International Journal of Engineering Applied Sciences and Technology, 2020
Vol. 5, Issue 5, ISSN No. 2455-2143, Pages 78-85
Published Online September 2020 in IJEAST (http://www.ijeast.com)

FINITE ELEMENT ANALYSIS OF SADDLE SUPPORT FOR STACK HEAT EXCHANGER

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Abstract— **Process equipment is a leak proof container designed to hold or carry the gas or liquid or solid at a substantially high pressure. Examples of common process equipment utilized within the petroleum refining and chemical processing industries are storage tanks, boilers, pressure vessels and heat exchangers. Stack heat exchanger is a device in which arrangement of two or three horizontal heat exchangers placed one above other. During this paper, the horizontally stacked shell and tube heat exchanger supported on saddles is analyzed. The finite element analysis for various configurations of saddle supports is completed using ANSYS. The stress intensities in various cases are analyzed and also the optimal stresses in saddle with the loading condition is taken into account as the most suitable design for the stack heat exchanger. The reduction in stress intensity is found for one amongst the cases.**

Keywords— **Process Equipment, Heat Exchanger, Stack, Saddle, Analysis**

I. INTRODUCTION

Process equipment is employed to carry gas or liquid or solid at a substantially high pressure that is usually different from the ambient pressure for storage purpose or processing purpose. In general, process equipment is utilized to store and transmit the liquid, solid, vapour and gases under pressure. Examples of common process equipment utilized in the petroleum refining and chemical processing industries include, but are not limited to, storage tanks, boilers and heat exchangers [1].

Stack heat exchanger are the arrangement of two or three horizontal heat exchangers placed one above other. Exchangers are stacked because of several aspects like process requirement, structural constraint, process plant requirement etc. Two exchangers series or parallel are usually stacked. [11] Two exchangers in dissimilar services can even be stacked. Sufficient clearance must be provided for shell and channel side piping between the 2 exchangers.

For the horizontal heat exchanger saddle is used as a support of the equipment and are welded or permanently fixed to the exchanger. The suitable design of saddle support is most significant factor for stresses developed in exchanger. If the design of saddle support isn’t correct it will end in higher stresses at exchanger junction and can result in failure of heat exchanger [2]. Therefore, the design of saddle support and determining the stresses developed in saddle and part of heat exchanger is a very important step during design of a heat exchanger. The forces applied on saddle support because of the weight of heat exchanger and internal pressure, causes stresses within the saddle supports [3-5].

In this paper, analysis of different saddle designs is carried out using ANSYS 19.1 software for stack heat exchanger. Von-mises stresses is evaluated for all four saddle designs in ANSYS and compared these stresses with each other for determining the optimal saddle design [6-10].

II. PROPOSED SYSTEM

a) Collection of different design models of top exchanger support

1. Saddle models for top exchanger

The different design model collections of saddle for top exchanger using CATIA are,

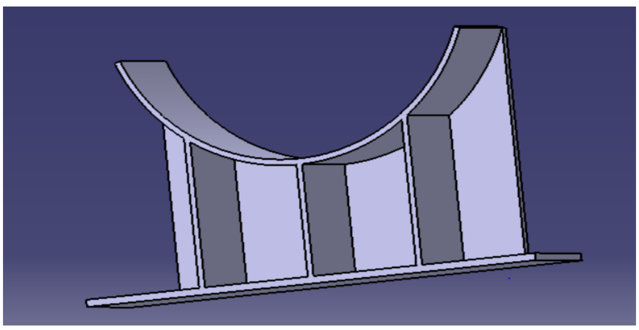

Fig.1.1-3D Model of Design 1

Fig.1.1: Shows Design collection of saddle with three ribs and web plate with rear side location. The ribs are placed at a specific distance from the center rib plate.

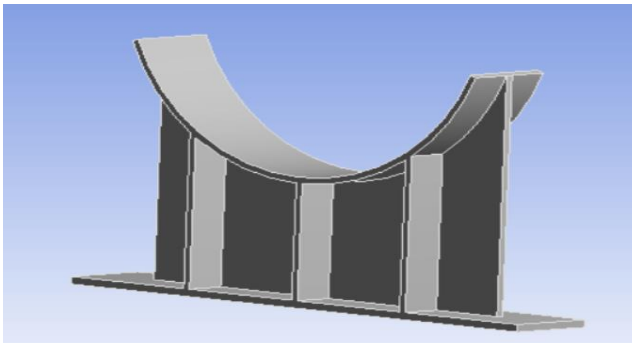

Fig.1.2-3D Model of Design 2

Fig.1.2: Shows Design collection of saddle with three ribs and web plate with center location. The ribs are placed at a specific distance from the center rib plate.

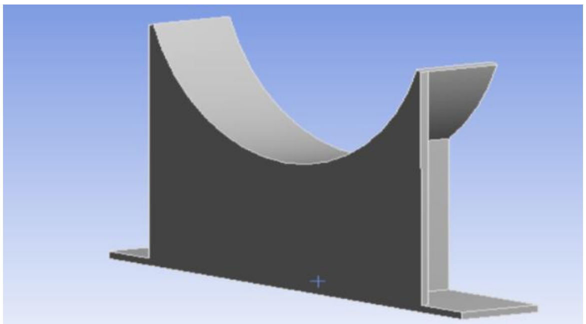

Fig.1.3-3D Model of Design 3

Fig.3.3: Shows Design collection of saddle with three ribs and web plate with front side location. The ribs are placed at a specific distance from the center rib plate.

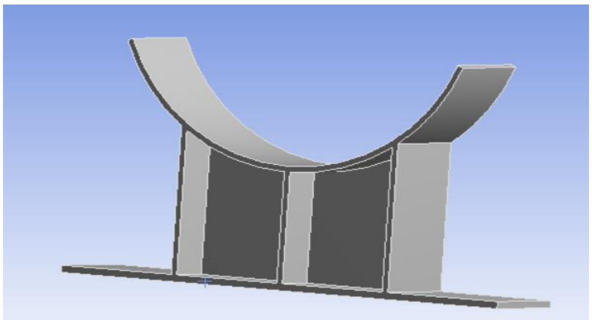

Fig.1.4-3D Model of Design 4

Fig.3.4: Shows Design collection of saddle with three ribs and web plate with center location and between ribs only. The ribs are placed at a specific distance from the center rib plate.

2. FEA mesh model's

The following Fig.3.5 to Fig.3.8 shows various design model collection of saddle i.e. Design 1 to Design 4 model meshing,

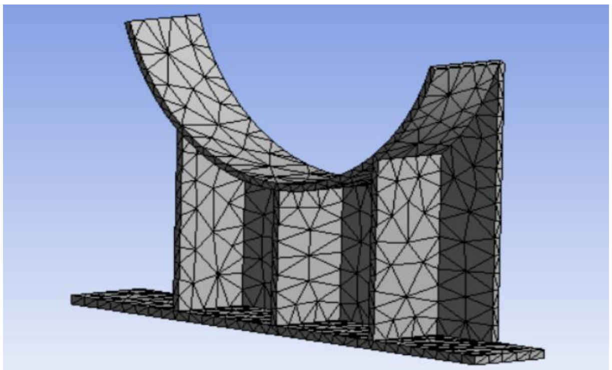

Fig.2.1: Mesh Model of saddle of design 1

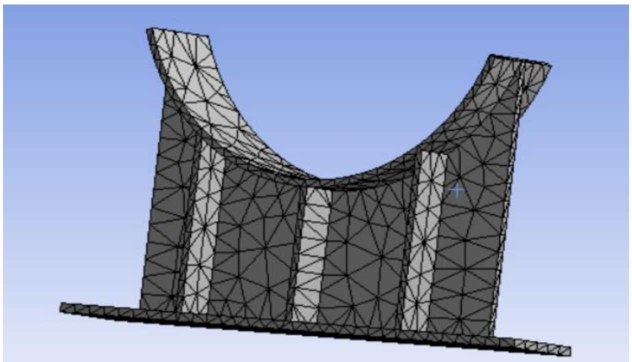

Fig.2.2: Mesh Model of saddle of design 2

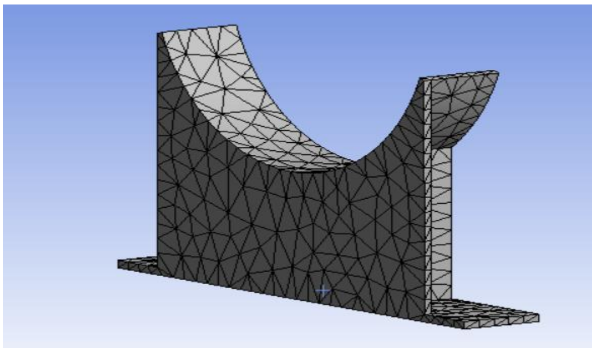

Fig.2.3: Mesh Model of saddle of design 3

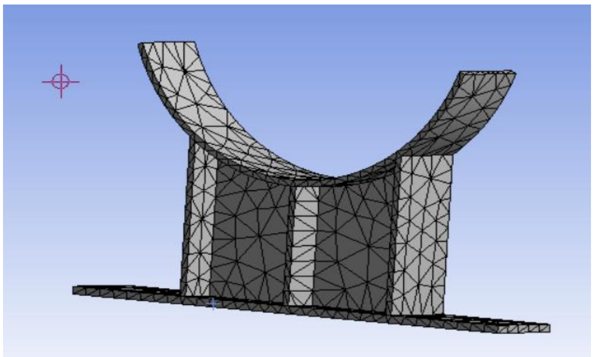

Fig.2.4: Mesh Model of saddle of design 4

3 BOUNDARY CONDITION

Boundary Conditions: total load of equipment is applied on the saddle of the top heat exchanger and base plate of saddle supports is fixed in all directions.

Total load on top exchanger

Operating weight of equipment, Wo = 65286.5 N
Saddle weight, Sw = 1626.50 N
Vertical load due to seismic, Vs = 6094.95 N

Total load on top exchanger, W = Wo + Vs – Sw
W = 65286.5 + 6094.95 – 1626.5
W = 69754.99 N

Load per saddle

Distance between LHS saddle to T.L = 786.5 mm
Load on LHS saddle,

$$Q = (1 - aLS/LS) * W + \max(\text{transverse, longitudinal})$$
$$Q = (1 - 786.5/1850) * 69754.99 + \max(9142.9, 4571.7)$$
$$Q = 49242.6\ N$$

Load on RHS saddle,

$$Q = \text{Total load} - \text{load on LHS saddle} + \max(\text{transverse, longitudinal})$$
$$Q = 69754.99 - 40099.69 + \max(9142.9, 4571.7)$$
$$Q = 39798.2\ N$$

III. RESULTS AND DISCUSSION

We have checked the result of designs models of design 1 to design 4 their FEA results with von-miss stress in the top heat exchanger saddle. The details are shown in the figures from Fig 4.1 to Fig 4.8.

For LHS saddle

Boundary condition for FEA analysis of LHS saddle is as per discussed above i.e. load on LHS saddle is 49242.6 N and baseplate is fixed.

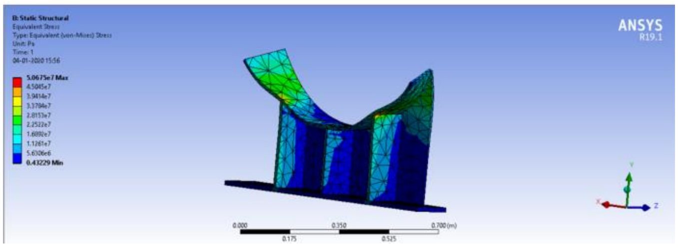

Fig.4.1- Static Structural Analysis of Design 1 Model Color Code shows Von-misses stresses over Saddle Support

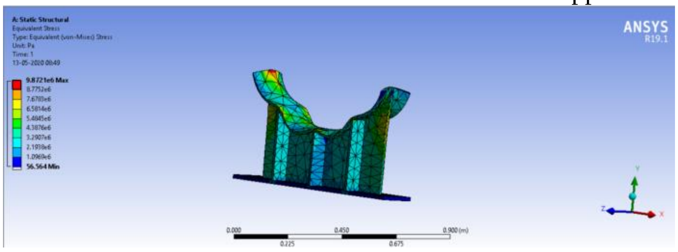

Fig.4.2- Static Structural Analysis of Design 2 Model Color Code shows Von-misses stresses over Saddle Support

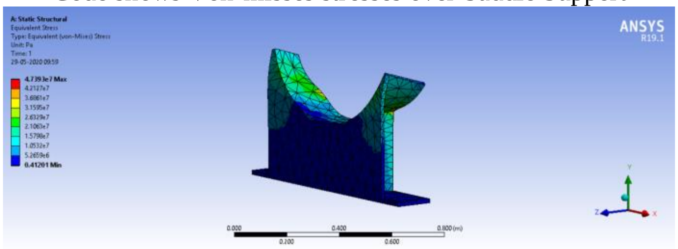

Fig.4.3- Static Structural Analysis of Design 3 Model Color Code shows Von-misses stresses over Saddle Support

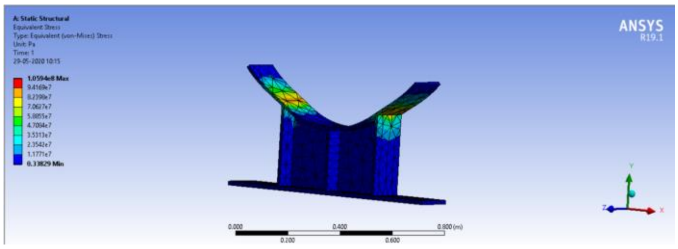

Fig.4.4- Static Structural Analysis of Design 4 Model Color Code shows Von-misses stresses over Saddle Support

For RHS saddle

Boundary condition for FEA analysis of RHS saddle is as per discussed above i.e. load on RHS saddle is 39798.2 N and baseplate is fixed.

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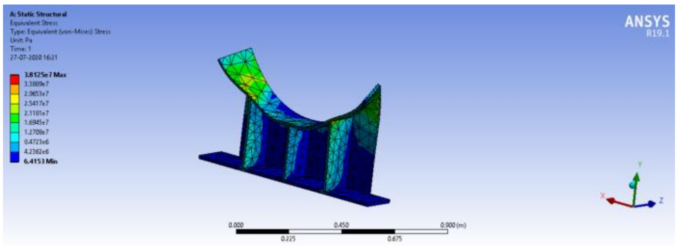

Fig.4.5- Static Structural Analysis of Design 1 Model Color Code shows Von-misses stresses over Saddle Support

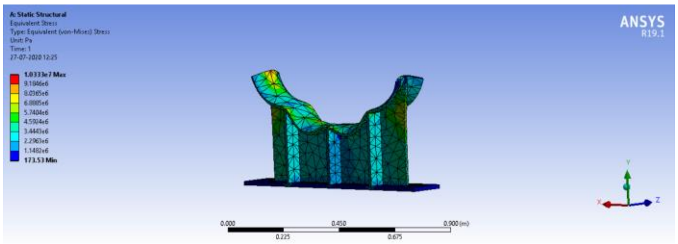

Fig.4.6- Static Structural Analysis of Design 2 Model Color Code shows Von-misses stresses over Saddle Support

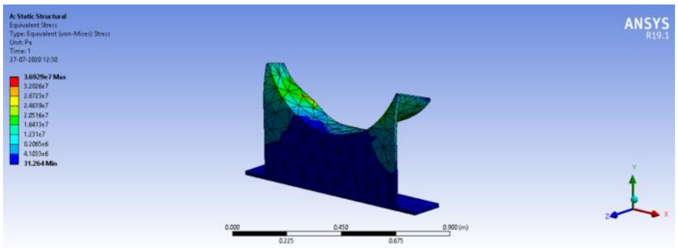

Fig.4.7- Static Structural Analysis of Design 3 Model Color Code shows Von-misses stresses over Saddle Support

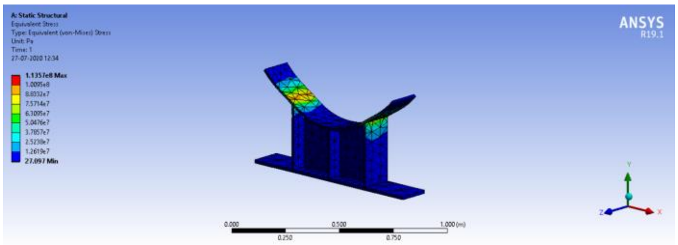

Fig.4.8- Static Structural Analysis of Design 4 Model Color Code shows Von-misses stresses over Saddle Support

	LHS Saddle (N/mm²)	**RHS Saddle** (N/mm²)
Design Model 1	**50.67**	**38.12**
Design Model 2	**9.87**	**10.33**
Design Model 3	**50.67**	**38.12**
Design Model 4	**105.94**	**113.57**

Table -1 Stress Result

Table 1 indicates the stress intensities of the LHS and RHS saddle of all four design models. According to the FEA analysis all four design models are safe means the stresses in the saddle are below the allowable stress value. From all the four design models, design model 2 which is web plate with center location has a minimum stress intensity.

b) Collection of different design models of bottom exchanger supports

1. Saddle models for bottom exchanger

The different design model collections of saddle for top exchanger using CATIA are,

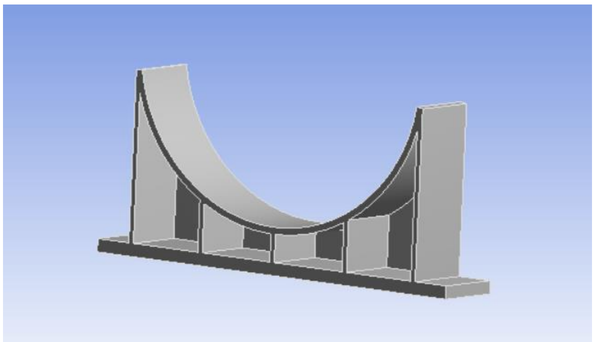

Fig.1.1: Shows Design collection of saddle with five ribs and web plate with rear side location. The ribs are placed at a particular distance from the middle rib plate

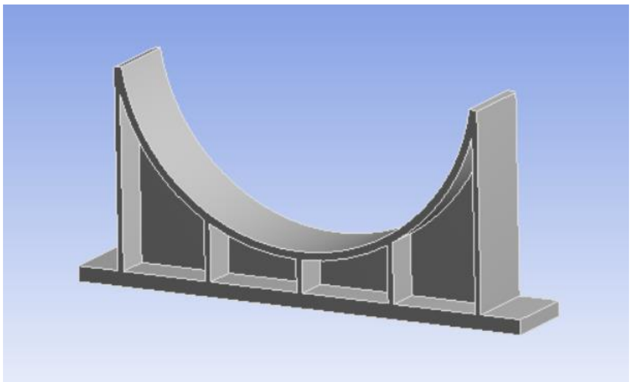

Fig.1.2: Shows Design collection of saddle with five ribs and web plate with center location. The ribs are placed at a particular distance from the middle rib plate

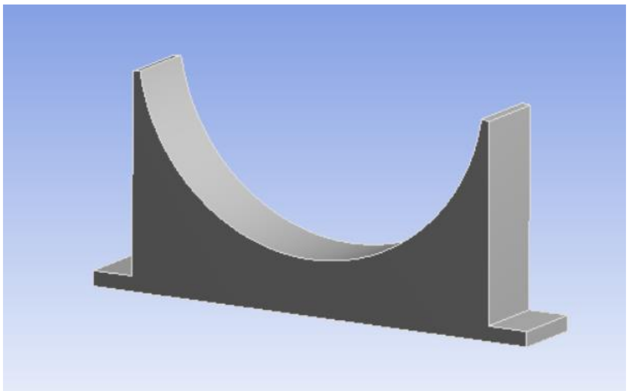

Fig.1.3: Shows Design collection of saddle with five ribs and web plate with front side location. The ribs are placed at a particular distance from the middle rib plate

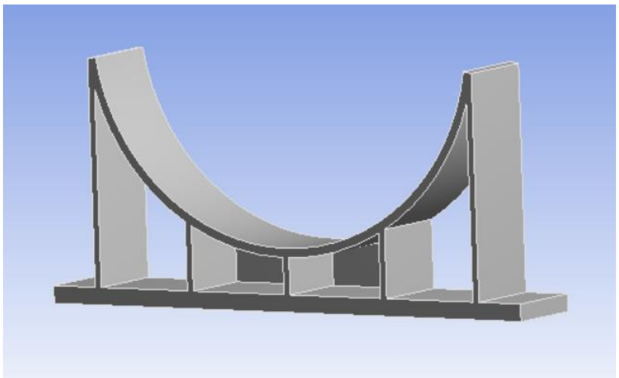

Fig.1.4: Shows Design collection of saddle with five ribs and web plate with center location and between three ribs only. The ribs are placed at a particular distance from the middle rib plate

2. FEA mesh model's

The following Fig.3.5 to Fig.3.8 shows various design model collection of saddle i.e. Design 1 to Design 4 model meshing,

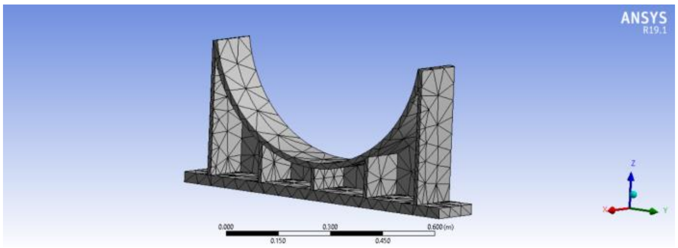

Fig.2.1: Mesh Model of saddle of design 1

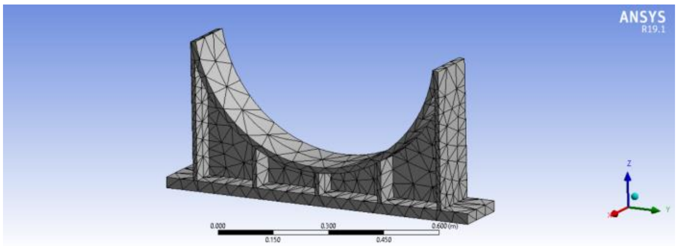

Fig.2.2: Mesh Model of saddle of design 2

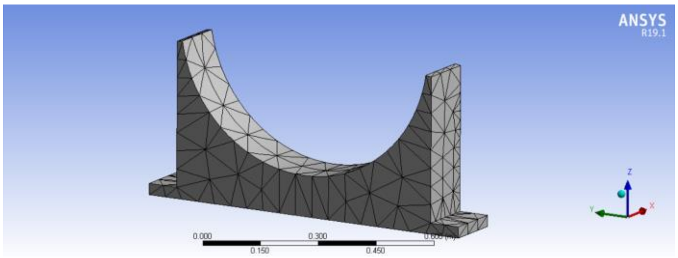

Fig.2.3: Mesh Model of saddle of design 3

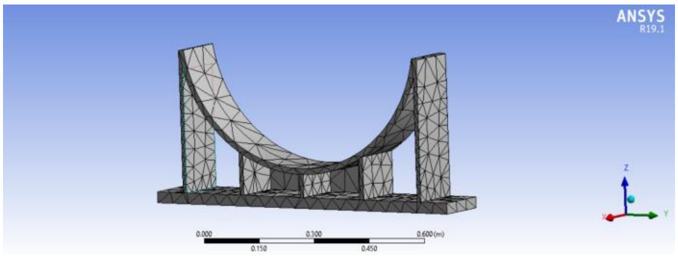

Fig.2.4: Mesh Model of saddle of design 4

3. Boundary condition

Boundary Conditions: total load of equipment is applied on the saddle of the bottom heat exchanger and base plate of saddle supports is fixed in all directions.

Total load on bottom exchanger

Operating weight of equipment, Wo = 64834.3 N
Total weight of upper shell = 73007.00 N
Total weight of equipment (with upper shell), Wo = 137841.3N
Saddle weight, Sw = 1692.25 N
Vertical load due to seismic, Vs = 6052.77 N

Total load on bottom exchanger,

$$W = Wo + Vs - Sw$$
$$W = 137841.29 + 6052.77 - 1692.25$$
$$W = 142201.041 \text{ N}$$

Load per saddle

Distance between LHS saddle to T.L = 786.5 mm
Load on LHS saddle,

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$$Q = (1 - aLS/LS) * W + \max(\text{transverse, longitudinal})$$
$$Q = (1 - 786.5/1850) * 142201.041 + \max(9076.8 + 16883.66, 4538.4 + 33737.33)$$
$$Q = 120022.11 \text{ N}$$

Load on RHS saddle,

$$Q = \text{Total load} - \text{load on LHS saddle} + \max(\text{transverse, longitudinal})$$
$$Q = 142201.04 - 81746.4 + \max(9076.08 + 16883.66, 4538.4 + 33737.3)$$
$$Q = 98731.13 \text{ N}$$

IV. RESULTS AND DISCUSSION

We have checked the result of designs models of design 1 to design 4 their FEA results with von-miss stress in the bottom heat exchanger saddle. The details are shown in the figures from Fig 4.1 to Fig 4.8.

For LHS saddle

Boundary condition for FEA analysis of LHS saddle is as per discussed above i.e. load on LHS saddle is 120022.11 N and baseplate is fixed.

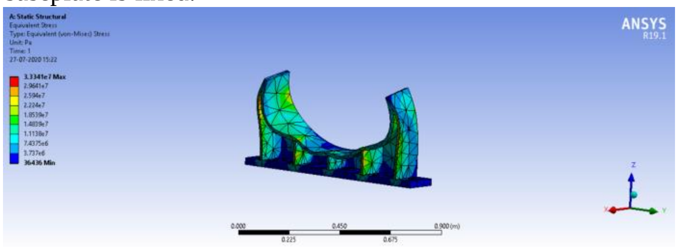

Fig.4.1- Static Structural Analysis of Design 1 Model Color Code shows Von-misses stresses over Saddle Support

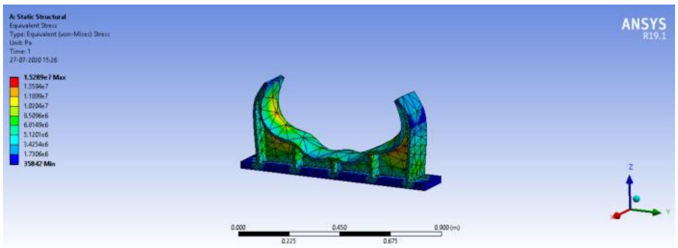

Fig.4.2- Static Structural Analysis of Design 2 Model Color Code shows Von-misses stresses over Saddle Support

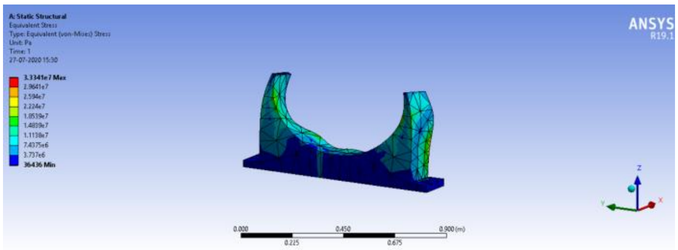

Fig.4.3- Static Structural Analysis of Design 3 Model Color Code shows Von-misses stresses over Saddle Support

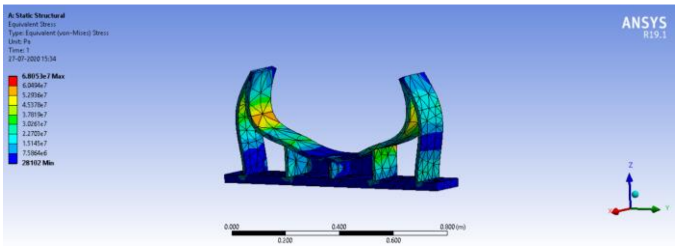

Fig.4.4- Static Structural Analysis of Design 4 Model Color Code shows Von-misses stresses over Saddle Support

For RHS saddle

Boundary condition for FEA analysis of RHS saddle is as per discussed above i.e. load on RHS saddle is 98731.13 N and baseplate is fixed.

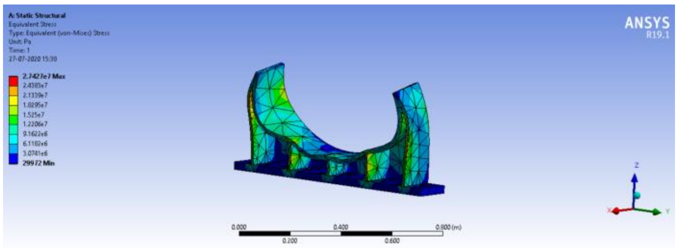

Fig.4.5- Static Structural Analysis of Design 1 Model Color Code shows Von-misses stresses over Saddle Support

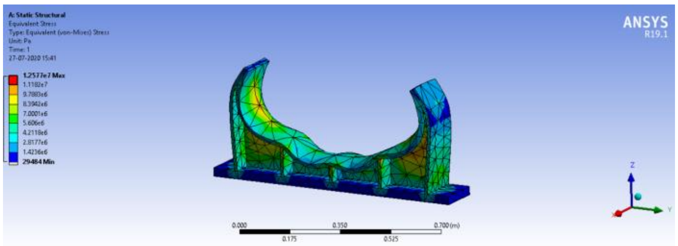

Fig.4.6- Static Structural Analysis of Design 2 Model Color Code shows Von-misses stresses over Saddle Support

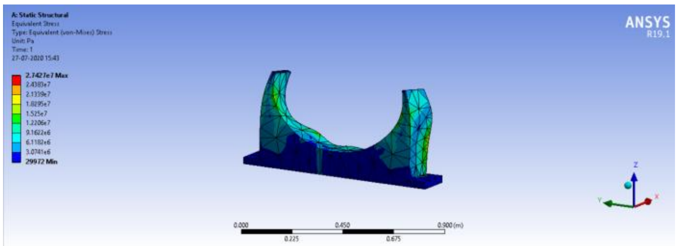

Fig.4.7- Static Structural Analysis of Design 3 Model Color Code shows Von-misses stresses over Saddle Support

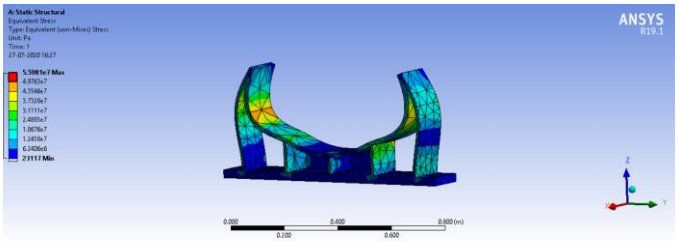

Fig.4.8- Static Structural Analysis of Design 4 Model Color Code shows Von-misses stresses over Saddle Support

	LHS Saddle (N/mm²)	RHS Saddle (N/mm²)
Design Model 1	**33.34**	**27.42**
Design Model 2	**15.28**	**12.57**
Design Model 3	**33.34**	**27.42**
Design Model 4	**68.05**	**55.98**

Table -2 Stress Result

Table 2 indicates the stress intensities of the LHS and RHS saddle of all four design models. According to the FEA analysis all four design models are safe means the stresses in the saddle are below the allowable stress value. From all the four design models, design model 2 which is web plate with center location has a minimum stress intensity.

V. CONCLUSION

According to the FEA results of design 1, 2, 3 and 4 it is concluded that the stress value over all saddle support is under the yield limit, so every design model of saddle supports will sustain the heat exchanger load but the design model 2 for the saddle support has minimum stress intensity to the applied load. Hence saddle with web plate center location is most optimal and suitable design.

VI. ACKNOWLEDGMENT

We would like to thank the researchers as well as publishers for making their resources available and teachers for their guidance. We are also thankful to reviewer for their valuable suggestions. We also thank the college authorities for providing the required infrastructure and support. Finally, we would like to extend a heartfelt gratitude to friends and family members.

VII. REFERENCE

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