Analysis of the Circumferential Joints (Double Strap Butt Joints) to be used in Boiler Shells-A Review Study

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Abstract— One of most important sector currently growing at a rapid rate is the manufacturing industry which is responsible for the production of heavy machinery. This heavy machinery can be considered as one of the basic elements in development of any country. As India is striving hard for the rapid and sustainable development, demand of heavy machinery has also increased. One of the basic components in this category is the power plant which is responsible for electricity generation. Boilers in power plants are one of the important components which are responsible for steam generation and also work as steam storage devices. In order to develop the boiler shell, a long length metallic is shaped into a cylindrical form and is connected through butt joints. These butt joints are one of the key features for the researchers as a lot of researchers are studying and researching about butt joints. Current paper reviews the research work already going on in the field of butt joints.

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

I. INTRODUCTION

Butt Joints- A butt joint is that in which the main plates are kept in alignment butting (i.e., touching) each other and a cover plate (i.e., strap) is placed either on one side or on both sides of the main plates. The cover plate is then riveted together with the main plates.

When two members to be connected are placed end to end, additional plate/plates provided on either one or both sides called cover plates and are connected to the main plates. If the cover plate is provided on one side it is called single cover butt joint but if the cover plates are provided on both the sides of main plates, it is called a double cover butt joint.

Analysis of Butt joints- Analysis of butt joints involve mathematical calculations through designing of the joint dimensions related to cover plates, rivets and the thickness of the plates to be joined together. Similar kind of analysis can be performed on analysis softwares like ANSYS, ABAQUS, Nastran in CAD etc. When considering ANSYS for the analysis of butt joints, Static Structural Analysis module is used for the stress strain related calculations performed through following very easy steps of the analysis.

Material Optimization of Butt Joints- Conventional materials to be used in butt joints for industrial applications has always been low carbon steel (mild steel) but this material is heavy and hence there evolved a need for a lighter material to be used which can also optimize other process parameters too. Hence a lot of research is being conducted in the concerned field.

Apart from above criterion, several other criteria are being researched for in butt joints. Current paper reviews all such fields.

II. LITERATURE REVIEW

Aslam kha Kausar kha Pathan et al. [1] studied about the stress analysis of boiler shell with riveted joints. By using finite element method, a stress analysis has been carried out under the application of pressure at the inner surface of boiler shell. Von-Mises stresses and maximum shear stresses are found. These stresses are compared with analytical results. Using the two materials, structural steel and aluminium alloy, stress values have been compared for same working conditions. It is found that structural steel is safer as compared to aluminium alloy at the same working conditions. Modeling has been done by Pro-E and analysis of riveted joint has been done by ANSYS (Workbench) with a version 14.5.

Brundaban Patro [2] studied about the study of combination tube boilers, as applicable to commercial use, along with the significant features, limitations, and applicability. A heat balance sheet is prepared to know the various heat losses in two different two-pass combination tube boilers, using low grade coal and rice husk as a fuel. Also, the efficiency of the combination tube boilers is studied by the direct and heat loss methods. It is observed that the dry flue gas loss is a major loss in the combination tube boilers. The loss due to the unburnt in the fly ash is very less in the combination tube boilers, due to the surrounded membrane wall. It is also observed that the loss due to the unburnt in the bottom ash has a considerable amount for the heat loss, and cannot be ignored.

Kamoru Olufemi OLADOSU et al. [3] studied about the Steam boilers which is an integral and important component of steam turbine used for electricity generation. Its design is however complex, time consuming and prone to errors if done manually. This study aimed at using computer-based approach to design palm kernel shell combusting furnace for generating a desired amount of electricity. The equations were coded and solved using C-Sharp programming language. The results showed that to generate 5 kW of electricity from palm kernel shell; 5.5 kW turbine, 3.1 m super heater, 3.8 m riser, furnace of 1.432 m height and 0.45 m3 volume were required having considered power loss due to friction and others. While these results are in good agreement with those calculated manually, human errors are virtually eliminated. In addition, calculations and drafting time were reduced from 5 hrs. 47 minutes when done manually to about 4 minutes when the developed code was used. This code can be used to size boiler for desired power output.

Kuldeep Singh et al. [4] studied about Pressure vessels, boilers or steam generators with riveted joints. These are the closed vessels and generally used for storing pressurized fluids in the severe pressure and temperature

conditions. This paper studied the finite element analysis of the boiler shell with riveted joints under static condition when shell is subjected to internal pressure along with analytical method. In the present work design and analysis of boiler shell with riveted joints using ANSYS software has been carried out using structural steel and aluminium alloy. The model of boiler shell has been developed in CATIA V5 and SOLIDWORKS. Then, model is saved in Parasolid x_t file in solid works and imported in ANSYS workbench. Static analysis of boiler shell has been carried out. The result for equivalent and maximum shear stress has been compared with analytical results. Then stress value compared for structural steel and aluminium alloy for same working conditions.

N K H Sameera et al. [5] studied about boilers for power generation. With the increase in the development and rise in the growth of population, there is also rise in the power consumption and usage. The development of technology in the area of boilers and pressure vessels have reached a level of technological maturity. However, the increase in the rise of technology also increased the challenges in the design of boilers and pressure vessels. This paper aims at designing a geometry for boiler shell which can operate at optimal conditions of Ultra-supercritical thermal power plants and analyse the design with advanced alloys like X38CrMoV5-3 alloy and Inconel 625 which can operate at high temperatures and resistive to sulphidation, slagging and corrosion and compare the results with alloy steel which is used in the production of boiler shells currently in the market. Bolted joints are used in the design in order to reduce the SCC on welded joints. The design of boiler shell is carried out in Solidworks Part Design and the analysis of boiler shell is carried out in Solidworks Simulation.

S. Anjani Devi et al. [6] studied about boiler or steam generator which is a closed component in which fluid is converted into steam by heating under pressure. Thus, steam produced from a boiler has many practical applications. The design considerations such as physical size, materials, cost and Thermal specifications of a boiler vary with applications. The aim of this thesis work is to develop optimized boiler to preserve temperature & pressure more efficiently; generally, boiler is made with Mild Steel (MS) / Stainless steel with coatings according to the conditions; in this project MS with reaper and dual shell will be analysed. Coupled field and fatigue analysis will be conducted on plain reaper (empty), & with filler materials to work as insulation layer; in coupled field analysis thermal and structural loads will be analysed at a time to fine stress, strain, and flux in dual load conditions. Fatigue analysis will be done to determine maximum life/ fatigue behavior.

Sejal C. Patne et al. [7] studied about boilers and according to her, now a day failure of refractory material in boiler furnace which is applied for different sites and different applications is the major problem has been faced by boiler manufacturing industries and they are trying to solve this. Different reasons of failure can be inappropriate transportation problem and loose application of refractory, excessive temperature developed in shell, sigma phase embrittlement, failure of anchors, improper storage of material etc. The materials and its properties used for refractory are studied here with its different types. This report is related to thermal and structural analysis of refractory which is 75 mm thick and temperature distribution at certain distance by using ANSYS software.3D Model is drawn in solid works and then imported to ANSYS for next analysis. By applying thermal and structural conditions we get the results.

T. Subramani et al. [8] studied about boiler. He stated that in 1909 Ritz developed an effective method for the approximate solution of problems in the mechanics of deformable solids. It includes an approximation of energy functional by the known functions with unknown coefficients. Minimization of functional in relation to each unknown leads to the system of equations from which the unknown coefficients may be determined. One from the main restrictions in the Ritz method is that functions used should satisfy to the boundary conditions of the problem. In 1943 Courant considerably increased possibilities of the Ritz method by introduction of the special linear functions defined over triangular regions and applied the method for the solution of torsion problems. As unknowns, the values of functions in the node points of triangular regions were chosen. Thus, the main restriction of the Ritz functions – a satisfaction to the boundary conditions was eliminated. The Ritz method together with the Courant modification is similar with FEM proposed independently by Clough many years later introducing for the first time in 1960 the term "finite element" in the paper "The finite element method in plane stress analysis". The main reason of wide spreading of FEM in 1960 is the possibility to use computers for the big volume of computations required by FEM. However, Courant did not have such possibility in 1943. An important contribution was brought into FEM development by the papers of Argyris, Turner, Martin, Hrennikov and many others. The first book on FEM, which can be examined as textbook, was published in 1967 by Zienkiewicz and Cheung and called "The finite element method in structural and continuum mechanics". This book presents the broad interpretation of the method and its applicability to any general field problems. Although the method has been extensively used previously in the field of structural mechanics, it has been successfully applied now for the solution of several other types of engineering problems like heat conduction, fluid dynamics, electric and magnetic fields, and others.

A. R. Kilhoffer et al. [9] examined design for manufacturability. The study of human experts in the areas of design and manufacturing has led to two hypotheses concerning the problem-solving methods which these engineers utilize to attack difficult problems. The basis of both hypotheses is a modular approach to problem solving. One hypothesis addresses the nature of the modules utilized while the other hypothesis deals with the organization of the modules. A knowledge-based system has been designed and implemented under the philosophy expressed in these hypotheses. The domain is the design and manufacture of riveted joints in sheet metal. Special emphasis is given to the integration of design knowledge and manufacturing knowledge for the concept of "designing for manufacturability". The implementation is described in some detail and two example problems are presented with their solutions.

Ankit Kumar Joshi et al. [10] analysed joints of steel material. The various elements of steel structure like tension member, compression member and flexural member are connecting by fasteners or connectors. Many a times, built-up sections are provided to meet the requirements of heavy loads and long spans. Such sections also need to be connected together to act in unison as one unit. The forces exerted by one element on another are transferred through these fasteners, which should therefore be adequate to transmit the forces safely. Only properly connected and detailed members and connections can transfer the forces safely from top to the foundation. Different types of fasteners available for making connections are rivets, bolts, pins and welds. Today, steel structures are constructed with bolting or welding or by combination of both. To simplify the analysis and design, a number of assumptions and approximations are made based on experimental results, past performance and ductility of steel. The ultimate aim of connection design is to produce a joint that is simple, compatible, feasible, easy to fabricate and is safe and economical.

Chengyu Song et al. [11] analysed the self-piercing riveting (SPR) single-strap butt joints (butt joint). These were fabricated in similar sheets of Al5052 aluminium alloy and 1420 aluminium–lithium alloy. Mechanical characteristics of SPR butt joints of different materials were discussed comparing with their corresponding SPR single-lap joints (lap joint). The effects of the rivet pitch and the strap length on the butt joints of different materials were investigated. Results indicated that the lap joints have better performance in strength and stiffness, while the butt joints have more superior shock resistance capacity. The strap length had some impact on the failure behaviour of the joint but not the joint strength. The load borne capacity of the butt joints was highly dependent on rivet pitch.

Dhairyashil Jadhav et al. [12] studied about riveted joints that play an important role in structural members used in automobile, shipping and aviation industry. Rivets are used to fasten metal plates and steel section in structural works such as bridges and roof trusses and in the construction of pressure vessels such as storage tanks and boilers. These have very effective designs subjected to pronounced vibration loads where welded joints are less reliable. These joints may also be employed to connect metals which are difficult to weld together and in the joints which permit no heating welded due to possible tempering or warping of the finished machine parts. Composite riveted joints have wide applications in aerospace industry. In present study, the composite plate having aluminums facings and the glass fiber epoxy as an intermediate layer are tested analytically and experimentally. The composite specimen is tested for the tensile strength using universal testing machine. The experimental results are compared with the FEA results for the for the purpose of Accuracy.

Farah Kamil Abid Muslim et al. [13] studied about software packages for designing different components. Most mechanical CAD software used in mechanical design involves different types of decisions. All these decisions require coordinate-geometric and descriptive data. The objective of this work is to establish software programs for designing and analyzing rivets for boiler shells as an example to use rivets in industry. In general rivets are considered as mechanical elements of wide range application. A software program using Visual Basic Version 5 with ACCESS database is used for design of rivets. When the user inters the input data to the system and depending on existing database, the software carries out a series of complex computations, after which it produces a comprehensive report that includes all engineering dimensions and efficiency. The program, designed in this research, has feasible ability to deal with data base in an easy and reliable way especially for unprofessional users. This is a database that can be updated and edited at any time to get proper results. The program can be applied also to different types of riveted joint.

Jintong Liu et al. [14] analysed joints in aircrafts. In aircraft manufacturing, riveting is one of the most important connection ways to fasten the sheet metal parts. The riveted single strap butt joints are mainly used in the load-bearing components of the aircraft such as the fuselage and wing panels. The connection quality and fatigue performance of the riveted joints directly affect the reliability and safety of the aircraft. In this paper, under the assumption of constant temperature, the fatigue strengthening mechanism of interference-fit riveting is introduced based on elastic-plastic mechanics and fracture mechanics. On this basis, the finite element (FE) models of the riveted single strap butt joints with various strap thickness and rivet sizes/arrangements are established. The residual stresses distribution around the riveted hole is analyzed. Furthermore, the fatigue tests of the riveted single strap butt joints with cyclic loading are carried out. The experimental results verified the correctness and effectiveness of the simulation model. Finally, the conclusion is drawn that increasing rivet size and strap thickness within the allowable weight range can improve the fatigue performance of the riveted single strap butt joints. The knowledge could be used to guide the structural design and optimization of the riveted butt joints against fatigue.

Johan Maljaars et al. [15] studied about joints in bridges. Many existing steel bridges are constructed by using hot-driven steel rivets as fasteners. It is known that the fatigue strength of these joints depends on their geometry, since it affects the load transfer mechanism and, therefore, the severity of the stress concentration. Attempts have been taken in the past to provide the characteristic fatigue strength of riveted joints based on test results, i.e., to provide a detail classification. However, the limited number of experimental results per geometry and their large scatter jeopardizes the accuracy of the classification, which has resulted into different classifications by different researchers. This paper presents a theoretical fatigue strength prediction model for hot riveted double covered butt joints. The model results agree very well with fatigue test data and the model provides a fundamental understanding of the empirical observations. The model reveals that the classification of joints as proposed in the past is inaccurate for many cases. As an example, the plate width over rivet diameter ratio and the surface finish has a much larger influence on the strength than what has always been considered, whereas the ultimate tensile strength of the plate material has limited influence.

K. S. Bodadkar et al. [16] studied about riveted joints that are used in many structural works like ship buildings, in bridge structure and in manufacturing of boiler shells etc. The failures of riveted joint take place by tearing

of the plate, shearing of rivet and crushing of rivet and plate under the action of overloading. Hence the stress pattern in riveted butt joint by varying parameters like thickness of plate, linear pitch, transverse pitch and method of riveting is studied. In this research, analytical, numerical and experimental stress analyses are carried out. For analysis purpose virtual model of riveted butt joint is prepared in Pro-E. And this CAD model is imported in ANSYS software where stress analysis is done by FEM. This analysis shows that, to have safe joint it is better to increase the thickness of main plate and linear pitch instead of increase in transverse pitch. Also, the analysis shows that von-mises stresses obtained in chain riveting are lesser as compared to diamond and zig-zag riveting. From this, it can be concluded that chain riveting is the safest method of riveting. From the analysis, it is revealed that the analytical results obtained are in good agreement to F.E.A results.

Lucjan Witek et al. [17] analysed the results of experimental investigations of the lap blind riveted joint. The main goal of the work is determination of destructive load of the blind riveted joints. The blind rivets were originally used in the aircraft structures where access to both sides of the riveted structure is impossible. Blind rivets are now commonly used in many branches of industry because of their low cost. Moreover, the riveting process is uncomplicated. There are many publications about analysis of strength of solid rivets in the research literature. However, the strength analysis of the blind rivets was rarely undertaken. There is the research gap in the analysis of both the strength and the load capacity of blind riveted joints. The influence of selected geometrical parameters of the joint on the stress distribution and the destructive force was not widely described in literature. The first part of the work presents a review of standards and publications related to stress and strength analysis of blind riveted joints. The next part of the study describes experimental investigations of joints. The examined specimens were made out of AW 2017 aluminum alloy, cut from 1[mm] thick sheet. Investigated blind rivets were made out of aluminum alloy. The lap joint with one rivet and the single row five-rivet joint were investigated. Moreover, the different size of hole chamfer was considered. The experimental tests were performed with the use of Zwick-Roell tension machine. The main results of experimental investigations are ultimate shear load diagrams. The influence of both the hole chamfer and the number of rivets on destructive force and shear diagrams of blind riveted joints were in detail analysed. After shear tests, the fractured rivets were magnified in order to explain the failure phenomenon of blind rivets. In the future research works the obtained results will be used in strength analysis of the blind riveted joints using the finite element method.

Maloth Prakash et al. [18] studied about Aluminum alloy 6061 which has gathered wide acceptance in the fabrication of light weight structures required a high strength to weight ratio. Compared to fusion welding processes that are routinely used for joining structural aluminum alloys, friction stir welding process is an emerging solid state joining process in which the material that is being welded does not melt and recast. This process uses non-consumable tool to generate frictional heat in the butting surfaces. The welding parameters tool pin profile plays a major role in deciding welding quality. An attempt is made to understand the effect of welding speed and tool pin profile on FSP zone formation in Aluminum alloy 6061 and 6082. Five different tool pin profiles are used to fabric the welding joints.

MD. Ziya Gous et al. [19] analysed riveted lap joints for stresses induced. This work involves setting up and characterizing these joints for maximum use. Stress and fracture analyze are carried out under both stress field and external tensile load using the finite element method. The riveting process and simulation of the lap joint's subsequent tensile loading using a two-step simulation to determine the residue and overall stress state. The residual stress state due to riveting is obtained through maladjustment interference and clamping method. The effects of the riveting process parameters on the stress state are examined by using different values of interference and maladaptation. Two cracks, namely the semi-elliptic surface crack on the plate coating surfaces and quarter-corner crack from elliptical to rivet hole, are the most widely observed crack types in rivet joints. Fractured crack fracture analysis is performed by introducing these two types of cracks to a perpendicular plane at loading on the outer plate. Throughout the analysis of this work, the finite element technique was used. The present work has shown that riveted joints are superior in strengthening riveted joints. The riveted joint appears to reinforce and balance stress and to be distributed evenly. This improves riveting joints ' efficiency and life.

Pashupati Pokharel et al. [20] studied about the microstructure and mechanical properties of the butt joint in high density polyethylene (HDPE) pipes which were evaluated by preparing the joints with increasing the cooling time from 10 s to 70 s before pressure created for fusion of the pipes. Here, cold fusion flaws in HDPE butt joint were created with increasing the cooling time around 70 s caused by the close molecular contact followed by insufficient interdiffusion of chain segments back and forth across the wetted interface. The tensile failure mechanism of the welded pipes at different fusion time was projected based on the tensile test of dog-bone shaped, fully notched bar type as well as round U-notched specimens. The mechanical properties of the joints at different fusion time were correlated with the corresponding fracture surface morphology. The weld seam as well as tensile fracture surfaces were etched using strong oxidizing agents. The crystallinity of surface etched weld zone by potassium permanganate-based etchant was found higher than unetched sample due to the higher susceptibility of amorphous phase of polyethylene with oxidizing agent. The U-notched tensile test of butt-welded HDPE pipe and surface etching of the weldments provided clear delineation about the joint quality.

R Udaya Prakash et al. [21] In Aviation sector, composite materials and its application to each component are one of the prime factors of consideration due to the high strength to weight ratio, design flexibility and non-corrosive so that the composite materials are widely used in the low weight constructions and also it can be treated as a suitable alternative to metals. The objective of this paper is to estimate and compare the suitability of a composite skin joint in an aircraft fuselage with different joints by simulating the displacement, normal stress, von-mises stress and shear stress with the help of numerical solution methods. The reference

Z-stringer component of this paper is modeled by CATIA and numerical simulation is carried out by ANSYS has been used for splice joint presents in the aircraft fuselage with three combinations of joints such as riveted joint, bonded joint and hybrid joint. Nowadays the stringers are using to avoid buckling of fuselage skin, it has joined together by rivets and they are connected end to end by splice joint. Design and static analysis of three-dimensional models of joints such as bonded, riveted and hybrid are carried out and results are compared.

Shubham Balasaheb Walake et al. [22] studied about the joints. The cylindrical portion of the rivet is called shank or body and lower portion of shank is known as tail. Use of rivets are to make long-lasting fastening between the plate's specimen such as in structural work, ship building, bridges, tanks and boiler shells. Adhesives act as a strength enhancer for many traditional joints such as weld, spot, rivet etc. Many time design constraints don't allow modifications, where there is need of strength enhancement of joint. We can use various industrial adhesive for achieving strength. In present research specimen of lap length 40 and 60 mm with single and double rivet with and without adhesive are investigated to obtain optimum specimen study of lap strength joint and single and double rivet joint. Tensile test will be done using UTM machine for both specimens. Similarly, both specimens will be modeled using CAD software and analysis with FEA package. Comparative analysis is done in present study between traditional bolted joint and adhesively bonded bolted joint.

T.T.B. Wardoyo et al. [23] studied about the effect of variation of the connection (butt joint) in low carbon steel resistance welding (shielded metal arc welding, SMAW). Three types of butt joint were varied: square, single V, and double V. The results from tensile test showed that welded specimens are of similar tensile properties with base metal and one another. When hardness test was performed on weld metal, HAZ, and base metal of each specimen, it was found that weld metal and HAZ were of higher hardness than the base metal. Specimen with square joint exhibits the highest hardness while specimens with single V and double V joints show similar hardness. Microstructure analysis revealed that weld metal of specimen with square joint is of bainite-martensite phases while weld metal of specimens with single V and double V joints are of ferrite-pearlite phases. This difference in microstructure, and hence in hardness, is related to the corresponding heat input during welding.

Tomasz Machniewicz et al. [24] analysed the secondary bending phenomenon, which largely affects the state of stress and fatigue life of lap joints used in aircraft structures. In the first case a neutral line model, originally proposed by Schijve to estimate secondary bending moments induced in mechanically fastened joints with eccentricities has been used. Numerical FEM analysis involved riveting process and then the loading of the join with consideration of non-linear material characteristics and frictional contact conditions between joint elements. The results of the above theoretical analyses were compared with each other and validated based on the experimental tests that involved the strain gauge measurements of the joint and measurements of its deformations provided by digital image correlation technique. All analyses were carried out for riveted lap joints typical for aircraft fuselage structures, consisting of 2024-T3 Alclad aluminium alloy sheets connected with MS20470-AD universal head rivets.

V.C Ikeh et al. [25] performed a comparative analysis of load carrying capacity of aluminium and mild steel bolted and riveted joints. Sample specimens were produced comprising of riveted lap joints, riveted butt joints, bolted lap joints and bolted butt joints from aluminium alloy and mild steel. Experiments were conducted using metallographic examinations, chemical composition analysis, tensile test, and comparative analysis were used to evaluate the results. From the experiments, the results showed that deformations in bolted members were generally smaller than those measured in similar riveted members, with riveted aluminium alloy butt joint having a higher ultimate strength to the Bolted Aluminium Alloy butt joints. For Mild steel material, the Bolted Steel Lap Joint showed a higher Load carrying capacity than Riveted Lap joint. The bolt tensions appear to have very little effect on the ultimate strength of bolted joints. The numerical results showed that the Riveted Steel Lap joint yield at 160Nm-2, the Bolted Steel Lap joint yielded at 90Nm-2 and strain hardening starts at 115Nm-2 and rises linearly until fracture occurs at 350Nm-2. The Riveted Aluminium Lap joint yielded at 23.3Nm-2 and plastically deform at a second yield point of 90Nm-2. Strain hardening commences immediately almost linearly till it fractures at the ultimate strength of 158.3Nm-2 while the Bolted Aluminium Lap joint yielded and strain hardened at 80Nm-2 and fractured at 140Nm-2 respectively. The Bolted Steel Butt yielded and strain hardened at 95Nm2 and 160Nm2 respectively and rises linearly until it fractures at 440Nm2. The strength of the rivets showed a slight increase as connection force increased up to 160Nm-2 where the joint deforms plastically. In Bolted Aluminium Butt joints, there was no significant effect on the tensile behaviour of the joint, although, with an increase in the edge distance the strength of the joint increased considerably up to a Load of 133.3Nm-2.

Vinay Kumar Reddy et al. [26] studied about mechanically fastened joints that have proven to be weak links in an aircraft structure. Therefore, it is important to design and manufacture these joints with high quality. Strength and Tightness are the two important qualities of Riveted Joint. Failure of the joint can be prevented by strength and tightness. Tightness is necessary to prevent leakage. In this paper various procedures were used to improve the efficiency of a Riveted Joint. Efficiency of Riveted Joint depends on various factors like number of rivets, Pitch of rivets, number of straps, width of the plate, diameter of rivet and thickness of plates etc.

III. CONCLUSIONS

On the basis of the literature review available in the paper one can easily conclude that-

- Boiler joints are being researched and studied about at a large scale now a days.
- The research is mainly focusing on the method of joining the plates of boiler shell.
- One of the key areas of research also includes material optimization for the boiler joints.
- Main focus of the researchers is on the lap joints.

– Butt joints haven't been able to attract the researchers as one found very less literature available in the field of butt joints.

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