Design and Analysis of Subsea Skid for Component Deployment Under Various Loading Conditions

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Abstract

When Subsea equipment (MEG Filter and Back Pressure Regulator) is damaged, the overall system is need to retrieved and taken to the offshore rig platform for replacement of Subsea equipment. This process usually takes 72-96 hours. During the removal of Subsea equipment, the process is disrupted and removal of subsea equipment using conventional retrieval tools is difficult due to absence of lifting arrangements and the tools may damage. Moreover, the process is need to stopped during retrieval. To get the better of these difficulties and reduce the breakdown time of production, a special Subsea Skid for Component Deployment frame is designed. The SSCD frame carries the Subsea components like Back pressure regulator and MEG Filter from Offshore rig to the Sea bed where the production process is going on. The main aim of this study is to analyze the SSCD frame for structural stability under various loading conditions. The time required to replace the damaged component with new component is 3 to 4 hours by this SSCD frame. The components are manipulated with the help of Remote Operated Vehicles (ROVs). Thus, with the help of this frame the components can be safely deployed to the production system with minimum time, cost & damage.

Keywords
Subsea, Offshore rig, Back pressure regulator, MEG Filter, SSCD frame.

1. Introduction
Subsea component Deployment system deploys Subsea components into Seabed where the process is going on. It can emplace large equipment into larger depths. The main aim of subsea component deployment systems is to safely emplace and place the subsea components considering the Mortal safety with low cost. In general, any operation performed in fluidic terrain which is out of reach for manual intervention, requires one or further tools installed there within that work in an automatic mode. A suitable illustration of such a terrain is aquatic terrain, and more particularly, subsea terrain. Subsea generally refers to outfit, technology used for aquatic operations similar as scientific study of organisms in the ocean, geological oceanography, Coastal canvas and gas production and aquatic mining. Generally, reclamation tools are used for subsea intervention, wherein permanently installed subsea component is recaptured for conditioning using the reclamation tools. Generally, component deployment system is used to emplace and handle the installed subsea component. Back pressure regulators are used as subsea component which sucks the gas from the seabed. A production system in subsea consists of a subsea tree, subsea completed well and wellhead systems, subsea tie-in to inflow line system, jumpers, umbilical and riser system and subsea equipment to operate the well (Figure 1).

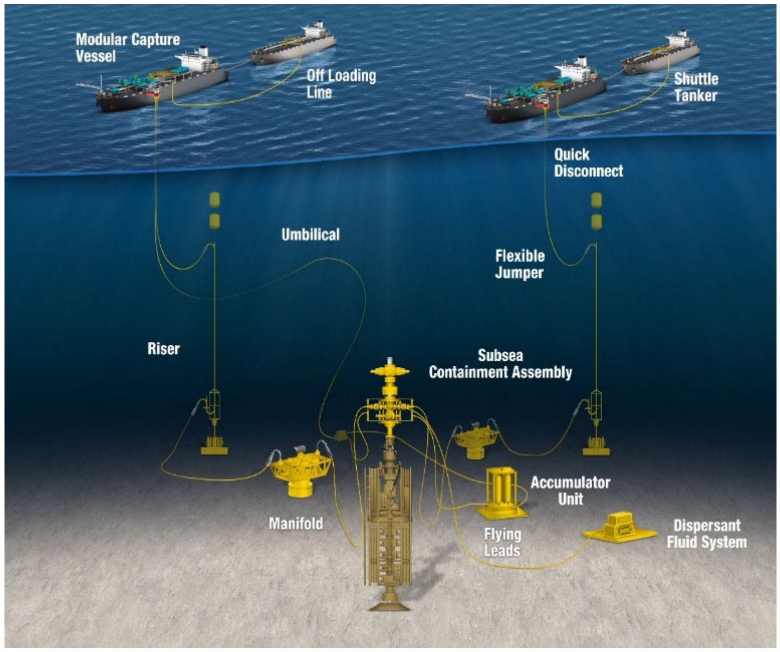

Figure 1. Layout of the Subsea equipment under the sea

The subsea equipment is usually exposed to harsh environment in deep sea, because of high pressure and high temperature gradients. Therefore, in all offshore pipeline the transportation of fluids like oil, gas, water or their mixtures should be analysed to optimize performance and minimize the operational risks.

Figure 2. Back Pressure Regulator

Back pressure regulator (shown in Figure 2) act as a control valve which maintains a constant fluid pressure output. When fluid pressure exceeds above limit, the regulator opens to release the excess pressure. The Subsea Back pressure regulator is a self-regulating device activated only when needed. It is robust and reliable which needs minimum maintenance.

Figure 3. MEG Filter

MEG filter (shown in Figure 3) filters the gas or oil by using a special fluid MEG. MEG (Mono Ethylene Glycol) is used as hydrate inhibitor while extracting natural gas. Lean MEG (90% MEG by weight and 10% Water by weight) is injected at the wellheads, where it is mixed with formation water (saturated with formation salts) and later with condensed water through the gas pipeline. When arriving to the slug catchers the Rich MEG (40-60% MEG by weight, depending on the well and on its age, water to 100%) is taken out and recycled for further usage. It works water removal process, also the regeneration system is responsible for removal of salts, both high and low soluble salts. Addition of these salts, especially low soluble salts, may result in major issues to the key equipment within the whole MEG loop, thus harming the production system stability.

1.1 Objectives

The main objective of this study is to design a frame which should carry the Subsea equipment like Back pressure regulator and MEG Filter from the offshore rig to production system under the sea. Static Structural analysis is performed on the SSCD Frame under various loading conditions.

2. Literature Review

Offshore Technology (2022), Global Data's latest thematic report, 'Subsea Technologies for Oil and Gas Offshore Exploration and Production', discusses the trends in subsea production systems that could open new opportunities in offshore oil and gas exploration and production. Subsea technology to thrive in current production economics. Subsea technology reduces production and operating costs, by eliminating the need to build fixed platforms. Subsea companies are increasingly working on the electrification of subsea systems. Subsea electrification optimizes equipment maintenance by eliminating the need for frequent replenishment of hydraulic fluids. It also lowers the emissions generated by to and fro voyages of the maintenance crew.

Christian Mudrak (2016) presented a paper on Subsea Production Systems that an installation of subsea equipment was analyzed via a dynamic model that permits the use of a varying length cable. The scenario presented the installation of a subsea chemical injection unit by the Skandi Salvador vessel at 3000 m depth.

Ashutosh Kumar (2016) described the study of prediction of failure rate for new subsea equipment is a challenge in oil and gas industry mainly due to lack of relevant data and use of increasingly novel technologies. There is a lack of common guideline or framework for failure prediction process of novel technology and different companies and experts follow different procedures.

Jorge Moreno-Trejo, Tore Markeset (2017) studied the inspection of installations without the use of divers in fields located in deeper water has made for more complex interventions. Hence, the strategy to carry out integrity programs using ROVs (remotely operated vehicle), AUVs (autonomous underwater vehicle) or ROTs (remotely operated tool) to verify the state of equipment has become increasingly important in the field development strategy.

Webb, G.D. (1980) studied the limitations of currently available underwater inspection and repair techniques, and assesses how these affect the design and operating philosophy of deep-water equipment. Finally, they discussed the desirability of inspection/repair equipment designed and built purposely for a particular deep-water installation and permanently stationed upon it.

Esaklul, K.A., Ahmed, T.M. (2008) studied some of the challenges that face the oil and gas industry with particular emphasis on prevention of failures due to hydrogen embrittlement (HE) under conditions of cathodic protection (CP). Efforts were made to carefully review factors that could play a significant role in HE. These factors include material selection and compatibility with CP, size effect, qualification testing, design criteria and finally applied stress level after assembly.

Byrne, S. (1994) studied the successful design of a subsea well control system depends chiefly upon the selection of highly reliable subsea components If a system fails regularly, due to unreliable components, then the cost to maintain that system may quickly escalate and surpass capital cost.

Brandt, H., Eriksen, R. (2001) presented a paper which describes the RAM analysis methodology, and illustrates some of the benefits of applying it. Furthermore, an overview of industry initiatives currently carried out by the deep-sea industry to develop and to qualify new technology is given.

3. Methods

3.1 Process of the Work

- The Subsea skid for Component Deployment (SSCD) frame is designed based on DNV (Det Norske Veritas) rules and standards.
- Design of SSED frame is done as per DNV-OS-C101 guidelines. Structural elements for frame are chosen as per DNV-OS-F 101. The parts of SSCD frame like baseplate, casting box, and some structural elements are modelled in part design module of CATIA software.
- These parts are assembled in assembly module of CATIA software.
- The SSCD frame is designed to carry the components like Back pressure regulator and MEG filter. Hence, it is checked for structural analysis.
- The static structural analysis is done in Ansys software. The weights of components are added and results are evaluated. The analysis is done for the following cases:
    - 1 Back Pressure Regulator alone in place.
    - 1 Back Pressure Regulator + 1 MEG Filter in place.
    - 2 Back Pressure Regulator + 1 MEG Filter in place.
    - 2 Back Pressure Regulator + 2 MEG Filter in place
    - 1 MEG Filter alone in place.
- In order to protect the SSCD frame from corrosion and surrounding working environment cathodic based design is done as per DNV-RP-B401.

3.2 Material

Generally, the material used for Subsea equipment is Structural steels A36 mild steel, which is most commonly used ASTM A36 mild steel. It is a low carbon steel which has ultimate tensile strength of 500 MPa, Yield strength of 250 MPa and elongation of 20%.

3.3 Modelling

All the parts were modelled using CATIA V5 R20. The SSCD frame has the four subassemblies like Bottom frame, Base plate, Carriage, Tower. The Base plate is position over the Bottom frame and the carriage is placed on casting boxes of the bottom frame. Finally, the tower is held on the base plate assembly as per calculated distances from edges of the base plate (Figure 4, 5, 6, 7, 8, and 9).

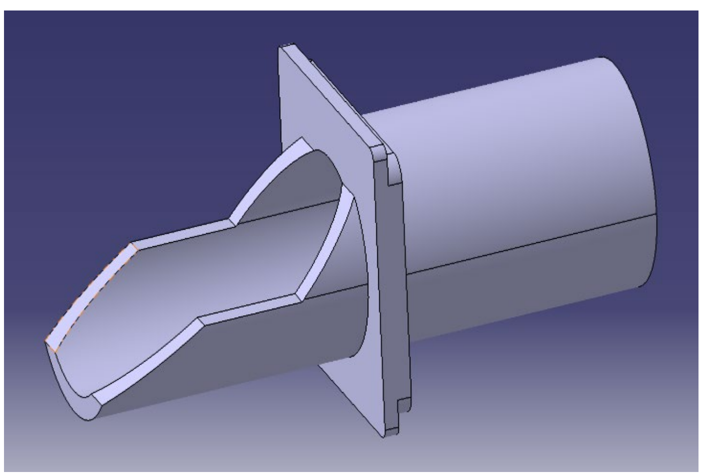

Figure 4. 3D Model of Back pressure regulator

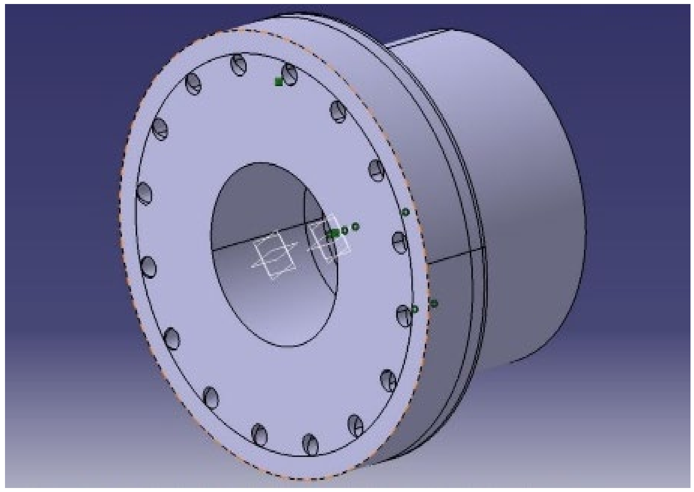

Figure 5. 3D Model of MEG Filter

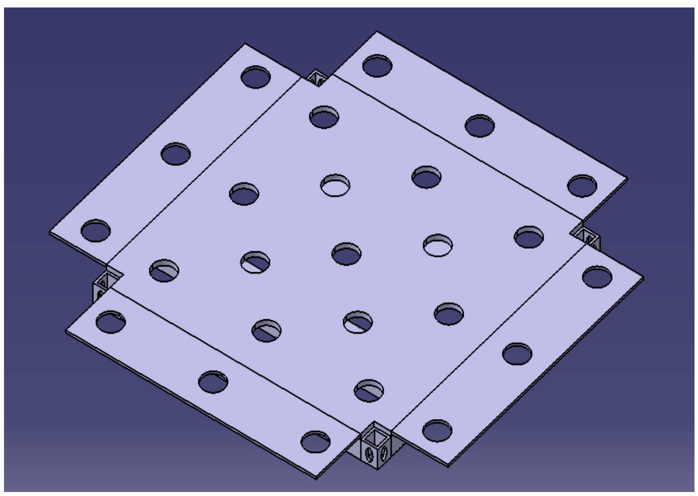

Figure 6. Subassembly-1 (Baseplate)

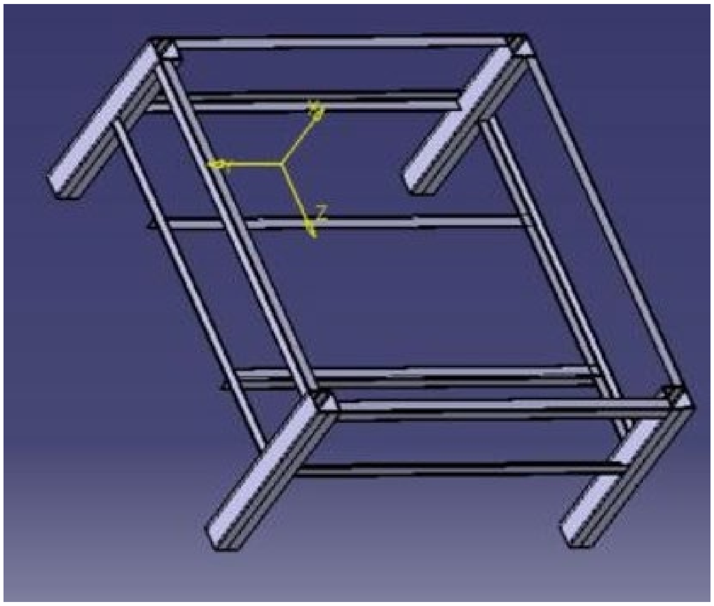

Figure 7. Subassembly-2 (Bottom frame).

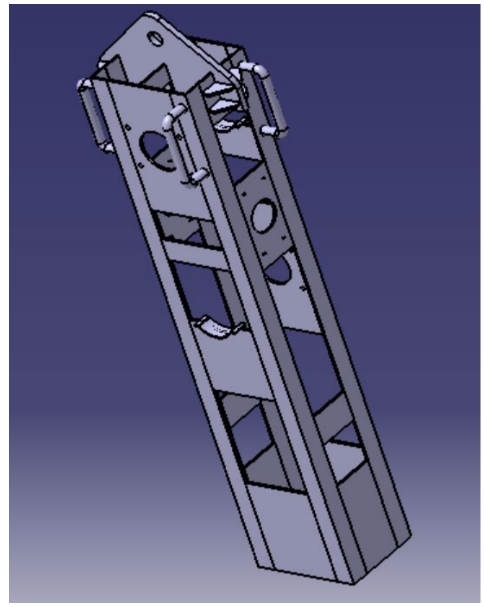

Figure 8. Subassembly-3 (Tower).

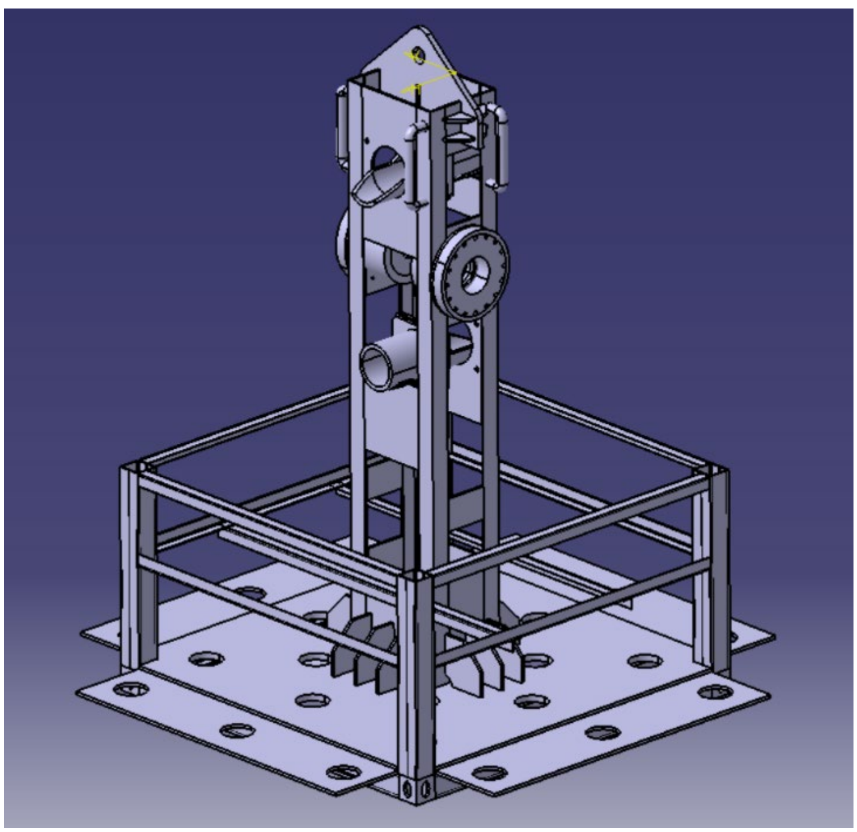

Figure 9. Overall Assembly of SSCD Frame.

4. Results and Discussion

The static structural analysis of SSCD frame is done in Ansys software. The CATproduct file of SSCD frame is imported to the Ansys workbench and checked for structural stability. Since the frame carries the Back pressure regulator and MEG Filter, the weights of these components are added at the places where the components are fixed. The SSCD frame is designed to carry maximum of two back pressure regulators and two MEG filters. So, the frame can have following possible loading conditions.

Case-1: (One Back Pressure Regulator alone in place)

In this case, the weight of one Back pressure regulator is added at the place. The mass of each Back pressure regulator is 125 Kg. By converting this mass into weight we got, 1250 N considering 'g' value as 10 N/m^2. The baseplate is fixed by applying fixed support. The weight is applied as shown in the Figure 10(a).

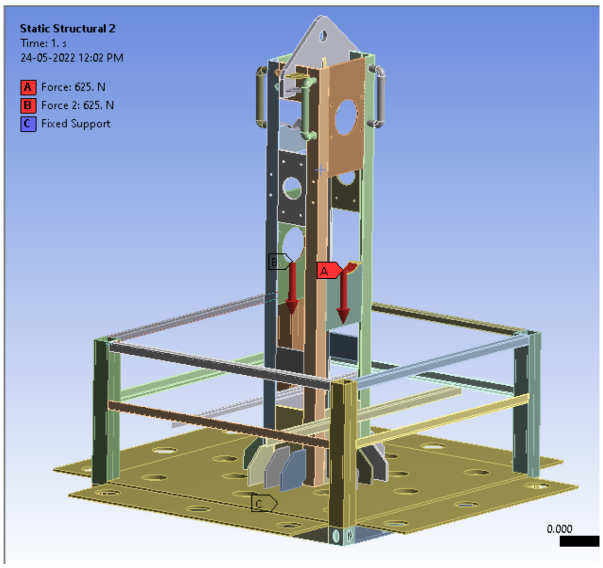

Figure 10(a). Loading diagram of SSCD Frame with 1 BPR

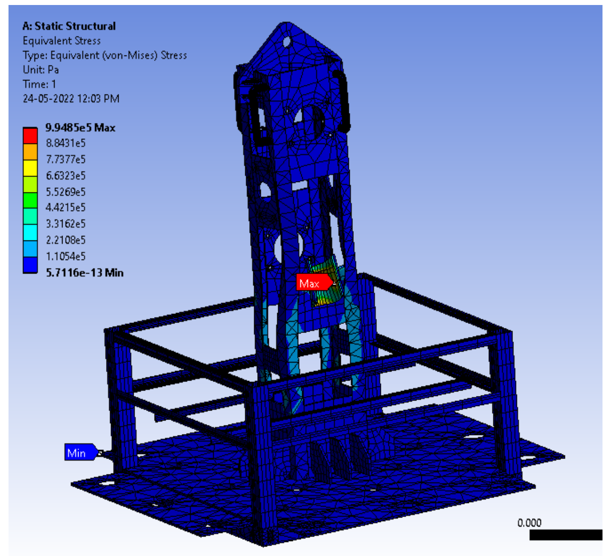

Figure 10(b). Analysis of SSCD Frame with 1 BPR alone in the place

The maximum stress that can be induced in the above case is 0.99485 MPa which is very small when compared with the yield strength of the material (250 MPa).

Case-2: (1 Back Pressure Regulator and 1 MEG Filter in place)

In this case, the weights of 1 Back pressure regulator and 1 MEG Filter are added at the places. The mass of 1 MEG Filter is 145 Kg. By converting this mass into weight we got, 1450 N considering 'g' value as 10 N/m^2. The weights of Back pressure regulator and MEG Filter are 1250 N and 1450 N respectively. The length of BPR is more than MEG Filter so, it is fitted to the frame with two supports as like simply supported beam. The front support is a Guided plate and the rear support is a hole as shown in Figure 9. The weight is equally divided to the two supports and each support reaction is 625 N. The weights are applied as shown in the Figure 11(a).

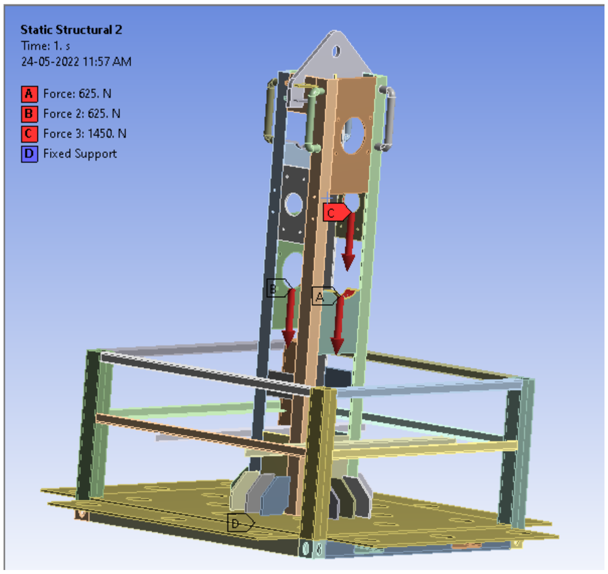

Figure 11(a). Loading diagram of SSCD Frame with 1 BPR and 1 MEG Filter

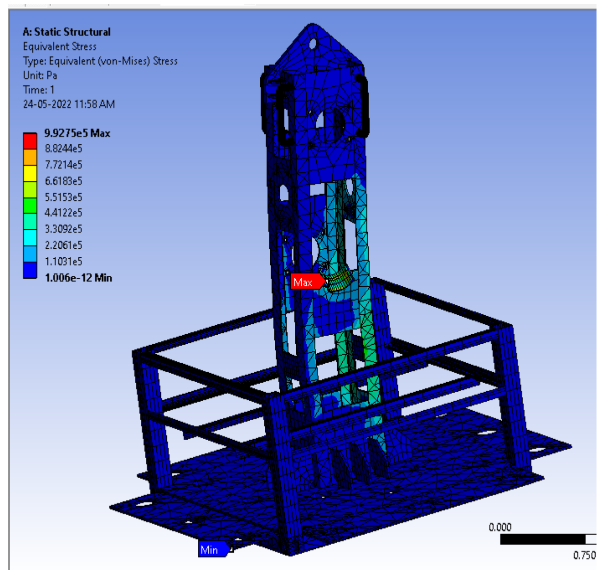

Figure 11(b). Analysis of SSCD frame with 1 BPR and 1 MEG Filter

The maximum stress that can be induced in the above case is 0.99275 MPa which is very small when compared with the yield strength of the material (250 MPa).

Case-3: (2 Back Pressure Regulator and 1 MEG Filter in place)

In this case, the weights of 2 Back pressure regulators and 1 MEG Filter are added at the places. The weights of Back pressure regulator and MEG Filter are 1250 N and 1450 N respectively. Since the length of BPR is more than MEG Filter, it is fitted to the frame with two supports as like simply supported beam. The BPR weight is equally divided to the two supports and each support reaction is 625 N. The weights are applied as shown in the Figure 12(a).

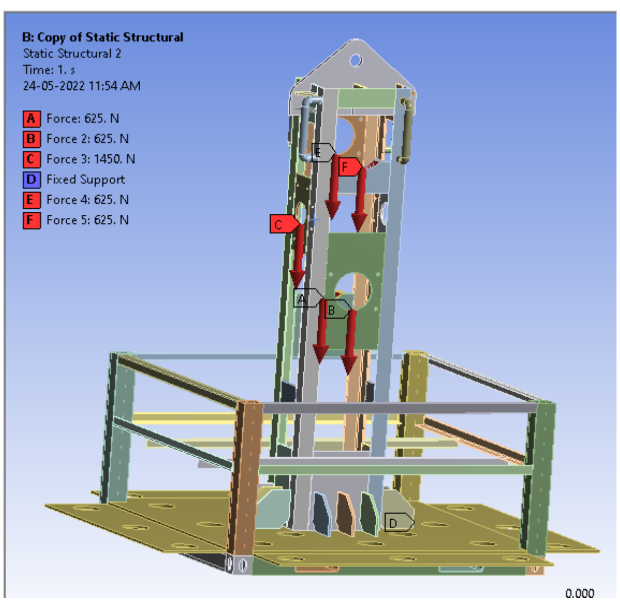

Figure 12(a). Loading diagram of SSCD Frame with 2 BPRs and 1 MEG Filter

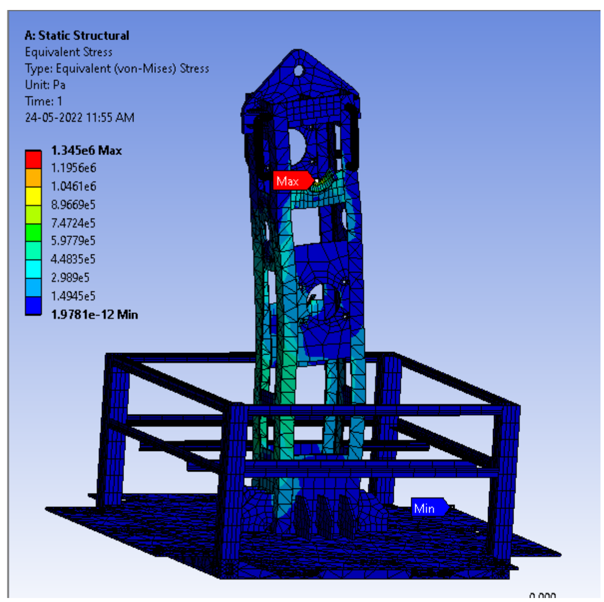

Figure 12(b). Analysis of SSCD frame with 2 BPRs and 1 MEG filter

The maximum stress that can be induced in the above case is 1.345 MPa which is very small when compared with the yield strength of the material (250 MPa).

Case-4: (2 Back Pressure Regulator and 2 MEG Filter in place)

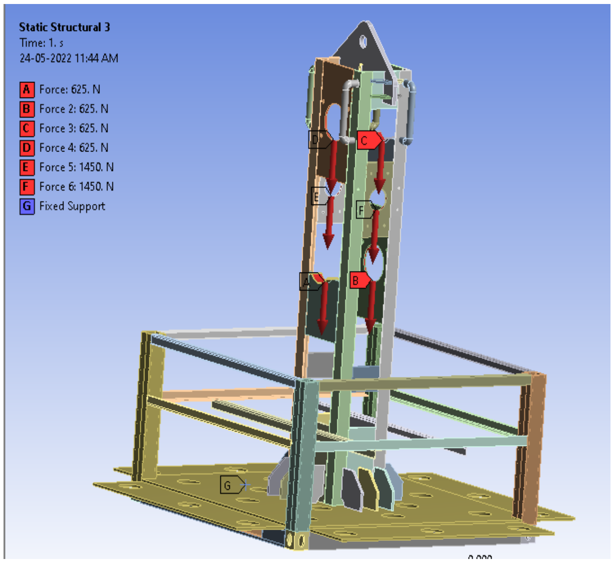

Figure 13(a). Loading diagram of SSCD Frame with 2 BPRs and 2 MEG Filters

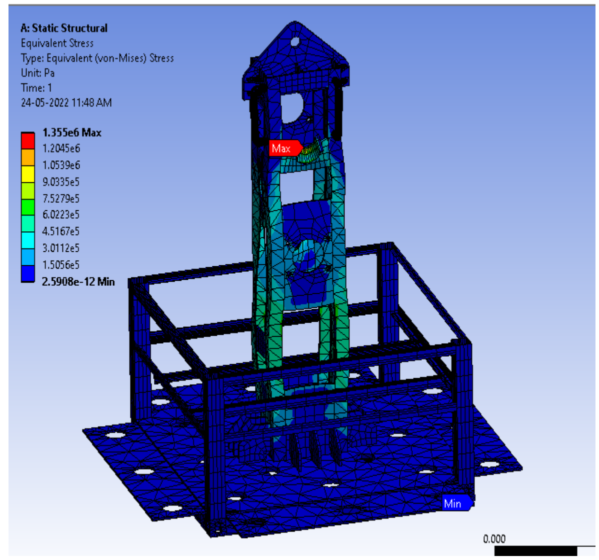

Figure 13(b). Analysis of SSCD frame with 2 BPRs and 2 MEG filters

In this case, the weights of 2 Back pressure regulators and 2 MEG Filters are added at the places. The weights of Back pressure regulator and MEG Filter are 1250 N and 1450 N respectively. The BPR weight is equally divided to the two supports and each support reaction is 625 N. The weights are applied as shown in the Figure 13(a).
The maximum stress that can be induced in the above case is 1.355 MPa which is very small when compared with the yield strength of the material (250 MPa).

Case-5 (1 MEG Filter alone)

In this case, the weight 1 MEG Filter are added at the place. The weight of one MEG Filter is 1450 N. The baseplate is fixed by applying fixed support. The weights are applied as shown in the Figure 14(a).

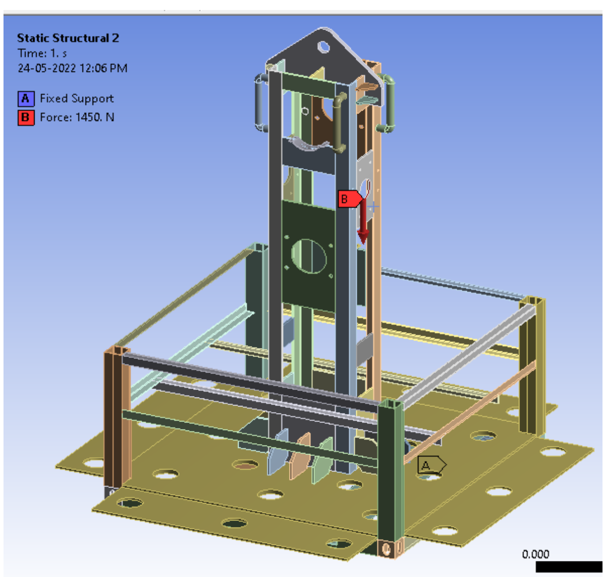

Figure 14(a). Loading diagram of SSCD Frame with 1 MEG Filter alone.

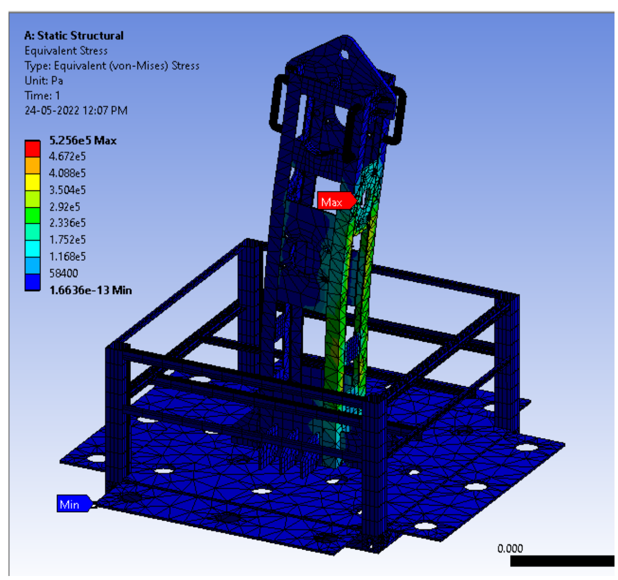

Figure 14(b). Analysis of SSCD Frame with 1 MEG Filter alone.

The maximum stress that can be induced in the above case is 0.5256 MPa which is very small when compared with the yield strength of the material (250 MPa).

4.1 Validation

The SSCD frame will have different stress values during each case. The maximum and minimum values of stress are shown in figures with the help of probes. In Ansys, the intensity of the design parameter is represented with some colours. Each colour will have some magnitude of stress. In all the cases, stress induced in the SSCD frame to the applied weights is less than the Yield strength of the material. Hence, the stresses induced are within the safe limit which is represent by blue and green colours.

5. Conclusion

The study on the SSCD frame which is used for deploying the Subsea Equipment led to the following conclusions:

- The SSCD frame is checked for Structural stability under various loading conditions. In each case, the stress induced is less than the material strength which is indicated with the bottom colours in the coloured bar in analysis figures. Hence the design of SSCD frame is safe.
- Since, the stresses induced are within the safe limit, we conclude that the SSCD frame can safely carry the two components from the Offshore rig to the Production system under the sea.
- As discussed before conventional retrieval process usually takes 74 to 92 hours. Now, by using the SSCD Frame the retrieval process takes 4 to 5 hours.
- The production process needs to be stopped until the maintenance work is completed, this increases the production cost. As the retrieval process time is less with the help of SSCD Frame, the cost can be reduced.

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