B_P}{2} + L_{in} \qquad (II.101)$$

Can express $R_\zeta^{in}\ and\ L_{in}$ by adding mass, we get

$$R_\zeta^{in} \approx \lambda_\zeta^0 \zeta \approx \lambda_\zeta^0 \frac{B_P}{2} \ddot{\vartheta} \qquad (II.102)$$

$$L_{in} \approx \lambda_\omega^0 \vartheta \qquad (II.103)$$

Adding the mass $\lambda_\zeta^{in}\ and\ \lambda_\omega^0$ and there are the same than in second period

The equations II.102 and II.103 to II.101

$$M_{in} = \left(\lambda_\zeta^{in} \frac{B^2{}_P}{4} + \lambda_\omega^0 \right) \dot{\vartheta} \qquad (II.104)$$

The equation II.97 and II.98 and II.104 to equation II.87, then

$$\ddot{\vartheta} + k^2 \vartheta = at^2 + bt + c \qquad (II.105)$$

$$a = \frac{D_0 g cos\varphi (sin\varphi - f_d cos\varphi)}{2J} \qquad (II.106)$$

$$b = \frac{D_0 g cos\varphi \dot{s}_{4_0}}{J} \qquad (II.107)$$

$$c = \frac{D_0 g cos\varphi - (\gamma V_{P_2} - D_P) y_P}{J} \qquad (II.108)$$

$$k^3 = \frac{\gamma\left[V_{P_2}\left(\frac{L_P B^3{}_P}{12 V_{P_2}} + \frac{V_{P_2}}{2 L_P B_P} - z_{G_P}\right) - \sum_{n=1}^{m} i_{xn}\right]}{J} \qquad (II.109)$$

$$J = J_{PO_4} + \lambda_\zeta^0 \frac{B^2{}_P}{4} + \lambda_\omega^0 \qquad (II.110)$$

The equation II.105 is analog equation in the second and third period. At this moment is necessary find C_1 and C_2

In the beginning of fourth period for $t - 0$; $\vartheta - \vartheta_3$; $\dot{\vartheta} - \dot{\vartheta}_3$; the equation II.41 and II.42

$$C_1 = \vartheta_3 - B_0 \qquad (II.111)$$

$$C_2 = \frac{\dot{\vartheta}_3 - B_1}{k} \qquad (II.112)$$

In the finish of fourth period beginning the separation of ship from pontoon. At this moment the inertial force and force of gravity are the same.

$$s = s_{0_5} - H\beta \qquad (II.113)$$

Where

$s_{0_5} - coordenate\ of\ point\ O_5\ (Fig\ 57)$

From fig.57

$$s_{0_5} = B_P - H_5\beta \qquad (II.114)$$

Where

$H_5 - Height\ of\ pontoon\ from\ bottom\ to\ boundary$

$H - Distance\ of\ center\ of\ gravity\ \ from\ sliptruck\ to\ slip\ plane$

If the equation II.113 in the place, s in equation II.94, we get

$$t^2 - pt + q = 0 \qquad (II.115)$$

Where

$$p = \frac{2\dot{s}_{4_0}}{g(sin\varphi - f_d cos\varphi)} \qquad (II.116)$$

$$q = -\frac{2\left(s_{0_5} - 2s_{4_0} - H\beta\right)}{g(sin\varphi - f_d cos\varphi)} \qquad (II.117)$$

The positive solution gives the time and moment of finish the fourth period

The velocity of center of gravity of ship in the finish of fourth period is possible with the equation II.94

Then

$$\dot{s}_4 = g(sin\varphi - f_d cos\varphi)t_4 - s_{4_0} \qquad (II.118)$$

The height of boundary in the moment of finish the fourth period, we can see in the fig.57

$$T_0 = \; H_0 cos\vartheta_4 \; + B_P sin\vartheta_4 - T_{0_4} \qquad (II.119)$$

Where

$$T_{0_4} = l_4 sin\left[arcsin\frac{\zeta_0 - T}{l_4} - \vartheta_2\right] - \zeta_0 \qquad (II.120)$$

$T_{0_4} - sinking\ side\ of\ pontoon$

$\zeta_0 - distance\ from\ cost\ to\ water\ line$

In the five period the pontoon is static, and after the movement of ship is the same them transversal ship launching. But in the finish of fourth period the ship has angular velocity and inclination angle.

By the relation between ship and pontoon, the angle of inclination of ship in the finish of four period is the same then inclination angle of pontoon, $\theta - \vartheta_4$,angular velocity of ship is the same then angular velocity of pontoon $\theta - \vartheta_4$.Is this reason, why in the five period we have new initial situation. Then for normal transversal launching

Velocity

$$y - y_P = y_{5_0} = s_4 cos(\beta - \vartheta_4) \qquad (II.121)$$

Coordinate

$$y = [\dot{s}_4 cos(\beta - \vartheta_4)]t + y_{5_0} \qquad (II.122)$$

Where

$$y_{5_0} = H\ sin\vartheta_4 \qquad (II.123)$$

velocity

$$z = \dot{y}(\beta + \theta) + y0 + z_{5_0} \qquad (II.124)$$

Where

$$z_{5_0} = s_1 sin(\beta + \vartheta_4) \qquad (II.125)$$

Inclination angle

$$\theta = \frac{g\rho_x}{2\dot{y}_1^2}\left(\frac{\dot{y}_1 t}{\rho_x} - arctg\frac{y_1 t}{\rho_x}\right) - \vartheta_1 \qquad (II.126)$$

Angular velocity

$$\dot{\theta} = \frac{g}{2\dot{y}_1}\frac{\left(\frac{y_4 t}{\rho_x}\right)^2}{1-\left(\frac{\dot{y}_4 t}{\rho_x}\right)^2} - \vartheta_4 \qquad (II.127)$$

The sixth and seventh period is one normal transversal ship launching

15.DINAMIC SIMULATION OF SHIP LAUNCH

For determining the dynamic characteristics of pontoon in the process of launch of ship, we will model, this process with Matlab language applicant by the dynamic theory for transversal ship launching.

For that process we will use one typical model of ship and pontoon. It is possible to apply the resultant of this model for launch of different types of ship.

But the principal idea is for launch of small and medium ship, which is common for small shipyards. The matlab modeling and resolve is presented in the Annex 1

For initial information for this modeling we will use:

L[m]=85

B[m]=12

T[m]=3.5

H[m]=5

Dc[tn]=1000

This ship has the characteristics of a ship built or repaired in a small shipyard.

The pontoon will be a typical model, which can comply with the process of ship launching as well as transport the ship without problems.

This pontoon will have the following characteristics:

Lp[m]=65

Bp[m]=18

Tp[m]=2.5

With the characteristics of the ship and pontoon, is possible to choose the suitable portable slipway.

For the portable slipway we use structural steel of 25 mm thickness and its dimensions will be:

L[m]=18

B[m]=1.6

Slope[grades]=7

16. NUMERICAL ANALYSIS OF STRUCTURE OF SLIPWAY

We will realize the numerical structural analysis, for every part of the device, we will also analyze the assembly.

For this analysis we will use the basic FEA (Finite Element Analysis) of software Autodesk Inventor. This portable slip way haa one preliminary structure and weight for every pieces. After this numerical analysis, we have the possibility to change the structures to reduce the weight of slip way or improve the safety this device.

The most important part of this analysis, we will find the regions where is the maximum stress and fatigue

In this case we will use one loads of 200 tn for every portable slipway, that value is the maximum for this structure, and for large time will apply to assemble.

The modeling in FEA and resolution is presented in the Annex 2

We will also make the simulations for the portable slipway in the down position, when use the jacks for change level of ship. That process is performed near of shipyard for more safety

In this case the support will be for jacks. In this case every jack will support average 40Tn.

For this modeling is no necessary to analyze the support because the point of higher concentration of stress is in the jacks and their internal support in the slip truck.

Also it is necessary to determinate which jack is needed and how much is the level of down.

The result is show in the Annex 3

17.RESULTS

From dynamic simulations of ship launch, it is possible affirm, the ship launching process is safe.Fig.61; the pontoon has 10 maximum degree in the point the maximum inclination. With this angle the returned process is also safe

The stability of ship in the launching process is in the normal range for this type of maneuver.

Also we can determine the velocity of pontoon, in this case is 6m/s. This value is acceptable for return to the initial positions of pontoon.

The angular velocity of ship at the moment of launch also is determined to be 0.2rad/s.

The time of process is 6 second, which is also acceptable for this process

We should know that although this process is very fast, in this case the stability of ship in the launching process is in the normal range for this type of maneuver.

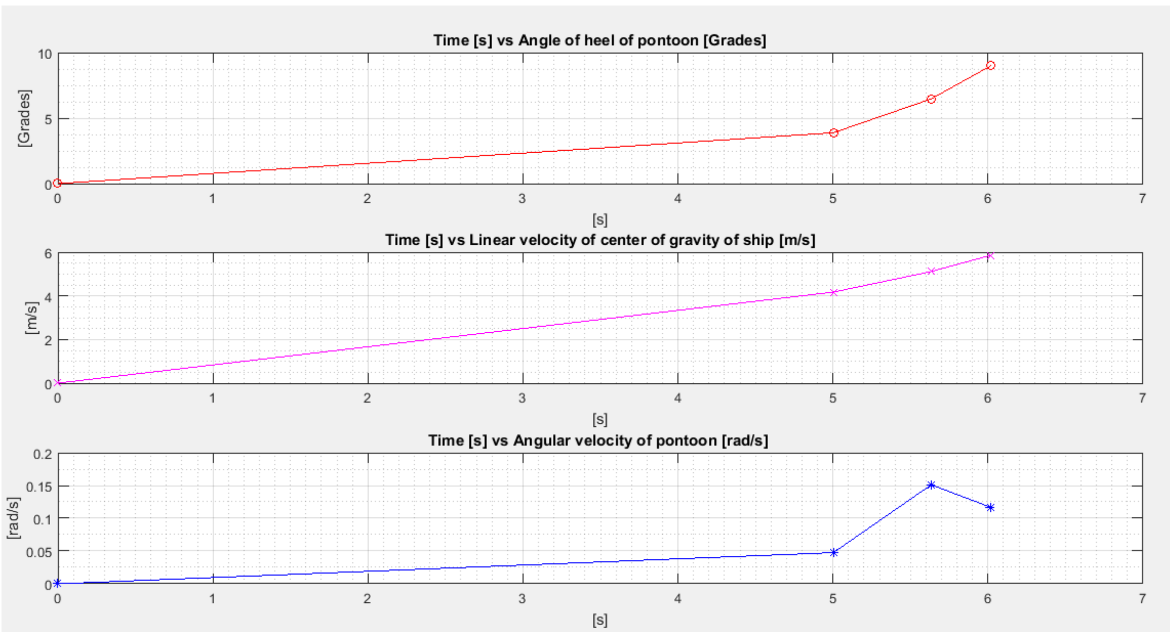

Fig.61Dynamic Modeling of Ship Launching

From the stress in the structural analysis (Annex 2), it is possible to determine the maximum point of stress. In this case it is in the region near of second jack, and has a value of 35.51MPas (Fig.62,Fig63)

Also we understand, what in that place is necessary will be careful because the von misses stress is maximum.

The maximum first Principal Stress is in the cradle, in the union of plates in the top, where has directly contact with ship or pieces of wood. The value is acceptable in this case is 26.96MPas.(Fig.64)

The maximum third Principal stress is also in the same region of the maximum First Principal, and the value is 11.29Mpas.

The displacement maximum is 0.51mm in the top plate of cradle, that value is acceptable.(Fig.65)

Also the safety factor maximum is 15 and minimum is 9.86.(Fig.66)

With that value it is possible verify the safety of construction of portable slipway.

From the FEA when in down position (Annex 3), it shows the region where the stress is maximum, in this case the connection of support of jacks.Fig.67-70

Annex 4 shows the plans for this portable slipway. It is possible to change the dimensions in that model for other types of barges or ships. In this case that model is the best for one small shipyard

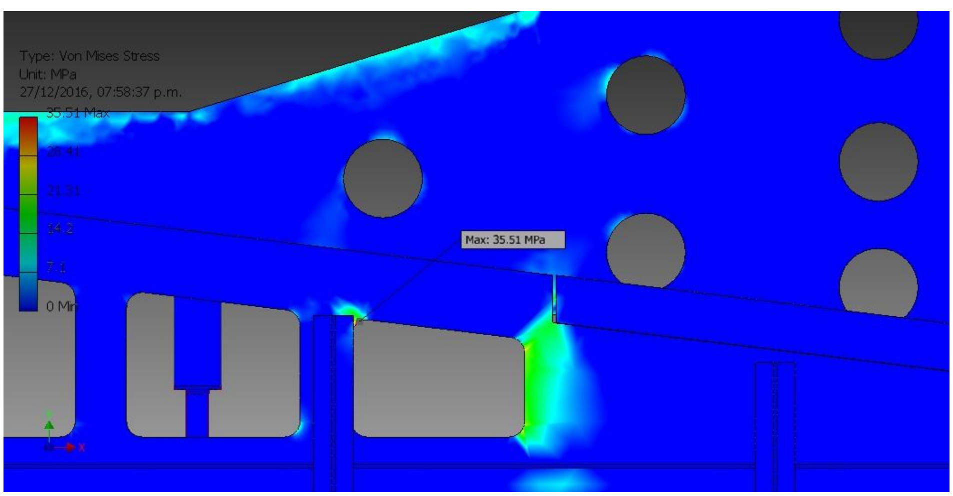

Fig.62 Maximum Von – Mises Stress

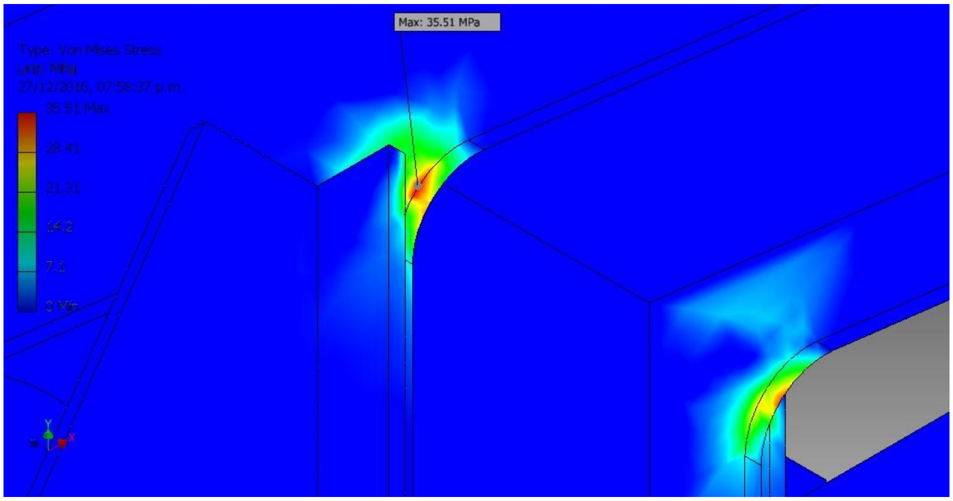

Fig.63 Point of Maximum Von – Mises Stress

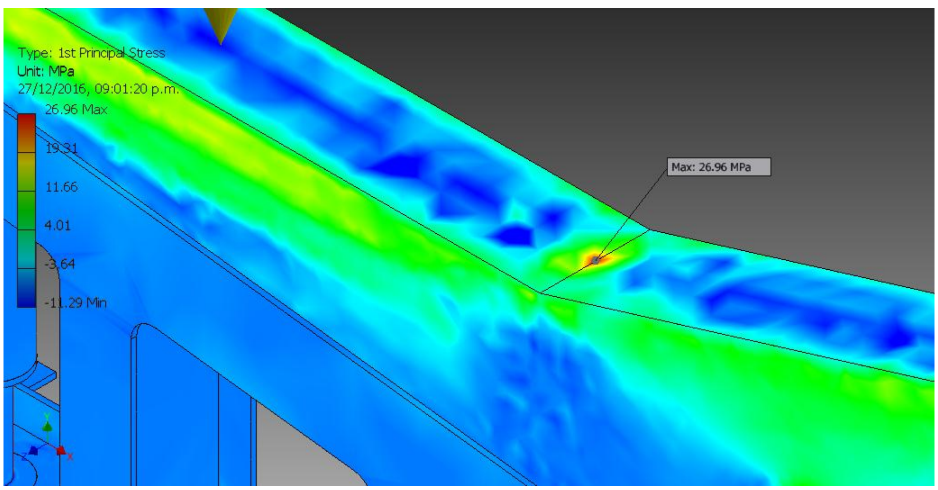

Fig.64 Maximum 1st Principal Stress

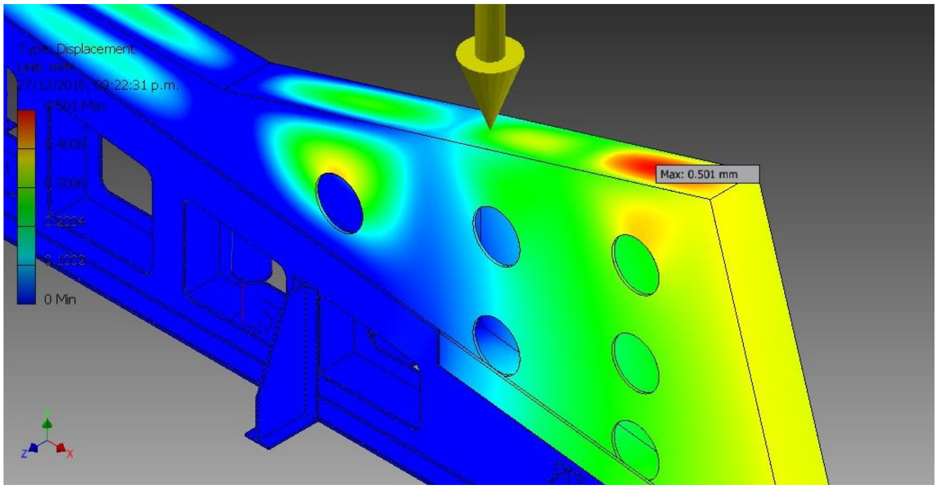

Fig.65 Maximum point of Displacement

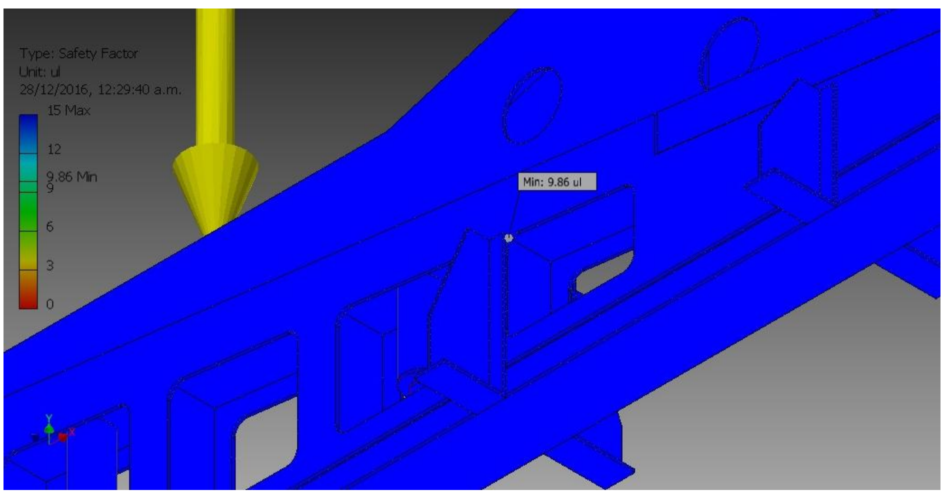

Fig.66 Minimum point of Safety Factor

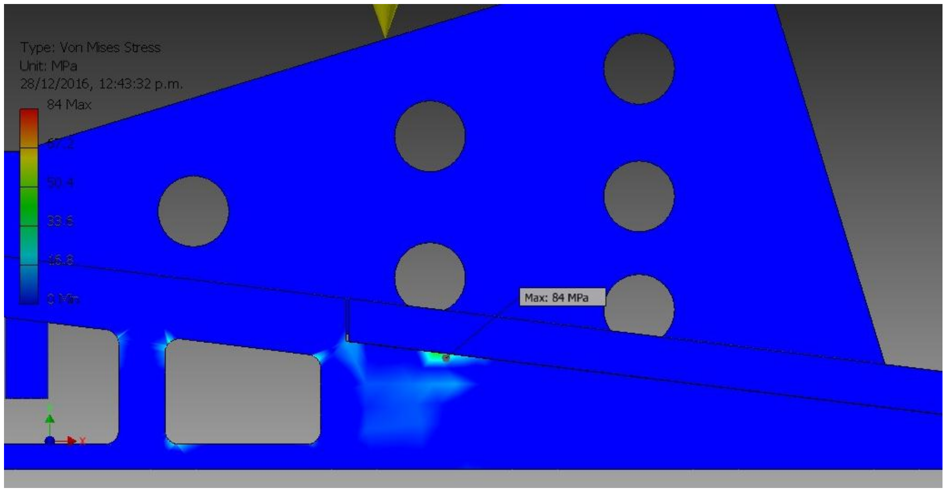

Fig.67 Maximum Von – Mises Stress

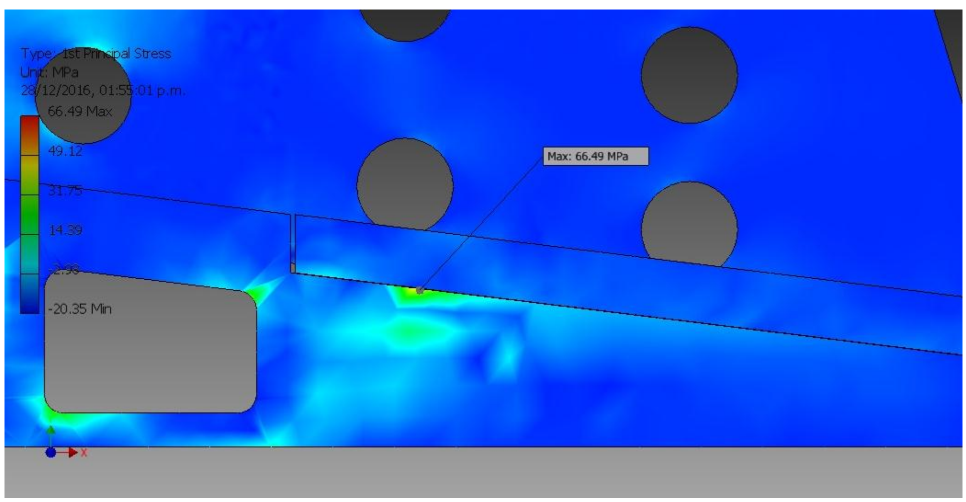

Fig.68 Maximum 1st Principal Stress

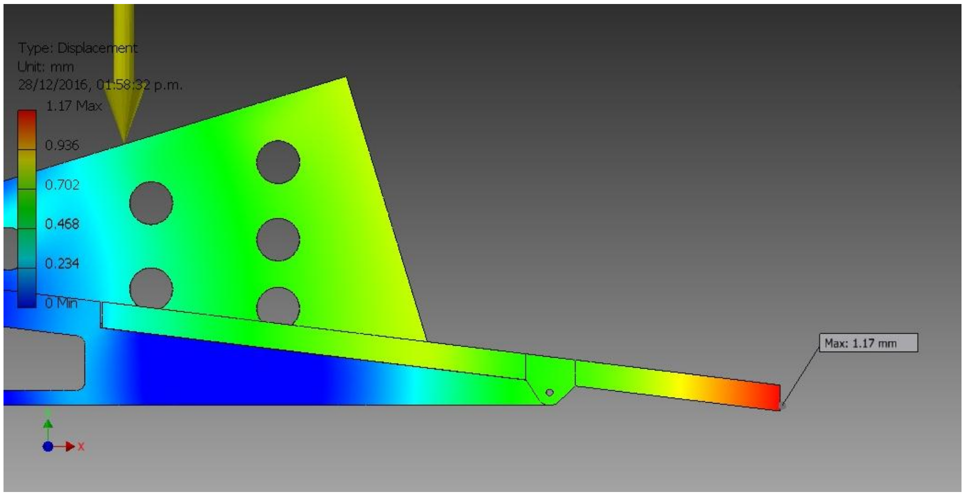

Fig.69 Maximum point of Displacement

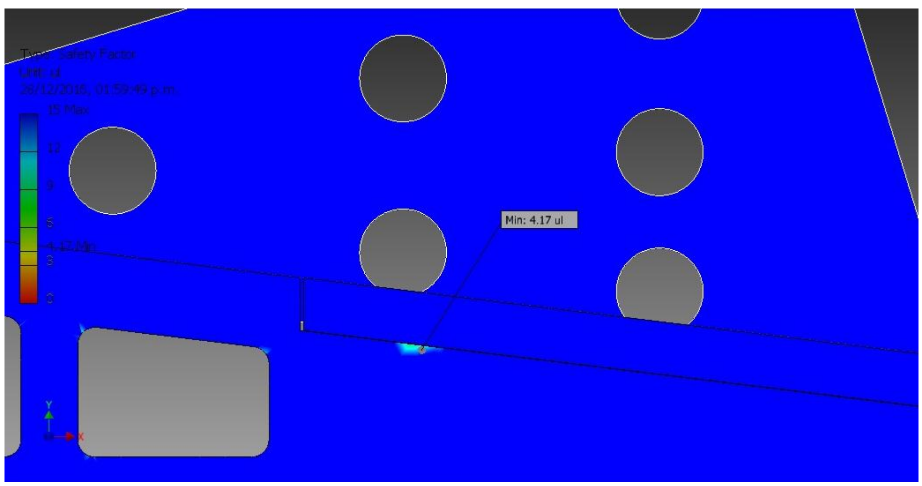

Fig.70 Minimum point of Safety Factor

18.CONCLUSIONS

In every ship yards optimization of economic efficiency is of paramount importance, even more in the current shipping industry market conditions, therefore it follows that efforts should be taken to improve the efficiency in each of the productive processes. Most conventional shipyards are large scale operations, which means that most large ship yards have carefully studied and developed their ship launching procedures.

Launch procedures may still present difficulties for small ship yards so in this project we are presenting a special case where the ship launch, which is a major task, can have an acceptable efficiency.

The ship launching procedure presented in this thesis, elaborated by the Author as an original idea, may be applied in different types of ship yards in different regions of the World. More importantly, this procedure may be used in ship yards with launch problems or located in seas, lakes or rivers with traffic difficulties near the ship yard.

With this methodology it is possible to model the launch process even when the slipway, floating dock or cranes are busy, unavailable or tied up on other tasks. Also, this methodology can be used for launching metallic structures like construction blocks for the offshore industry. This methodology is a new resource for the shipyard because it can free space at the shipyard by transferring the ship being build or repaired to a different location for launch. This methodology is flexible enough so it can be applied to all kinds of ships and on the majority of shipyards, specially small shipyards. As ships can be transferred away from the shipyard it is no longer necessary to get a permit or authorization from maritime or port authorities, which makes the launch no longer dependent on them.

An important result of this project is that the cost is comparatively low versus other launch methods, as the equipment has a low cost and can be used repeated times. The design of the portable slipway allows for ship launch avoiding an impact or damage between the ship and the floating pontoon. The design allows for transferring the ship to the floating pontoon regardless of the water level, because jacks will adjust the level of the portable slipway.

Finally, this method requires less time for ship launch which reduces the cost because it only requires an appropriate floating pontoon and maybe tugboats. Cranes or a floating dock are no longer required.

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ANNEX 1

Matlab cod of Modeling of Ship Launch

```
clc,clear all


% % ---------------------------------------------------------------------
% % ---------------------------------------------------------------------
% % Modeling of transversal ship launching from potoon
% % ---------------------------------------------------------------------
% % ---------------------------------------------------------------------

% DATA OF PONTTON
Dp=2500;        % D_p         = Weight of displacement of pontoon (tn)
Lp=65;          % L_p         = Lenght of pontoon(m)
Bp=18;          % B_p         = Breadth of pontoon(m)
Tp=2.5;         % T_p         = Draft of pontoon(m)
Hp=3.0;         % H_p         = Depth of pontoon(m)

% DATA OF SHIP

Dc=1000;         % D_c        = Weight of ship in launching  (tn)
L=85;            % L          = Lenght of ship(m)
B=12;            % B          = Breadth of ship(m)
T=3.5;           % T          = Draft of ship(m)


% DATA OF SLIPTRACK


beta=0.125;     % a      = Slope of slipway track
fd=0.04;        % f_d    = Coefficient of dynamic friction
hx=0.5;         % diference of level by jacks

% OTHERS DATA

sigma=1;        % sig=Specific weight of water (m)
g=9.81;         % Gravity force

% % ---------------------------------------------------------------------
% % Calculation
% % ---------------------------------------------------------------------



Eo=Hp-Tp+Bp*tan(beta)+hx;                    % E_0       = Distance from the
axis O2 to the water horizon (m)
h2=0.5*(T+Bp*tan(beta)+hx)*cos(beta);        % H_2       = Elevation ot the
center of gravity over axis ¨s¨ in second period (m)
hk=h2;                                       % H         = Elevation ot the
center of gravity over slip plane (m) (take iqual H2)
H5=Hp+hx;                                    % H_5       = Height on side of
pontoon from the bottom up to the threshold (m)
s1x=0;                                       % s_1       =Lenght of part of
coast where is located the slipway track(m)
e=0.0001;                                     % e         = Separation of
axis of coast abutments to wall (m)(Take e=0)
```

```
lA=Hp+hx+Bp*tan(beta);                     % l_A       = Separation of hull of pontoon from axis of coast abutments (m)(Take lA maximun Eo)
lb=Bp;                                     % l_b       = Distance of tranfer of moment of inertia of mass of pontoon relative to axis O_4 x (m)(Take lb maximun Bp)
H2p=0.5*(hx+Hp+Bp*tan(beta));              % H_2p      = Length of the perpendicular lowered from the center of gravity of the pontoon over the slip plane (m)
zGp=0.5*Hp;                                % z_(G_p ) = Ordinate of center of gravity of the potoon (m)
JGp=Dp*Bp*Bp/g;                            % J_(G_p ) = Moment of inertia of mass of potoon relative to central axis passing through center of gravity (tn.m.s^2)
lGp=((Eo)^2+ (0.5*Bp)^2)^(0.5);            % l_(G_p ) = Distance of transfer of moment of inertia of mass of potoon relative to axis O_2 x (m)
nGp=0.5*Bp;                                % n_(G_p ) = Separation of center of gravity of potoon to axis O_2  (m)
ap=0.5*(Bp-Tp);                            % a_p       = Elevation of center of gravity of potoon over his center of buoyancy  in initial position (m)
sGp=0.5*(((Bp*tan(beta))^2+Bp^2)^(0.5))+0.5*(Hp*Bp*tan(beta))*sin(beta);
% SG_p = Distance from the point O_2  to the perpendicular lowered on slip plane (m)
summ=(1/12)*Tp*Bp^3;                       % s(n=1)^m?X_X   = Sum of  the moments of inertia of the free surface area relative to the central axis,perpendicular to the slip plane (m^4)


% First period
% % --------------------------------------------------------------------
S1=((2*g*(beta-fd)*s1x)^(0.5));

velos2o=S1;


% Ship position relative to pontoon
s2o=(-1)*(h2*beta);


% Second period
% % --------------------------------------------------------------------

% Inertial moment of potoon,relative to axis O2x
Jpo2=JGp+(Dp/g)*((lGp)^2);

lamdaoE=(3.1416/8)*(sigma/g)*Lp*((Bp)^2);

lamdaoO=(1/81.5)*(sigma/g)*Lp*((Bp)^4);

kVp=sigma*Lp*Bp*nGp*(2/3)*(nGp+0.5*Bp);

J=Jpo2+lamdaoE*(nGp^2)+lamdaoO;
```

```
a=Dc*g*((beta-fd)/(2*J));

b=Dc*velos2o/J;

c=Dc*h2*beta/J;

k2=(kVp-Dp*ap-sigma*summ)/J;

B2=a/k2;

B1=b/k2;

Bo=(-1)*(c/k2)-(2*a/k2^2);    %

C1=Bo*(-1);                   %

C2=((-1)*B1)/(k2^(0.5));      %

p=2*velos2o/(g*(beta-fd));

q=(-1)*(2*(h2*beta+(kVp-Dp*ap-sigma*summ)/(sigma*Lp*Bp*nGp)))/(g*(beta-
fd));

% Time of second period
t2=(-1)*0.5*p+(((0.5*p)^2)-q)^(0.5);

kt=(k2^(0.5))*t2;

ktgrad=360*kt/(2*3.1416);

comkt=180-ktgrad;

argcoskt=cos(kt);

argsinkt=sin(kt);

v2=C1*cos(kt)+C2*sin(kt)+Bo+B1*t2+B2*(t2^2);


% Angle of heel  of pontoon in the finish of 2 period (grades)
v2grad=v2*360/(2*3.1416);


% Angular velocity of pontoon in in the finish of 2 period (rad/sec)
velov2=(-1)*(k2^(0.5))*C1*sin(kt)+(k2^(0.5))*C2*cos(kt)+B1+2*B2*t2;

% Position of pontoon in the finish of 2 period
s2=0.5*g*(beta-fd)*(t2^(2))+velos2o*t2+s2o;

% Velocity of ship in the finish of 2 period
velos2x=g*(beta-fd)*t2+velos2o;
```

```
velos3o=velos2x;

% Thrid period
% % ---------------------------------------------------------------------


% Ship position in the initial of thrid period (m)
s3o=s2-sGp;

% Displacement of potoon in the finish of second period (m3)
Vp2=(Dp/sigma)+Lp*Bp*nGp*v2;

J1=JGp+lamdao0;

fi=beta+v2;

figrad=fi*360/(2*3.1416);

argcosfi=cos(fi);

argsinfi=sin(fi);

a1=Dc*g*cos(fi)*(sin(fi)-fd*cos(fi))/(2*J1);

b1=(Dp*cos(fi)*velos3o)/(J1);  %

c1=(Dp*cos(fi)*s3o)/(J1);      %

k21=sigma*(Vp2*(Lp*(Bp^3)/(12*Vp2)+Vp2/(2*Lp*Bp)-zGp)-summ)/J1;

B21=a1/k21;

B11=b1/k21;

Bo1=(c1/k21)-(2*a1/(k21^2));

C11=v2-Bo1;

C21=(v2-B11)/(k21^(0.5));

deltayp=lA*cos((acos((nGp-0.5*Bp)/lA)+v2))-e;

deltaVp2=Lp*Bp*nGp*v2;

D=0.5*g*sin(2*fi)*(Dc+sigma*deltaVp2)/Dp;

% Coordinat center of gravity of potoon in the finish of second period
(m)
zp2=sGp*sin(fi)+H2p*cos(fi);

% Horizontal velocity of center of gravity of potoon in the finish of
second period (m/s)
```

```
veloyp2=zp2*velov2;

p1=2*veloyp2/D;

q1=(1)*2*deltayp/D;                    %

% Time of thrid period (s)
t3=(-1)*0.5*p1+(((0.5*p1)^2)-q1)^(0.5); %

kt1=((k21)^(0.5))*t3;

kt1grad=360*kt1/(2*3.1416);

comkt1=180-kt1grad;

argcoskt1=cos(kt1);

argsinkt1=sin(kt1);

v3=C11*cos(kt1)+C21*sin(kt1)+Bo1+B11*t3+B21*(t3^2);

% Angle of heel  of pontoon in the finish of 3 period (grades)
v3grad=360*v3/(2*3.1416);

% Angular velocity of pontoon in in the finish of 3 period (rad/sec)
velov3=(k21^(0.5))*C11*sin(kt1)+(k21^(0.5))*C21*cos(kt1)+B11+2*B21*t3;

% Ship position of ship relative of center of gravity of pontoon in in
the finish of 3 period (m)
s3=0.5*g*(sin(fi)-fd*cos(fi))*(t3^2)+velos3o*t3+s3o;

% Velocity of ship in in the finish of 3 period (m/s)
velos3x=g*(sin(fi)-fd*cos(fi))*t3+velos3o;

% Four period
% % -------------------------------------------------------------------

velos4o=velos3x;

Jpo4=JGp+Dp*(lb^2)/g;

s4o=0.5*Bp-zGp*beta+s3;

so5=Bp-H5*beta;

fi2=beta+v3;

fi2grad=fi2*360/(2*3.1416);

argcosfi2=cos(fi2);

argsinfi2=sin(fi2);
```

```
J2=Jpo4+0.25*lamdaoE*(Bp^2)+lamdaoO;

yp2=0.5*Bp+zGp*v3;

a2=Dc*g*(cos(fi2))*((sin(fi2))-fd*cos(fi2))/(2*J2);

b2=Dc*(cos(fi2))*velos4o/J2;                         %

c2=(Dc*(cos(fi2))*s4o-(sigma*Vp2-Dp)*yp2)/J2;        %

k22=sigma*(Vp2*(Lp*(Bp^3)/(12*Vp2)+Vp2/(2*Lp*Bp)-zGp)-summ)/J2;

B22=a2/k22;

B12=b2/k22;

Bo2=(c2/k22)-(2*a2/(k22^2));

C12=v3-Bo2;

C22=(v3-B12)/(k22^(0.5));

p2=2*s4o/(g*((sin(fi2))-fd*cos(fi2)));

q2=(-1)*2*(so5-s4o-hk*beta)/(g*((sin(fi2))-fd*cos(fi2)));

% Time of 4 period (s)
t4=(-1)*0.5*p2+((((0.5*p2)^2)-q2)^(0.5));

kt2=((k22)^(0.5))*t4;

kt2grad=kt2*360/(2*3.1416);

argcoskt2=cos(kt2);

argsinkt2=sin(kt2);

v4=C12*cos(kt2)+C22*sin(kt2)+Bo2+B12*t4+B22*(t4^2);

% Angle of heel  of pontoon in the finish of 4 period (grades)
v4grad=360*v4/(2*3.1416);

% Angular velocity of pontoon in in the finish of 4 period (rad/sec)
velov4=(-
1)*(k22^(0.5))*C12*sin(kt2)+(k22^(0.5))*C22*cos(kt2)+B12+2*B22*t4;

% Linear velocity of center of gravity os ship in the finish of 4 period
(m/s)
velos4x=g*(sin(fi2)-fd*cos(fi2))*t4+velos4o;

% Height of inmersion of bilge strake of potoon (m)
```

```
To4=lA*sin((asin((Eo+Tp)/lA))+v2)-Eo;

% Height of position of point 5,in the finish of 4 period (m)
Tox=H5*cos(v4)-Bp*sin(v4)-To4;

% Proyection of initial velocity of center of gravity of ship O5y in the
5
%  period
veloy5o=velos4x*cos(beta-v4);

% Proyection of initial velocity of center of gravity of ship O5z in the
5
%  period
veloz5o=velos4x*sin(beta+v4);

% Cordinat Y5O of center of gravity of ship in the initial of 5 period

y5o=hk*sin(v4);



xf=[0 t2 t2+t3 t2+t3+t4];

yf=[0 v2grad v3grad v4grad];

yv=[0 velos2o velos3o velos4o];

yr=[0 velos2x velos3x velos4x];

ys=[0 velov2 velov3 velov4];

subplot(3,1,1),plot(xf,yf,'-or'),title('Time [s] vs Angle of heel of
pontoon [Grades]');
xlabel(' [s] ');
ylabel('[Grades]');
grid on
grid minor

subplot(3,1,2),plot(xf,yr,'-xm'),title('Time [s] vs Linear velocity of
center of gravity of ship [m/s]');
xlabel(' [s] ');
ylabel('[m/s]');
grid on
grid minor

subplot(3,1,3),plot(xf,ys,'-*b'),title('Time [s] vs Angular velocity of
pontoon [rad/s] ');
xlabel(' [s] ');
ylabel('[rad/s]');
grid on
grid minor

hold on
```

ANNEX 2

Autodesk® Inventor® - Stress Analysis of Portable slipway

Stress Analysis Report 200tn

Autodesk®

Analyzed File:	Assembly rev2-1000t.iam
Autodesk Inventor Version:	2013 (Build 000000000, 000)
Creation Date:	00/00/2016, 12:16 p.m.
Simulation Author:	Edwin Salas
Summary:	

⊟ Project Info (iProperties)

⊟ Summary

Author usuario

⊟ Project

Part Number	Assembly rev2-1000t
Designer	Edwin Salas
Cost	S/. 0.00
Date Created	00/00/2016

⊟ Status

Design Status WorkInProgress

⊟ Physical

Mass	38431.6 kg
Area	341346000 mm^2
Volume	4.8833E+009 mm^3
Center of Gravity	x=-12629.7 mm y=1673.2 mm z=-2337.8 mm

Note: Physical values could be different from Physical values used by FEA reported below.

⊟ Simulation:1a

General objective and settings:

Design Objective	Single Point
Simulation Type	Static Analysis
Last Modification Date	27/12/2016, 11:03 a.m.
Detect and Eliminate Rigid Body Modes	No
Separate Stresses Across Contact Surfaces	No
Motion Loads Analysis	No

Mesh settings:

Avg. Element Size (fraction of model diameter)	0.05
Min. Element Size (fraction of avg. size)	0.1
Grading Factor	1.5
Max. Turn Angle	20 deg
Create Curved Mesh Elements	No
Use part based measure for Assembly mesh	Yes

⊟ Material(s)

Name	Steel, Carbon	
	Mass Density	7.87 g/cm^3
General	Yield Strength	350 MPa
	Ultimate Tensile Strength	420 MPa
	Young's Modulus	200 GPa
Stress	Poisson's Ratio	0.29 ul
	Shear Modulus	77.5194 GPa
	Expansion Coefficient	0.000012 ul/c
Stress Thermal	Thermal Conductivity	52 W/(m K)
	Specific Heat	486 J/(kg c)
Part Name(s)	Slip2a- 1000t jack2 jack2 jack2 jack2 jack2 jack3 jack3 jack3 jack3 jack3 jack1 jack1	

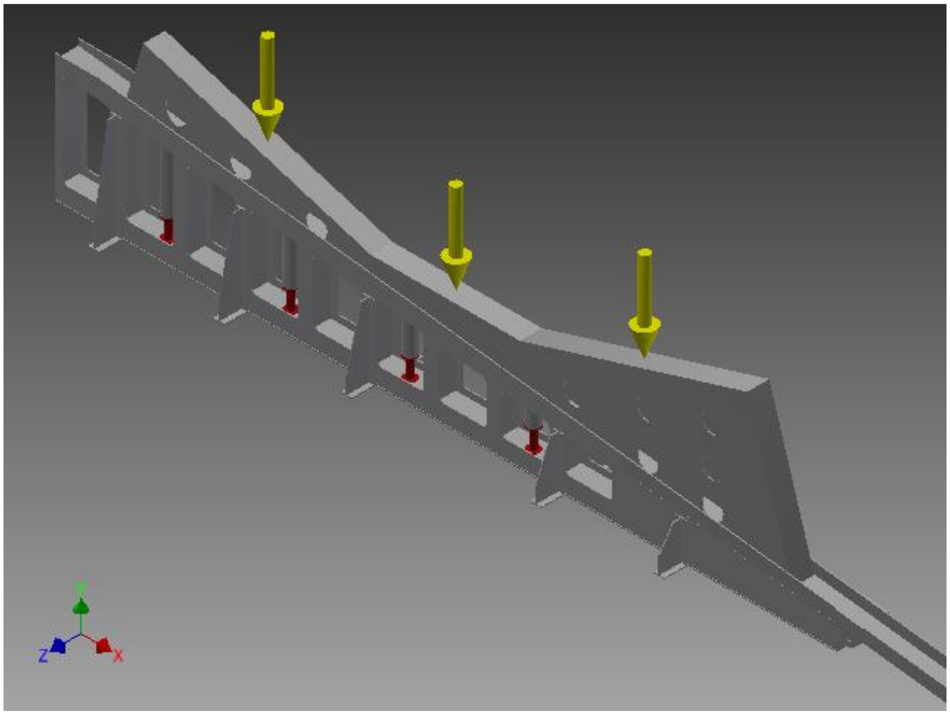
jack1
jack1
jack1
Slip5- 1000t
reforce 900-1000t
reforce 1200-1000t
reforce 1700-1000t
reforce 2000-1000t
reforce 2400-1000t
reforce 900-1000t_MIR
reforce 1200-1000t_MIR
reforce 1700-1000t_MIR
reforce 2000-1000t_MIR
reforce 2400-1000t_MIR
Slip6- 1000t
Slip8- 1000t

⊟ Operating conditions

⊟ Gravity

Load Type	Gravity
Magnitude	9810.000 mm/s^2
Vector X	0.000 mm/s^2
Vector Y	-9810.000 mm/s^2
Vector Z	-0.000 mm/s^2

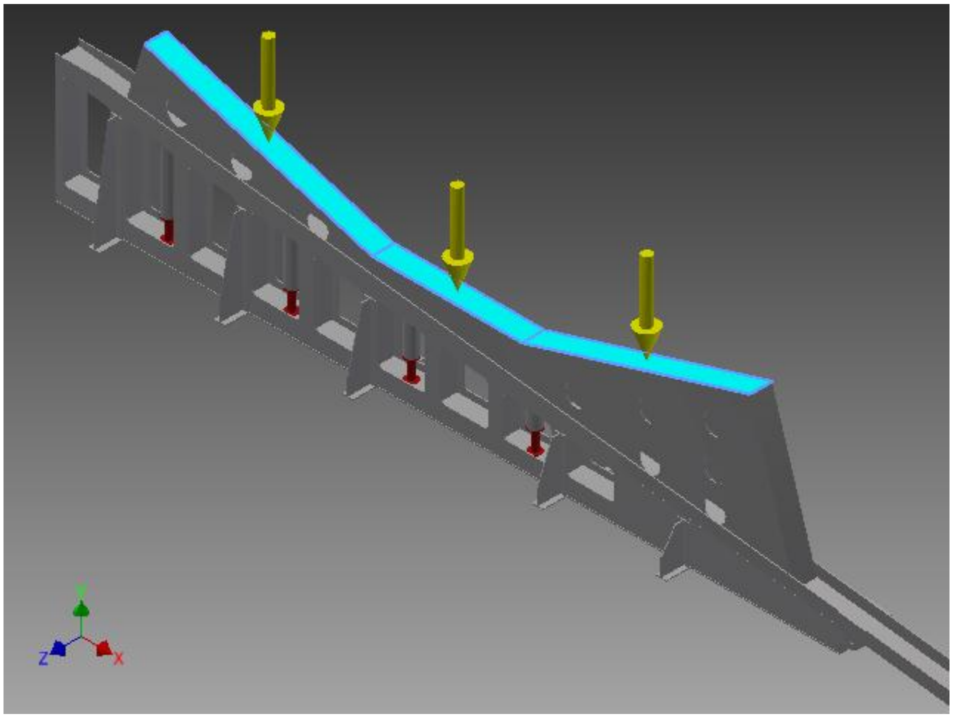
⊟ Selected Face(s)



⊟ Force:1

Load Type	Force
Magnitude	2000000.000 N
Vector X	0.000 N
Vector Y	-2000000.000 N
Vector Z	0.000 N

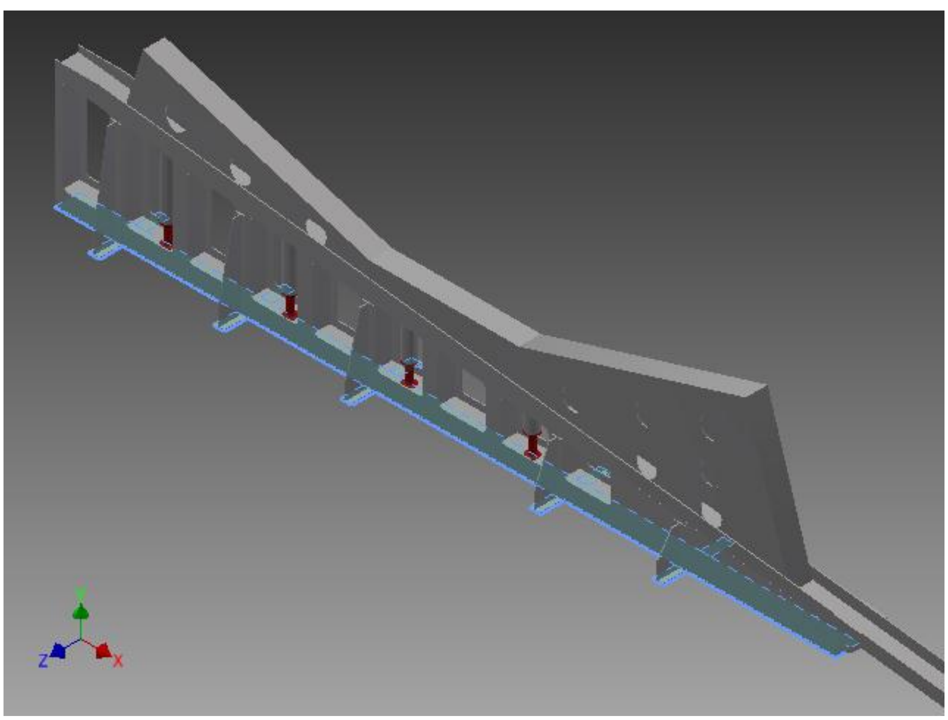
⊟ Selected Face(s)



⊟ Fixed Constraint:1

Constraint Type Fixed Constraint

⊟ Selected Face(s)



⊟ Contacts (Bonded)

Name	Part Name(s)
Bonded:1	Slip2a- 1000t:1 jack2:1
Bonded:2	Slip2a- 1000t:1 jack2:2
Bonded:3	Slip2a- 1000t:1 jack2:3
Bonded:4	Slip2a- 1000t:1 jack2:4
Bonded:5	Slip2a- 1000t:1 jack2:5
Bonded:6	Slip2a- 1000t:1 jack1:1
Bonded:7	Slip2a- 1000t:1 jack1:2
Bonded:8	Slip2a- 1000t:1 jack1:3
Bonded:9	Slip2a- 1000t:1 jack1:4
Bonded:10	Slip2a- 1000t:1 jack1:5
Bonded:11	Slip2a- 1000t:1 Assembly total reforce-1000t:1/Slip5- 1000t:1
Bonded:12	Slip2a- 1000t:1 Assembly total reforce-1000t:1/reforce 900-1000t:1
Bonded:13	Slip2a- 1000t:1 Assembly total reforce-1000t:1/reforce 1200-1000t:1
Bonded:14	Slip2a- 1000t:1 Assembly total reforce-1000t:1/reforce 1700-1000t:1
Bonded:15	Slip2a- 1000t:1 Assembly total reforce-1000t:1/reforce 2000-1000t:1
Bonded:16	Slip2a- 1000t:1 Assembly total reforce-1000t:1/reforce 2400-1000t:1
Bonded:17	Slip2a- 1000t:1 Assembly total reforce-1000t:1/reforce 900-1000t_MIR:1
Bonded:18	Slip2a- 1000t:1 Assembly total reforce-1000t:1/reforce 1200-1000t_MIR:1
Bonded:19	Slip2a- 1000t:1

	Assembly total reforce-1000t:1/reforce 1700-1000t_MIR:1
Bonded:20	Slip2a- 1000t:1 Assembly total reforce-1000t:1/reforce 2000-1000t_MIR:1
Bonded:21	Slip2a- 1000t:1 Assembly total reforce-1000t:1/reforce 2400-1000t_MIR:1
Bonded:22	Slip2a- 1000t:1 Slip6- 1000t:1
Bonded:23	Slip2a- 1000t:1 Slip6- 1000t:1
Bonded:24	Slip2a- 1000t:1 Slip8- 1000t:1
Bonded:25	jack2:1 jack3:5
Bonded:26	jack2:2 jack3:4
Bonded:27	jack2:3 jack3:3
Bonded:28	jack2:4 jack3:2
Bonded:29	jack2:5 jack3:1
Bonded:30	jack3:1 jack1:1
Bonded:31	jack3:1 Assembly total reforce-1000t:1/Slip5- 1000t:1
Bonded:32	jack3:2 jack1:2
Bonded:33	jack3:2 Assembly total reforce-1000t:1/Slip5- 1000t:1
Bonded:34	jack3:3 jack1:3
Bonded:35	jack3:3 Assembly total reforce-1000t:1/Slip5- 1000t:1
Bonded:36	jack3:4 jack1:4
Bonded:37	jack3:4 Assembly total reforce-1000t:1/Slip5- 1000t:1
Bonded:38	jack3:5 jack1:5
Bonded:39	jack3:5 Assembly total reforce-1000t:1/Slip5- 1000t:1
Bonded:40	jack1:1

	Assembly total reforce-1000t:1/Slip5- 1000t:1
Bonded:41	jack1:2 Assembly total reforce-1000t:1/Slip5- 1000t:1
Bonded:42	jack1:3 Assembly total reforce-1000t:1/Slip5- 1000t:1
Bonded:43	jack1:4 Assembly total reforce-1000t:1/Slip5- 1000t:1
Bonded:44	jack1:5 Assembly total reforce-1000t:1/Slip5- 1000t:1
Bonded:45	Assembly total reforce-1000t:1/Slip5- 1000t:1 Assembly total reforce-1000t:1/reforce 900-1000t:1
Bonded:46	Assembly total reforce-1000t:1/Slip5- 1000t:1 Assembly total reforce-1000t:1/reforce 1200-1000t:1
Bonded:47	Assembly total reforce-1000t:1/Slip5- 1000t:1 Assembly total reforce-1000t:1/reforce 1700-1000t:1
Bonded:48	Assembly total reforce-1000t:1/Slip5- 1000t:1 Assembly total reforce-1000t:1/reforce 2000-1000t:1
Bonded:49	Assembly total reforce-1000t:1/Slip5- 1000t:1 Assembly total reforce-1000t:1/reforce 2400-1000t:1
Bonded:50	Assembly total reforce-1000t:1/Slip5- 1000t:1 Assembly total reforce-1000t:1/reforce 900-1000t_MIR:1
Bonded:51	Assembly total reforce-1000t:1/Slip5- 1000t:1 Assembly total reforce-1000t:1/reforce 1200-1000t_MIR:1
Bonded:52	Assembly total reforce-1000t:1/Slip5- 1000t:1 Assembly total reforce-1000t:1/reforce 1700-1000t_MIR:1
Bonded:53	Assembly total reforce-1000t:1/Slip5- 1000t:1 Assembly total reforce-1000t:1/reforce 2000-1000t_MIR:1
Bonded:54	Assembly total reforce-1000t:1/Slip5- 1000t:1 Assembly total reforce-1000t:1/reforce 2400-1000t_MIR:1
Bonded:55	Slip6- 1000t:1 Slip8- 1000t:1

⊟ Results

⊟ Reaction Force and Moment on Constraints

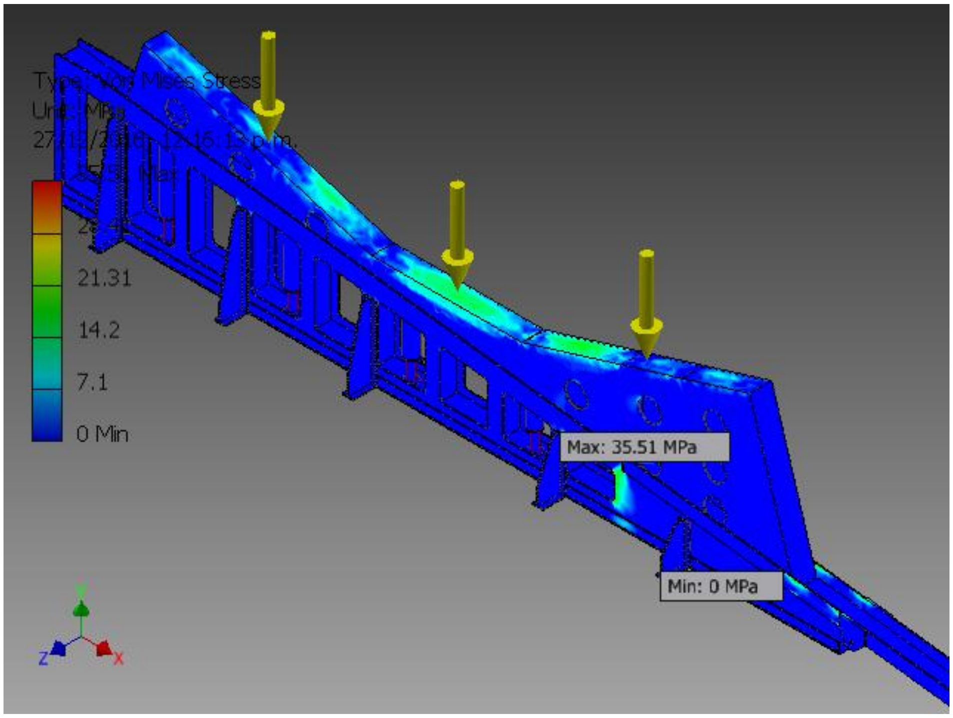
Constraint Name	**Reaction Force**		**Reaction Moment**	
	Magnitude	**Component (X,Y,Z)**	**Magnitude**	**Component (X,Y,Z)**
Fixed Constraint:1	2376740 N	0 N 2376740 N 0 N	88039.1 N m	-13481.4 N m 5814.26 N m 86806.3 N m

⊟ Result Summary

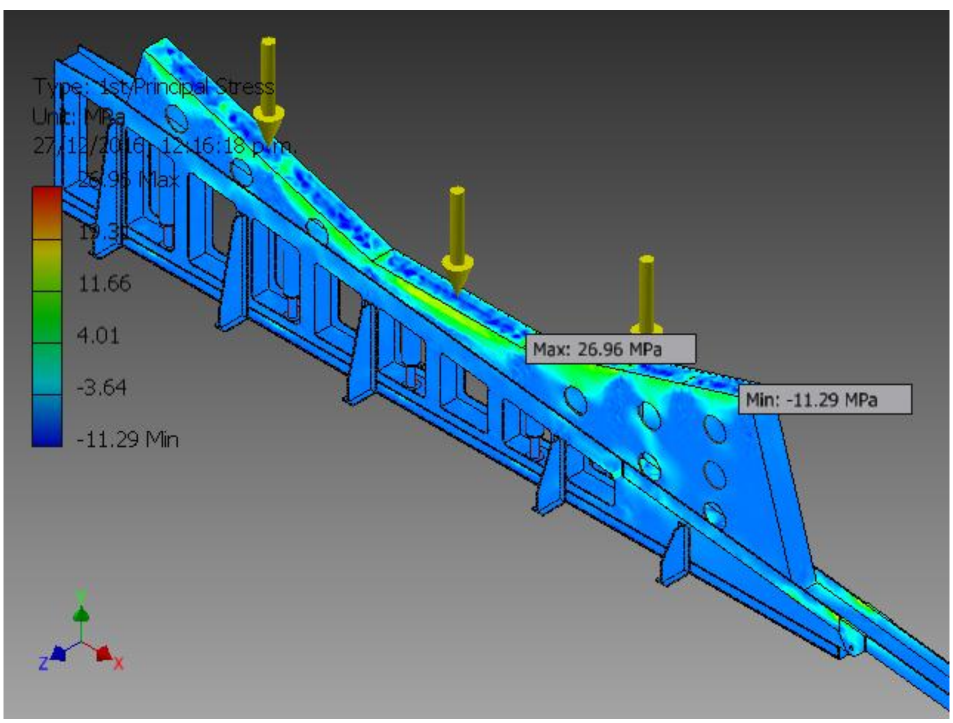
Name	Minimum	Maximum
Volume	4.88333E+009 mm^3	
Mass	38431.8 kg	
Von Mises Stress	0.000127746 MPa	35.511 MPa
1st Principal Stress	-11.2895 MPa	26.9597 MPa
3rd Principal Stress	-38.94 MPa	11.2896 MPa
Displacement	0 mm	0.501022 mm
Safety Factor	9.8561 ul	15 ul
Stress XX	-25.0564 MPa	26.9385 MPa
Stress XY	-17.4477 MPa	10.489 MPa
Stress XZ	-7.15971 MPa	6.39185 MPa
Stress YY	-35.9186 MPa	18.4263 MPa
Stress YZ	-7.79221 MPa	7.46792 MPa
Stress ZZ	-23.4107 MPa	22.2479 MPa
X Displacement	-0.103894 mm	0.166469 mm
Y Displacement	-0.470682 mm	0.0214209 mm
Z Displacement	-0.384363 mm	0.411148 mm
Equivalent Strain	0.000000000610644 ul	0.000157544 ul
1st Principal Strain	-0.00000737953 ul	0.000122994 ul
3rd Principal Strain	-0.00018007 ul	0.0000110102 ul
Strain XX	-0.000124006 ul	0.00011658 ul
Strain XY	-0.000112538 ul	0.0000676538 ul
Strain XZ	-0.0000461801 ul	0.0000412274 ul
Strain YY	-0.000169518 ul	0.0000863414 ul
Strain YZ	-0.0000502598 ul	0.0000481681 ul
Strain ZZ	-0.000109102 ul	0.000094241 ul
Contact Pressure	0 MPa	53.4107 MPa
Contact Pressure X	-9.96378 MPa	9.94806 MPa
Contact Pressure Y	-52.1738 MPa	26.2587 MPa
Contact Pressure Z	-18.1258 MPa	17.1508 MPa

⊟ Figures

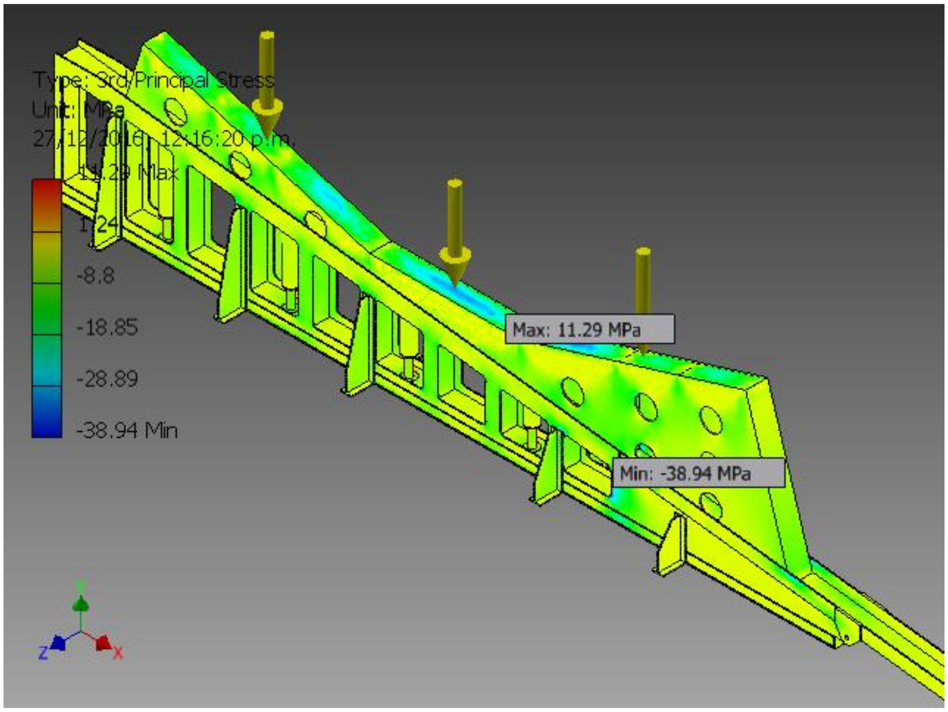
⊟ Von Mises Stress



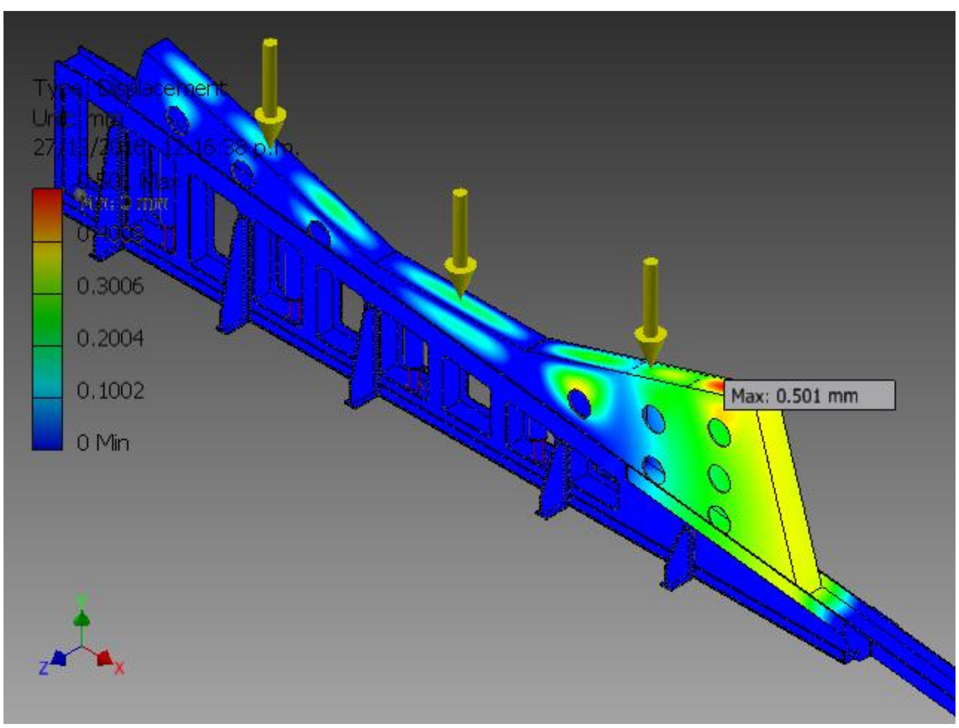
⊟ 1st Principal Stress



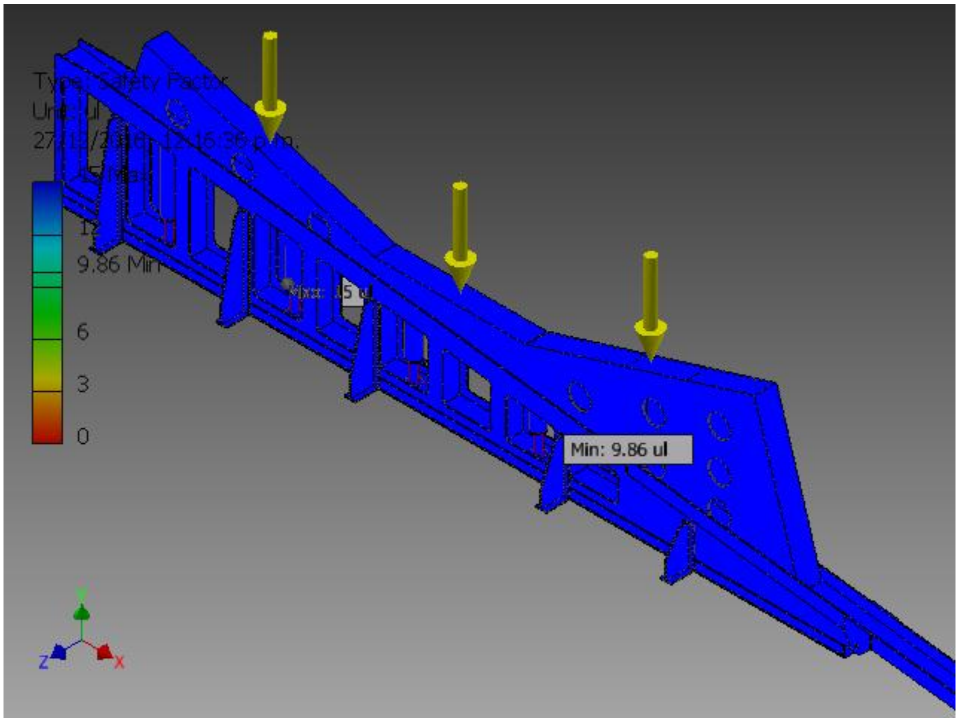
⊟ 3rd Principal Stress



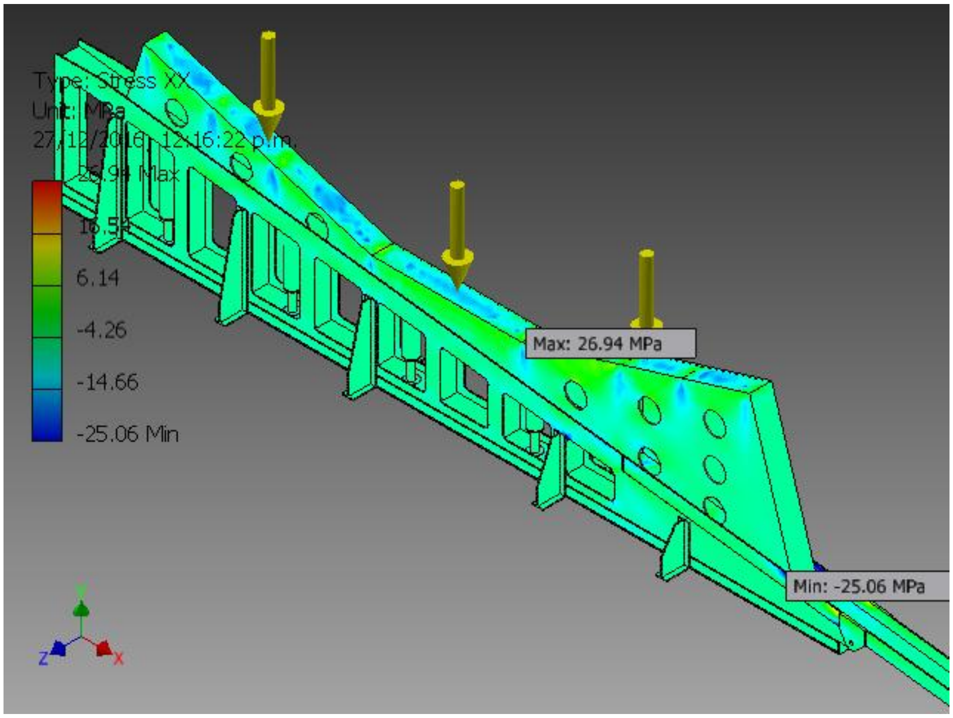
⊟ Displacement



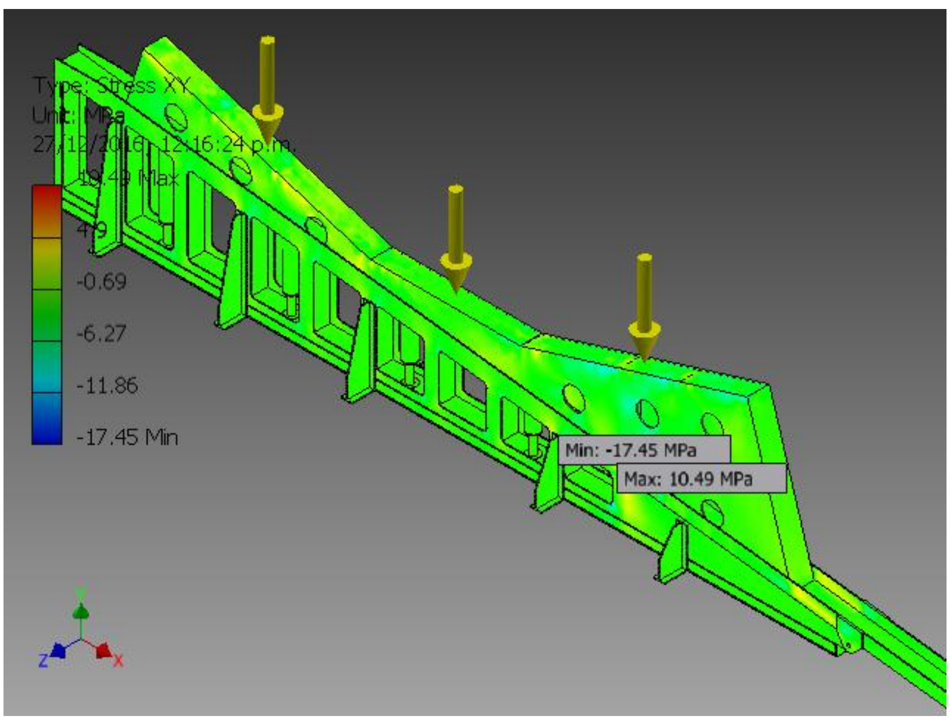
⊟ Safety Factor



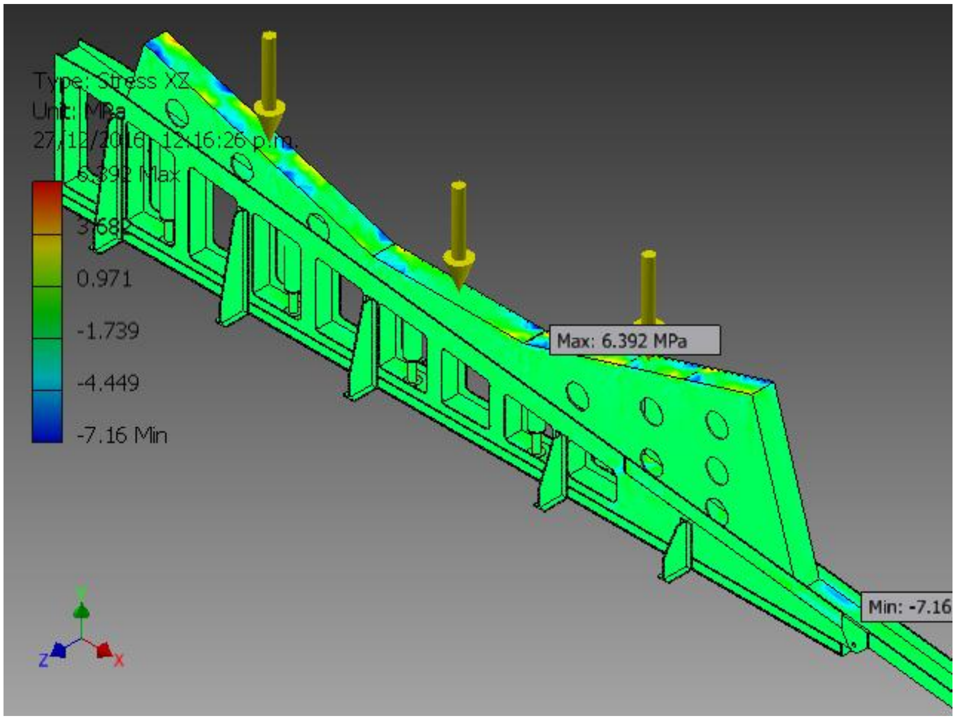
⊟ Stress XX



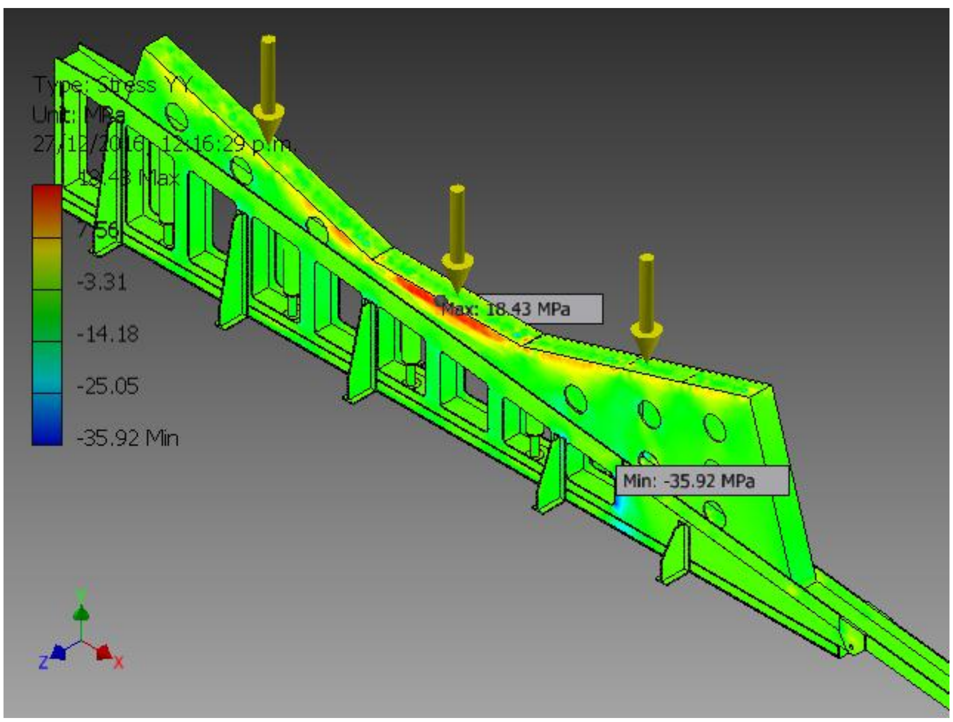
⊟ **Stress XY**



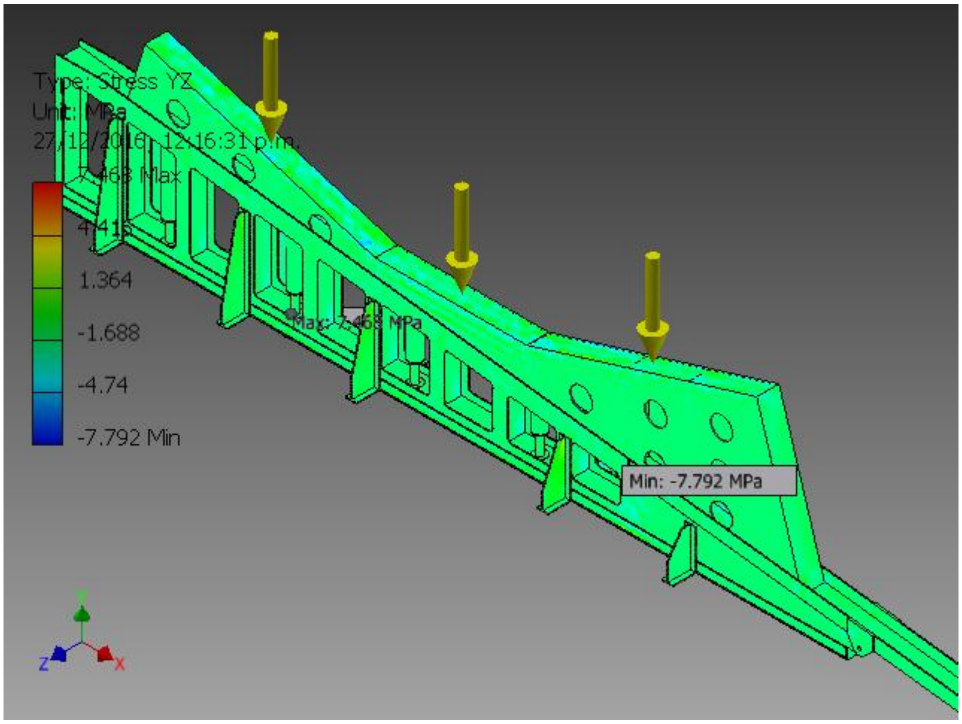
⊟ **Stress XZ**



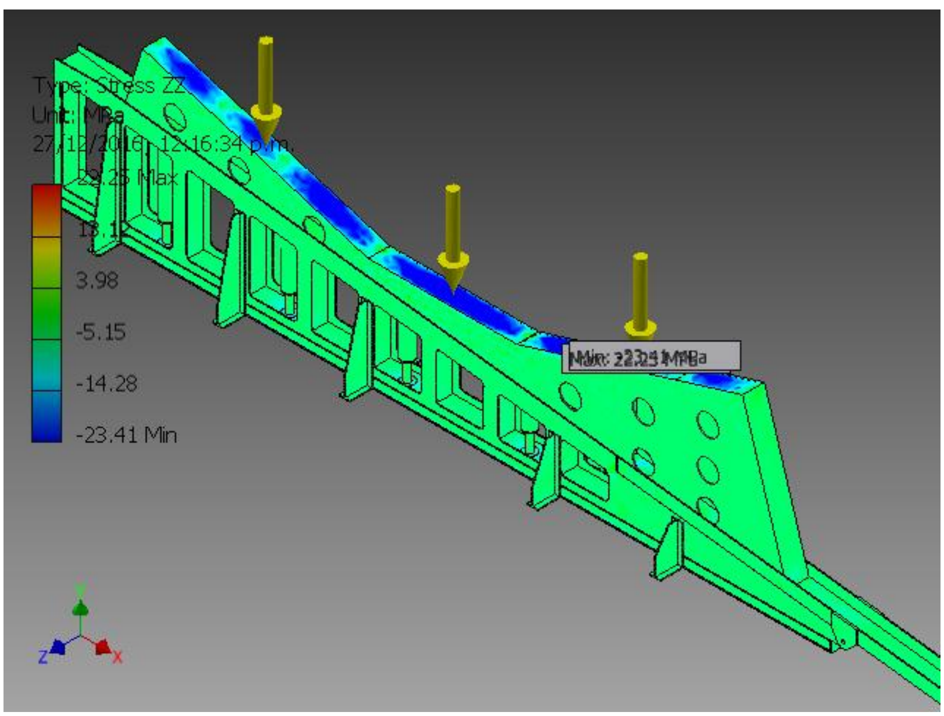
⊟ **Stress YY**



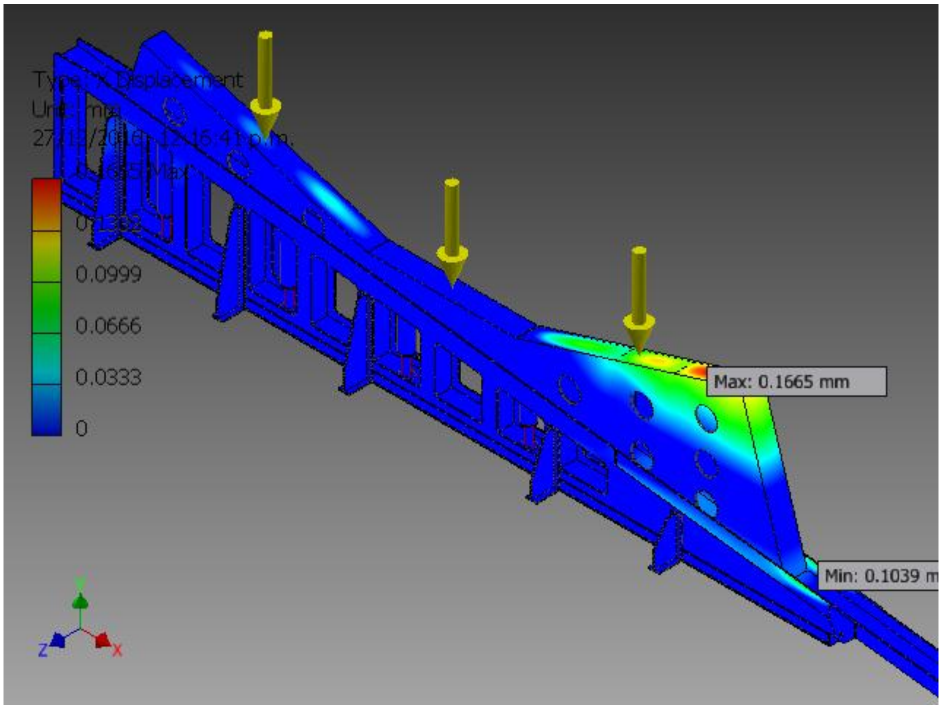
⊟ **Stress YZ**



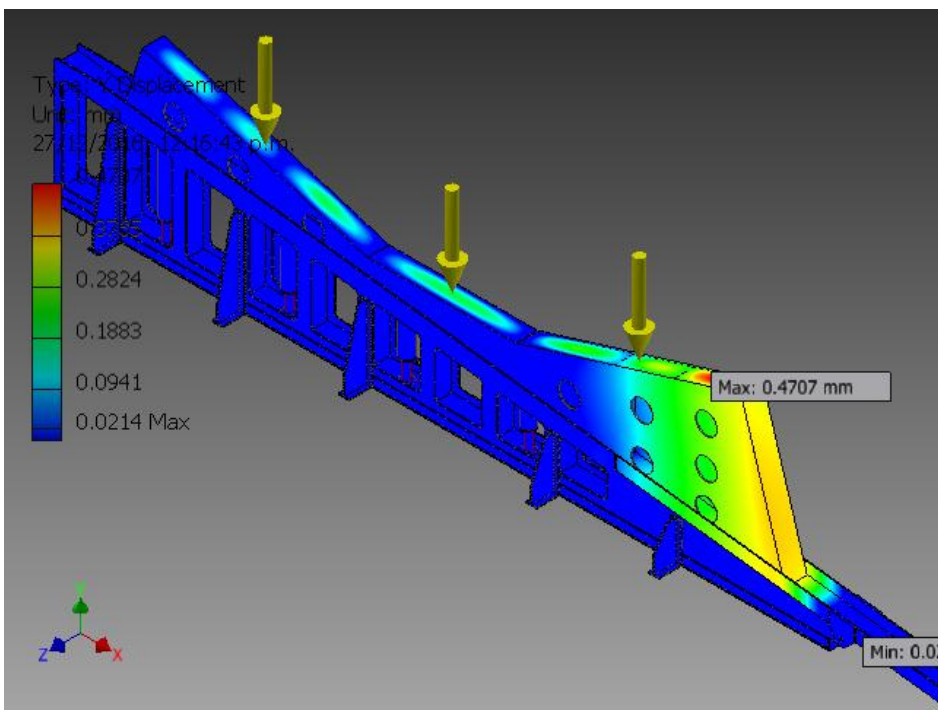
⊟ **Stress ZZ**



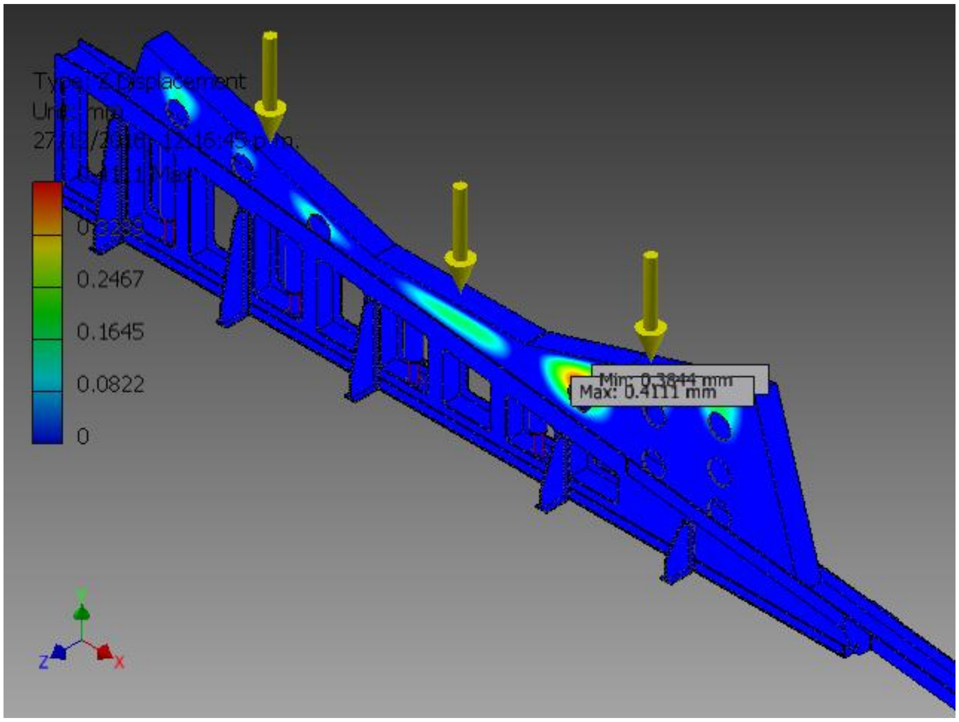
⊟ **X Displacement**



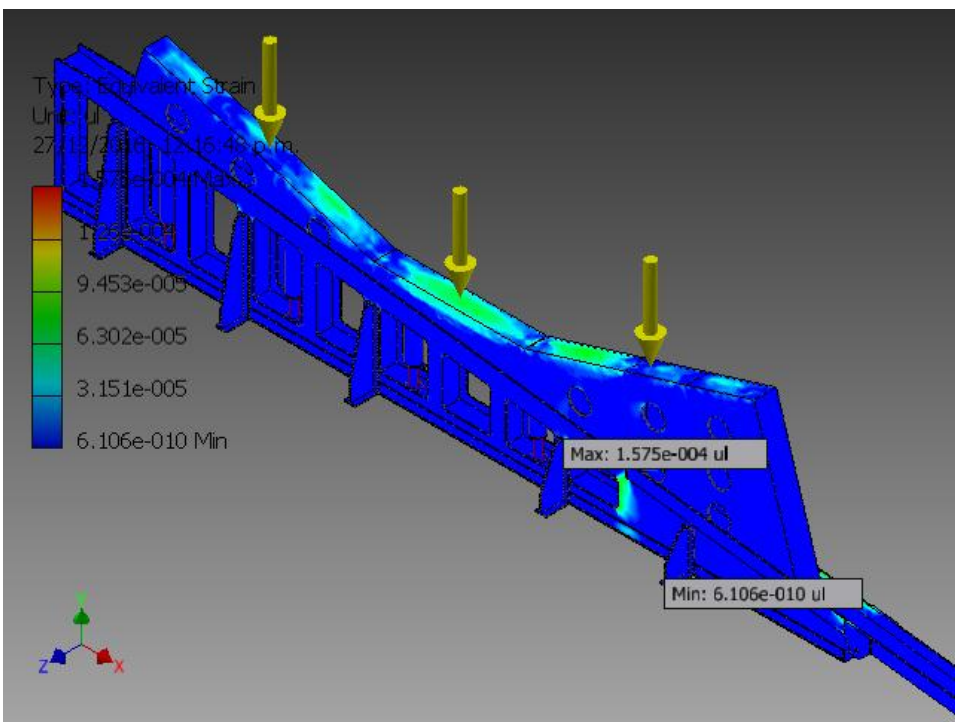
⊟ **Y Displacement**



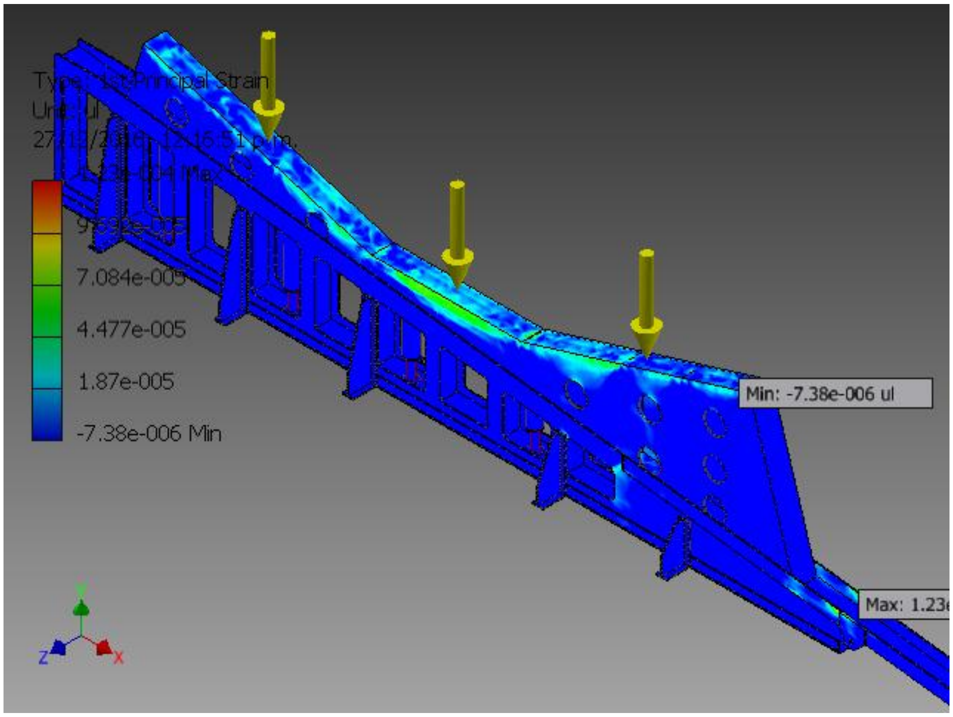
⊟ **Z Displacement**



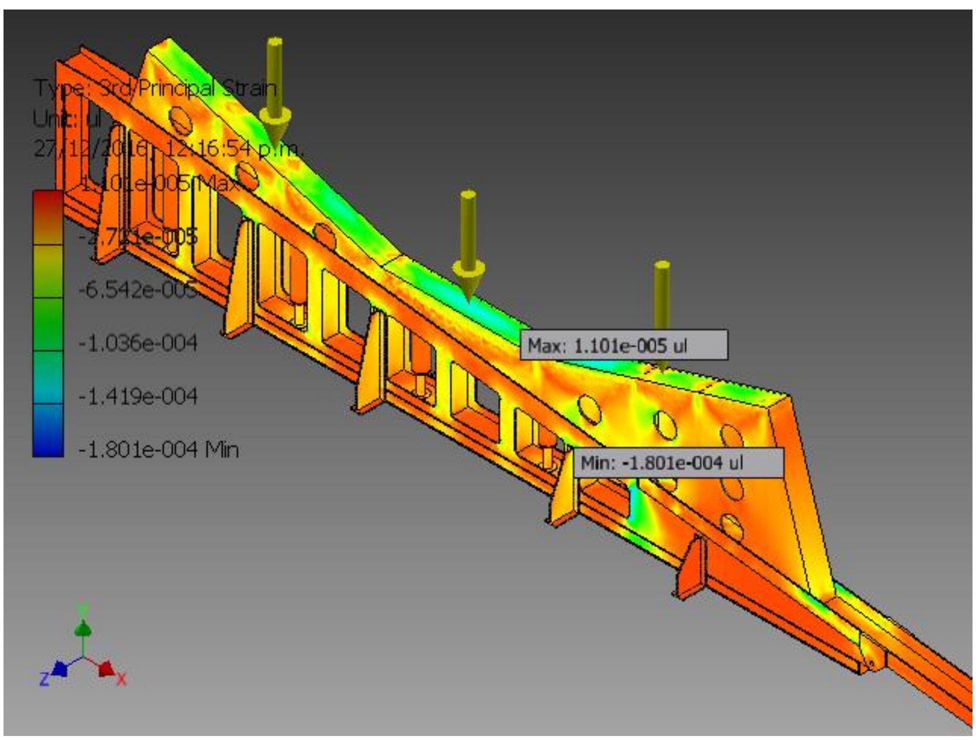
☐ **Equivalent Strain**



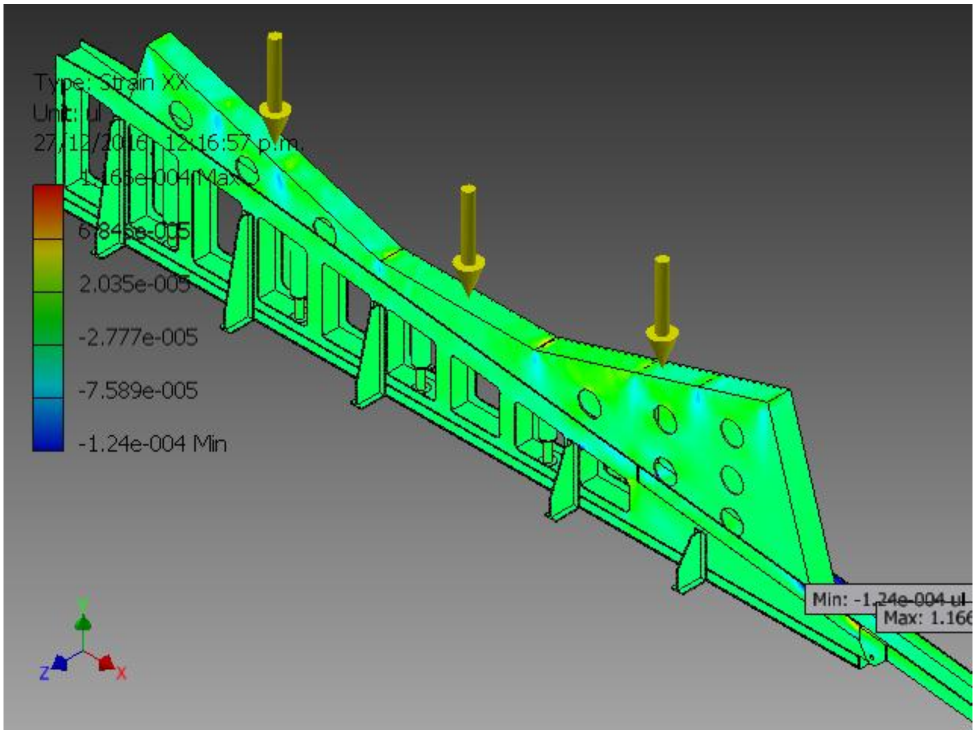
⊟ **1st Principal Strain**



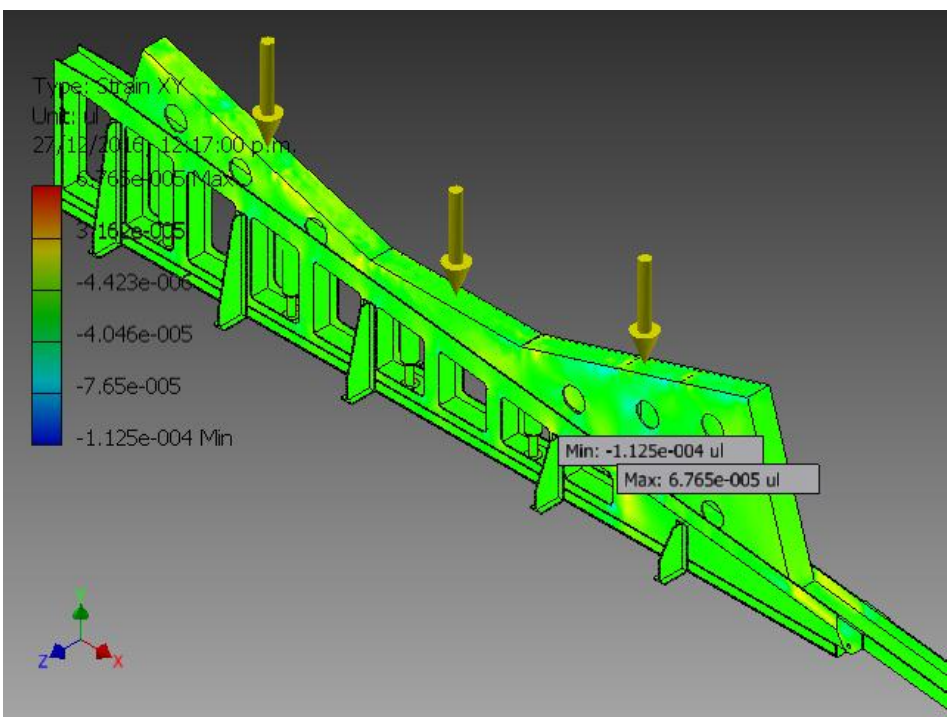
⊟ **3rd Principal Strain**



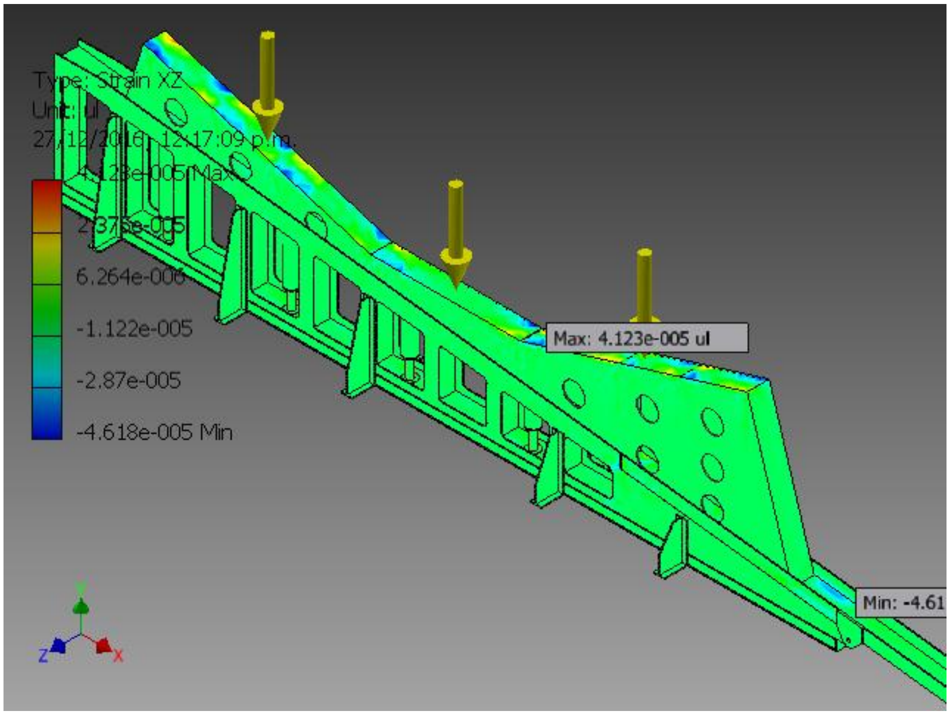
⊟ **Strain XX**



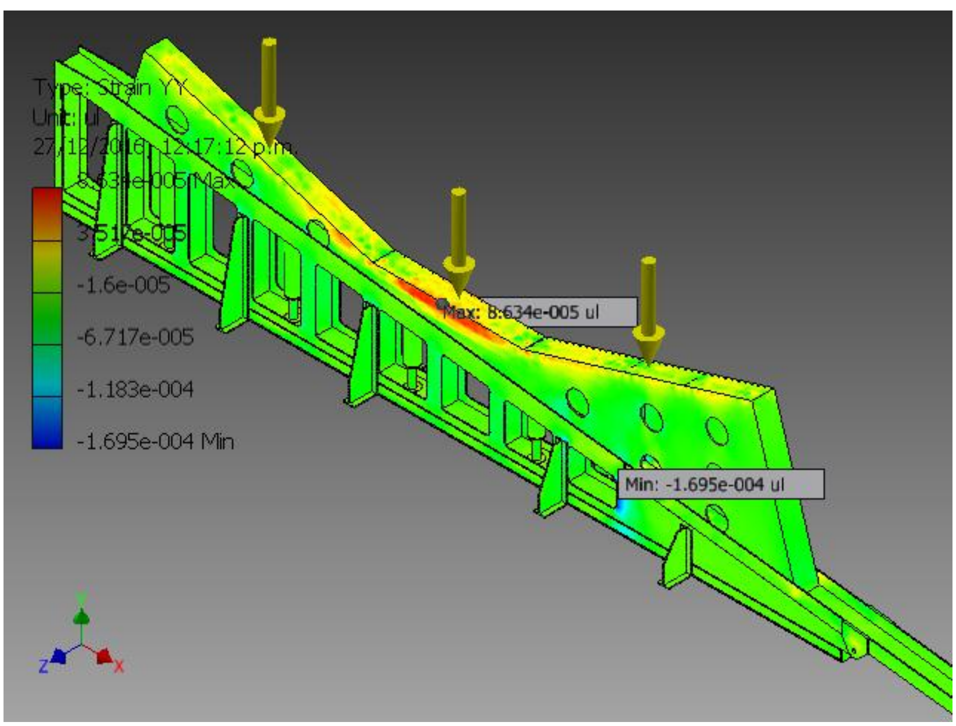
⊟ **Strain XY**



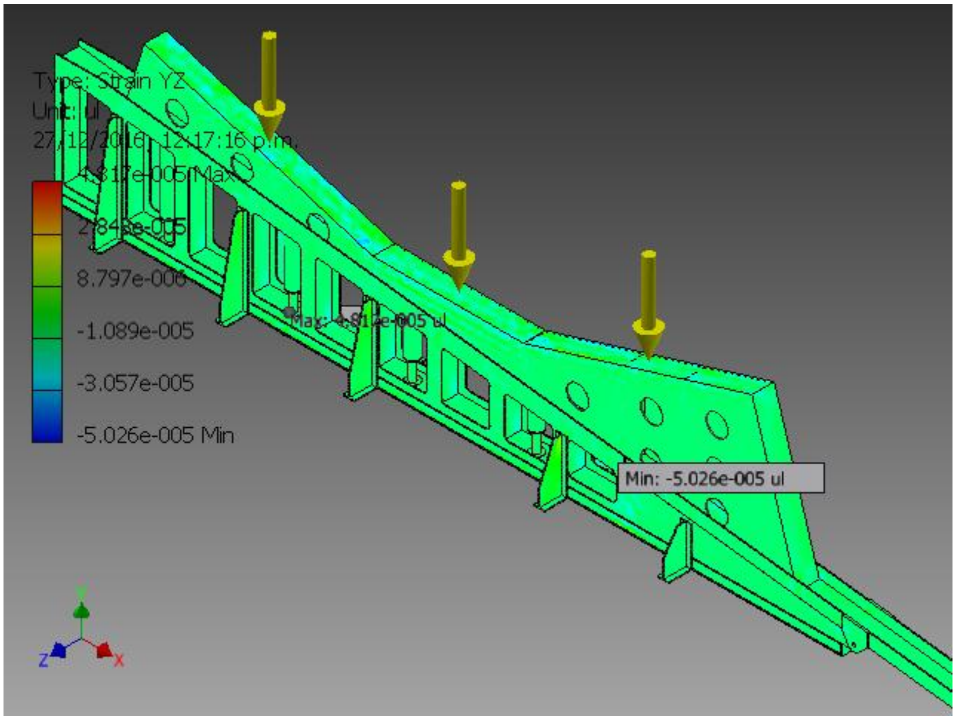
⊟ **Strain XZ**



⊟ **Strain YY**



⊟ **Strain YZ**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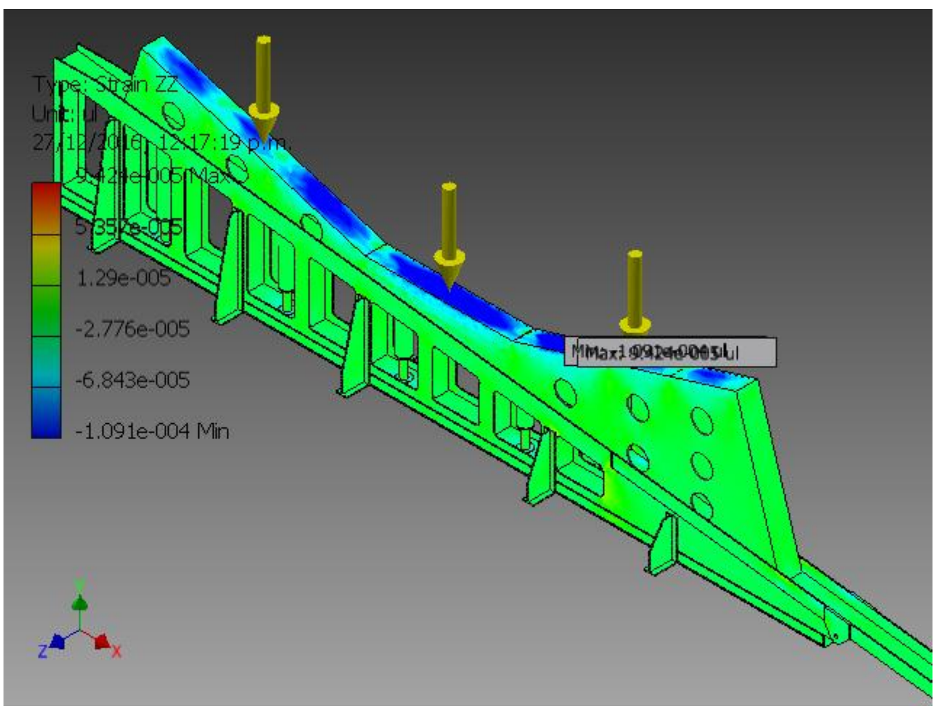
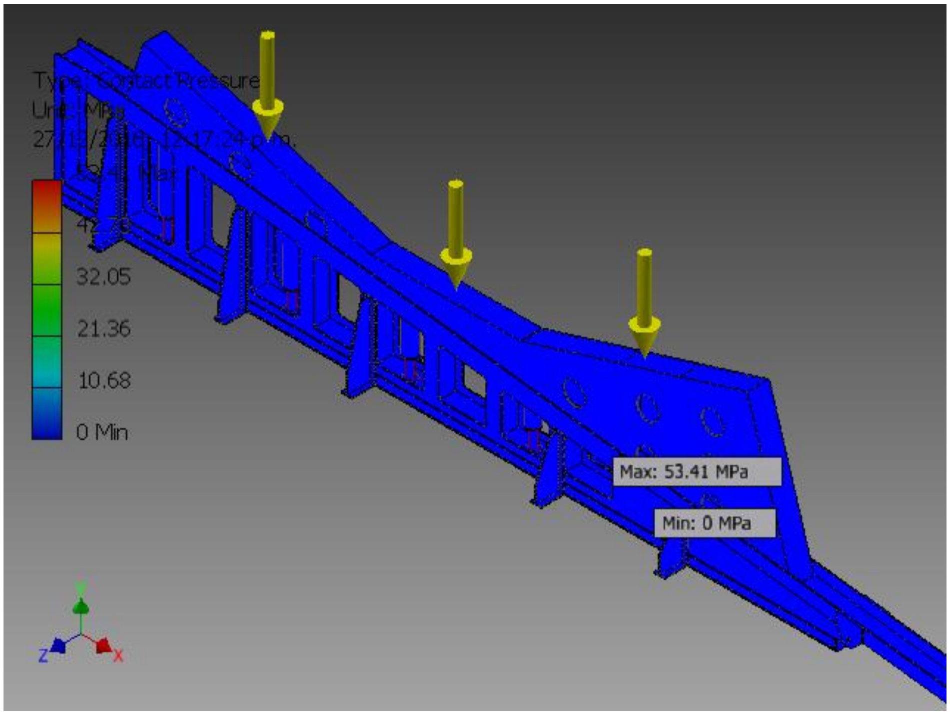
Unit: ul
27/12/2016, 12:17:16 p.m.
4.812e-005 Max
2.843e-005
8.797e-006
-1.089e-005
-3.057e-005
-5.026e-005 Min
Max: 4.812e-005 ul
Min: -5.026e-005 ul

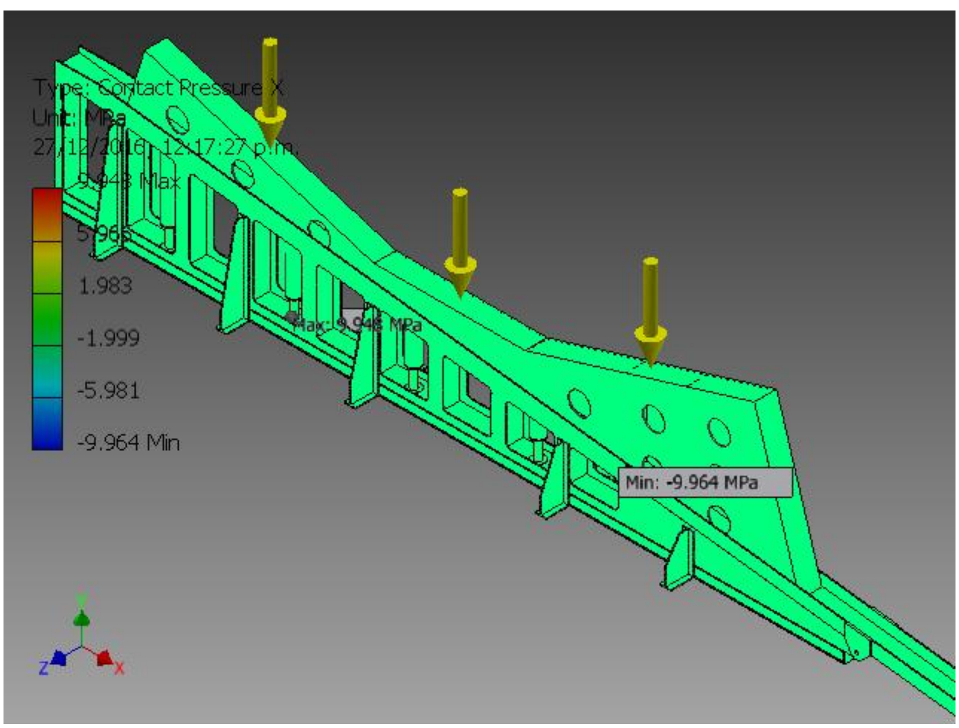
⊟ **Strain ZZ**


Type: Strain ZZ
Unit: ul
27/12/2016, 12:17:19 p.m.
9.424e-005 Max
5.357e-005
1.29e-005
-2.776e-005
-6.843e-005
-1.091e-004 Min

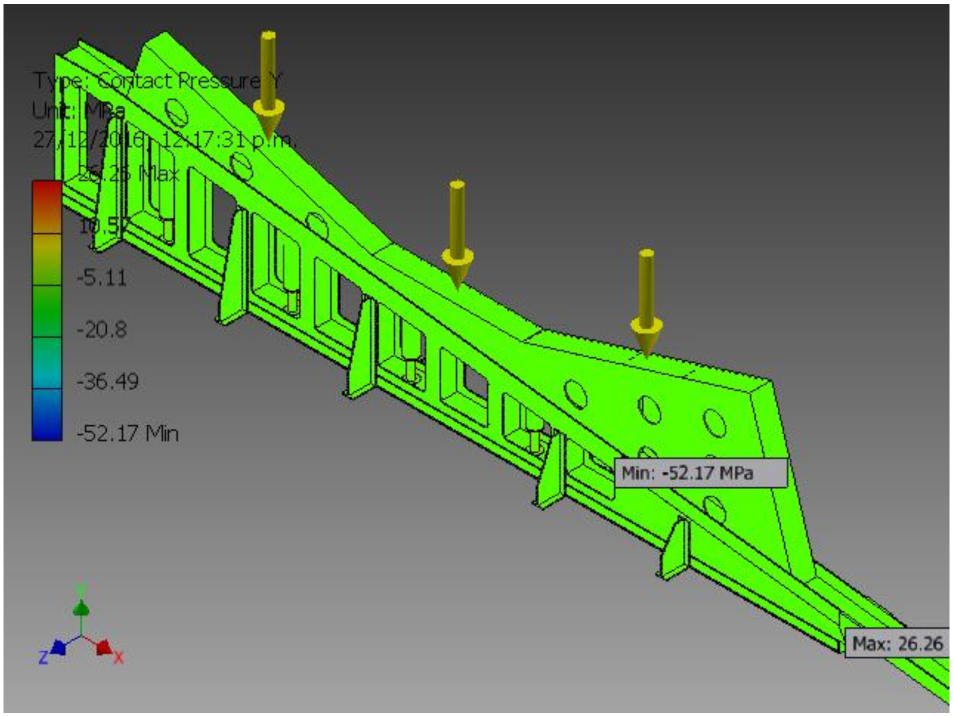
⊟ Contact Pressure



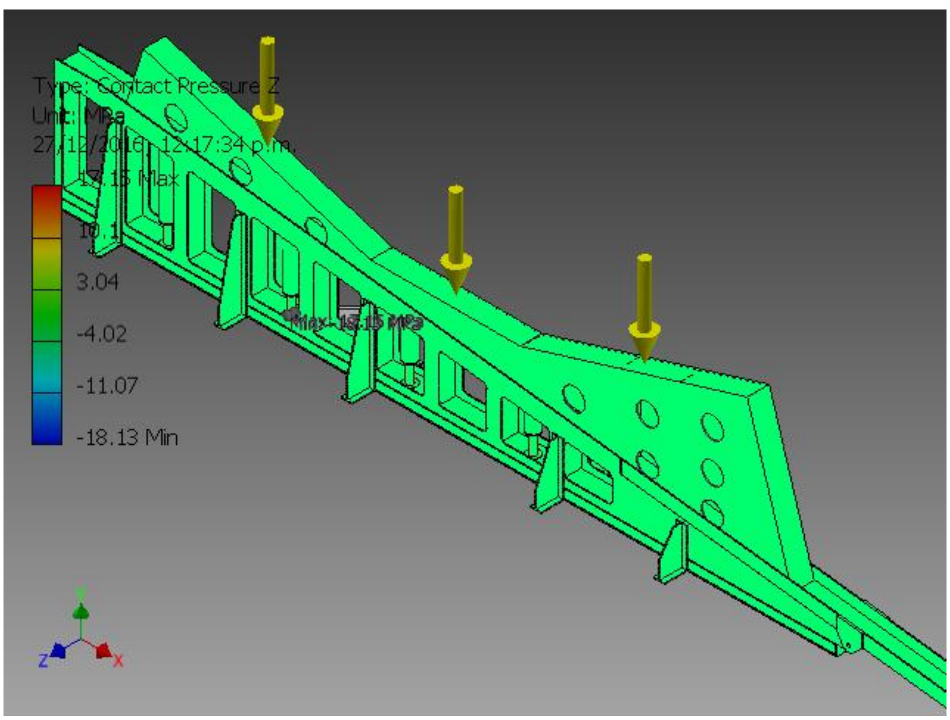
⊟ Contact Pressure X



⊟ **Contact Pressure Y**



⊟ **Contact Pressure Z**



ANNEX 3

Autodesk® Inventor® - Stress Analysis of Portable slipway in down position

Stress Analysis Report-200tn-In Down Position

Autodesk®

Analyzed File:	Assembly not jacks.iam
Autodesk Inventor Version:	2013 (Build 000000000, 000)
Creation Date:	00/00/2016, 02:05 p.m.
Simulation Author:	Edwin Salas
Summary:	

⊟ Project Info (iProperties)

⊟ Summary

Author usuario

⊟ Project

Part Number	Assembly not jacks
Designer	Edwin Salas
Cost	S/. 0.00
Date Created	00/00/2016

⊟ Status

Design Status WorkInProgress

⊟ Physical

Mass	30296.9 kg
Area	257646000 mm^2
Volume	3.84967E+009 mm^3
Center of Gravity	x=1309.09 mm y=-194.587 mm z=272.5 mm

Note: Physical values could be different from Physical values used by FEA reported below.

⊟ Simulation:not jacks 200tn

General objective and settings:

Design Objective	Single Point
Simulation Type	Static Analysis
Last Modification Date	28/12/2016, 11:39 a.m.
Detect and Eliminate Rigid Body Modes	No
Separate Stresses Across Contact Surfaces	No
Motion Loads Analysis	No

Mesh settings:

Avg. Element Size (fraction of model diameter)	0.05
Min. Element Size (fraction of avg. size)	0.1
Grading Factor	1.5
Max. Turn Angle	20 deg
Create Curved Mesh Elements	No
Use part based measure for Assembly mesh	Yes

⊟ Material(s)

Name	Steel, Carbon	
General	Mass Density	7.87 g/cm^3
	Yield Strength	350 MPa
	Ultimate Tensile Strength	420 MPa
Stress	Young's Modulus	200 GPa
	Poisson's Ratio	0.29 ul
	Shear Modulus	77.5194 GPa
Stress Thermal	Expansion Coefficient	0.000012 ul/c
	Thermal Conductivity	52 W/(m K)
	Specific Heat	486 J/(kg c)
Part Name(s)	Slip2a- 1000t Slip8- 1000t Slip6- 1000t	

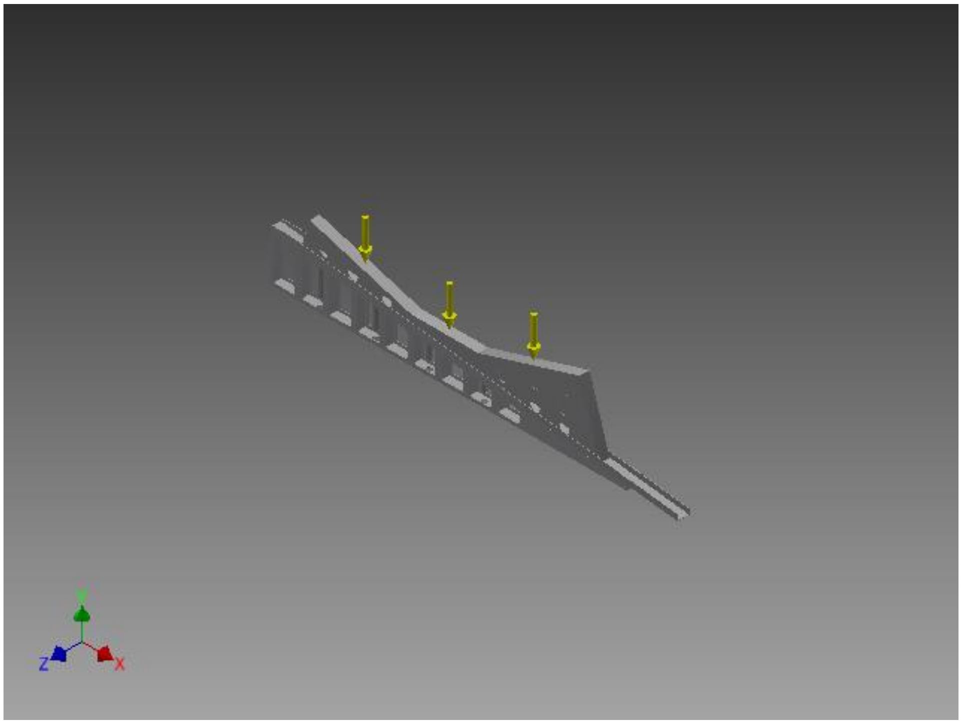
⊟ Operating conditions

⊟ Gravity

Load Type	Gravity
Magnitude	9810.000 mm/s^2
Vector X	-0.000 mm/s^2

Vector Y -9810.000 mm/s^2
Vector Z 0.000 mm/s^2

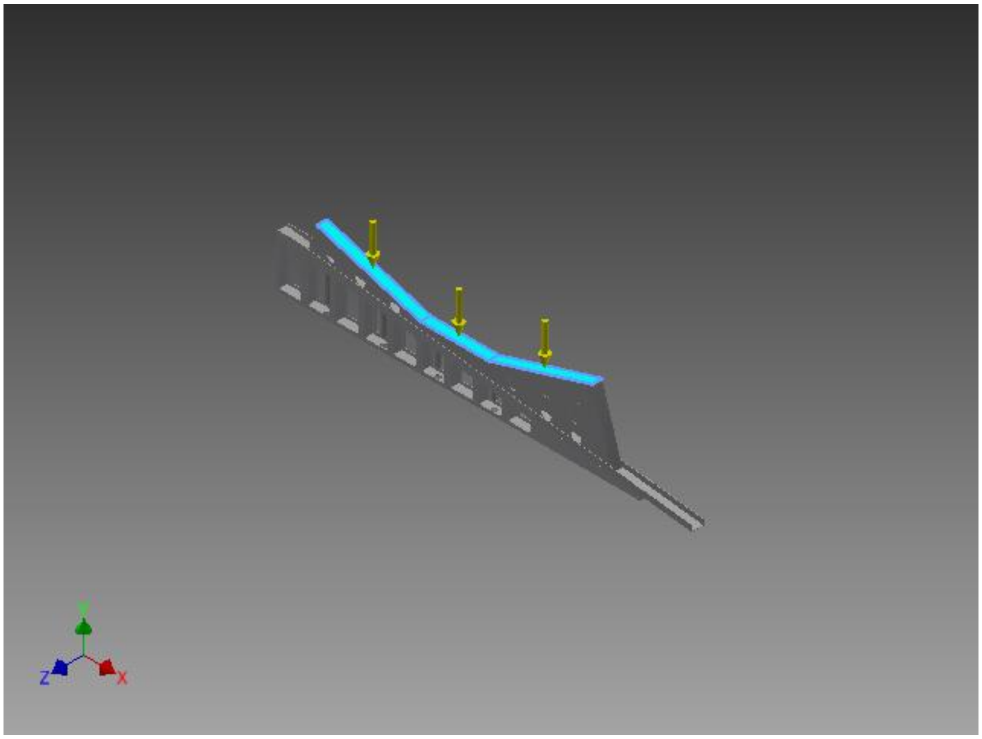
⊟ **Selected Face(s)**



⊟ Force:1

Load Type Force
Magnitude 2000000.000 N
Vector X 0.000 N
Vector Y -2000000.000 N
Vector Z 0.000 N

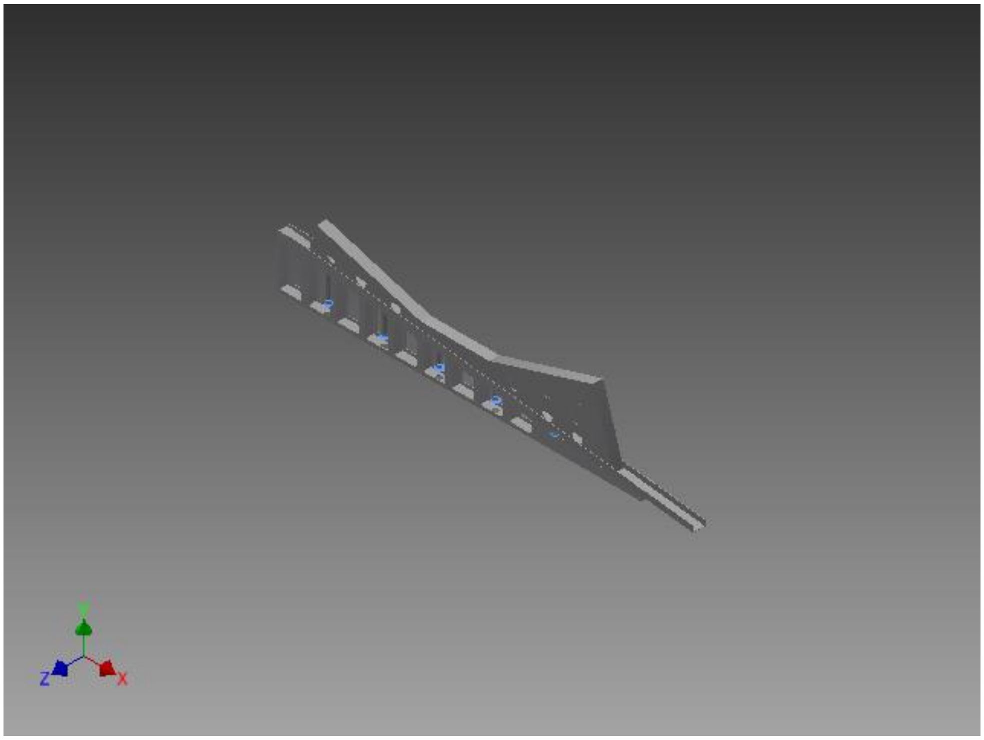
⊟ **Selected Face(s)**



⊟ Fixed Constraint:1

Constraint Type Fixed Constraint

⊟ Selected Face(s)



⊟ Contacts (Bonded)

Name	Part Name(s)
Bonded:1	Slip2a- 1000t:1 Slip8- 1000t:1
Bonded:2	Slip2a- 1000t:1 Slip6- 1000t:1
Bonded:3	Slip2a- 1000t:1 Slip6- 1000t:1
Bonded:4	Slip8- 1000t:1 Slip6- 1000t:1

⊟ Results

⊟ Reaction Force and Moment on Constraints

Constraint Name	**Reaction Force**		**Reaction Moment**	
	Magnitude	**Component (X,Y,Z)**	**Magnitude**	**Component (X,Y,Z)**
Fixed Constraint:1	2296990 N	0 N 2296990 N 0 N	1862200 N m	-5565.01 N m 0 N m 1862190 N m

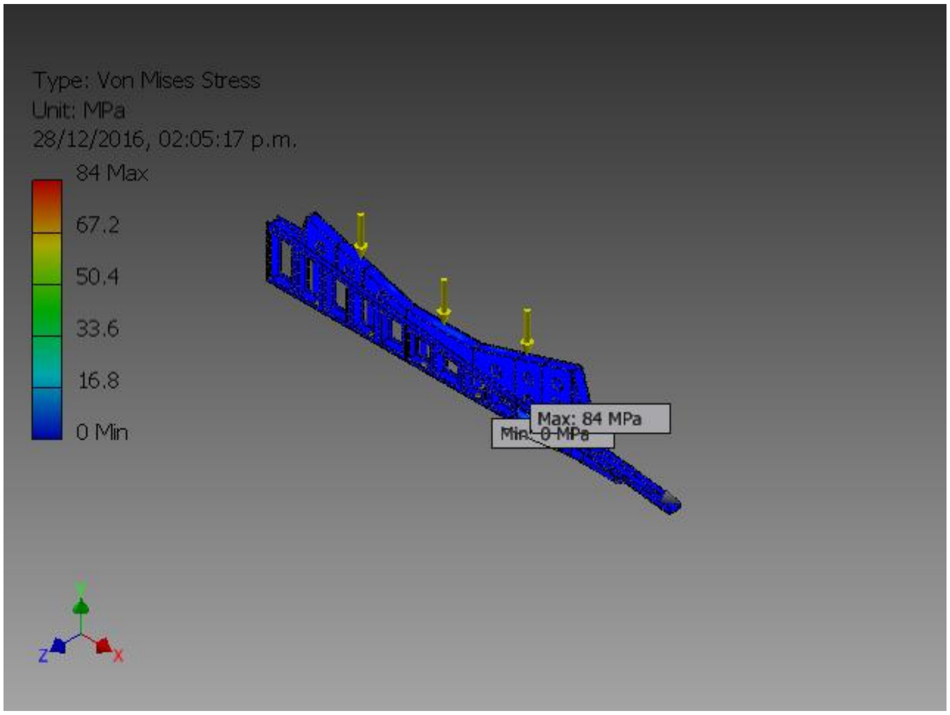
⊟ Result Summary

Name	**Minimum**	**Maximum**
Volume	3.84969E+009 mm^3	
Mass	30297.1 kg	
Von Mises Stress	0.00415836 MPa	83.9967 MPa
1st Principal Stress	-20.3477 MPa	66.4897 MPa
3rd Principal Stress	-92.9984 MPa	15.3145 MPa
Displacement	0 mm	1.16991 mm
Safety Factor	4.16683 ul	15 ul
Stress XX	-33.6684 MPa	38.7242 MPa
Stress XY	-24.3822 MPa	36.1893 MPa
Stress XZ	-11.1489 MPa	11.0752 MPa
Stress YY	-89.8278 MPa	49.1474 MPa
Stress YZ	-35.8343 MPa	26.1145 MPa

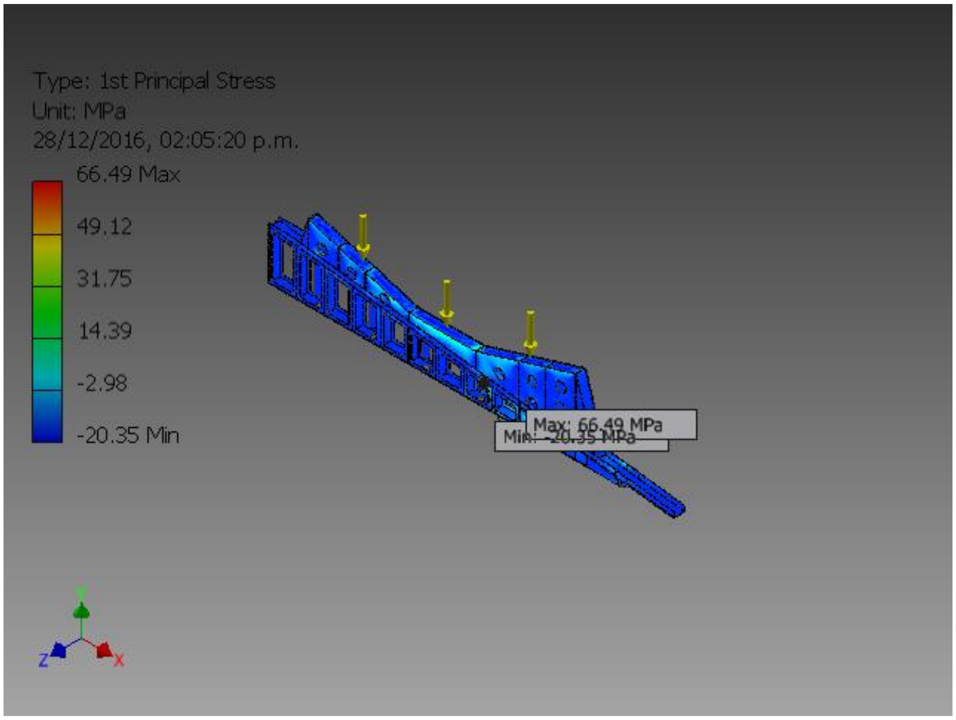
Stress ZZ	-42.3132 MPa	48.4134 MPa
X Displacement	-0.0919937 mm	0.321894 mm
Y Displacement	-1.16664 mm	0.0000150777 mm
Z Displacement	-0.387166 mm	0.380216 mm
Equivalent Strain	0.0000000180547 ul	0.000378696 ul
1st Principal Strain	-0.0000127364 ul	0.000290598 ul
3rd Principal Strain	-0.000433121 ul	0.0000099277 ul
Strain XX	-0.00015788 ul	0.000191105 ul
Strain XY	-0.000157265 ul	0.000233421 ul
Strain XZ	-0.0000719107 ul	0.0000714353 ul
Strain YY	-0.000413334 ul	0.000200924 ul
Strain YZ	-0.000231131 ul	0.000168438 ul
Strain ZZ	-0.000137429 ul	0.000182202 ul
Contact Pressure	0 MPa	68.8888 MPa
Contact Pressure X	-8.66884 MPa	15.1973 MPa
Contact Pressure Y	-65.7121 MPa	31.4423 MPa
Contact Pressure Z	-20.677 MPa	17.0675 MPa

⊟ Figures

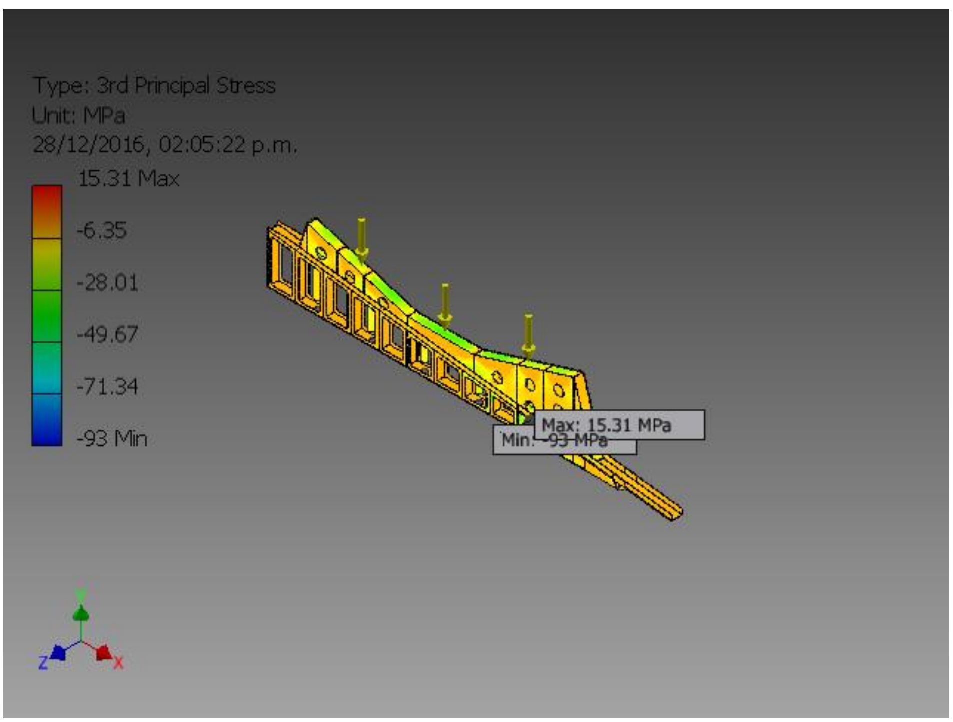
⊟ Von Mises Stress



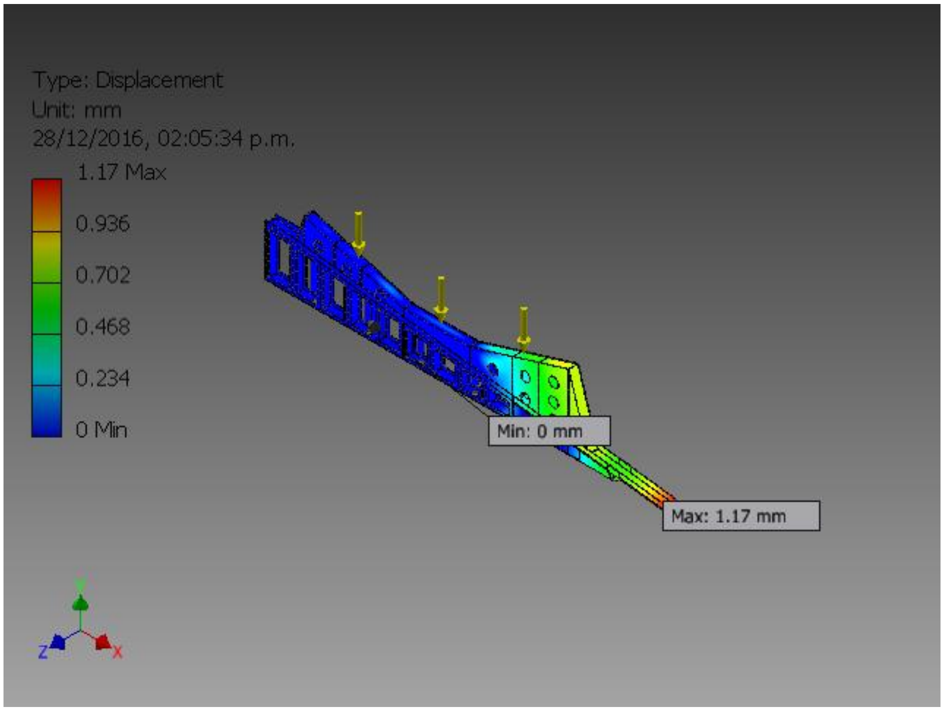
⊟ 1st Principal Stress



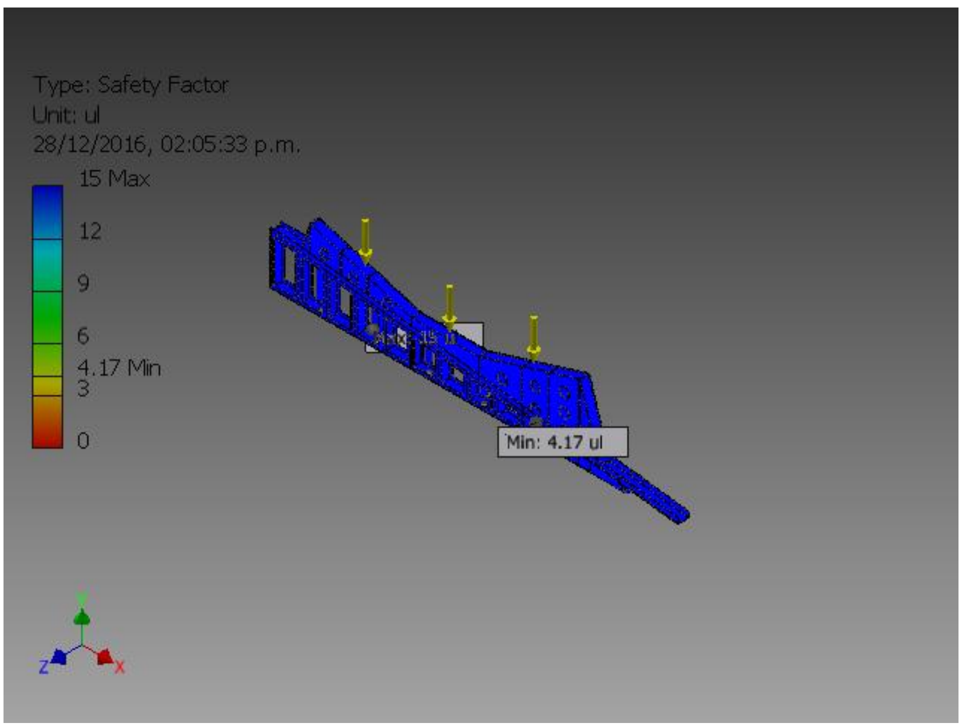
⊟ 3rd Principal Stress



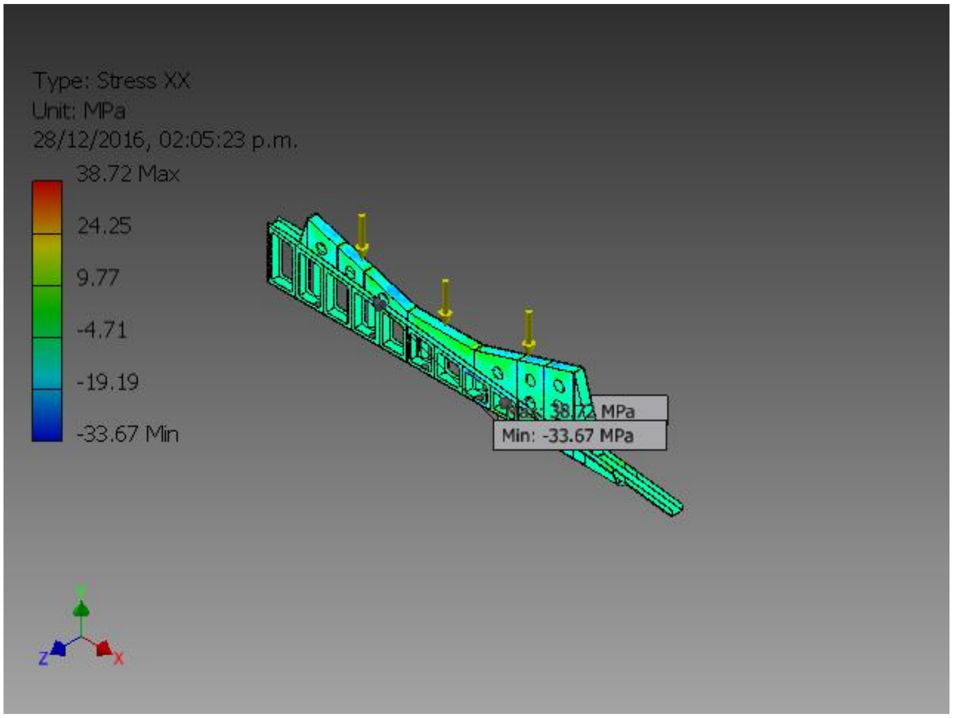
⊟ Displacement



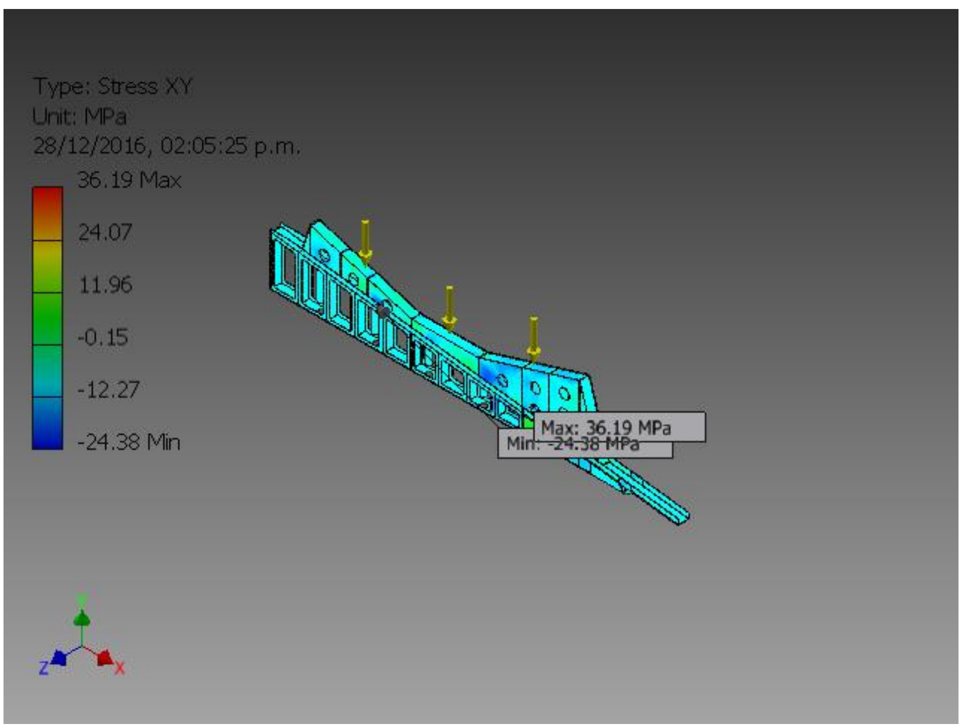
⊟ Safety Factor



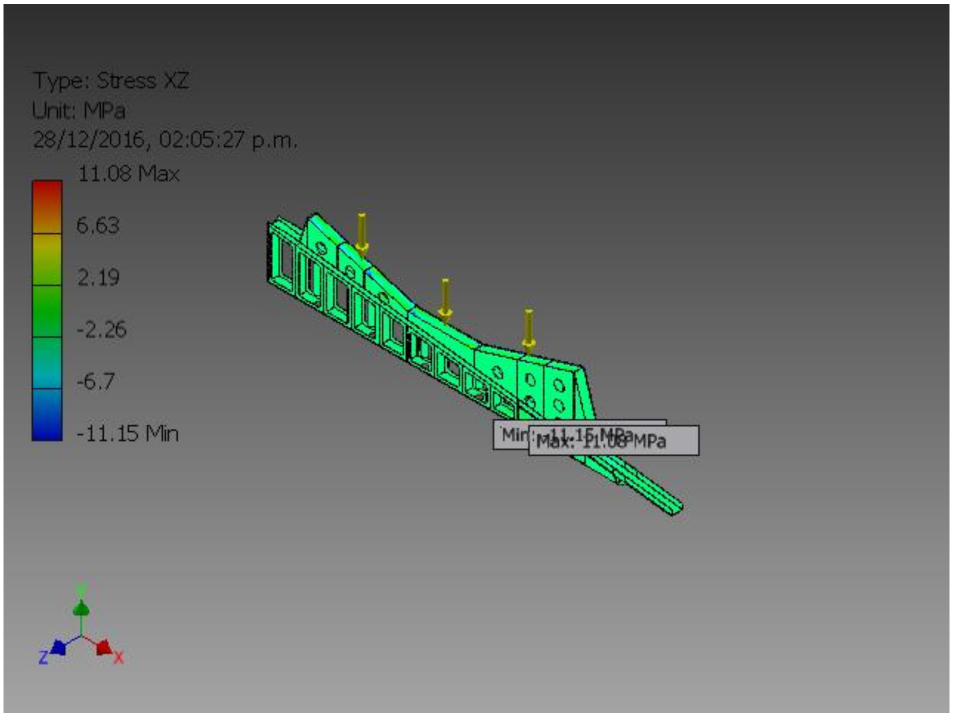
⊟ Stress XX


Type: Stress XX
Unit: MPa
28/12/2016, 02:05:23 p.m.
38.72 Max
24.25
9.77
-4.71
-19.19
-33.67 Min
Min: -33.67 MPa

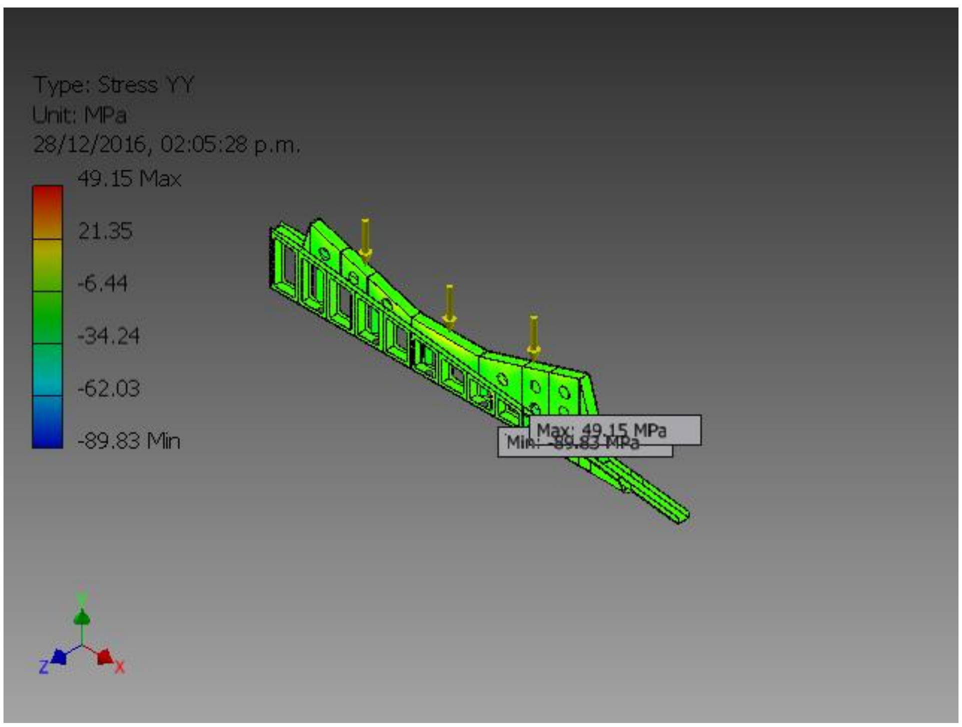
⊟ **Stress XY**


Type: Stress XY
Unit: MPa
28/12/2016, 02:05:25 p.m.
36.19 Max
24.07
11.96
-0.15
-12.27
-24.38 Min
Max: 36.19 MPa

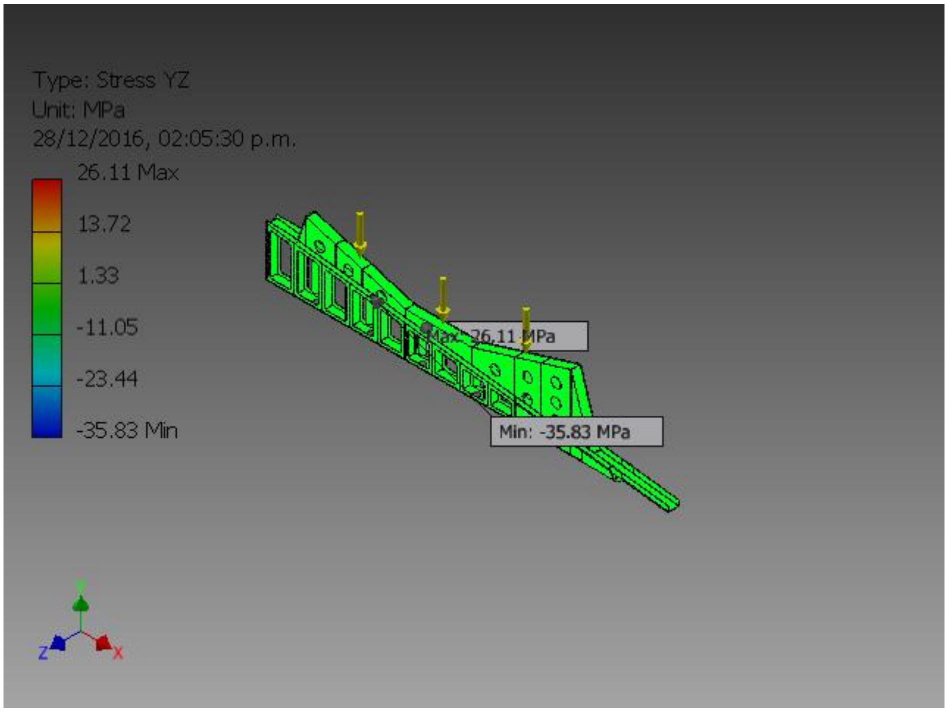
⊟ **Stress XZ**



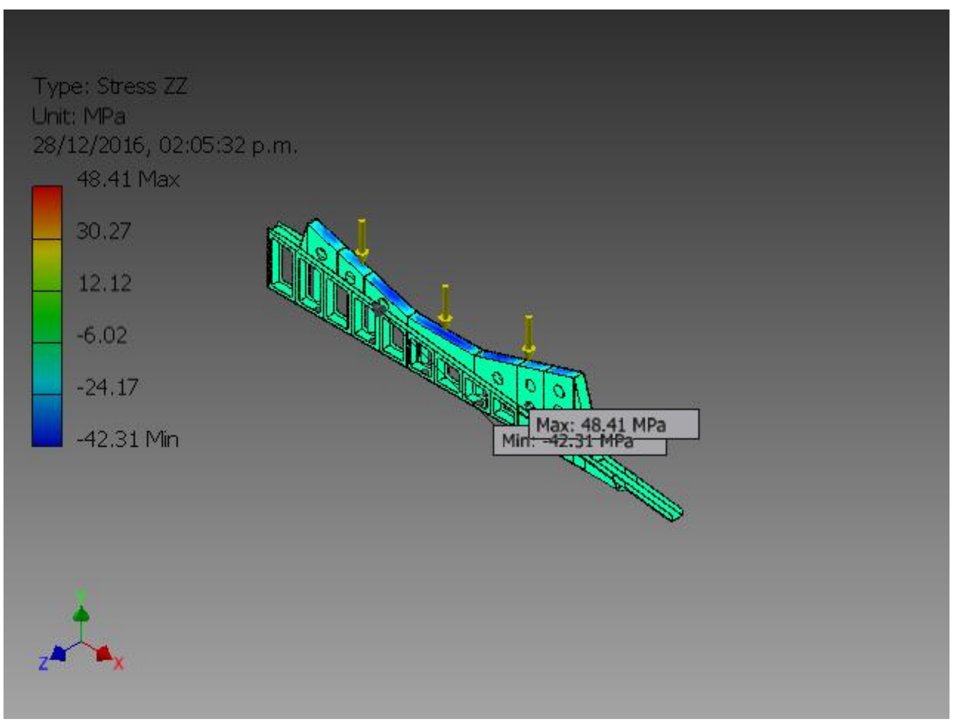
⊟ **Stress YY**



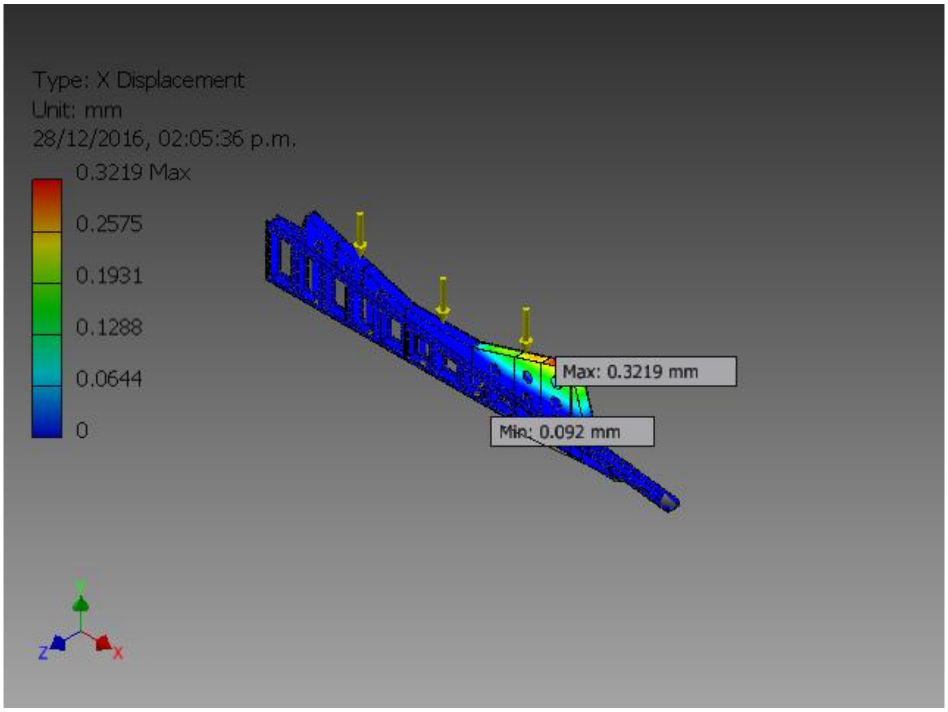
⊟ **Stress YZ**



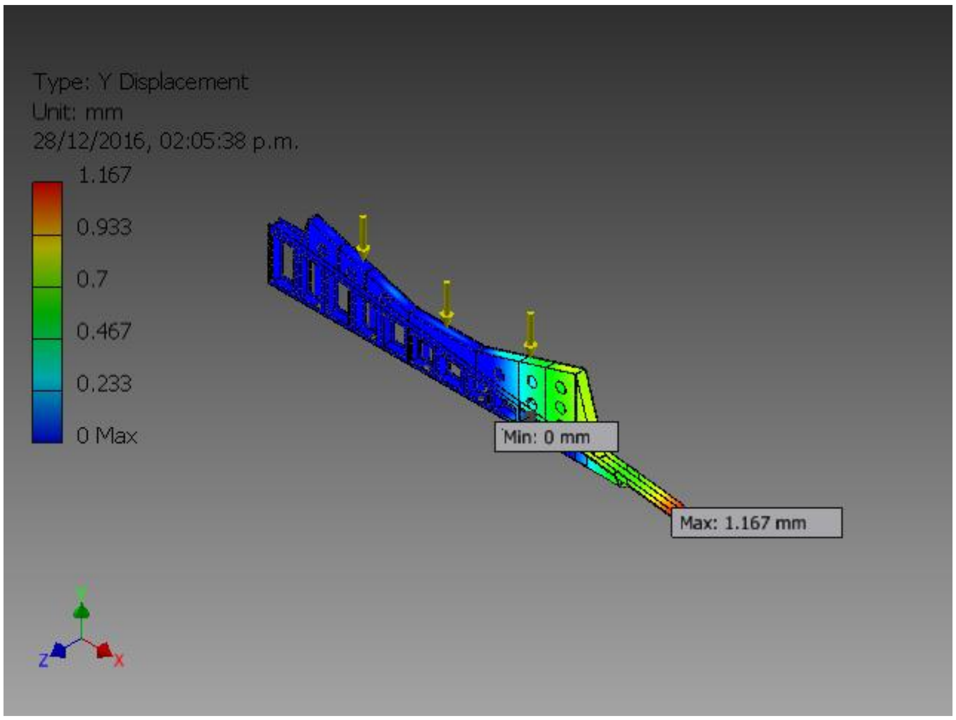
⊟ **Stress ZZ**



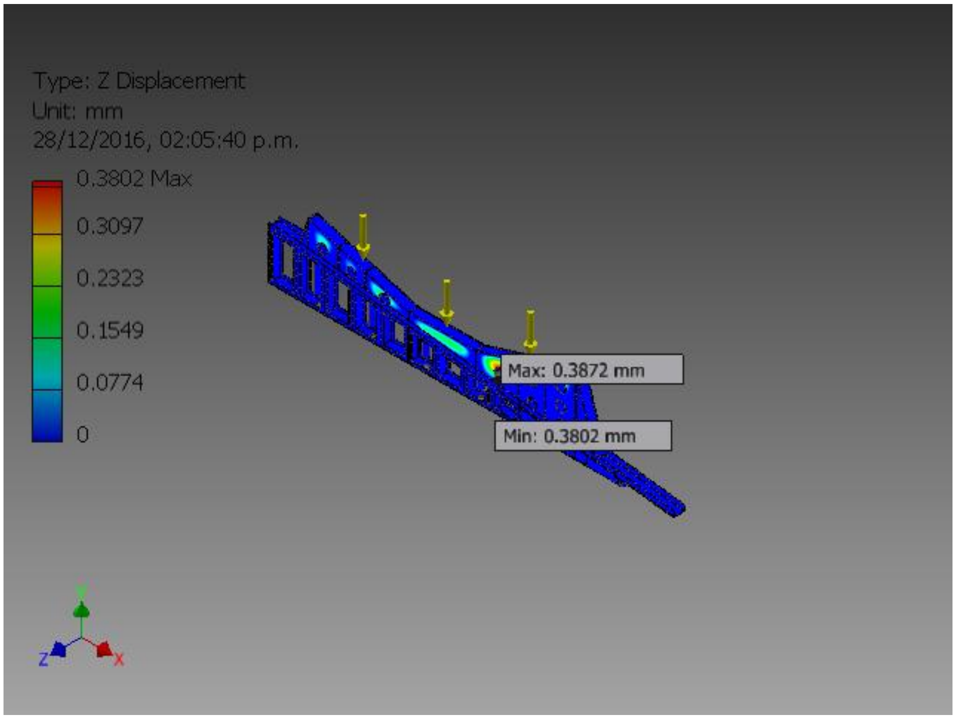
⊟ X Displacement



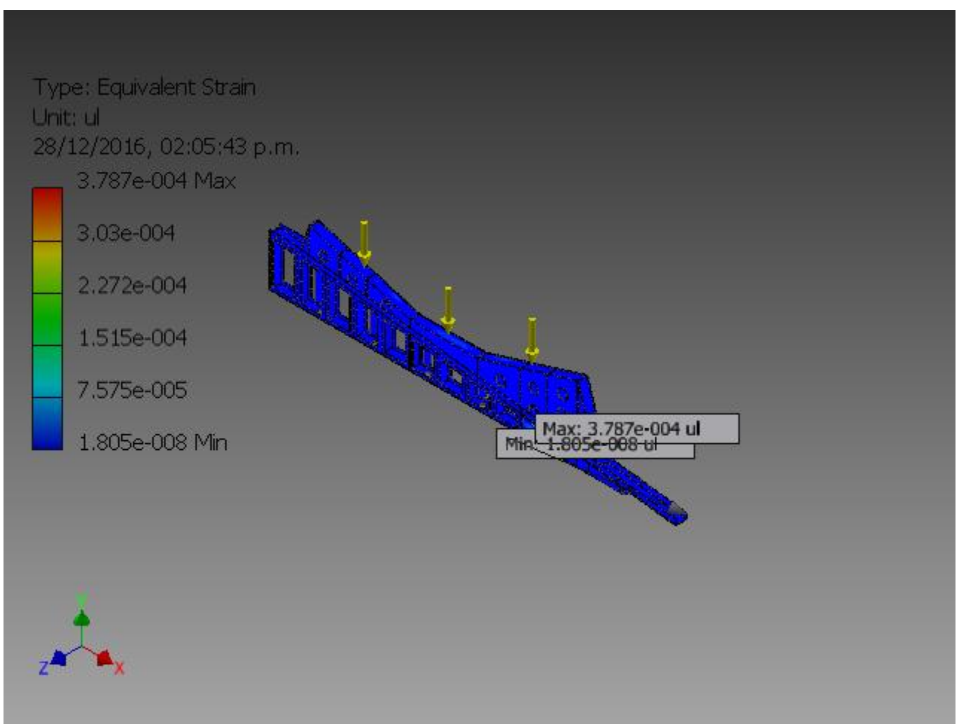
⊟ Y Displacement



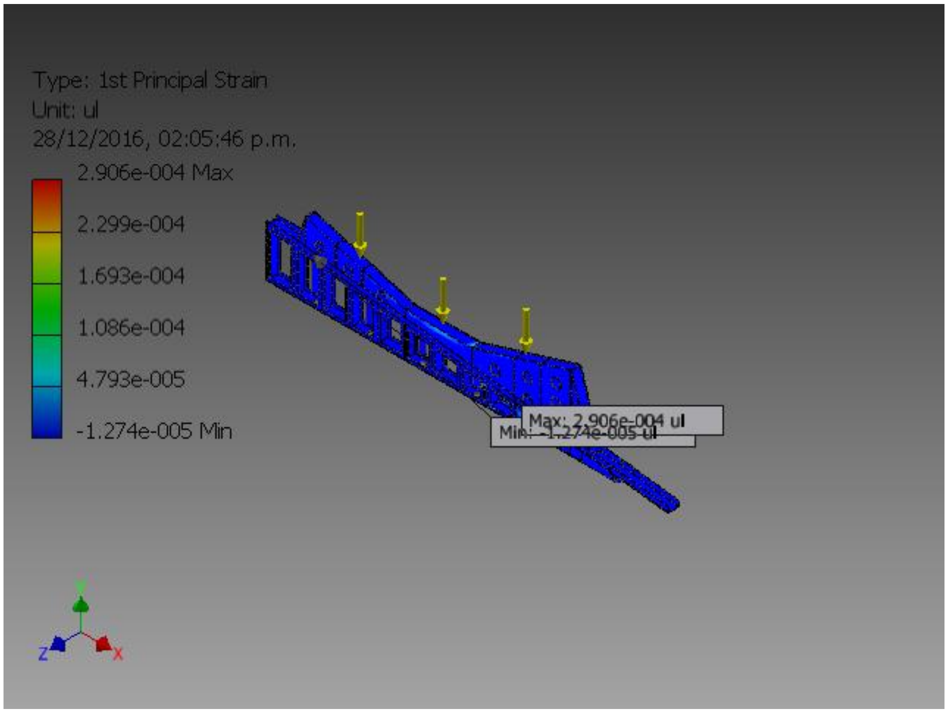
⊟ **Z Displacement**



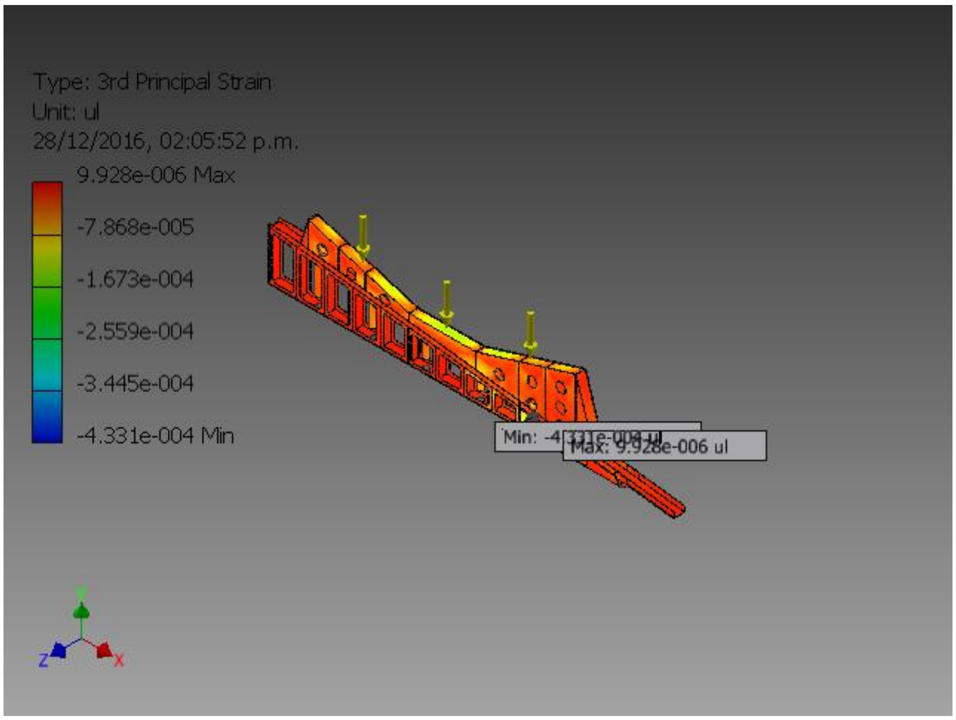
⊟ **Equivalent Strain**



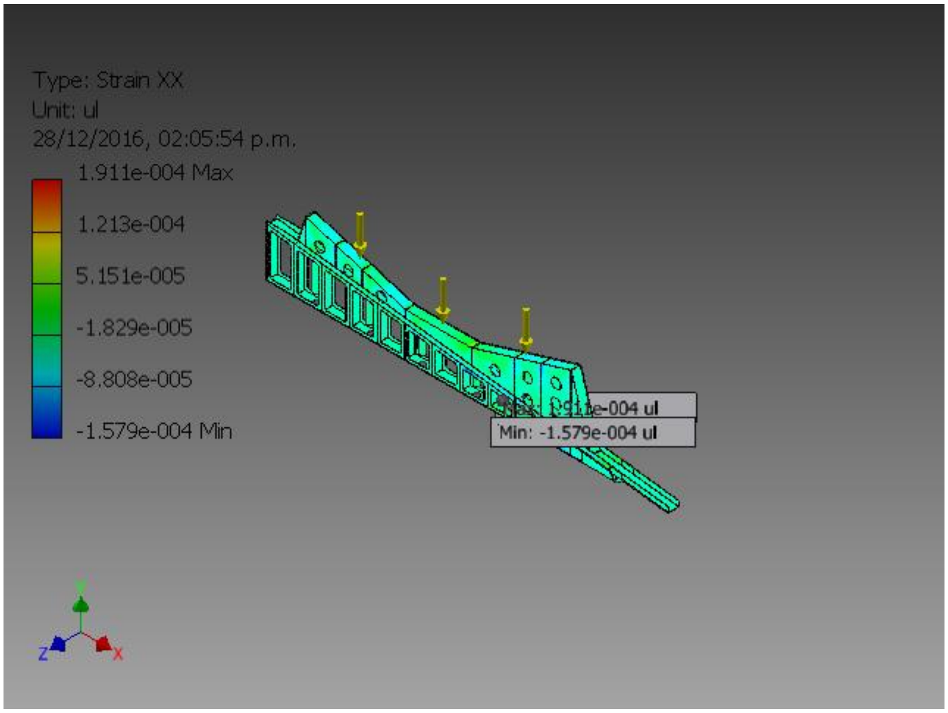
⊟ **1st Principal Strain**



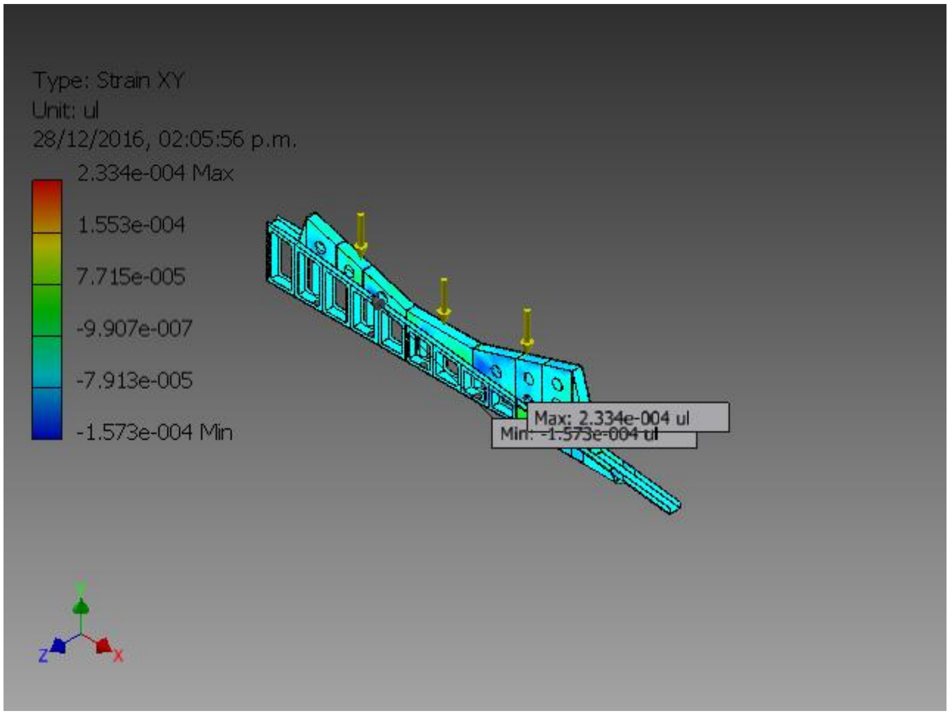
⊟ **3rd Principal Strain**



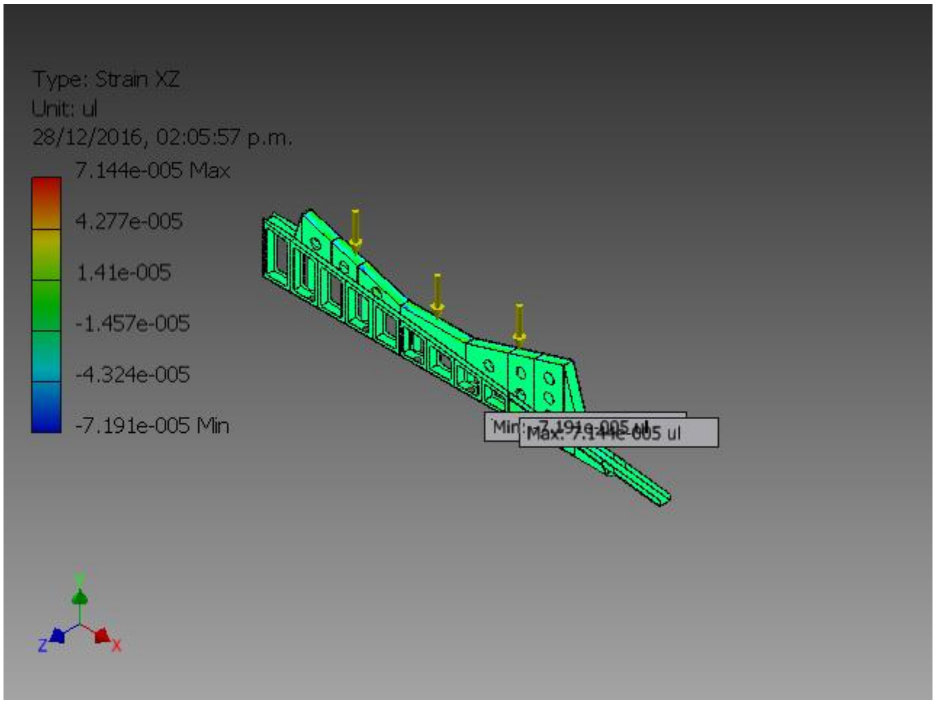
⊟ **Strain XX**



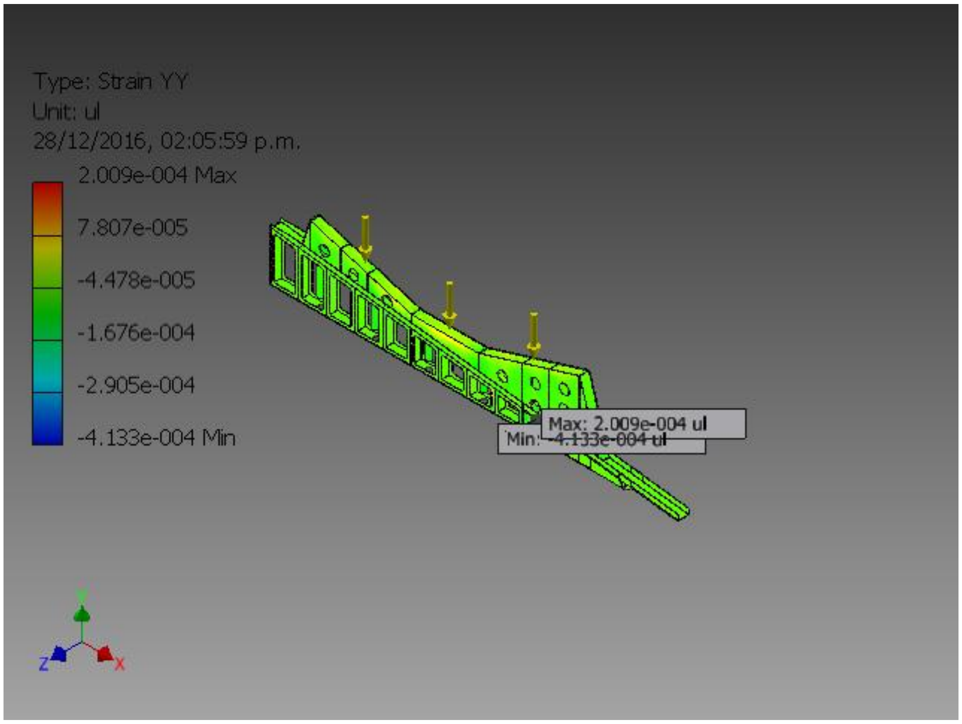
⊟ **Strain XY**



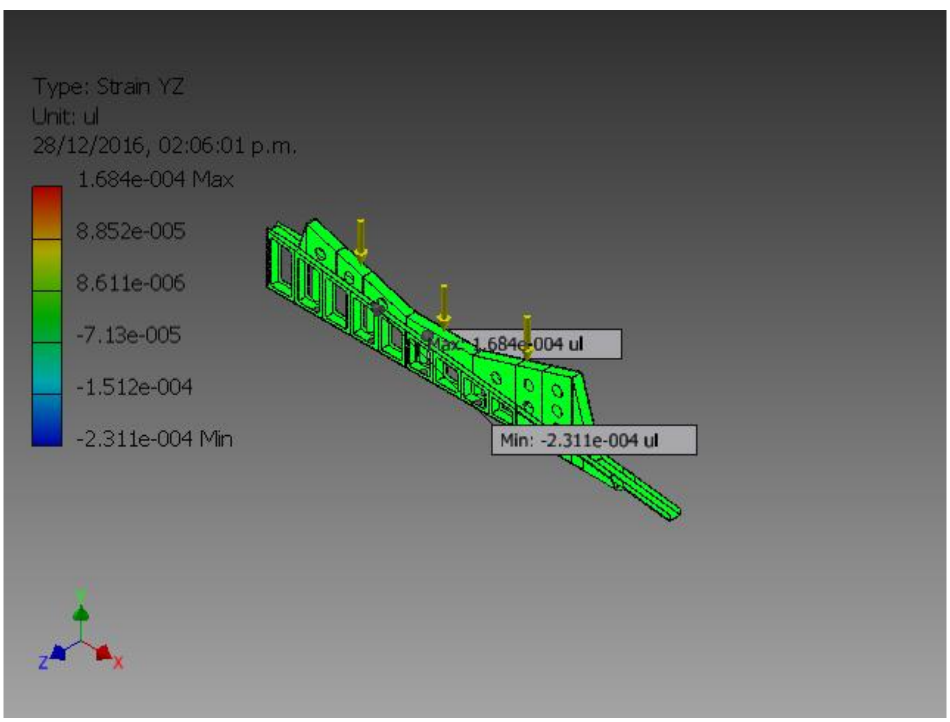
⊟ **Strain XZ**



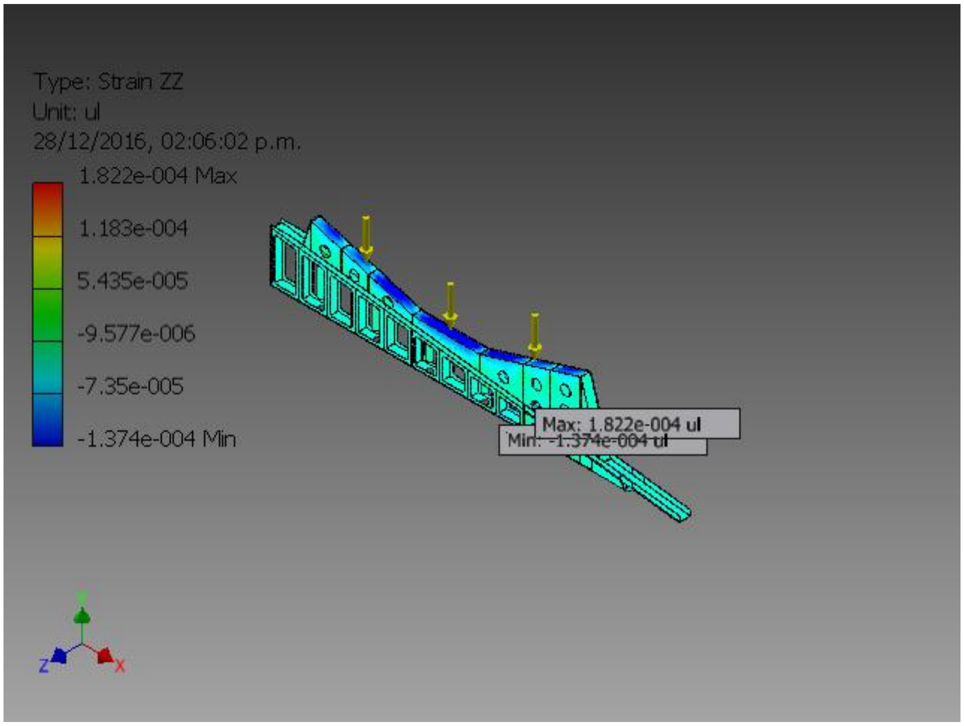
⊟ **Strain YY**



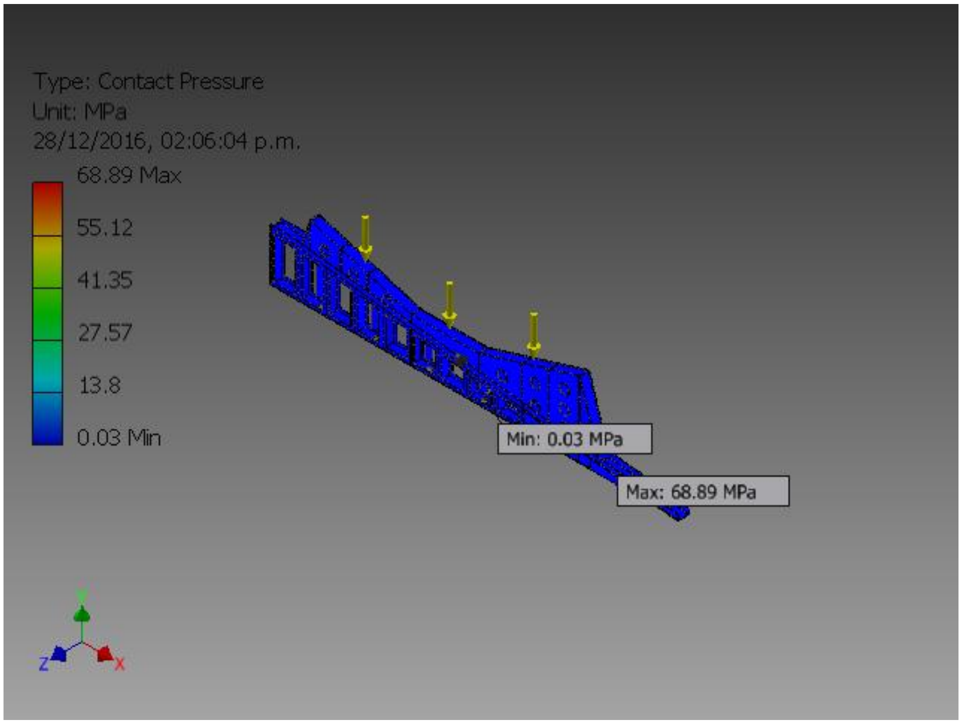
⊟ **Strain YZ**



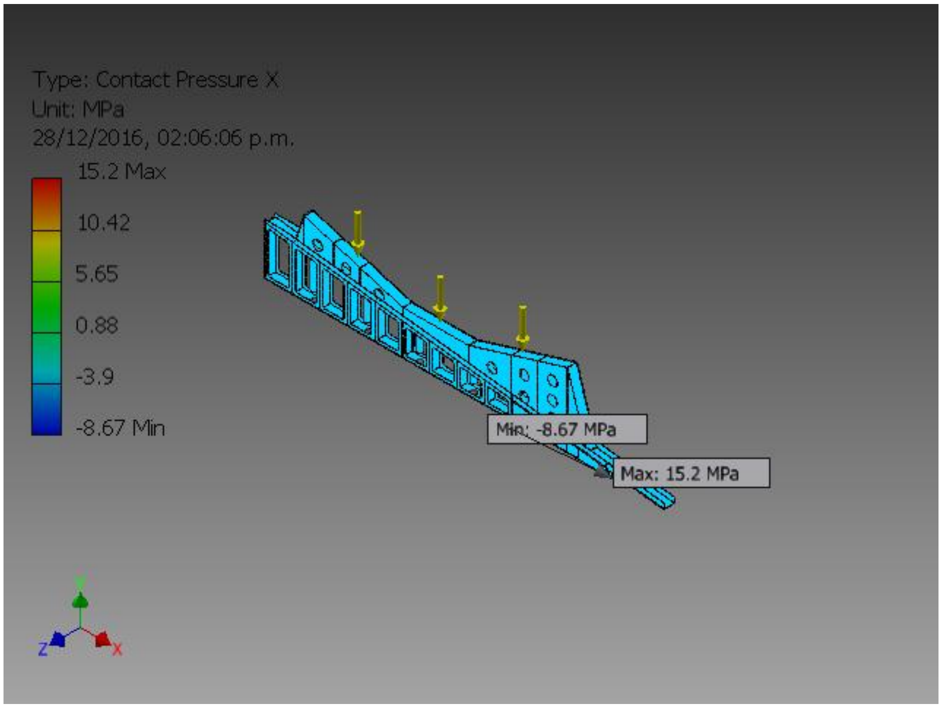
⊟ **Strain ZZ**



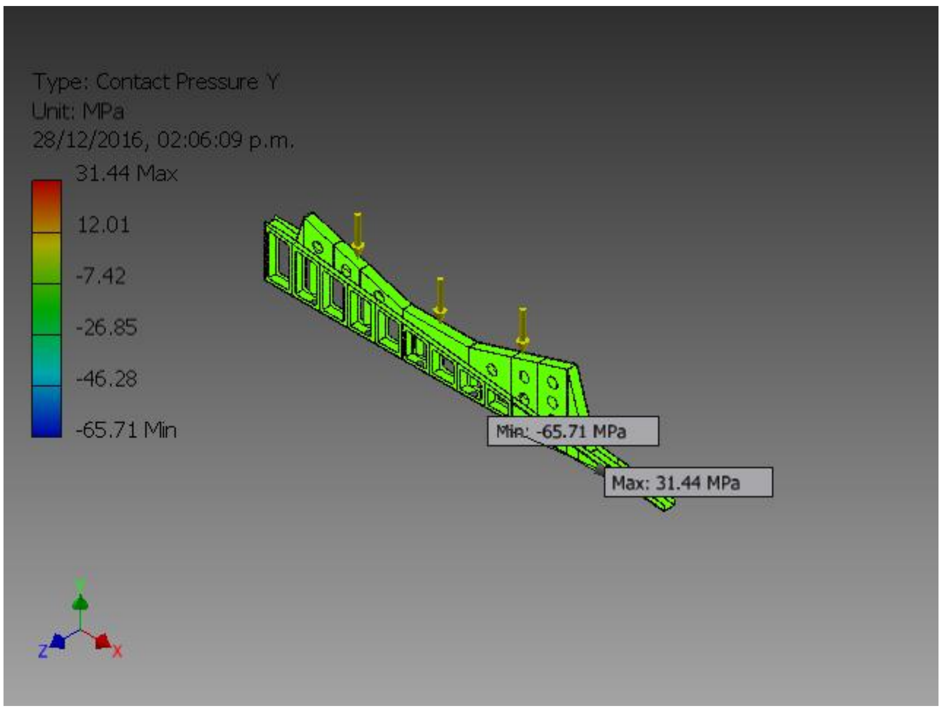
Contact Pressure



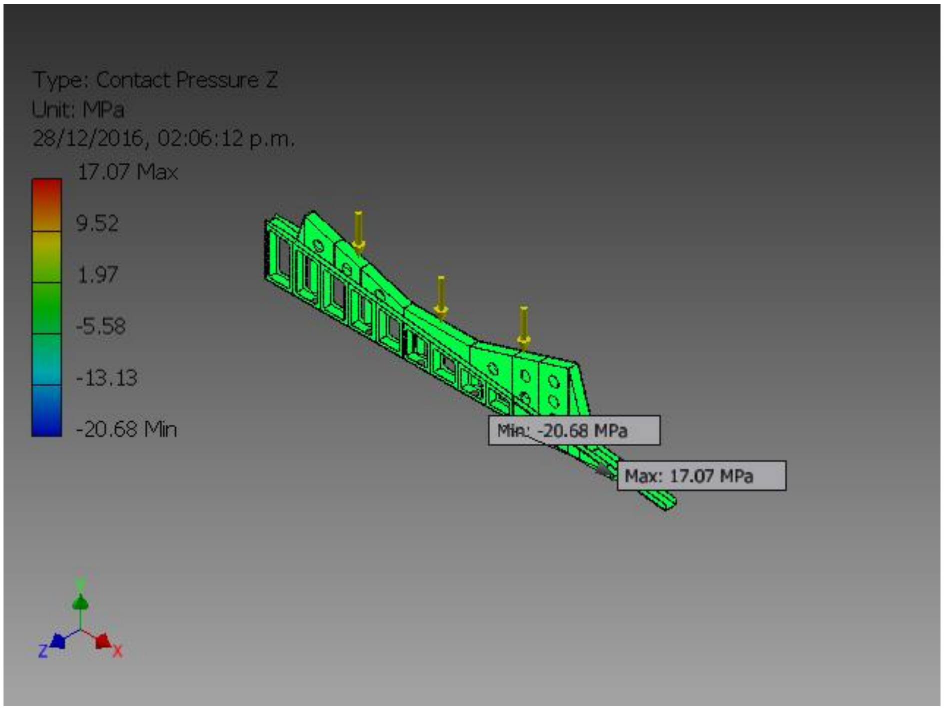
⊟ **Contact Pressure X**



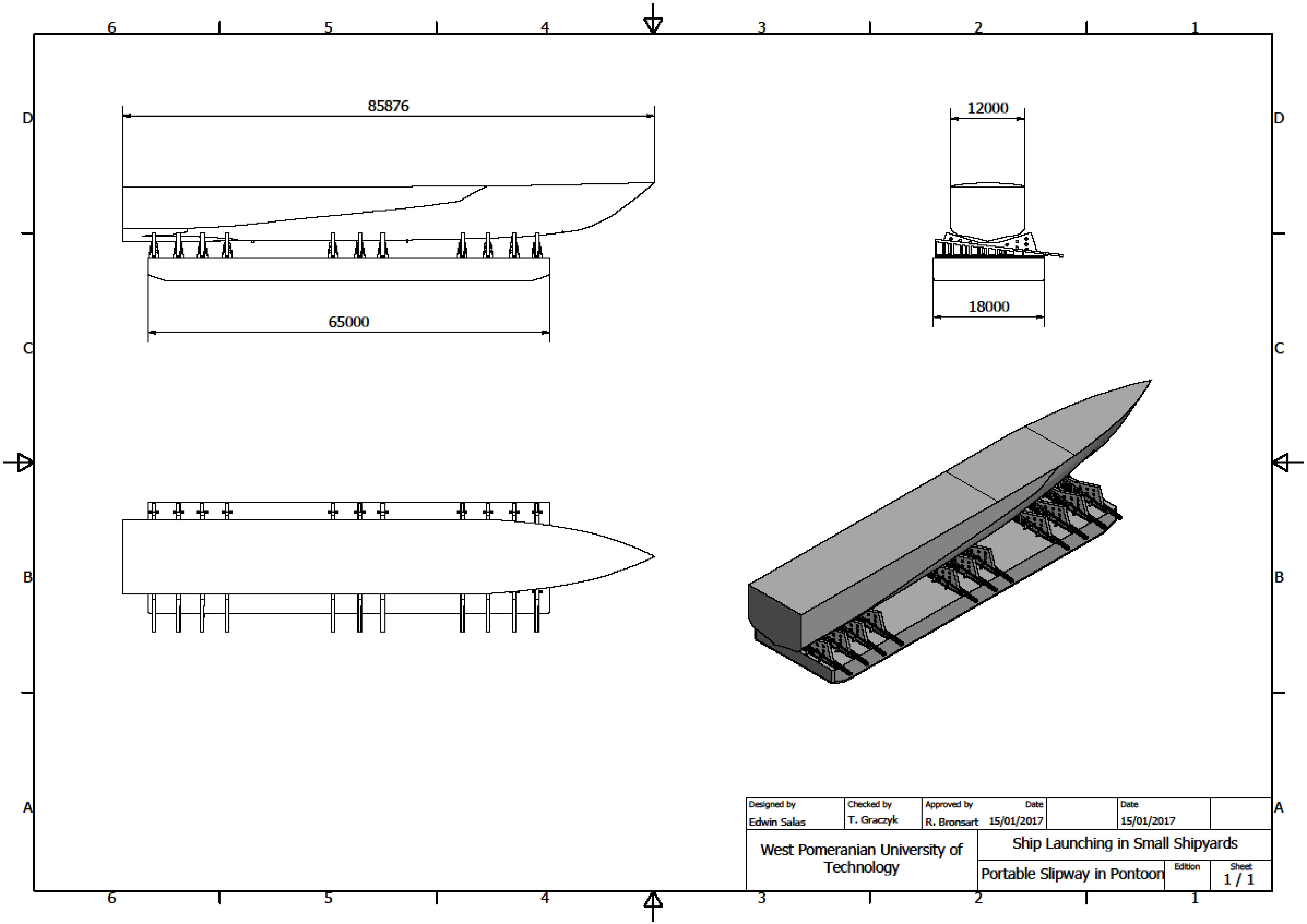
⊟ **Contact Pressure Y**



⊟ **Contact Pressure Z**



ANNEX 4
Plans of Portable slipway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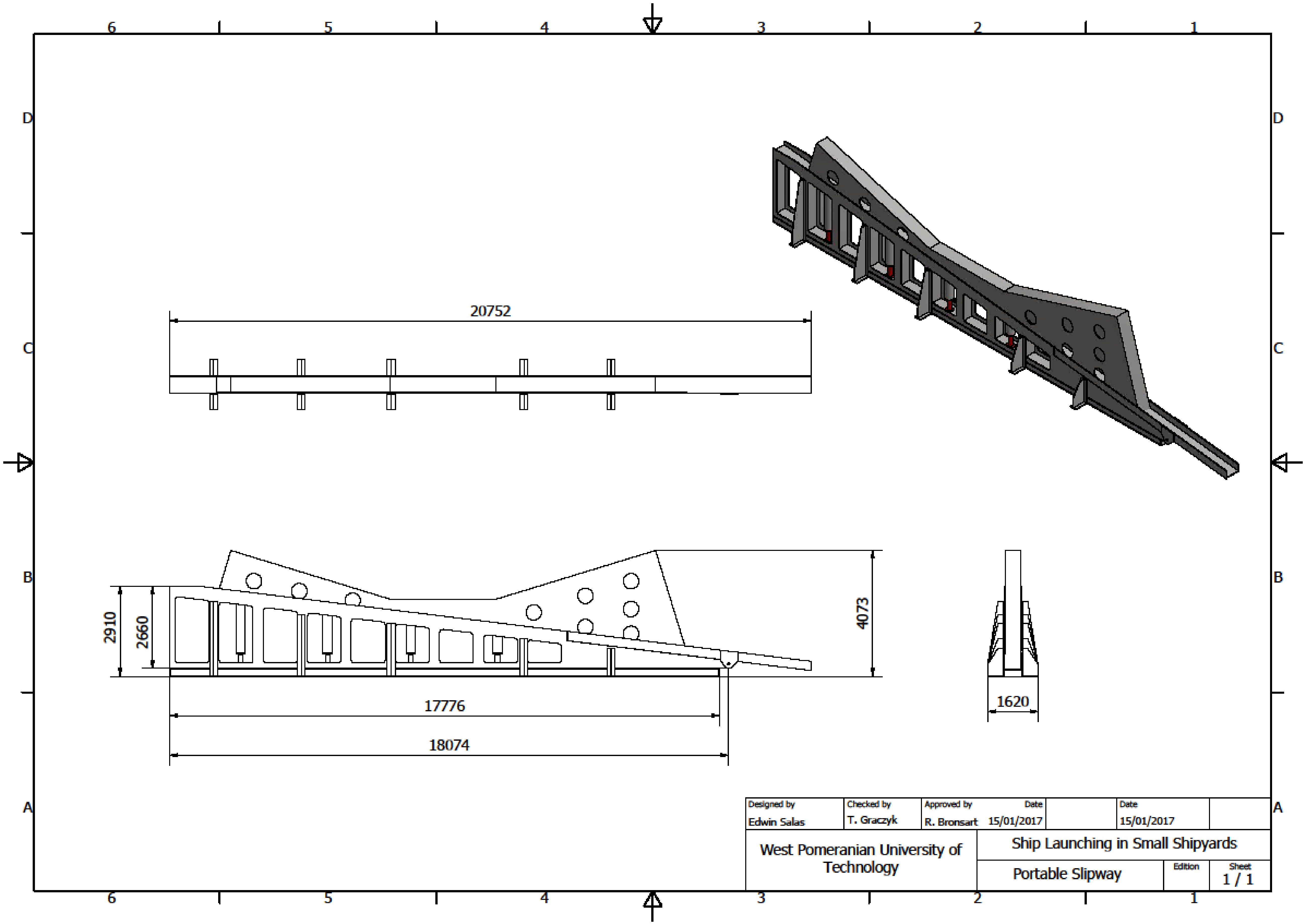
Designed by
Edwin Salas
Checked by
T. Graczyk
Approved by
R. Bronsart
Date
15/01/2017
Date
15/01/2017
West Pomeranian University of Technology
Ship Launching in Small Shipyards
Portable Slipway in Pontoon
Edition
Sheet
1 / 1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Checked by
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Approved by
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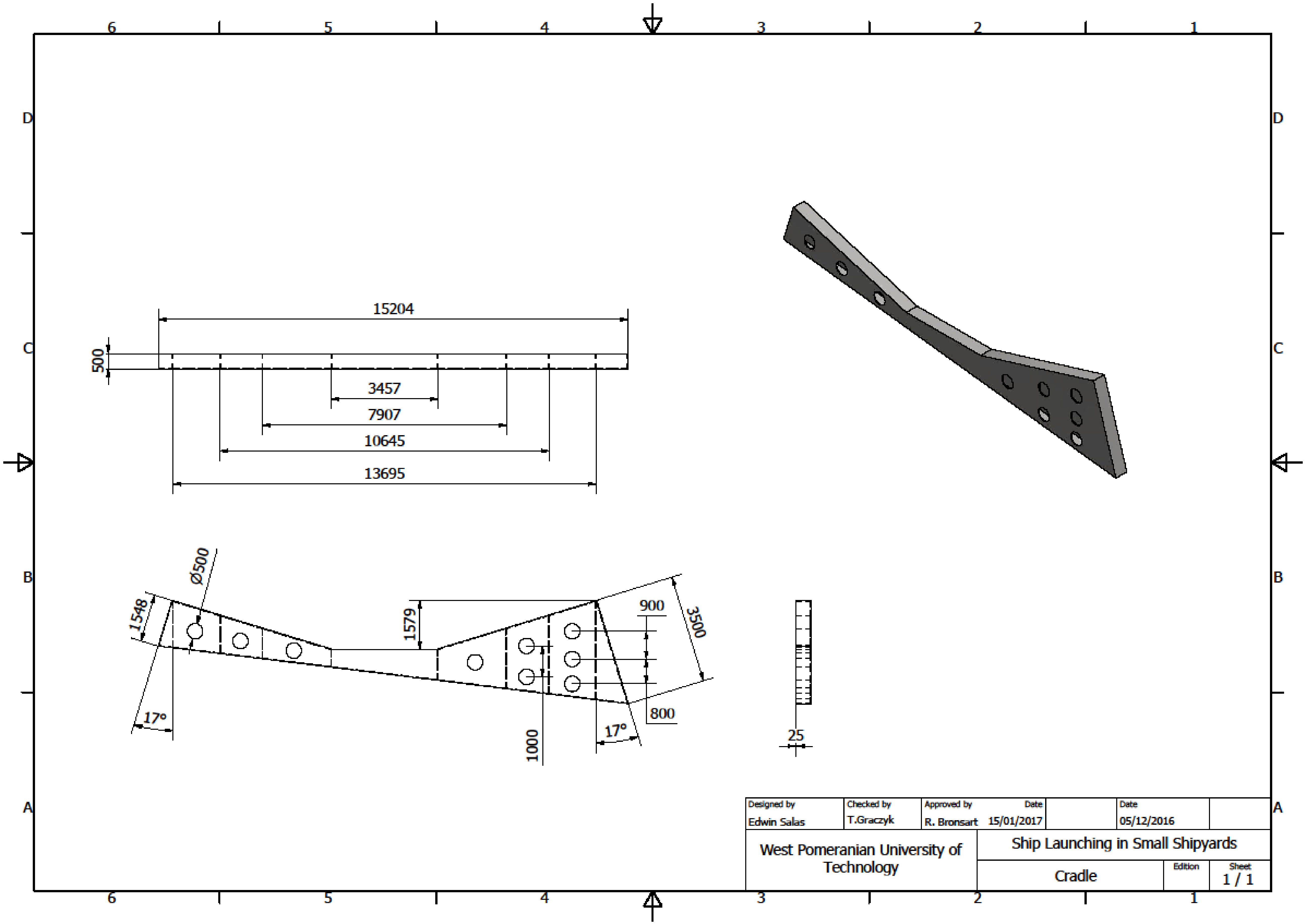
Date
15/01/2017
West Pomeranian University of Technology
Ship Launching in Small Shipyards
Portable Slipway
Edition
Sheet
1 / 1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800
17°
25
Designed by
Edwin Salas
Checked by
T.Graczyk
Approved by
R. Bronsart
Date
15/01/2017
Date
05/12/2016
West Pomeranian University of Technology
Ship Launching in Small Shipyards
Cradle
Edition
Sheet
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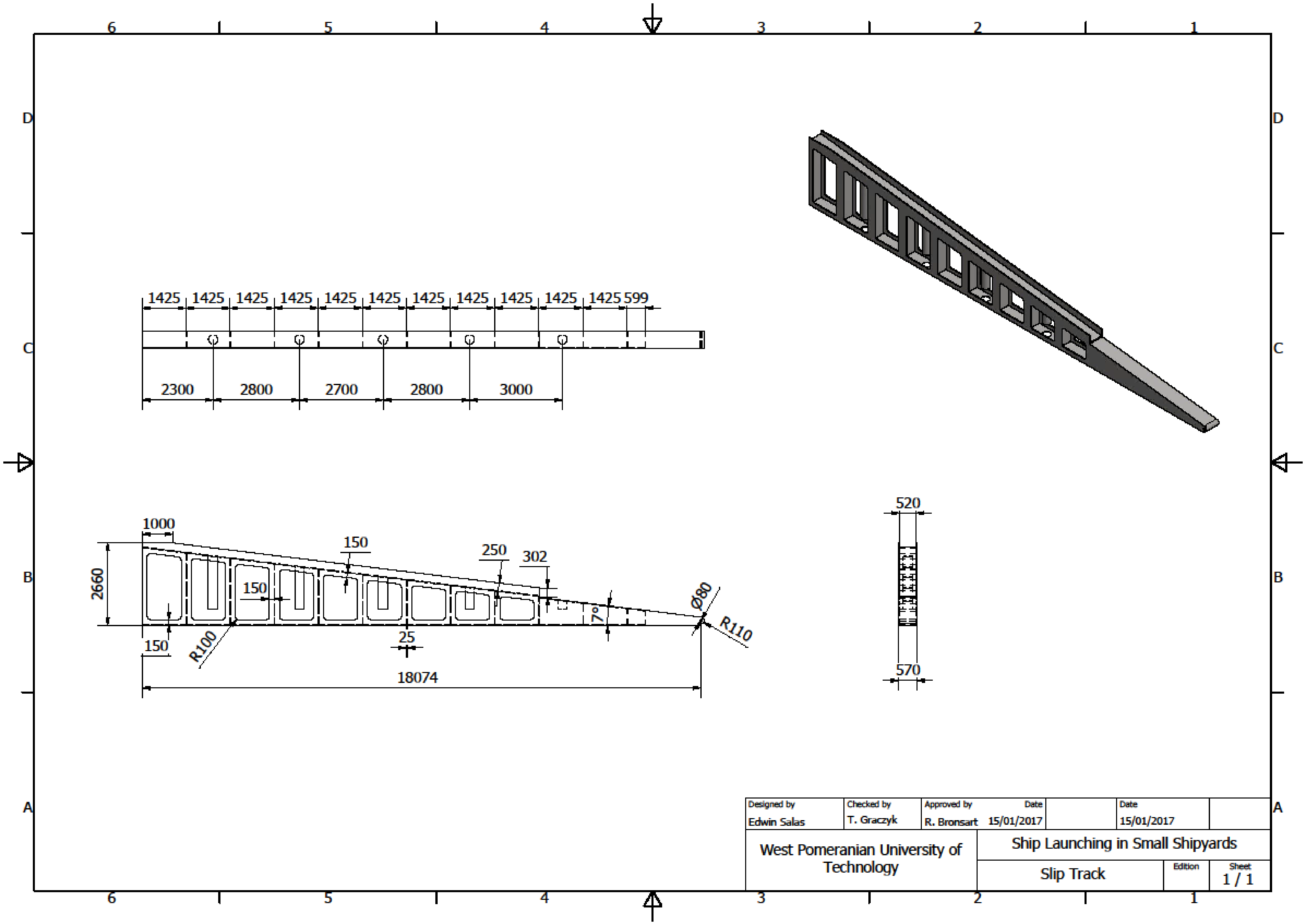
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Designed by
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Checked by
T. Graczyk
Approved by
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Ship Launching in Small Shipyards
Slip Track
Edition
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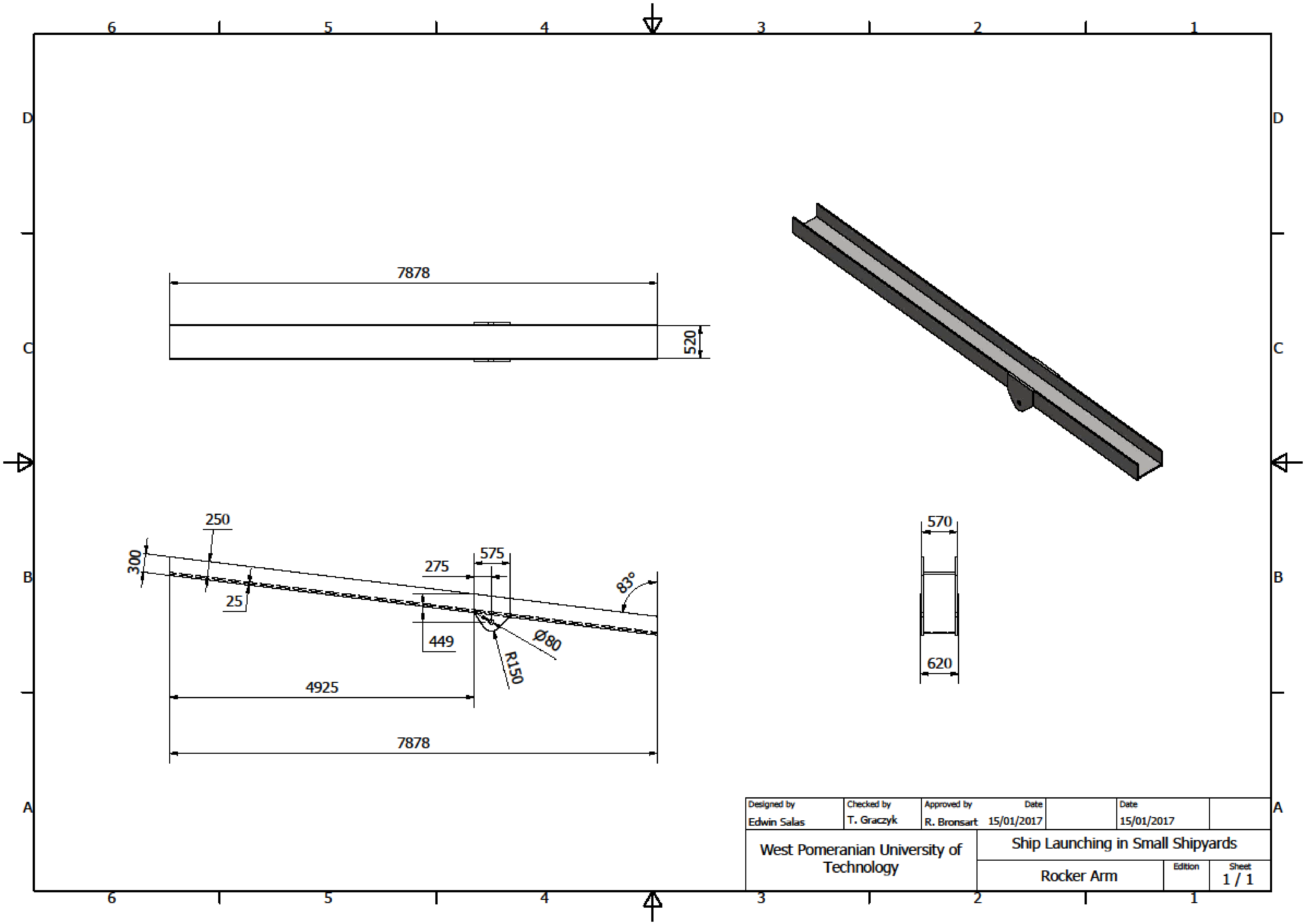
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Ship Launching in Small Shipyards
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Edition
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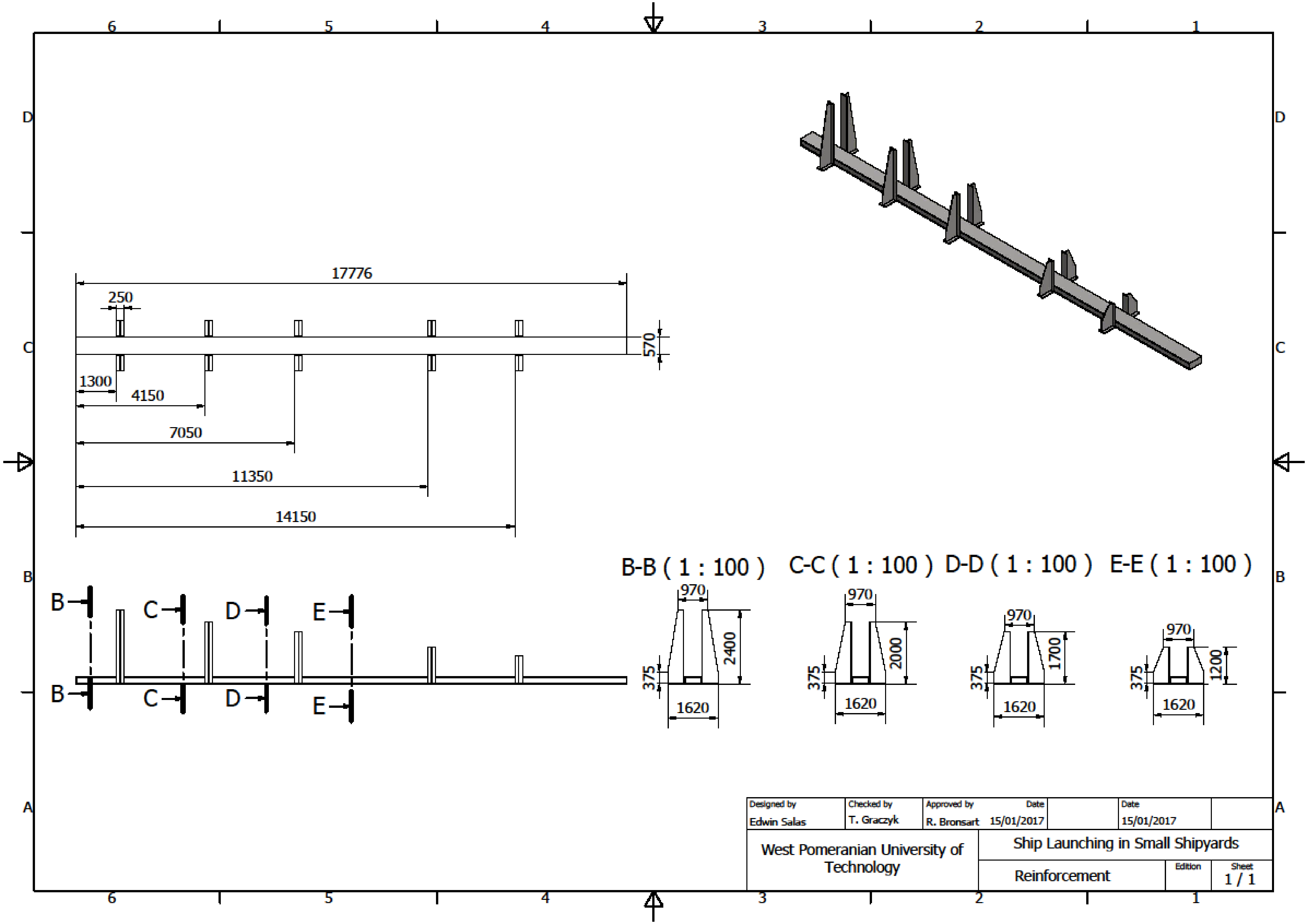
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B-B (1 : 100)
C-C (1 : 100)
D-D (1 : 100)
E-E (1 : 100)
970
2400
2000
1700
1200
375
1620
B
C
D
E
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