DETERMINATION OF THE CRITICAL POSITION DURING THE ASSEMBLY OF THE BOILER HEAT EXCHANGER PACKAGE DUE TO THE STRESSES OF THE AUXILIARY FRAME STRUCTURE

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Abstract
Construction of the Thermal power plant boiler is usually large in size and weight. The aim of the production is to deliver the boiler assemblies on the construction site with maximal dimensions. This depends on the possibilities of transport and assembly. For such large and sensitive parts of the boiler structure it is necessary to carefully plan the mode of transportation and assembly. Very often it is necessary to create auxiliary structures which will stiffen the boiler component, so that it prevents damage and permanent deformation during the lift and assembly. In this paper will be analyzed strength of the auxiliary frame structure for lifting and rotating transport unit of the boiler heat exchanger package Tampere, during the rotation. Assembly unit is rotated from horizontal to vertical position. Rotation leads to changes in the amount and direction of load of the auxiliary frame structure. Aim will be to determine the critical position of the assembly unit, in which will occur maximal stress on the auxiliary framework structure. Stress calculations of the auxiliary frame structure will be made using the finite element method and beam finite element. Five different positions of the assembly unit will be analyzed; 0 °, 30°, 45°, 60° and 90°.

Keywords:
boiler heat exchanger assembly, auxiliary structure, critical position, finite element analysis

1. Introduction

There are many way in which can be transported and montaged parts as boiler heat exchanger assembly with its transport auxiliary structure. It is necessary to point out the need for more than one crane when doing complex procedure as it is rotation of the auxiliary structure with boiler heat exchanger assembly. Cranes for montage of the boiler heat exchanger assembly are used briefly on the construction site, so better to consider only mobile cranes. During the selection of the mobile crane it is important to have in mind reliability of devices, rated capacity limiters, motion limiting devices, working radius indicator, load indicators, etc. Every crane has its own load chart in which is clearly written lifting capacity of a crane. The lifting capacity of a crane is limited by its structural strength when the working radius is small and stability when the working radius is greater. The need to subtract the mass of the hook block and lifting slings from the capacity of the crane at the particular radius, unless otherwise noted on the load chart. For example, if the load chart states the crane can lift 20 tons at a given radius, but the hook and lifting gear have a combined mass of one ton, the load to be lifted cannot be greater than 19 tons. The crane counterweight is critical in ensuring crane stability. A counterweight that is too light for a load and boom configuration will cause the crane to overturn in the direction of the suspended load. On the majority of smaller mobile cranes, the counterweight is fixed and cannot be easily removed. However, on an increasing number of larger cranes, some of the counterweights are designed to be removed for road travel, or when smaller boom and lifting configurations are required. In this situation, it is particularly important to attach the correct type and number of counterweights to the crane for the particular lift to be undertaken. Many other notes on necessary conditions for proper use and selection of the cranes can be found in the literature [1]. Depending on the terrain on which montage is done, on the bearing capacity of the crane and the height which needs to be reached there is many different cranes from which can be chose for example: Telescopic Truck cranes with lifting capacities of 35 to 220 metric tons and working radius of 40 to 88 m, All Terrain cranes with lifting capacities of 30 to 1,200 metric tons and maximal main boom length of 30 to 100 m, Rough Terrain cranes with lifting capacities of 25 to 120 metric tons with maximal boom length of 30 to 50 m, there are several more of them which have higher capacities available and higher working radius such as Lattice Boom Crawler Cranes and Tower Cranes [2, 3]. During the montage it is not only necessary for the crane to endure the weight of the boiler heat exchanger assembly and its auxiliary structure but that auxiliary structure endures under the applied mass of the boiler heat exchanger assembly. Mass of the boiler heat exchanger assembly and its auxiliary structure is taken from the Technical report for Tampere project [4]. For the insurance that auxiliary structure will not brake during the montage it is necessary to calculate with safety factors for steel construction [5]. Safety factors used in the Technical report for Tampere are for dynamical load 1,5 and for static load 1,35. During the montage auxiliary frame with boiler heat exchanger assembly is rotating from horizontal position to vertical position. In this paper finite element analysis is done for angular positions of the auxiliary structure of 0°, 30°, 45°, 60° and 90°.

2. Method

I this paper it is used beam finite element to get the proper results of the stress, displacement, internal forces and momentums distributed in the auxiliary structure. In the finite element analysis beam finite elements [6] are used for numerical analysis. Finite element analysis is made in the software ANSYS [7] where wireframe numerical model of frame with keypoints locations with characteristic profiles of cross sections is made. Beam used in the analysis with ANSYS is linear finite strain beam marked as BEAM188. Figure 1 shows the whole wireframe model of transport frame with plotted characteristic profiles on particular beams.

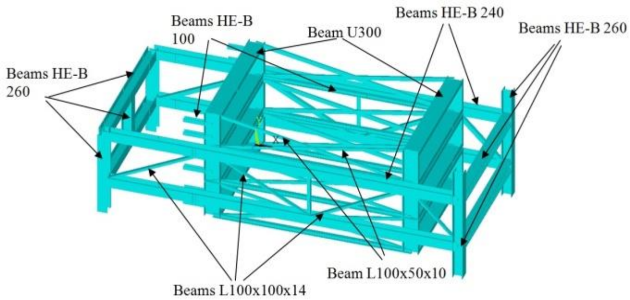

Figure 1. Characteristic profiles of an auxiliary structure

Material used for auxiliary frame is S235JRG2 [8]. Modulus of elasticity, yield stress, and allowed stress for beam material are:

$$E = 200000 \text{ MPa} \rightarrow t_c = 20\ ^\circ\text{C}\,, \tag{1}$$

$$R_e = 225 \text{ MPa} \rightarrow \text{for } \delta = 16 \div 40 \text{ mm}\,. \tag{2}$$

$$\text{Allowed stress: } \sigma_{\text{all}} = \frac{R_e}{1{,}1} = 204{,}5 \text{ MPa}. \tag{3}$$

Geometrical characteristics of cross sections are determined for particular profiles. It this paper used profiles are U300 [9], HE-B100, HE-B240, HE-B260 [10], L100x50x10 and L100x100x14 [11]. Example of profile characteristics used in ANSYS are shown in figure 2, 3 and 4. Auxiliary structure is loaded with boiler heat exchanger assembly which is shape as a harp, outline dimensions of the boiler heat exchanger assembly and auxiliary frame used for transportation which are used in the Technical report for Tampere are given in figures 5 and 6.

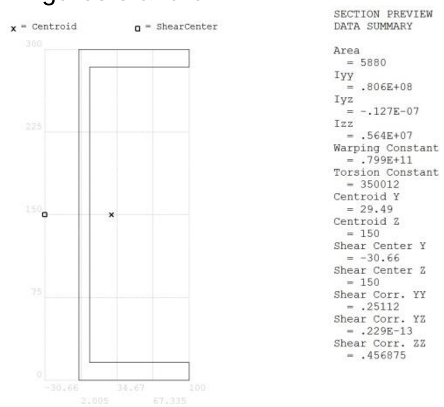

Figure 2. Profile characteristics of an U300

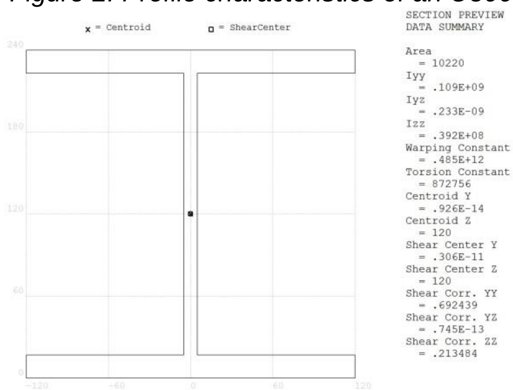

Figure 3. Profile characteristics of an HE-B240

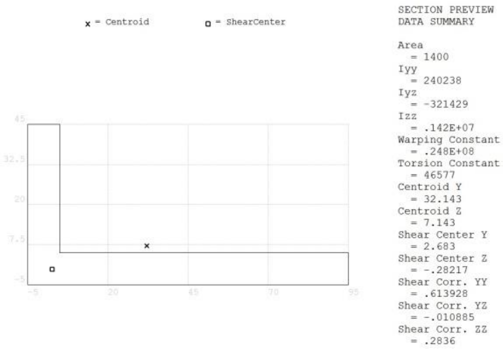

Figure 4. Profile characteristics of an L100x50x10

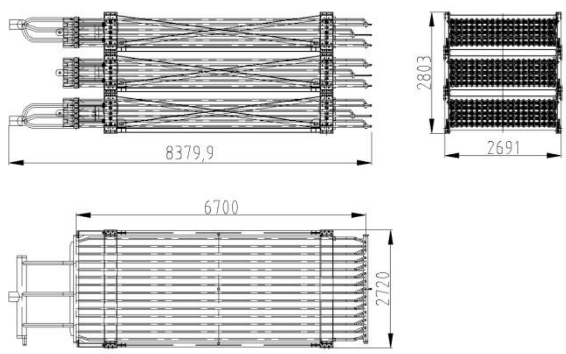

Figure 5. Boiler heat exchanger assembly's partial modulus with frame for rotation and lifting during erection

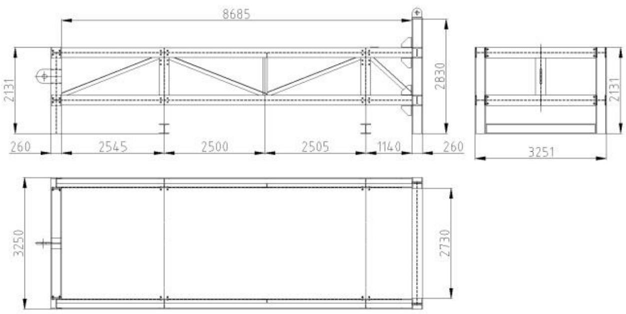

Figure 6. Auxiliary structure for rotation and lifting during erection

Finale vertical position after the montage is shown in figure 7.

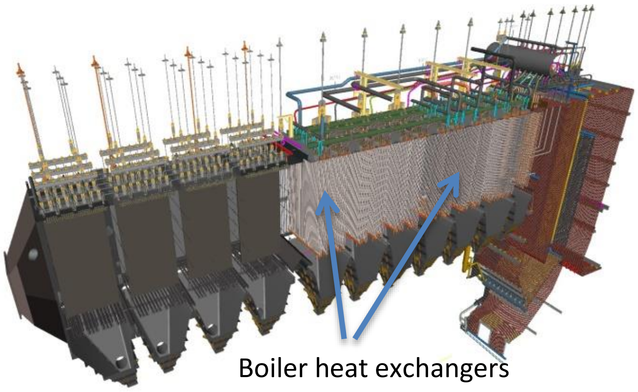

Figure 7. Boiler heat exchanger assembly stationed inside of the boiler

For calculations dynamic load factor k_d=1,5 and partial safety factor for weight loading S_m=1,35 have been taken into account. Safety factors are used to determinate the forces and momentums which are applied on the auxiliary structure. During the rotation there are 5 different positions that are analyzed in this paper. For each position it was necessary to determinate proper forces and momentum and to apply chosen safety factors on them. In this finite element analysis during horizontal position, pressure from boiler heat exchanger assembly is applied directly on U300 beams. All auxiliary structure is supported by the ground. During the rotation on positions 30°, 45° and 60° weight is distributed on the U300 and HE-B100 beams, depending on the rotation. During that time one crane is rotating while other one is holding and supporting the end, which is to remain on the ground. On the vertical finite element analysis weight is only distributed on the HE-B100 beams. Example of boundary conditions, and forces applied on the frame is show on the horizontally placed auxiliary structure in Figure 8.

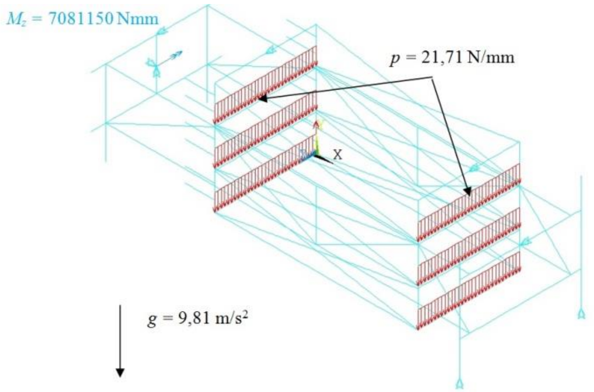

Figure 8. Illustration of boundary conditions of the auxiliary structure positioned horizontally

Data from finite element analysis is taken and for each position tested if auxiliary structure will manage to endure the weight of the boiler heat exchanger assembly. The displacement of the beams in *x* and *y* direction is tested as well as the stress on the auxiliary structure. Example of these calculations is shown on 60° rotational position:

Allowed displacement on *x*-axis is:

$$u_{\mathrm{all}} = \frac{l}{250} = \frac{2460}{250} = 9{,}84\,\mathrm{mm}\,,$$

$$u = 2{,}627\ \mathrm{mm}, \tag{4}$$

$$u < u_{\mathrm{all}} \rightarrow \mathrm{Ok!}$$

Allowed displacement on *y*-axis is:

$$w_{\mathrm{all}} = \frac{l}{250} = \frac{2460}{250} = 9{,}84\,\mathrm{mm}\,,$$

$$w = 2{,}828\ \mathrm{mm}, \tag{5}$$

$$w < w_{all} \rightarrow \mathrm{OK!}$$

Allowed stress:

$$\sigma_{\mathrm{all}} = \frac{R_e}{1{,}1} = 204{,}5\,\mathrm{MPa}\,,$$

$$\sigma_{\max} = 104{,}11\,\mathrm{MPa}\,, \tag{6}$$

$$\sigma_{\max} < \sigma_{\mathrm{all}} \rightarrow \mathrm{OK!}$$

After all the calculations of the auxiliary structure, in all 5 different positions it has been determinate that the structure was able to endure the process of montage.

3. Results

This paper goal is to find out the position during the rotation which has higher values of stress and displacement then other, so that during further analysis it would be necessary only to do those critical positions without doing this extensive analysis of 6-7 different positions. That position is to be further called as the critical position of the auxiliary structure during this kind of montage. To determine the critical position it is necessary to select different beams. The auxiliary structure is symmetric around the *x*-axis, so it is only necessary to select a beam from one side of the symmetry. On figure 9 it is shown an illustration of the beams that are selected for this process of finding out the critical position.

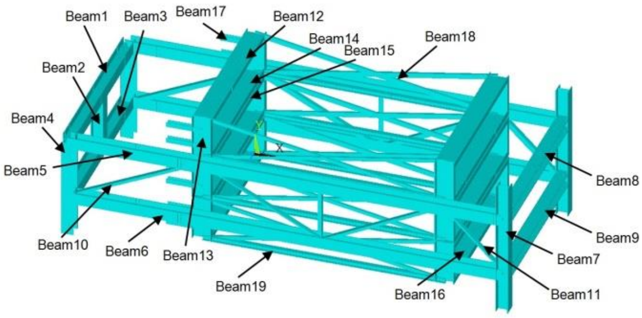

Figure 9. Illustration of the selected beams that are shown in the result graphs

All the data gained through finite element analysis has closely been collected and used to make graphs that can be used to determine the critical position. All graphs have same *x*-axis, which is angle of rotation in degrees. Figure 10 show colors and marks on the lines used in the graphs.

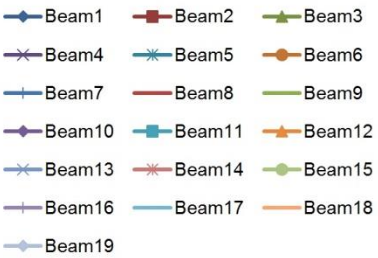

Figure 10. Marks and colors of the lines used in the result graphs

Maximal values of axial forces occur in the position of the 30° on beams 6 and 13. Rest of the data shows that the highest values of axial forces are in horizontally positioned auxiliary structure as shown in figure 10.

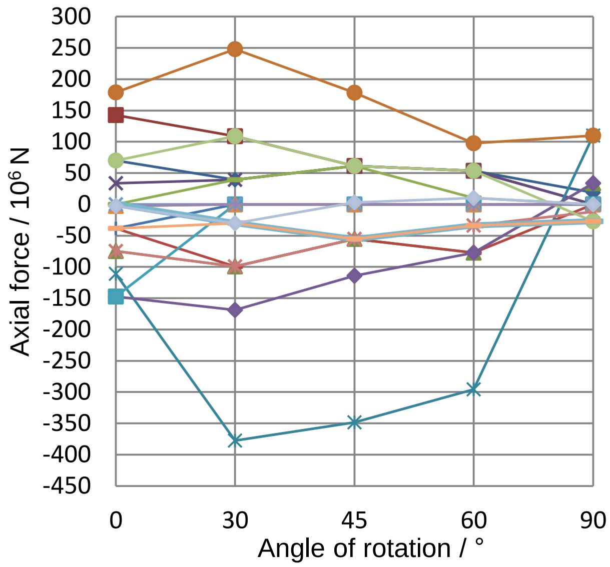

Figure 11. Graph which shows change of the axial forces in the selected beams during the rotation of the auxiliary structure

Bending moment in y-direction in the auxiliary structure is the highest in vertical and horizontal position. As *y*-axis is the one which is aligned with the auxiliary structure when is positioned vertically it is normal to see the highest values of the bending momentum in the *y*-direction in vertical position as shown in figure 12. Same goes for horizontal positioned auxiliary structure and *x*-axis as shown in figure 13.

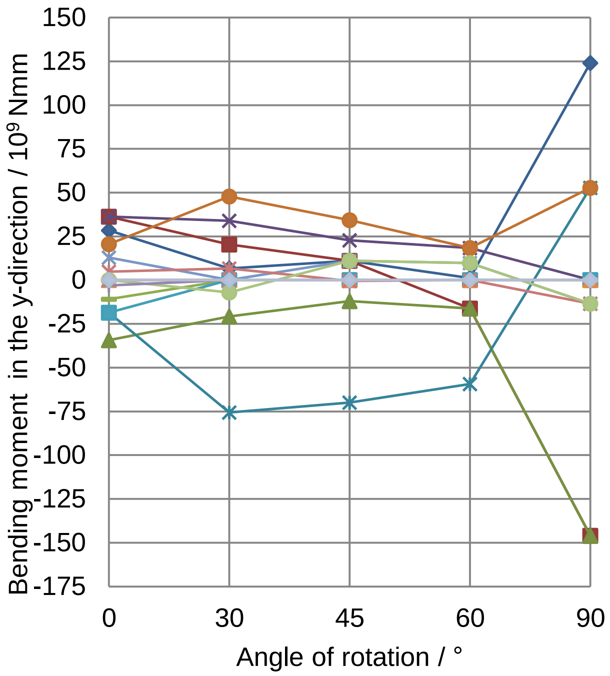

Figure 12. Graph which shows change of bending moment in the y-direction on the selected beams during the rotation of the auxiliary structure

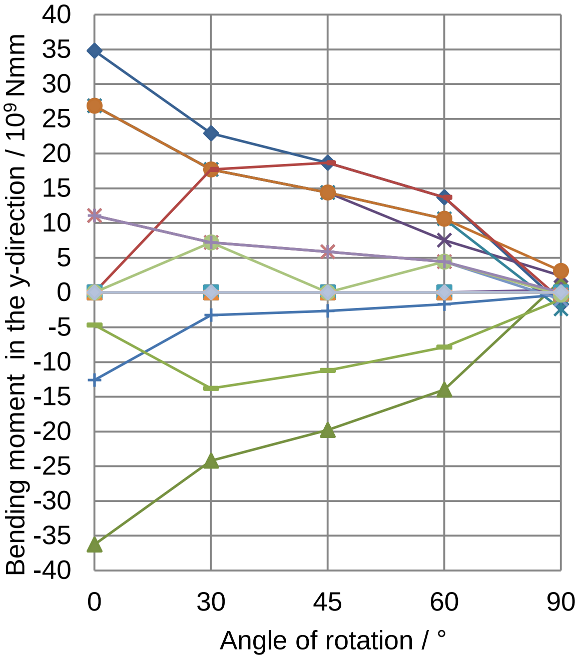

Figure 13. Graph which shows change of bending moment in the y-direction on the selected beams during the rotation of the auxiliary structure

The most important graph in this finite element analysis is the one that shows change of von Mises stress. As shown in figure 14, highest values of von Mises stress occurs while the auxiliary structure is placed horizontally and vertically.

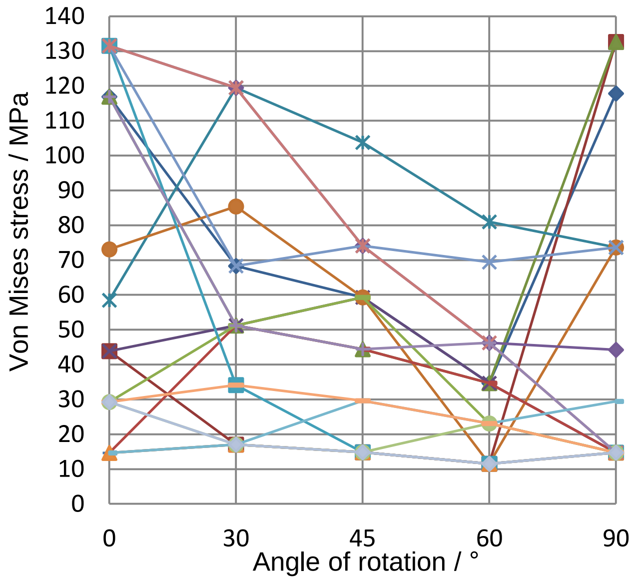

Figure 14. Graph which shows change of von Mises stress on the selected beams during the rotation of the auxiliary structure

Considering displacement it is visible in figure 15 that the highest values of the displacement in *x*-direction is while the auxiliary structure is placed vertically. Displacement in the *y*-direction has the highest values in the rotational position of 30° of the auxiliary structure.

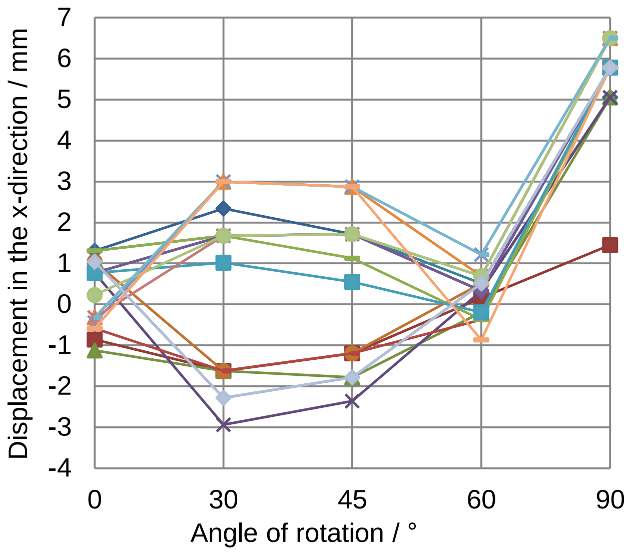

Figure 15. *Graph which shows change of displacement in the x-direction on the selected beams during the rotation of the auxiliary structure*

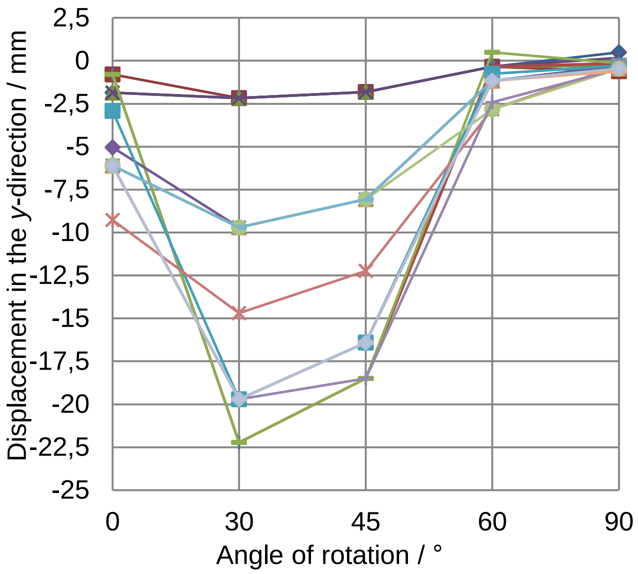

Figure 16. Graph which shows change of displacement in the y-direction on the selected beams during the rotation of the auxiliary structure

4. Conclusion

Considering von Mises stress and the displacement in the *x*-direction it is visible that the critical position is the one when auxiliary structure is placed vertically. Furthermore, considering displacement in the *y*-direction and values of the axial forces as well as high displacements in the *x*-direction during the angular position of 30° of the auxiliary structure there is a need for its analysis when we have a high need for stiffness of the auxiliary structure. Considering only von Mises stress there is a high value occurring when the auxiliary structure is positioned horizontally. Comparing horizontally placed and 30° angular positioned auxiliary structure during the finite element analysis it is visible that horizontally placed auxiliary structure has more support than the one that is tilted. In this kind of situations strength of the auxiliary structure is more important than its stiffness. So, concluding this we could say that critical positions are ones where higher stress occurs and that is when auxiliary structure is placed vertically and horizontally.

5. References

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