MANUFACTURING ASPECTS OF LOWER CYLINDER FABRICATION CUM TRANSPORTATION FRAME FOR ITER CRYOSTAT

Final year project report

Submitted by

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Under the guidance of

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Dehradun

2015

Declaration

This is to certify that:

1. Thesis compromises of my original work towards the degree of Masters of Technology in Nuclear Science and Technology at University of Petroleum and Energy Studies and has been not submitted elsewhere for the degree or diploma.

2. Due acknowledgement has been made in text to all other materials used.

Varun Vijay Savadi

(R108213008)

Certificate

This is to certify that the Major Project Report entitled "**Manufacturing Aspects of Lower Cylinder Fabrication cum Transportation Frame for ITER cryostat"** submitted by Varun Vijay Savadi (R108213008), towards the partial fulfilment of the requirements for the award of Degree of Master Of Technology, UPES, Dehradun is the record of the work carried out by him under our supervision and guidance. In our opinion the submitted work has reached a level required for being accepted for examination. The result embodied in this major project, to the best of our knowledge, has not been submitted to any other University or Institution for award of any degree.

Mr Pandurang Jadhav

Larsen & Toubro Limited

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ABSTRACT

ITER, meaning the way in Latin, is an experimental Fusion reactor being constructed presently at Cadarache, in South of France. ITER originally an acronym of International Thermonuclear Experimental Reactor is a step towards future production of electricity from Fusion energy. An unprecedented international scientific and technological collaboration representing more than half the world's population is presently involved in construction of ITER. Cryostat is a 29m×29m complex structure, completely made up of stainless steel. The main purpose of cryostat is to provide the necessary vacuum environment for the function of cryogenics. Larsen & Toubro Heavy Engineering Unit, Hazira is responsible for the complete fabrication of the cryostat. Cryostat is mainly divided into four sections Top Lid, Upper Cylinder, Lower Cylinder and Base Section. Base section, Lower cylinder and Upper cylinder are divided into two divisions Tier1 and Tier 2 and top lid is made up of one tier, which are further divided into smaller segments to carry out the fabrication activities.

This work presents the manufacturing aspects of fabrication cum transportation frame for assembly of lower cylinder of Cryostat. Scope of work includes working on the manufacturing aspects of the transport frame. The transportation frame on which the whole Lower Cylinder assembly rests has to be fabricated with stringent industrial practices in compliance with the international codes and standards. This work gives overview of the challenges being confronted in the manufacturing of Lower Cylinder transportation frame. Transportation frame rests on the stools and supports are provided above the frame to hold the job for carrying out fabrication. The manufacturing shall include relevant inspection to guarantee the desired quality. The transportation cum fabrication frame will be used to transport the Lower Cylinder from site workshop to Tokamak pit during assembly process.

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Chapter 1 Introduction

1.1 About L&T

L&T'S Hazira campus is mainly divided into two further divisions, known as Heavy Engineering Works and Ship Building facility. L&T is a pioneer in welding technology and fabrication of large components supported by the in-house Modular Fabrication Facility (MFF). Modular Fabrication Facility at Hazira campus can carry out manufacturing of several modules simultaneously with annual fabrication capacity of 50, 000 MT.

All the Nuclear related engineering and technology projects are carried under L&T Nuclear Power Business Group which is a part of Heavy Engineering Division. L&T is specialized in manufacturing of Nuclear Components which are in compliance with ASME standards and other International Standards. L&T with its expertise and use of cut to edge welding and fabrication technology has successfully delivered Large vessels, Reactors, End Shields, Steam Generators, Heat Exchangers, Core Subassemblies to the Nuclear Power Plants.

Apart from manufacturing of nuclear components L&T has carried out even Erection and Commissioning at various nuclear power plant locations. Some of prestigious projects include installations of reactor and safety vessels at Kudankulam Nuclear Power Plant Site at Kudankulam, Tamil Nadu.

1.2 About ITER

Scientist, Engineers, and various technology experts from applied sciences background from 7 Nations viz India, US, European Union, China, Russia, Japan and Korea are working together as a team in with a common goal of producing cleanest form of energy produced by fusion of hydrogen atoms. ITER project is marked as the world's biggest ever project in terms of fusion energy production. In MOU inked in between 7 nations the goal is achieve to the clean and green energy through fusion device for the first time. ITER site is located at Cadarache, south of France. The members of the ITER project are supposed to bear cost inculcated during the construction and operational phase which is estimated to be 10 years and 20 years respectively.

ITER Tokomak is very huge complex structure comprising of nearly a million parts. Its dimensions range as high as 30 meters high and nearly same in width with whole structure weighing nearly 23,000 tonnes.

ITER is based on the 'Tokamak' concept of magnetic confinement, in which the plasma is contained in a doughnut-shaped vacuum vessel. The fuel is a mixture of deuterium and tritium, two isotopes of hydrogen, is heated to temperatures in excess of 150 million°C, forming hot plasma. Strong magnetic fields are used to keep the plasma away from the walls; these are produced by superconducting coils surrounding the vessel, and by an electrical current driven through the plasma. The whole ITER machine is majorly divided into two main parts which are further divided into many subparts as listed below.

The Tokomak	External Systems
Magnets	CODAC
Vacuum Vessel	Vacuum Pumping System
Blanket	Cryogenics
Divertor	Remote Handling
Diagnostics	Power Supply
External Heating	Fuel cycle, Hot Cell
Cryostat	Cooling Water, Tritium Breeding

The plasma generated inside the vacuum vessel will power the whole fusion device. The energy created by hot plasma would be immense and vital also as it is source of energy to generate power through fusion. As the temperature of plasma is very high and at these temperatures it is obvious that instabilities would be generated which is undesirable. To control the plasma and confine it properly at the centre Tokomak is provided with superconducting magnets system. 18 superconducting toroidal fields, 6poloidal fields and a central solenoid will be responsible to confine the plasma centrally along with the correction magnets. It is estimated that all the magnetic elements of the machine together would be generating the magnetic fields nearly 200,000 times higher than that of our earth. The whole fusion reaction needs to be carried out in clean vacuum environment conditions hence the vacuum vessel. It also acts as primary safety barrier in which the whole reacting plasma would be contained. The ITER vacuum vessel will be twice as large and sixteen times as heavy as any previous tokomaks, with an internal diameter of 6 metres. It will measure a little over 19 metres across by 11 metres high, and weigh approximately 8,000 tons. The proper shielding of the vacuum vessels and inner components is going to be great challenge as the whole hot plasma and the fusion reaction is carried out inside vacuum vessel, it is provided with the blankets which are placed inside the vacuum vessel. Slowing of the high energy neutrons is achieved as they approach close to the blankets where they give out the kinetic energy which is then further transformed into heat energy.

This heat energy is used for the generation of electricity at fusion power plants. The divertor is one of the key components of the ITER machine. Placed at the very bottom of the vacuum vessel it is responsible for the extraction of helium ash and heat which are both products of the fusion reaction. The role of diagnostics system would be a key to study the plasma behaviour and the various parameters associated with it. ITER machine would have 50 independent diagnostics systems which would be responsible for studying the various parameters such as heat, density, flux and many more. To achieve the goal of producing fusion power, the plasma has to attain nearly a temperature as high as 150 million degree Celsius or ten times more than that the temperature of the sun which is why it is driven by auxiliary heating system to achieve the desirable conditions needed to extract the energy from fusion.

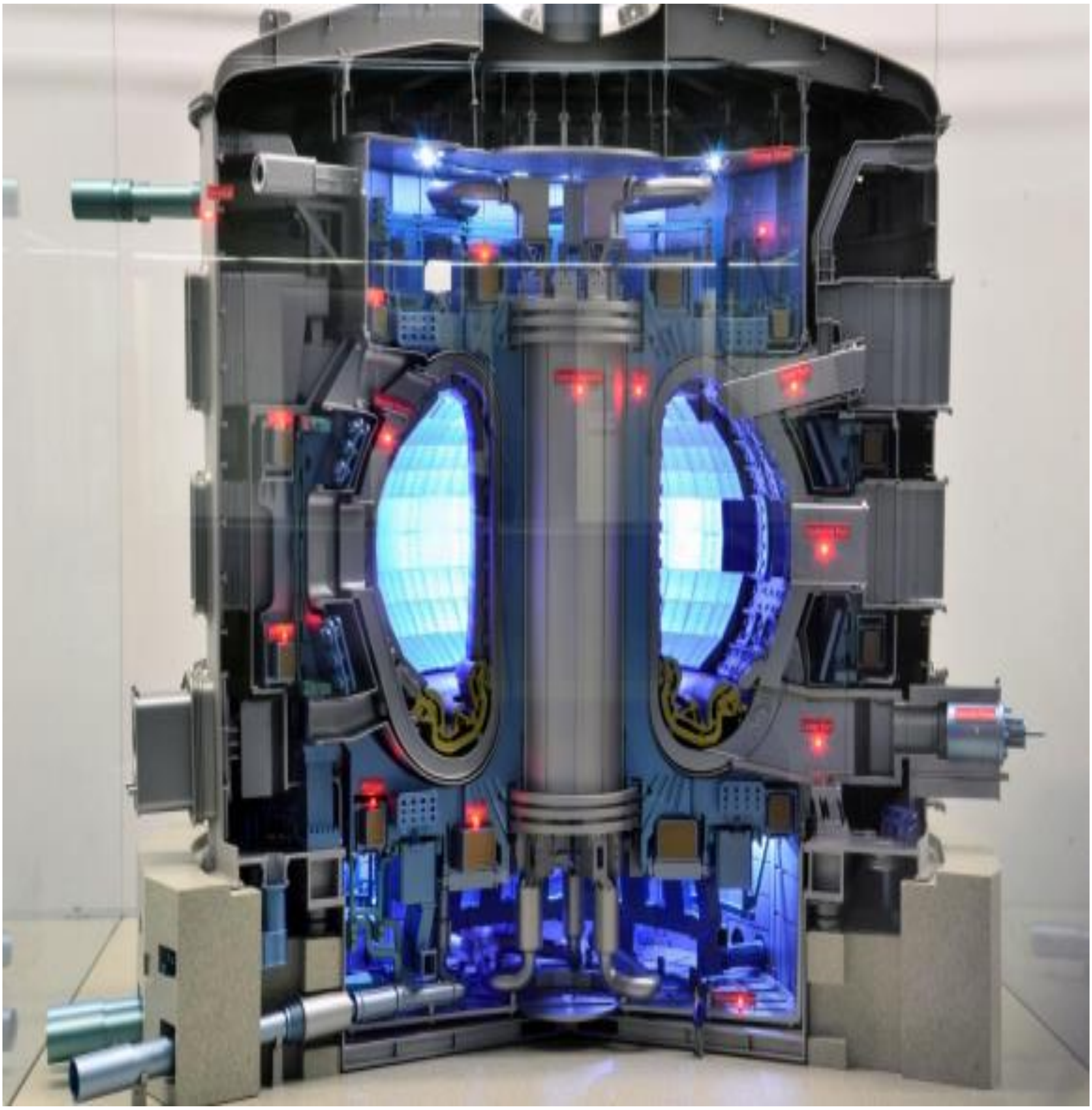


Figure 1.1 Tokomak Prototype Model

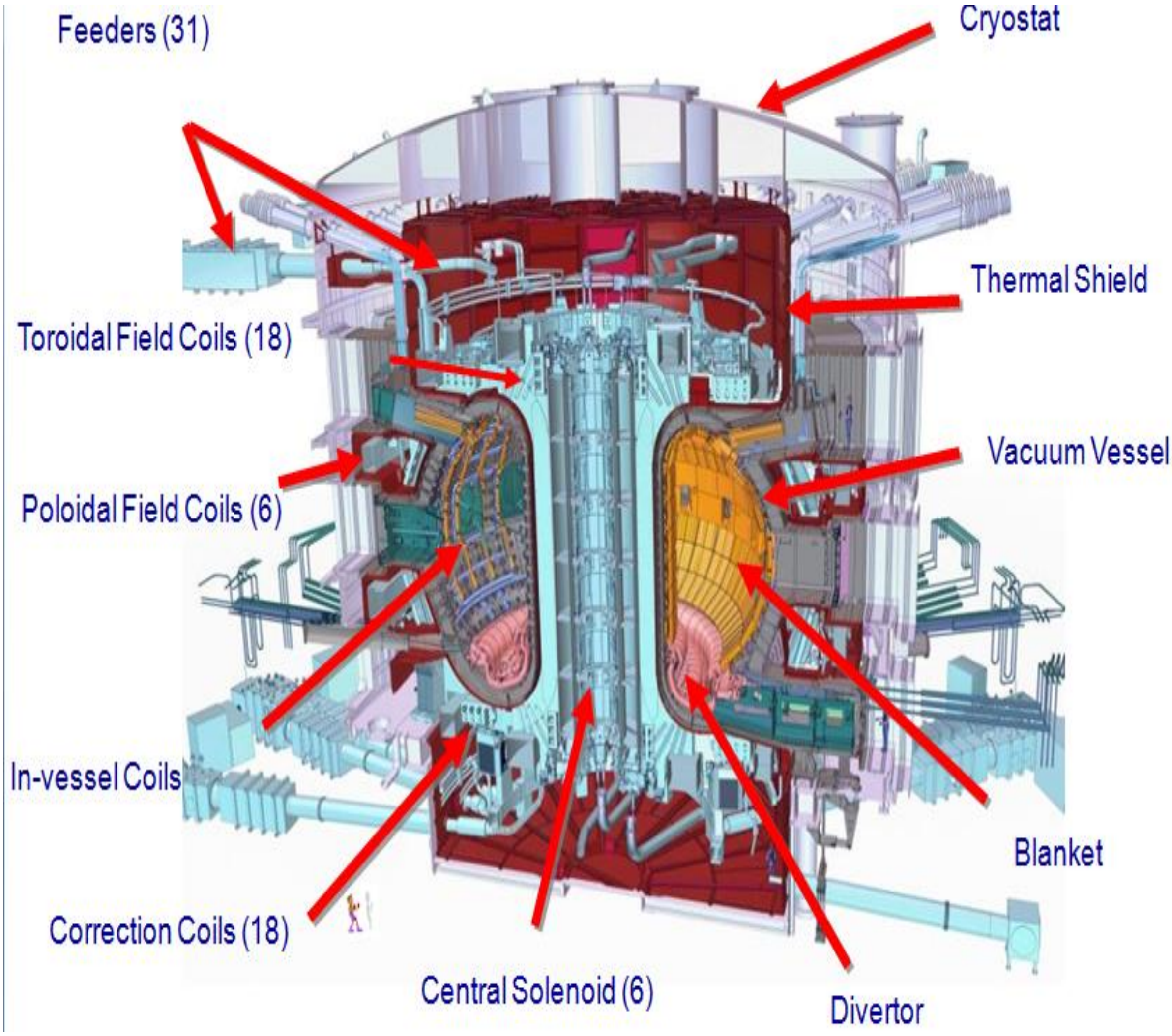


Figure 1.2 ITER Tokomak Components

ITER Tokomak with its components is as shown in the above figure

1.3 Cryostat

The ITER cryostat will be the world's largest high-vacuum pressure chamber. On 17 August, the contract for the manufacturing of the 3,500 ton steel-structure was signed with the Indian company **Larsen & Toubro (L&T) Ltd**.

The ITER cryostat is a complex and one of largest structure of the ITER machine made of completely stainless steel structure with thickness ranging from 50mm to 250mm. The volume is to be estimated to be 8500 cubic meter and dimensions are as high as 29.4 meters in height and same as in width. The cryostat as a whole will act as an enclosure to provide the working conditions desired for the cryogenics involved in the ITER machine. Overall weight of component is more than 3,500 tons making it the world's first and largest vacuum vessel ever built of stainless steel.

The cryostat will have 23 penetrations to allow internal access for maintenance as well as over 200 penetrations some as large as four metres in size providing access to the vacuum vessel for cooling systems, magnet feeders, auxiliary heating, diagnostics, and the removal of blanket sections and parts of the diverter. Large bellows will be used between the cryostat and the vacuum vessel to allow for thermal contraction and expansion in the structures.

As the dimensions of the cryostat are nearly as 29.4 meters in height as well as width there are many manufacturing constraints involved one of them primarily being the transportation of the structure as a whole. The limitation for transportation is 9 x 9 x 19 m by volume while being exported to France. Hence whole cryostat is divided into four major sections which are further divided into many sections as per the limit. The main sections of cryostat are as listed below with figure

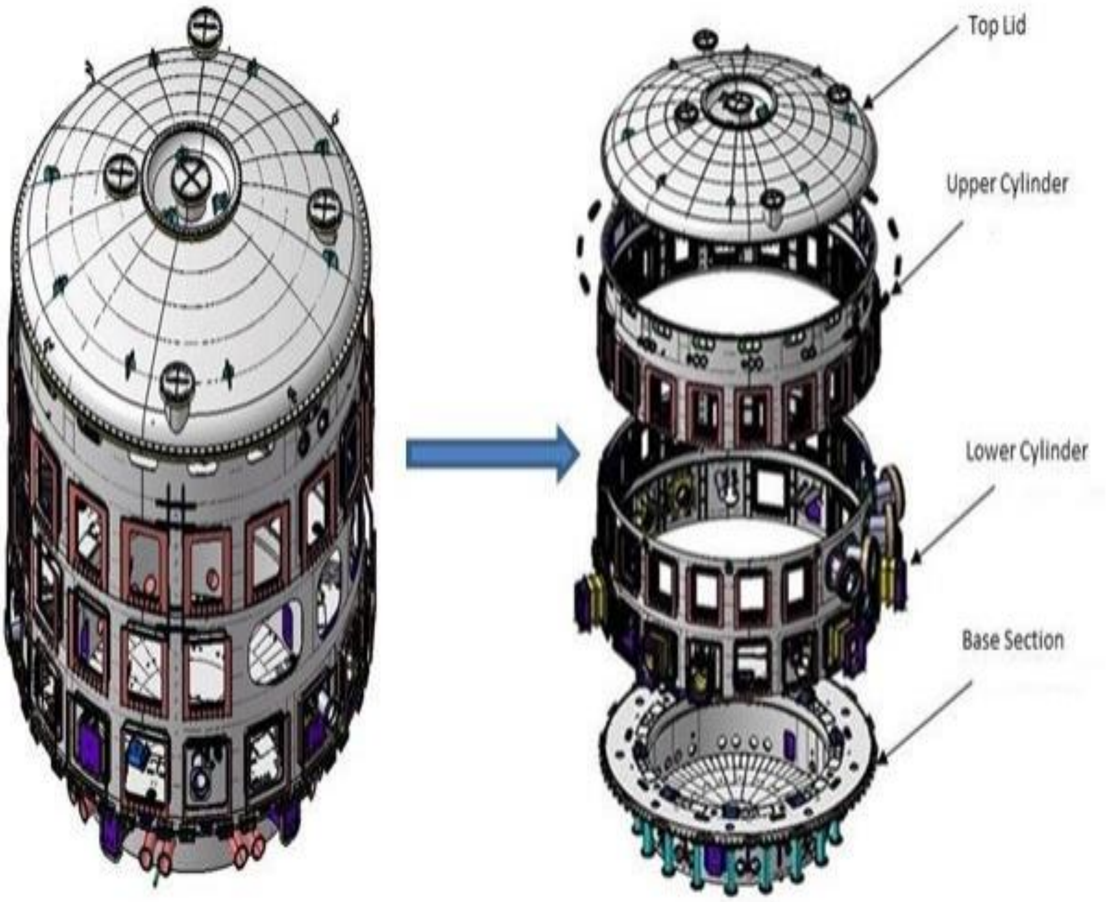


Figure 1.3 Cryostat With Segments

1.4 Cryostat Segmentation

1) Base Section
2) Lower Cylinder
3) Upper Cylinder
4) Top Lid

Cryostat dimension being nearly 29.4 meters in height and as well as in width and manufacturing constraints involved along with it, it is segmented into many sections for the ease of manufacturing. As listed above cryostat is majorly divided into 4 main sections out of which Base Section BS, Lower Cylinder LC and Upper Cylinder UC and each of these four sections is further divided into two tiers known as tier 1 and tier 2 sectors. Further each of these tiers are divided into six sectors of 60 degrees each. Hence there are now totally 12 sectors to be manufactured for each major section of the cryostat. In case of Top-Lid there is no further segregation. After manufacturing sectors this sections would be transported to Cadarche, France within the transportation limit. Long seam welding will be performed to join two sections with each other and a circumferential welding will be done to join the two tiers together at site. After assembling the components each section starting with base section will be installed into tokomak pit from bottom to top. For transporting the sections from workshop to pit transportation frame will be used on which the whole section would be resting supported by SPMT vehicles for movement.

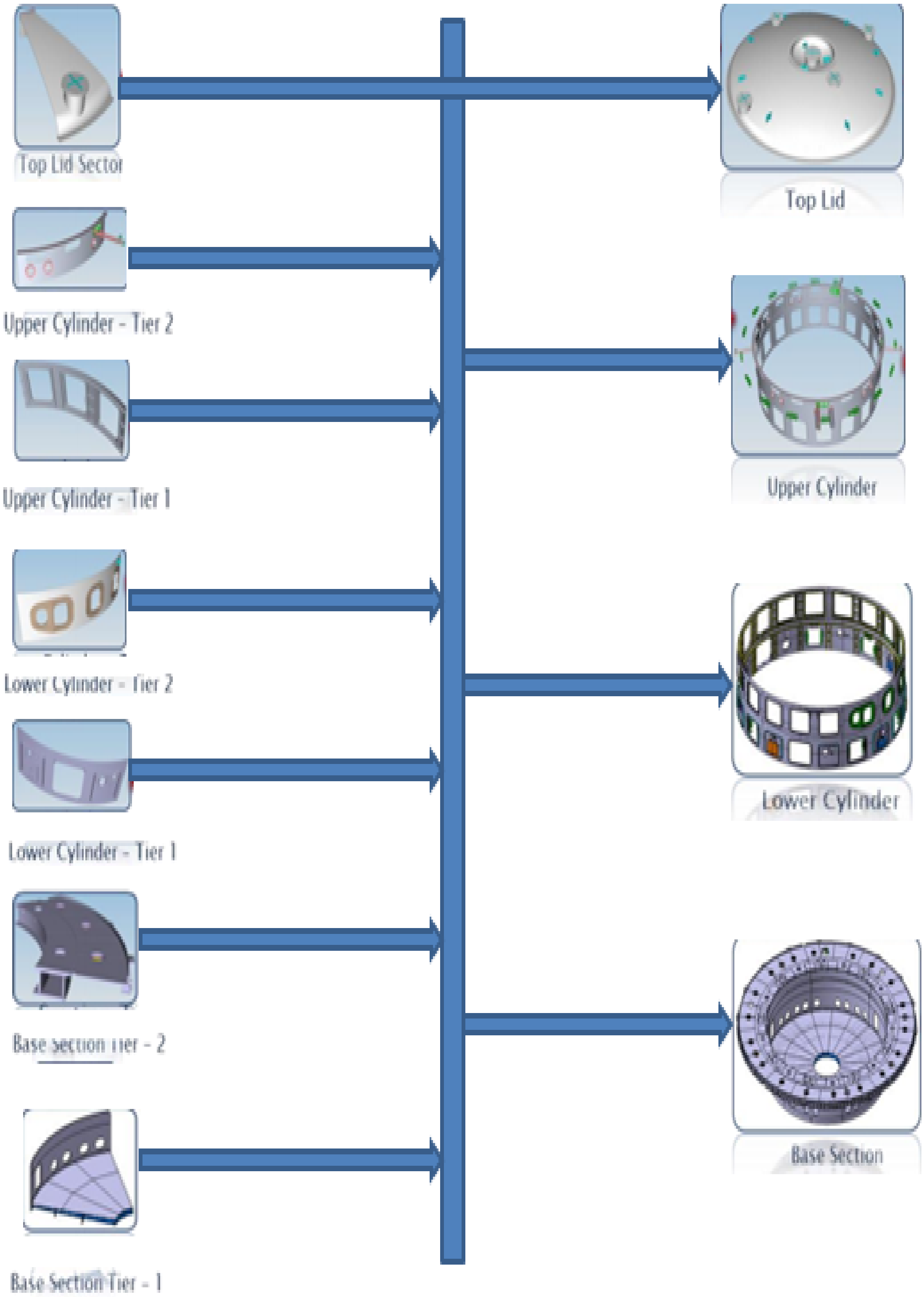


Figure 1.4 Segregation of sections into two tiers and again into sectors

1.5 Pathway from site to tokomak pit

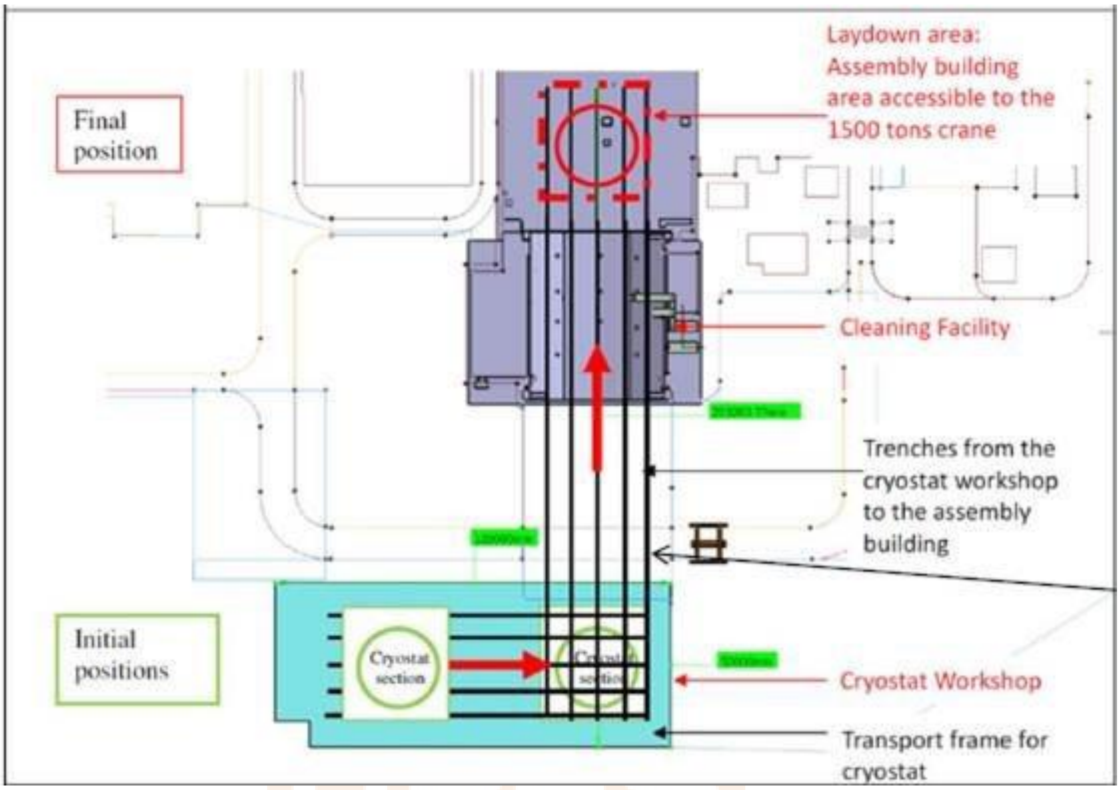


Figure 1.5 Pathway from temporary workshop to tokomak pit

The above figure shows the details of the pathway of transportation cum fabrication frame from site workshop to the tokomak pit. Initially the frame will be used as a support to hold the job which is lower cylinder sectors in the above case. After the fabrication is carried out on the frame, it will be used also to transport the job from the site workshop to the tokomak pit which is around 300 meters away.

As the same transportation frame will be used to fabricate and transport the upper cylinder of the cryostat so compatibility of the frame with upper cylinder is desirable from manufacturing stand. The same frame being used for the fabrication activities as well as transportation serves in multiple ways by optimising the manufacturing cost and the amount of time required to perform the assembly.

1.6 Project Statement

The aim of the project is to manufacture the fabrication cum transportation frame for the Lower Cylinder of the Cryostat. As there would be total 12 numbers of sectors to be manufactured for completing the lower cylinder, there are many manufacturing constraints involved which are to be taken care of. The size constraint for the frame is 30.2 meters in length and as well as in width. An approximated load of the lower cylinder is around 600 tonnes which would be resting on the frame. Hence it is desired that the frame should be as stiff as possible and rigid with required strength to support the whole component to be fabricated. The fabrication cum transportation frame used will be kept at height of 1300mm from the ground to facilitate the movement of the SPMT vehicles which will transport the job along with the frame from site workshop to the tokomak pit. The height of the stools is fixed as 1250mm from ground.

Twelve sectors from tier one and tier two will be joined with welding process, so accessibility of welding is also major challenge as each 60 degrees section will be joined by long seam welding and circumferential welding will be performed to join the two tiers together. All the assembly tools, jigs and fixtures required to perform welding and other machining activities will also be resting on frame so as to facilitate the fabrication of the component being rested on it. Apart from the lower cylinder, a support structure will also be placed on frame. The frame cannot be directly rested on the floor because of the movement of SPMT vehicles and supporting stools from bottom. The locations of the stools and placing is also a challenging task from manufacturing point of view as SPMT vehicles have to move in between the stools to transport the component from site to tokomak pit. Any changes in the stools position will create hindrance to the movement of the SPMT vehicles which is undesirable.

Keeping into consideration all the above constraints a transport frame has to be manufactured which is rigid and is stiff enough to take all the load acting upon it. Suitable manufacturing methodology has to be adapted while fabricating the frame which satisfies all the limits and above discussed constraints having enough strength.

1.7 About Lower Cylinder

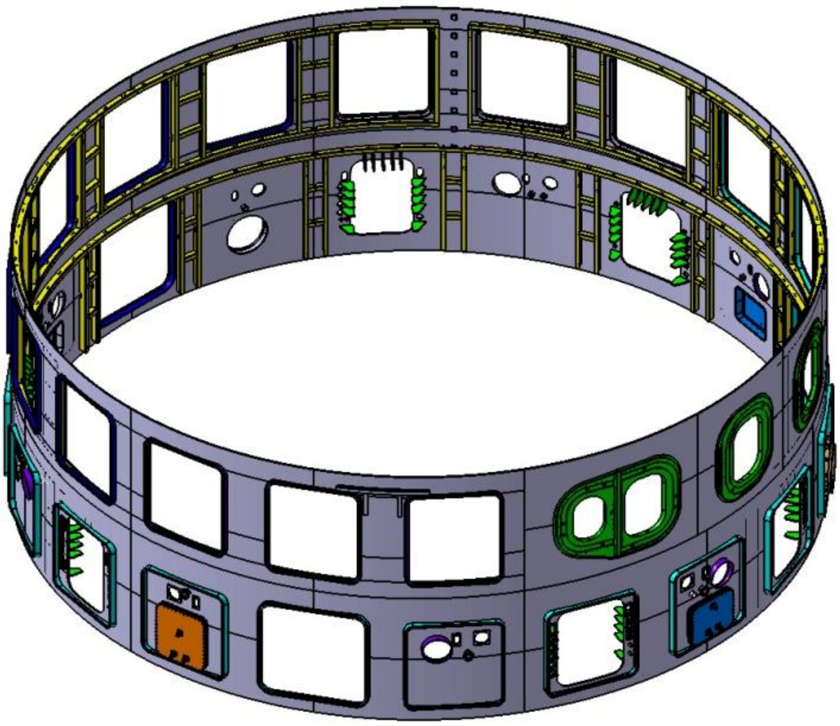


Figure 1.6 Lower Cylinder along with access ports

Dimensions of the lower cylinder are as below.

Outer Diameter (O.D) = 29540 mm

Thickness of Shell = 50 mm

Total weight = 600 tonnes

Total Height = 10,300mm

Lower cylinder component of the cryostat will be assembled after the installation of the base section into the tokomak pit. Above shown figure is of lower cylinder with the external connections, and 18 ports. These 18 ports are equally placed at an angle of 20 degrees each. There are many external connections running into the lower cylinder and about 18 ports for access. Major connections being of cryo-pumps which will provide the vacuum environments necessary for the working of the cryogenics system involved. The Tier1 and Tier 2 sectors of the lower cylinder are shown with details in the below figure

1.8 About Lower Cylinder Tiers

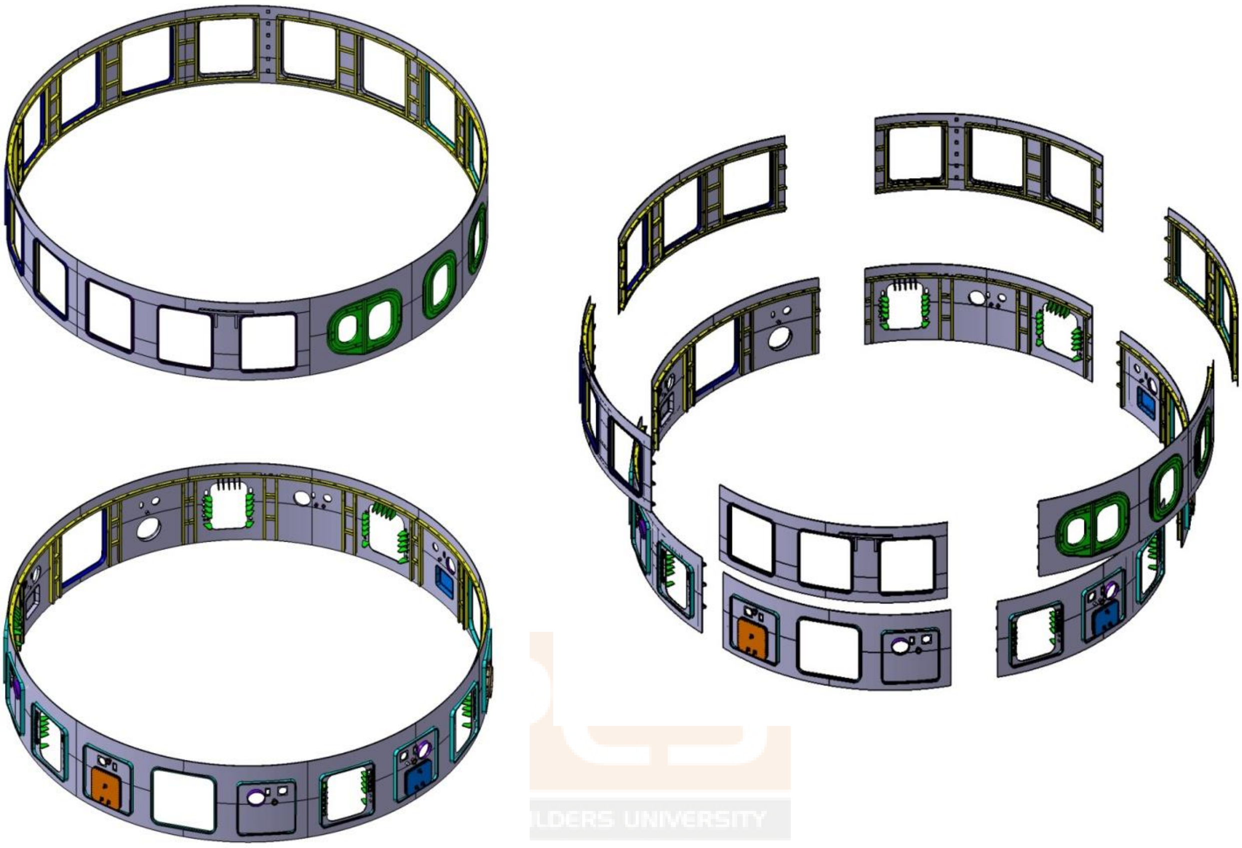


Figure 1.7 Lower Cylinder Tier 1 and Tier2 Sectors

1.9 Objective of the Project

Manufacturing and fabrication of the transportation frame for the lower cylinder section of the cryostat within the specified allowable limits. Stringent practices are to be followed while manufacturing the frame. The same frame has to be compatible with the upper cylinder component of the cryostat hence optimizing the cost.

Chapter 2 Literature Survey

2.1. Introduction

“Man is a tool-using animal. Without tools he is nothing, with tools he is all.” - Thomas Carlyle, Sartor Resarks, book I, 1833.

For any product to be manufactured with desired precision planning for assembly, servicing and disassembly of a product plays very important role in the phase of design. Inputs derived from the plan of assembling planning will provide the support to design engineers from manufactuchring point of view. For any manufacturing procedure optimization of cost, time and labour always is an priority which can be achieved by the means of computer aided design tools. While manufacturing there will be many constraints being created which are to be taken care of. Hence a methodology with clear plan of assembly has to be adopted in achieving the desired quality aspects of the product being manufactured. This paper presents the overview of many such constraints involved while manufacturing a heavy component and also how to approach further with new concept or methodology of manufacturing by overcoming the constraints.

Transportation frame is a rigid structure laced with assembly tools, jigs and fixtures which help in geometric accessibility of the large and complex components being manufactured. Assembly tools are used to carry out machining activities during the assembly and disassembly process of a component. Depending upon the requirements the assembly tools can be used at different time intervals maybe they can be implemented before joining of any two components or also can be used post assembly of component to carry out the machining activities. Tools resting on the frame can be of various types according to the requirement of the machining activities to be carried out. They can be manual tools, semiautomatic or completely automatic such as welding machines. The author further goes on explaining with the framework to represent and reason about the geometric accessibility of tools in assembly resulting in necessary constraints on assembly plans. It is desired to find out the position details of the tool being placed and also studying its compatibility at that location with the component being manufactured. This is an instance of the “FINDPLACE” problem.

Cheng Hui, Li Yuan and Zhang-Kai-Fu made a detailed study on the efficient method of assembly sequence planning based on GAAA and optimizing by assembly path feedback for complex product. In the detailed study it has been observed that any complex product assembly has to follow a fix cycle in which all the associated tools, fixtures and so on has to undergo the process required for the assembly with parts together to rapidly finish the product assembly. As this process demands considerations of the very minute details of the activities during assembly it becomes little tedious job for a design engineer to accommodate all the constraints involved which results into assembly failures and redesign for the assembly sequence. After thorough investigations of the problems associated with the assembly author comes up with an efficient method of assembly sequence planning based on genetic algorithm and ants algorithm (GAAA) and optimizing by assembly path feedback to assembly process planning including assembly resources for complex products. Long and Yufeng studied on Variation simulation for compliant sheet metal assemblies with applications. Sheet metals are widely used in discrete products, such as automobiles, aircraft, furniture and electronics appliances, due to their good manufacturability and low cost. A typical automotive body assembly consists of more than 300 parts welded together in more than 200 assembly fixture stations. Such an assembly system is usually quite complex, and takes a long time to develop. As the automotive customer demands products of increasing quality in a shorter time, engineers in automotive industry turn to computer-aided engineering (CAE) tools for help. Computers are an invaluable resource for engineers, not only to simplify and automate the design process, but also to share design specifications with manufacturing groups so that production systems can be tooled up quickly and efficiently. It is a well-known fact that assembly architectures (joints, fixtures, and assembly lines) have a profound impact on dimensional quality of compliant sheet metal assemblies. Author comes up with an unified variation model is developed to predict variation in compliant sheet metal assemblies by considering fixture-induced rigid-body motion, deformation and spring back. Based on the unified variation model, variation propagation models in multiple assembly stations with various configurations are established. To evaluate the dimensional capability of assembly architectures, quantitative indices are proposed based on the sensitivity

matrix, which are independent of the variation level of the process. Arnulf Horn and Huw Lewis with their study proposed for the flexible system to reduce tooling costs in assembly cells. Flexible Machine Cells (FMC) has become very popular in many manufacturing environments due to reduction in set-up down-time using off line set up. A similar procedure is not yet available for assembly cells. This arises from the need for accurate positioning of the parts from bulk storage containers prior to assembly. Author investigates the development of tactile array sensor that would define the type of the component and the position relative to a datum point. The type of the component would be given by its shape and weight. This would, in conjunction with software and a suitable control system, enable the assembly cell to identify, locate and assemble a component without the need for expensive and complex orientating devices. Whilst there are some vision systems available capable of carrying out a similar task, they tend to be slow in analysis and high in cost. It is hoped to develop a low cost method of parts identification that removes the need for expensive tooling.

2.2 Manufacturing aspects of the transport frame

The overall dimensions of the lower cylinder and upper cylinder in terms of O.D and I.D remain same hence from manufacturing stand point it is important that the same frame should be applicable while fabricating the upper cylinder also hence minimizing the overall cost.

1) It should be easy in manufacturing.

2) It should compatible with upper cylinder

3) It should be economical.

4) It should be strong enough to support the components and structures resting on it.

5) It should support the tools and jigs being mounted on it to give the desired kind of geometric accessibility for machining of the sections.

6) It should satisfy by all demands required from mechanical point of view.

The above listed aspects would be major challenges while fabricating the transportation frame for the lower cylinder of the cryostat.

Chapter 3 Conceptual model

3.1 Conceptual model of the lower cylinder transportation frame

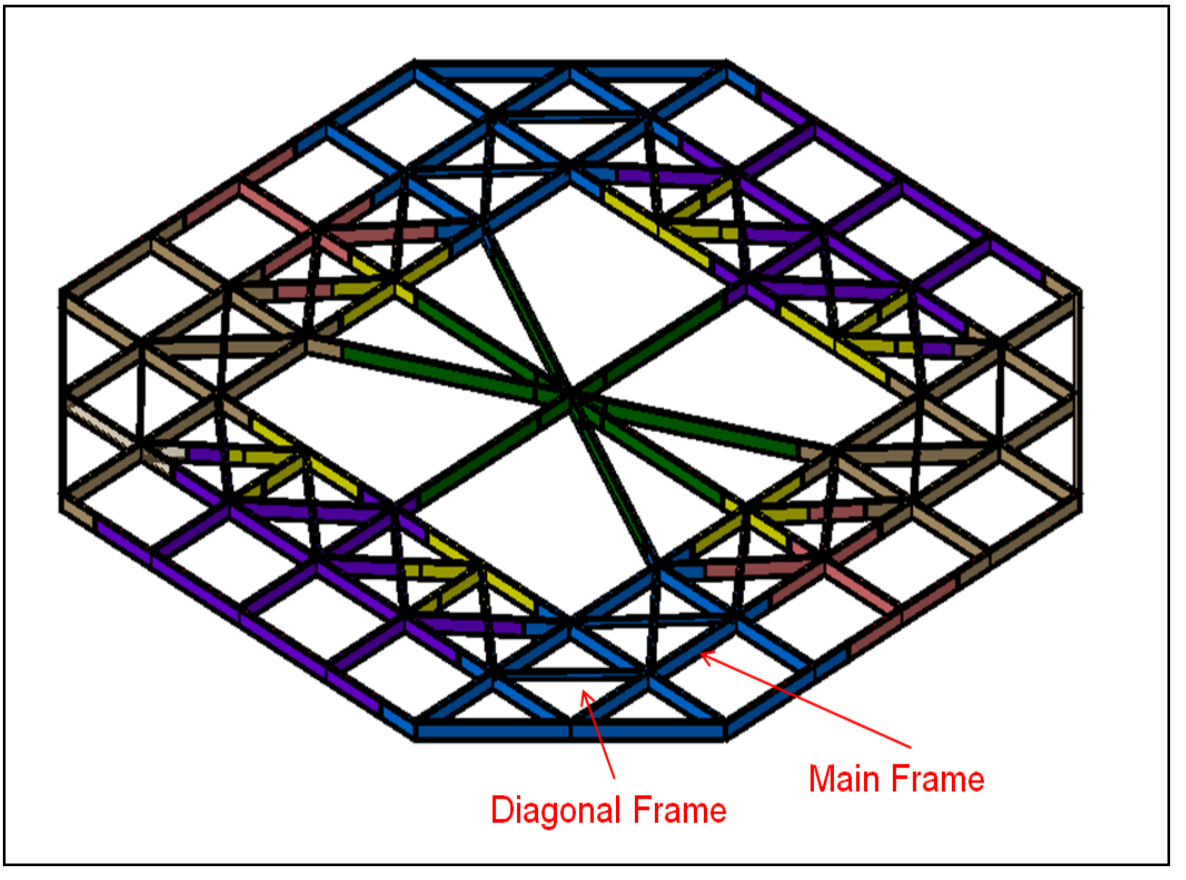


Figure 3.1 Lower Cylinder Transport Frame Model

The above shown figure explains the conceptual model of the lower cylinder transport frame. The overall dimension of the frame is limited with 30.2m X 30.2m upon which the lower cylinder is going to be placed while being fabricated. The whole structure of the transport frame is made up of carbon steel material. The I-Beam cross section used for manufacturing the frame is standard ISMB 300 type.

The whole frame is made up of modules of (maximum size is 8m X 16m) as shown in the above figure. Connections between the modules are bolted type. The details of which are as shown in the below figure.

3.2 Bolted view of the modular frame joints

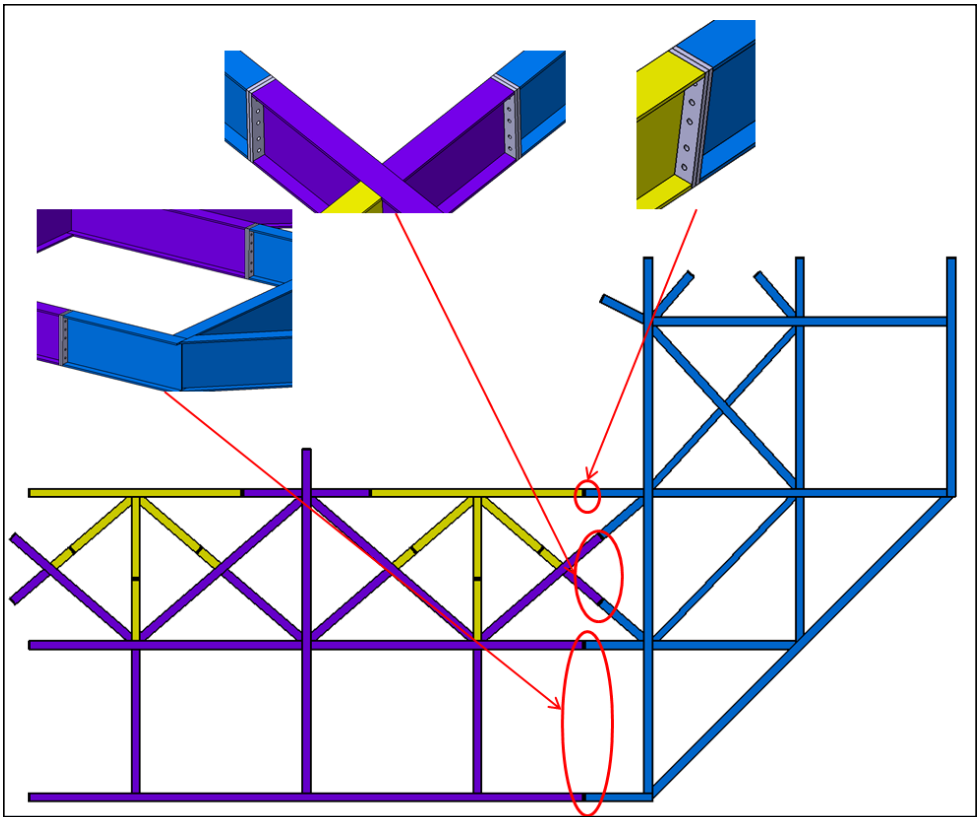


Figure 3.2 Bolted view of modular frame

The frame is divided into total 9 numbers of modules and each of these modules will be shipped to France one by one. Finally the assembly of these modules will be done by bolting the two joints together.

Chapter 4

Manufacturing Constraints and Challenges

1) Manufacturing constraints involved.

In this all the manufacturing constraints involved while fabricating the transportation frame will studied and evaluated in detail. Some of them are as below listed,

a) Machining/ Grinding constraints involved.
b) Welding accessibility and machining accessibility.
c) Support structure fabrication details.

2) Manufacturing methodology for lower cylinder transportation frame.

In this the manufacturing procedures and techniques used for fabrication of the frame shall be evolved.

With the above mentioned details of manufacturing constraints we proceed further in finding out the solutions by detail study. The manufacturing constraints with the appropriate solutions are as listed below.

1. Preventing contact of Stainless Steel (SS) surfaces from Carbon Steel surfaces (CS)
2. Modularity of the Frame due to large size
3. Welding Accessibility that is avoiding weld over weld
4. Stools and SPMT locations
5. Optimizing the height of the frame
6. Material procurement of I beams
7. Placing of pillars and horizontal arms

4.1 Preventing contact of Stainless Steel (SS) surfaces from Carbon Steel (CS) surfaces.

The frame is being manufactured for the site assembly of lower cylinder segments. Lower cylinder being a component of cryostat is made up of completely stainless steel material. As this is an integrated part of cryostat, which has to provide the vacuum working conditions it is undesirable that any type of impurities coming in the system. Since the frame material is made of carbon steel hence it is obvious that when the lower cylinder is going to be placed on the frame SS to CS contact will be direct which could lead to carbon impurities into the lower cylinder thereby affecting the whole cryostat working. This is one of the major constraints while manufacturing the transport frame.

The details of the solution to the above constraint have been explained below with figure.

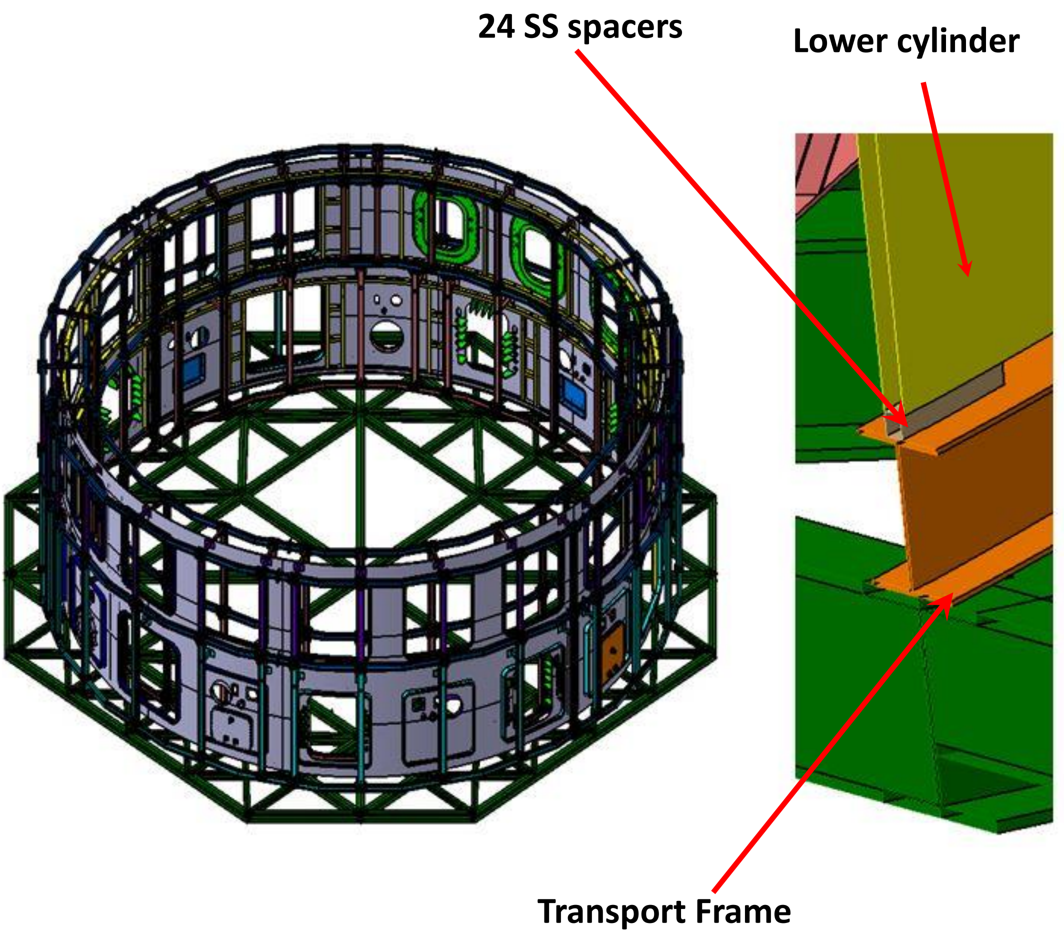
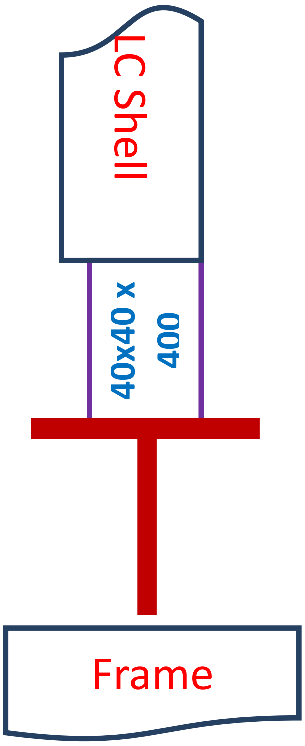


Figure 4.1 24 SS spacers installed between Lower Cylinder and Transport Frame



To avoid the direct contact of the lower cylinder from frame it is planned to place 24 numbers of spacers placed equidistant keeping initial position 1000mm away from the sector joining seams in between the lower cylinder and frame. The dimensions of the spacer are taken to be 40 X 40 X 400.

Modularity of the transport frame

Frame has to be shipped to the France and the transportation by volume is limited to dimension 9 x 9 x 19m. Considering this demand whole frame is made up of modules of (maximum size is 8m X 16m) as shown in the above figure. Connections between the modules are bolted type. The details of which are as shown in the below figure.

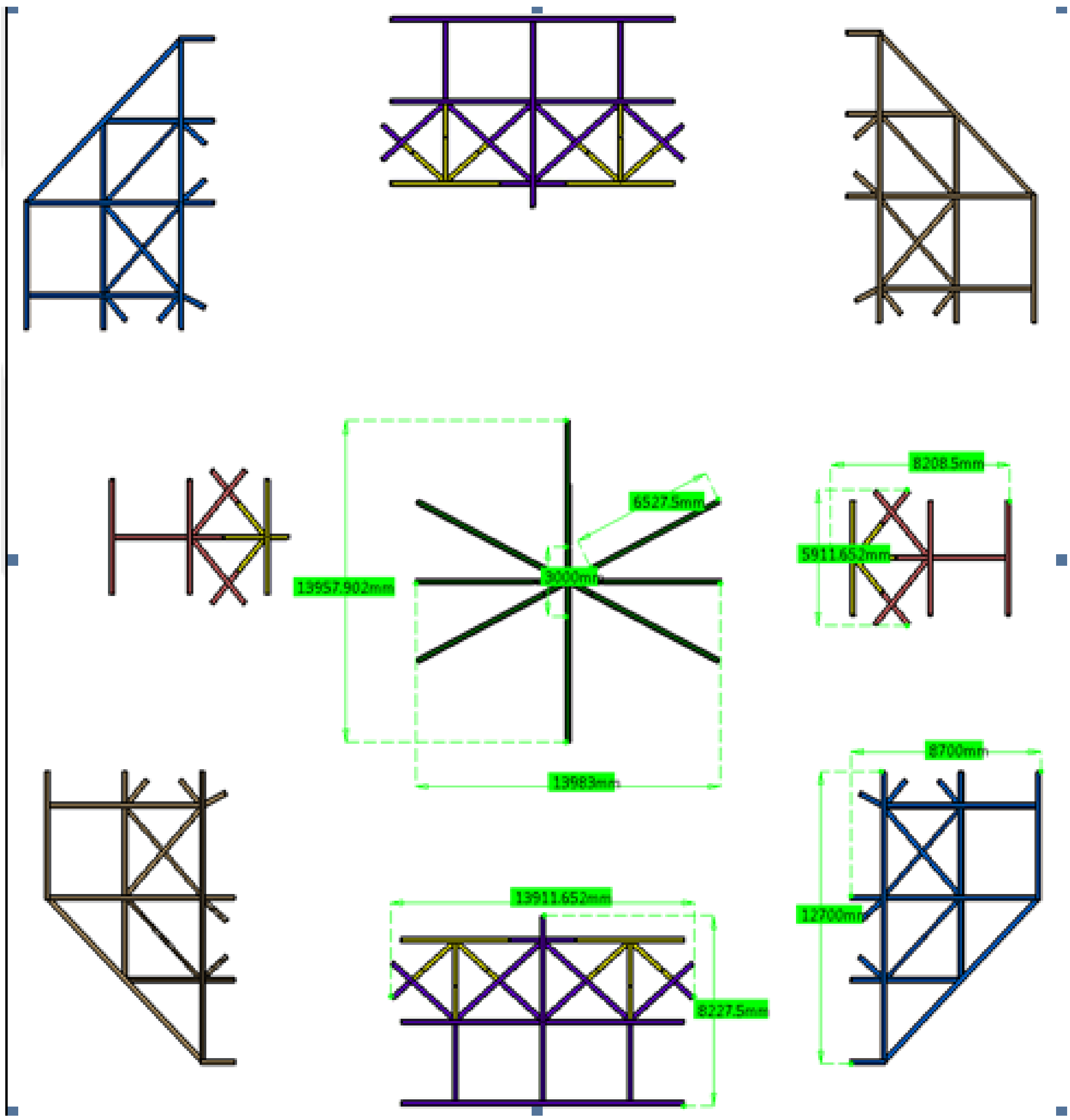


Figure 4.2 Modularity of transport frame

4.2 Welding accessibility of diagonal members of transport frame.

The frame is manufactured by joining ISMB 300 cross section I-Beams but then arises a problem when joining the diagonal members. The diagonal members are to be fixed by 100% full penetration welding.

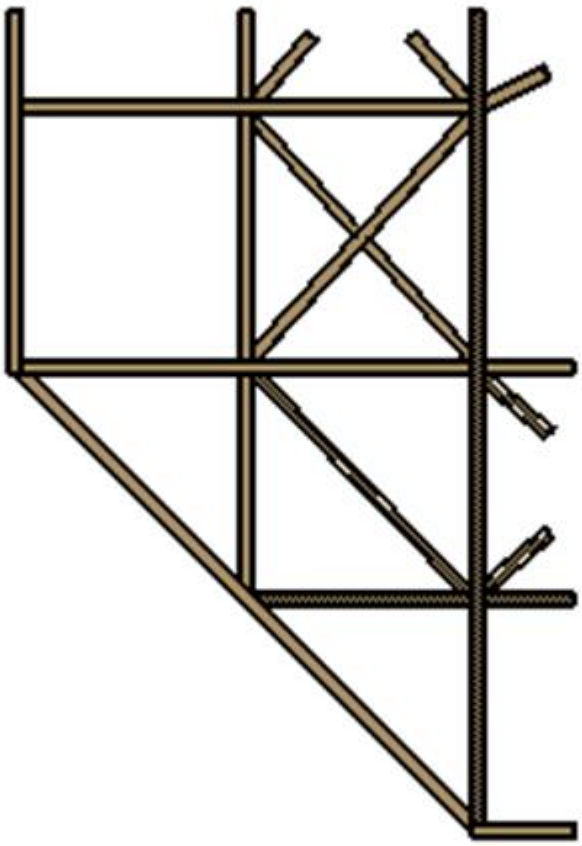


Figure 4.3 Weld to Weld Overlay

To give the frame stiffness and strength the diagonal members have to be welded with the vertical members with which they are intersecting. After performing the welding operation from one side on the member it will be filled with some amount of weld thickness. Now when the welding has to be performed from the other side of member the weld being performed will get deposited on the weld thickness already performed on the other side which is not desirable from manufacturing standpoint. Non uniform layer of weld deposit is not acceptable in manufacturing of components.

Hence in order to overcome this weld over other weld the diagonal members have to be shifted from their initial position. A 50mm translation in the position of the diagonal members helped to overcome the weld over other weld constraint. Apart from this added advantage was that now with a 50mm clearance machining required such as grinding can be performed with ease after performing welding.

4.3 Stools and SPMT locations.

The locations of the stools for the frame considering the accessibility for SPMT is as shown in the below figure. The minimum clearance maintained between the stools and SPMT one side is 400mm.

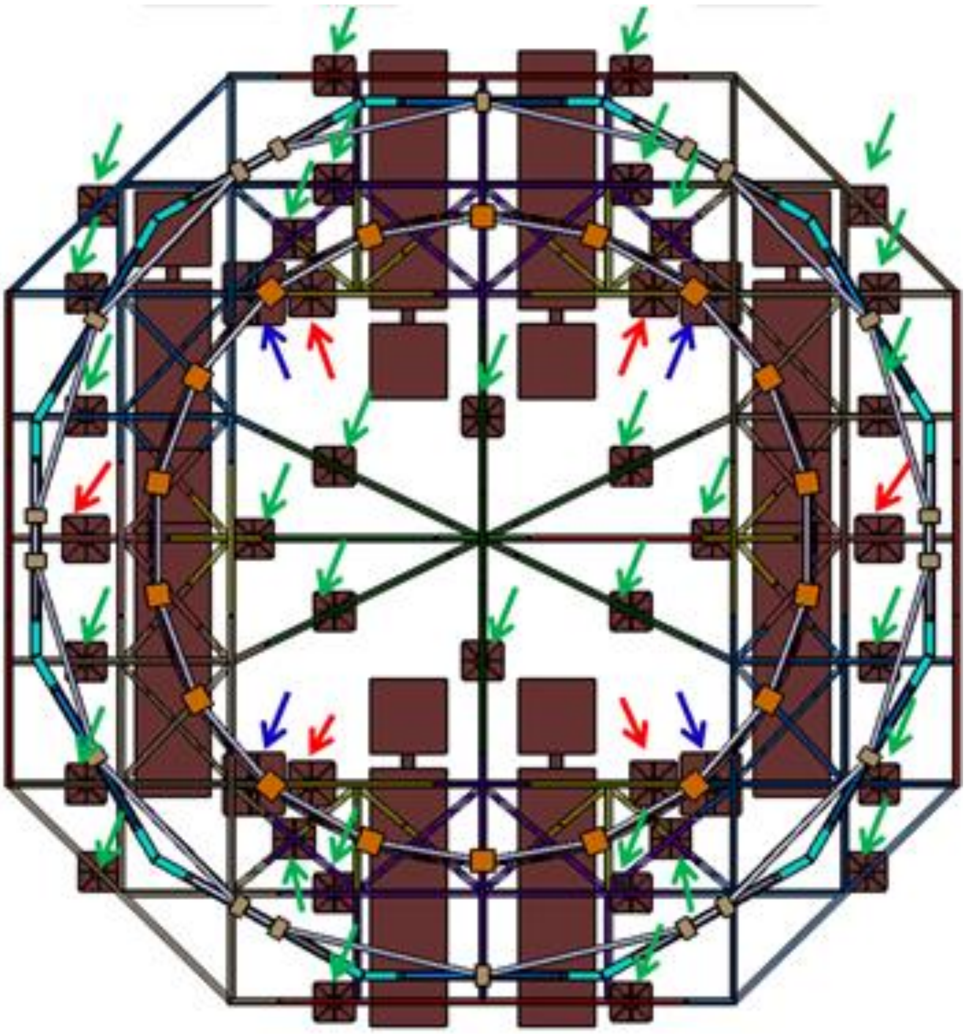


Figure 4.4 Typical view for positioning of Stools and SPMT

Height of the SPMT vehicles which are going to be used for transporting the components from the site workshop to the tokomak pit is 1250mm. Hence it is very clear that the frame has to rest more than 1250mm from the ground level. As the frame used for fabrication is supported by the stools from the bottom, it is required to maintain a clearance between the height of the stools and SPMT vehicles so that frame can be transported easily by SPMT. The clearance gap between the SPMT and the stools from bottom is 50mm.

4.4 Optimization of the frame height

The overall dimension of the workshop is 100m X 40m X 27m. The entry door is 33m wide from which the Lower cylinder rested on the transport frame can be easily moved in and out.

The lower cylinder along with the frame will be transferred to the cleaning building. The clear height of the entry door for transport of components is fixed as 12m. So there was a necessity in optimization of the frame height as per the dimensions of cleaning facility entry block. Now considering lower cylinder transportation frame along with the lower cylinder mounted on it the total height of the structure would be as discussed below.

Height of the job is 10300 mm.

Minimum height required for the movement of the SPMT vehicles is 1300 mm.

So adding together we have a total height of 11600 mm. Hence we are left out with 400 mm to fabricate the frame, considering the minimum clearance of 100 mm required while transferring the component into the cleaning facility we optimized the height of frame by keeping 300 mm.

4.5 Placing of inner and outer pillars and horizontal arms

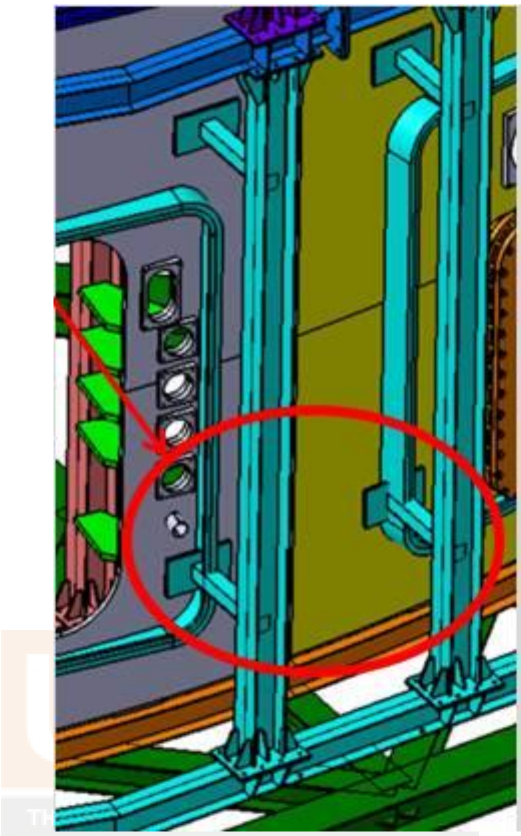


Figure 4.5 Inner and Outer pillars and horizontals arms positioning

The long seam welding requires 1000mm clearance on both sides of the seam. Considering this point following steps in the manufacturing procedures have to be adopted.

1) Inner and Outer pillars shall be placed radially1000mm away from the shell
2) Horizontal arms shall be placed 1000 mm away from circumferential seam ,

top edge and bottom edge.

3) Horizontal arm shall be kept at 4 places.

   The above listed points are necessary to be incorporated with respect to the lower cylinder transportation frame but it has been observed that horizontal arms are interfering with lower cylinder parts.

   Hence placing of the horizontal arms has to be changed accordingly. Once the point 2 gets satisfied point 3 can be incorporated automatically.

4.6 Material Procurement of I-Beams (MOQ)

The I-Beam material used for manufacturing the frame is of grade ISMB 300 type. There will be huge number of the I-beams required for manufacturing considering the complete dimension of the frame. According to the dimensions and the inputs of the frame it is evaluated that there would be 40 metric tons of requirements of the I-beams for frame to be manufactured. This is less than the minimum order quantity for large mills and it is not economical. Hence Material procurement is one of the biggest challenges without which the manufacturing will not begin. Even after the market survey it was difficult to manage the material as per our requirement.

The above problem was finally solved by procuring the plate girders instead of the beams. The plate girders of the custom made sizes were available from M/S. ESSAR, Hazira and also in the required amount of quantity.

Chapter 5 Conclusion and further scopes

Conclusion

Manufacturing challenges and constraints related to the transportation cum fabrication were identified and evaluated in detail. Conceptual model of the lower cylinder frame has been prepared and in principal approved. Optimization of the frame has been done to meet the cleaning building height limitation. All the modules of the frame are to be connected by means of the bolted joints with required strength and stiffness instead of performing welding which once again cuts the manufacturing cost. The frame is being manufactured meeting international standards.

Further Scope

The positioning of the stools is going to be challenge as the SPMT vehicles have to move in between the stools to lift the component and transport it to the tokomak pit assembly. Proper allocation and reduction in the number of stools can further reduce the manufacturing cost. Any changes in the positioning of the stools will lead to hindrances in the movement of SPMT vehicles further leading to changes in the design of frame which is undesirable. So positioning of the stools is very important aspect. Optimization of the manufacturing cost of frame is another important aspect.

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