Static Structural Analysis of the Circumferential Joints (Double Strap Butt Joints) to be used in Boiler Shells

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Abstract— Manufacturing & production engineering is mostly concerned with heavy machinery which is a must for mass production. One such component is a boiler which is used in power plants for steam production. For steam production Water is boiled inside boiler assembly with the help of combustion of fuel in furnace. The water in liquid state is made to pass through pipes which come in contact with of heat being generated in the furnace. This heat increases the temperature of water above its boiling point and ultimately the water is converted into steam. This steam is stored inside boiler shell which is developed with the help of lap joints & butt joints. Boiler shell comprises a longitudinal joint which is a double strap double riveted butt joint. In this dissertation work Static structural analysis of this boiler joint will be performed mathematically & with the help of ANSYS simulation. The results of both will be compared in order to validate the simulation. Once the validation is completed, then some new materials will be tried in place of conventional low carbon steel. This way the boiler joint will be optimized. Mathematical analysis will be completed with the help of literature already available in machine design of mechanical engineering. Conventional material which will be used is low carbon steel (mild steel). ANSYS simulation will be performed using aluminium alloy, Asbestos, Carbon Fibre, Inconel materials and Epoxy Carbon. The results obtained through simulation will be then compared with the results obtained through mathematical calculations. In order to complete the simulation work, model of double strap double riveted butt joint will be developed in CATIA V5-6 R2017 & then this model will be exported to ANSYS. The Analysis part will be completed in ANSYS 19.2.

Keywords: Circumferential Joints, Boiler Shells, Double Strap Butt Joints

I. INTRODUCTION

A mechanical joint is a phase of a device that's used to connect one or extra mechanical component to every other. Mechanical joints may be temporary or everlasting; maximum sorts are designed to be disassembled. Most mechanical joints are designed to permit relative movement of these mechanical components of the device in a single degree of freedom, and restriction motion in one or more others. Mechanical joints are lots inexpensive and are usually sold equipped assembled.

A butt joint is a technique wherein two portions of fabric are joined with the aid of certainly placing their ends together with none special shaping. The name 'butt joint' comes from the way the fabric is joined together. The butt joint is the best joint to make since it simply includes reducing the steel to the suitable period and butting them collectively.

A rivet is a permanent mechanical fastener. Before being hooked up, a rivet includes a smooth cylindrical shaft with a head on one stop. The quite opposite to the head is referred to as the tail. On installation, the rivet is positioned in a punched or drilled hollow, and the tail is dissatisfied, or bucked (i.e., deformed), so that it expands to about 1.5 instances the authentic shaft diameter, keeping the rivet in place.

The boiler has a longitudinal joint as well as circumferential joint. The longitudinal joint is used to join the ends of the plate to get the required diameter of a boiler. For this purpose, a butt joint with two cover plates is used. The circumferential joint is used to get the required length of the boiler.

Composite material (additionally known as a composition fabric or shortened to composite that is the commonplace name) is a material made from two or more constituent substances with considerably considered one of a kind physical or chemical residence that, even as mixed, produce a material with characteristics precise from the individual components.

Structural analysis is the determination of the effects of loads on physical structures and their components. Structures subject to this type of analysis include all that must withstand loads, such as buildings, bridges, vehicles, furniture, attire, soil strata, prostheses and biological tissue.

II. PROBLEM STATEMENT

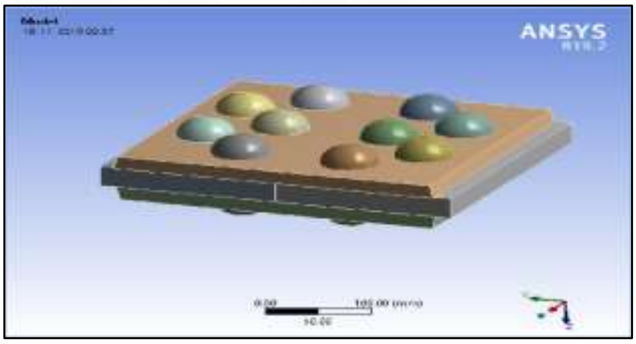

Fig. 1: Circumferential joint of Boiler

A lot of work has been already done in but still there is a scope of research work in case of butt joints used in making longitudinal joints of boiler shells. This literature survey shows that we can perform structural analysis of butt joints as it is the area where very less amount of work has been noted. So, in this research work a structural analysis of a butt joint will be performed.

The workpiece to be examined would be of different sizes & gap size of it too would be different. A static structural analysis would be conducted on ANSYS workbench and the experimental & analytical data will be compared with each other. After the analysis of workpiece using conventional material, some other workpiece using composite materials will also be analysed in order to study the effects of change in material. Some boundary conditions will also be taken care of in order to confine this study, some of which are stated below-

- Tensile load acting on the joint
- Shear load acting on the joint

Butt joint will be analysed for different materials other than mild steel (low carbon steel) which has already been used for the conventional material for longitudinal joints of boiler shells.

III. ANSYS ANALYSIS OF THE JOINT

Depending upon the data calculated in previous chapter, the model of disc butt joint is now developed using CATIA. CATIA is a modelling & analysis software or we can say a PLM software which is used for modelling various mechanical designs & their analysis. After building the model in CATIA we need to import that geometry into ANSYS for analysis purpose because analysis portion of CATIA doesn't provide precise results. In order to import the geometry, model build in CATIA must be saved in igs or stp format.

Modelling of butt joint is p
erformed on CATIA V5-6 R2017. Procedure of modelling this butt joint is discussed as cited below-

There are different procedures available for modelling of butt joint namely top-down approach & bottom-up approach. Here we are utilizing bottom-up approach for the modelling of this butt joint.

- Create the sketch with the help of double strap double riveted butt joint data. All the components will be modeled separately.
- After the modelling of all the components in Part Design workbench of CATIA, these will be assembled according to the need.
- After creating solid model of butt joint in CATIA V5-6 R2017 proceed as follows-
- Start the analysis process of the model in ANSYS Workbench through selecting the module of static structural analysis.
- Select double strap double riveted butt joint material Low carbon steel.

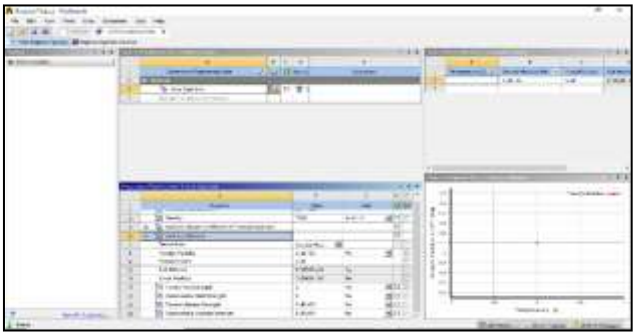

Fig. 2: Selecting the material for the joint

- Assign the material to the assembly butt joint

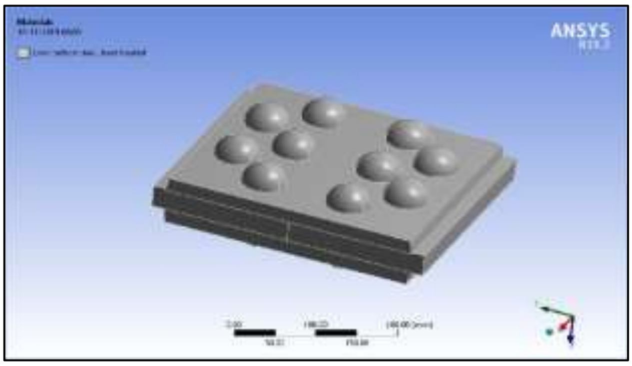

Fig. 3: Assigning the Material

- Define contact among contacts of butt joint

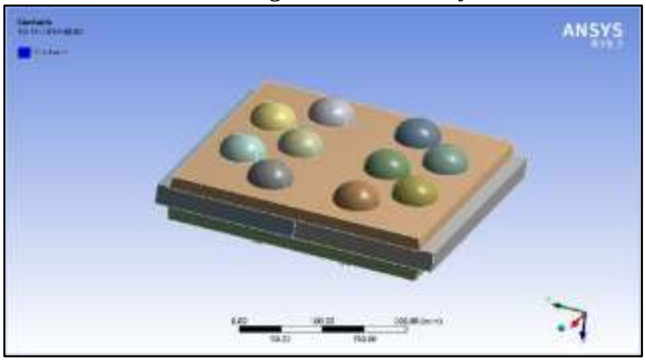

Fig. 4: Defining contacts among components

- Create meshing of double strap double riveted butt joint

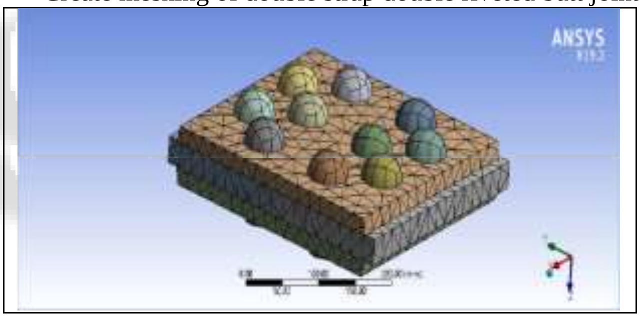

Fig. 5: Meshing of the joint assembly

- Apply boundary conditions

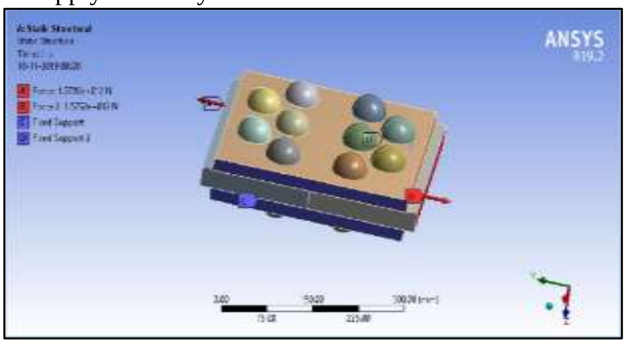

Fig. 6: Boundary conditions being applied on the assembly

- Run the analysis
- Get the results

Similar kind of analysis is performed for different materials, the result analysis for which is being presented here for reference.

S. No.	Material	Process Parameter	Value
1		Weight	65.276 Kg
2		Equivalent Stress	363.65 MPa

3	Low Carbon Steel	Total Deformation	0.70724 mm
4		Elastic strain (Equivalent)	0.0025151 mm/mm
5		Stress (Maximum Principal)	307.41 MPa
6		Stress (Shear)	203.87 MPa
7		Shear Elastic Strain	0.0025047 mm/mm
8		Max. Shear Stress	207.03 MPa
9	Aluminium Alloy	Weight	39.08 Kg
10		Equivalent Stress	347.06 MPa
11		Total Deformation	0.75294 mm
12		Elastic strain (Equivalent)	0.0041954 mm/mm
13		Stress (Maximum Principal)	397.92 MPa
14		Stress (Shear)	140.23 MPa
15		Shear Elastic Strain	0.0052536 mm/mm
16		Max. Shear Stress	175.18 MPa
17	Carbon Fibre	Weight	34.078 Kg
18		Equivalent Stress	439.68 MPa
19		Total Deformation	0.75513 mm
20		Elastic strain (Equivalent)	0.0074454 mm/mm
21		Stress (Maximum Principal)	501.88 MPa
22		Stress (Shear)	82.084 MPa
23		Shear Elastic Strain	0.0073109 mm/mm
24		Max. Shear Stress	221.99 MPa
25	Asbestos	Weight	38.771 Kg
26		Equivalent Stress	350.15 MPa
27		Total Deformation	0.7568 mm
28		Elastic strain (Equivalent)	0.0042783 mm/mm
29		Stress (Maximum Principal)	401.72 MPa
30		Stress (Shear)	137.62 MPa
31		Shear Elastic Strain	0.0053597 mm/mm
32		Max. Shear Stress	269.93 MPa
33	Inconel 625	Weight	68.318 Kg
34		Equivalent Stress	326.39 MPa
35		Total Deformation	0.8239 mm
36		Elastic strain (Equivalent)	0.0028743 mm/mm
37		Stress (Maximum Principal)	355.02 MPa
38		Stress (Shear)	139.88 MPa
39		Shear Elastic Strain	0.0017186 mm/mm
40		Max. Shear Stress	170.19 MPa
41	Inconel 718	Weight	67.179 Kg
42		Equivalent Stress	327.24 MPa
43		Total Deformation	0.8203 mm
44		Elastic strain (Equivalent)	0.0028265 mm/mm
45		Stress (Maximum Principal)	351.84 MPa
46		Stress (Shear)	140.86 MPa
47		Shear Elastic Strain	0.0017306 mm/mm
48		Max. Shear Stress	170.57 MPa
49	Epoxy Carbon	Weight	64.44 Kg
50		Equivalent Stress	361.34 MPa
51		Total Deformation	0.76279 mm
52		Elastic strain (Equivalent)	0.002693 mm/mm
53		Stress (Maximum Principal)	309.14 MPa
54		Stress (Shear)	200.75 MPa
55		Shear Elastic Strain	0.0027252 mm/mm
56		Max. Shear Stress	248.32 MPa

Table I: Result Analysis for Different Materials

IV. Result Analysis

All the results have been simulated in ANSYS and now we need to compare the result distributions of all the materials. In order to achieve our requirement, we need to present the data in a graphical form. Graphical representation of all the results is being shown as follows-

A. Equivalent Stress Distribution

When we plot the data for equivalent (von-mises) stress we see that in case of low carbon steel value of equivalent stress is 363.65 MPa which reduces for aluminium alloy and the actual value for both of this material is equal to 347.06 MPa. For Carbon Fibre & Asbestos it increases to a value of 439.68 MPa & 537.84 MPa. In case of Inconel 625 & Inconel 718 the value further reduces to 326.39 MPa & 327.24 MPa. For Epoxy Carbon this value moves to 493.12 MPa. So according to this criterion Aluminium alloy, Inconel 625 & Inconel 718 may be supposed to be the better materials for the development of circumferential boiler joint. Asbestos is having the maximum equivalent (Von-mises) stress which is equal to 439.68 MPa.

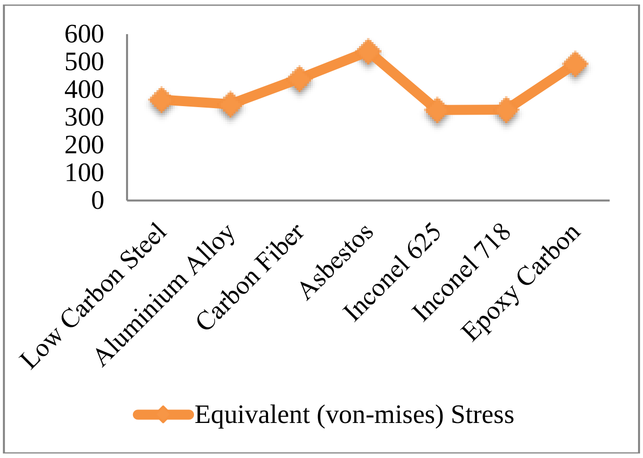

Fig. 7: Equivalent Stress Distribution

B. Total Deformation Distribution

When we plot the data for total deformation, we can see that mild steel shows the total deformation of 0.70724 mm which increases for aluminium alloy & carbon fiber are having the actual value for both of these materials is equal to 0.75294 mm & 0.75513 mm. For Carbon Fibre it reduces to a value of 0.19666 mm. When we consider Inconel 625 & Inconel 718, the total deformation further increases to 0.8239 mm & 0.8203 mm. For Epoxy carbon this value moves to 0.78516 mm. So according to this criterion although aluminium alloy is having more deformation than mild steel but it is totally because of its density is far lesser than mild steel, it may be supposed to be the better material for the development of circumferential boiler joints. As far as minimum value of total deformation is concerned, Asbestos is the best material.

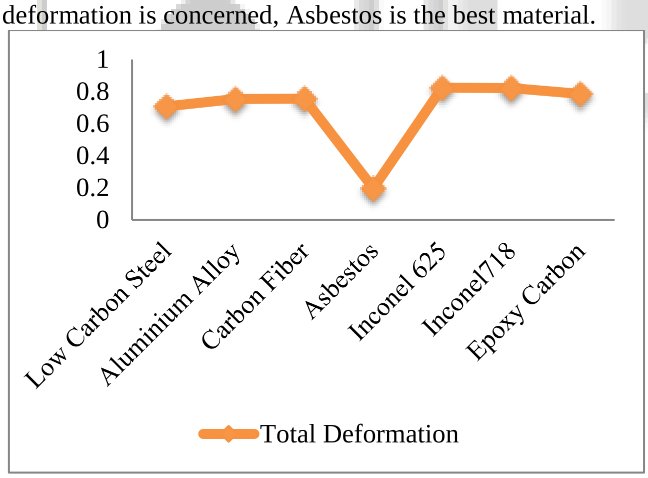

Fig. 8: Total Deformation Distribution

C. Equivalent Elastic Strain Distribution

When we plot the details of elastic strain (equivalent), we find that elastic strain (equivalent) increases little bit when we move from low carbon steel to aluminium alloy and Carbon fiber but we see a sudden and a large amount of decrease in case of Inconel 625 & Inconel 718. For Epoxy Carbon this value moves to 0.010039 mm/mm. This criterion gives us the indication that mild steel is the best for this particular application but we may also use aluminium alloy.

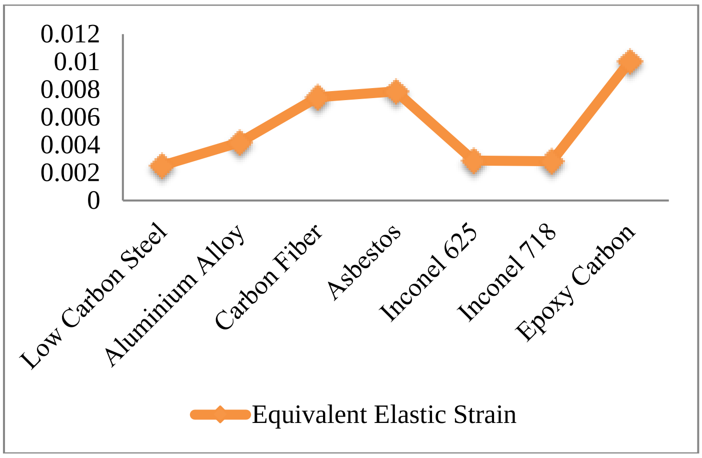

Fig. 9: Equivalent Elastic Strain Distribution

D. Principal Stress Distribution

When we plot the details of maximum principal stress for all the materials, we find that the maximum principal stress increases again as we move from low carbon steel to aluminium alloy and carbon fiber & it is maximum in case of Asbestos but we see a sudden and a small amount of decrement in case of Inconel 625 & Inconel 718. For Epoxy Carbon this value moves to 554.69 MPa. This criterion gives us the indication that all the materials will provide similar amount of stress and all maybe used.

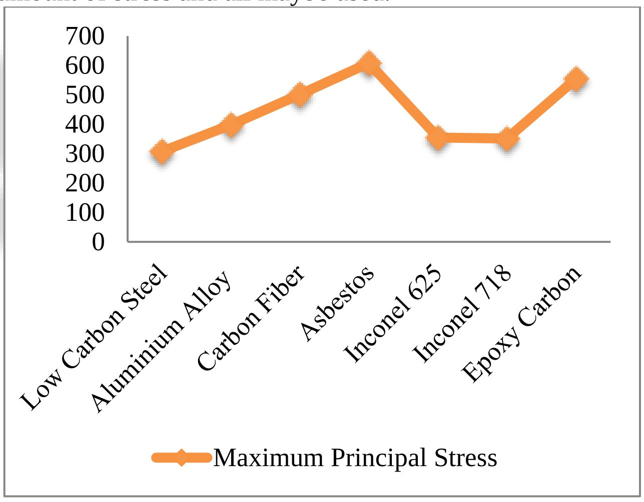

Fig. 10: Principal Stress Distribution

E. Shear Stress Distribution

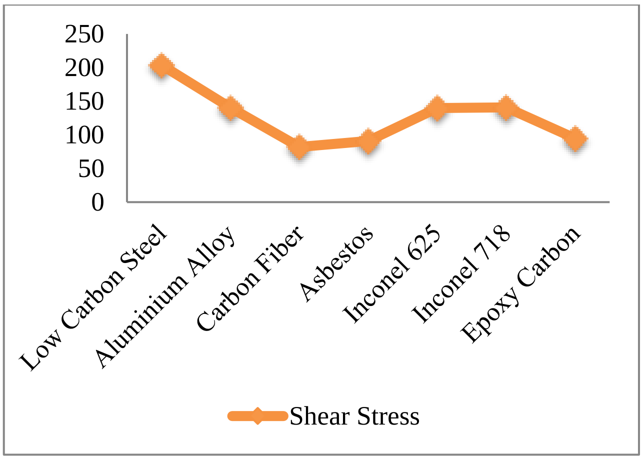

Fig. 11: Shear Stress Distribution

When we plot the details of shear stress for all the materials, we find that the value of shear stress decreases a fair bit when we move from low carbon steel to aluminium alloy and carbon fiber but we see small amount of increase in case of Asbestos, Inconel 625 & Inconel 718 which again rises a little bit. For Epoxy carbon this value moves to 94.552 MPa. This criterion gives us the indication that aluminium alloys may be effectively used for this particular application. Here one must be clear that Inconel 625 & Inconel 718 may also be used along with Asbestos & Epoxy Carbon.

F. Weight Comparison

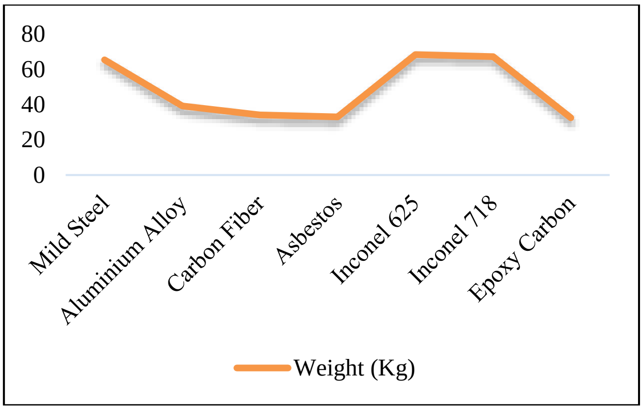

Fig. 12: Weight Comparison

When we plot the details of weight for all the materials, we see that for mild steel the mass is 65.276 Kg. When we use aluminium alloy and carbon fiber the mass reduces to 39.08 Kg & 34.078 Kg which suddenly rises to 68.318 Kg when we use Inconel 625 boiler joints. For Epoxy Carbon and Asbestos this value again reduces to 32.48 Kg & 33.047 Kg. According to this criterion, any of the aluminium alloy, Carbon fibre, Asbestos or Epoxy Carbon may be used for the particular application.

G. Maximum Shear Stress Comparison

When we plot the data for maximum shear stress among all the materials, we see that low carbon steel, Asbestos and Epoxy Carbon are having the maximum amount which is equal to 207.03 MPa, 269.93 MPa & 248.32 MPa respectively which reduces for all the other materials. For aluminium alloy it is 175.18 MPa, for carbon fiber the value is minimum among all the materials at 82.084 MPa, for Inconel materials too we are seeing depreciation in the value of maximum shear stress when compared to lo carbon steel.

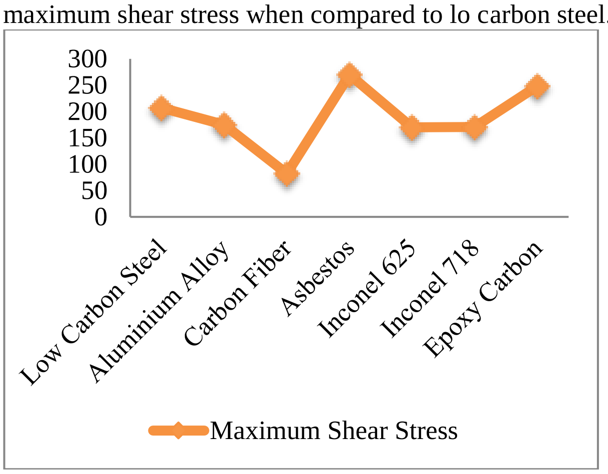

Fig. 12: Max. Shear Stress Distribution

V. CONCLUSIONS

Looking at the numerical analysis & ANSYS simulation of all these materials I propose that

1) Aluminium alloy may be used as the alternate material when compared to low carbon steel for the manufacturing of double strap double riveted butt joint which is being used as longitudinal joint of a boiler shell.
2) This proposal is being made because by doing so one can clearly reduce the overall weight of boiler drums & boiler shells considerably.
3) The deformation plot also confirms the above proposal although one can see a slight increment in total deformation in case of aluminium alloys. It is totally because of the fact that aluminium alloys have lesser amount of density when compared to mild steel.
4) Equivalent stress in case of Aluminium Alloy is also less than low carbon steel.
5) Maximum Shear Stress in case of aluminium alloys is again minimum across all the material which is being examined in this dissertation work.
6) Equivalent elastic strain is minimum in case of low carbon steel but aluminium alloys can also be used for this application as the difference in the amount of this strain between low carbon steel is very less and is of the order of µm (0.001 mm).
7) Shear Stress is also seen to be minimum for aluminium alloy material.
8) It also shows that the performance of a boiler may be increased by applying changes in materials.
9) As the current time is asking us to move towards some newer methods of manufacturing, there has been the incorporation of some newer kind of materials like Inconel materials. In the present analysis Inconel 625 & Inconel 718 too have been incorporated & one can see that Inconel materials are proved to be better materials than mild steel in a lot of aspects. But still the overall impact of aluminium alloy is better when compared to conventional material (Low Carbon Steel). Hence the proposal is being made to use aluminium alloy for developing longitudinal joints of boilers.

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