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Stress Analysis of Bolts Failure in Flange Joint of Coiler Drum In Steckel Furnance

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Abstract—This paper presents the insight of stress analysis in a bolted joint of Collar Drum in Steckel Mill under load. Present work includes mathematical element approach to study the results of failure of flange joint of Coiler Drum. A three-dimensional simple element model of a bolted joint has been developed by using mathematical element approach and stress analysis has been done in packages. Model of Flange joint is done and then Stress analysis has been performed. Results obtained after analysis was then articulated which show good agreement. Finally, critical areas were identified and confirmed with the stress distribution results from simulation. In future scope the FEA outputs, such as stress and strain (Deformation), will be also used with failure criteria to predict failure of Bolt in the a bolted joint of Collar Drum in Steckel Mill under loading condition.
Keywords — Flange joint, Bolts failure, load, Stress Analysis.

I. INTRODUCTION

HRM complex Lloyd's steel, Wardhaincorporate a hot rolling mill. The purpose of the hot rolling mill is to convert cast slabs into hot rolled steel, usually by means of a rolling operation, which may involve either hot tandem or hot reverse rolling. The steckel mill is a single 4-high reversing mill stand. On the ingoing and outgoing sides of the mill stand there are two gas-fired hot coiling steckel furnaces with heated coiler drums onto which the coil is coiled during each successive pass. When the desired steel gauge is reached, after three, five or seven passes, it runs out of the mill stand, via roller tables to the down coiler.

There are two down coilers, i.e. Down Coiler –2 and Down Coiler-3. Down Coiler – I were shut down since past one and half year. The capacity of D.C-I was 18 ton and its specifications was same as that of D.C-2. Following table shows the comparison between D.C-2 and D.C-3

TABLE I

Sr. No	Characteristics	D.C – 2	D.C-3
1	Capacity	18	22
2	Rolls	Wrapper roll & Pinch roll	Wrapper roll & Pinch roll
3	Pushing mechanism	Hydraulic DC valves	Servo valves
4	Mandrel	Single expand & collapse, Bean shape links for expand and collapse for Inner diameter tightening.	Double expand & collapse, wedge type expand and collapse for inner diameter tightening.
5	Max. Expansion	25 mm	50 mm

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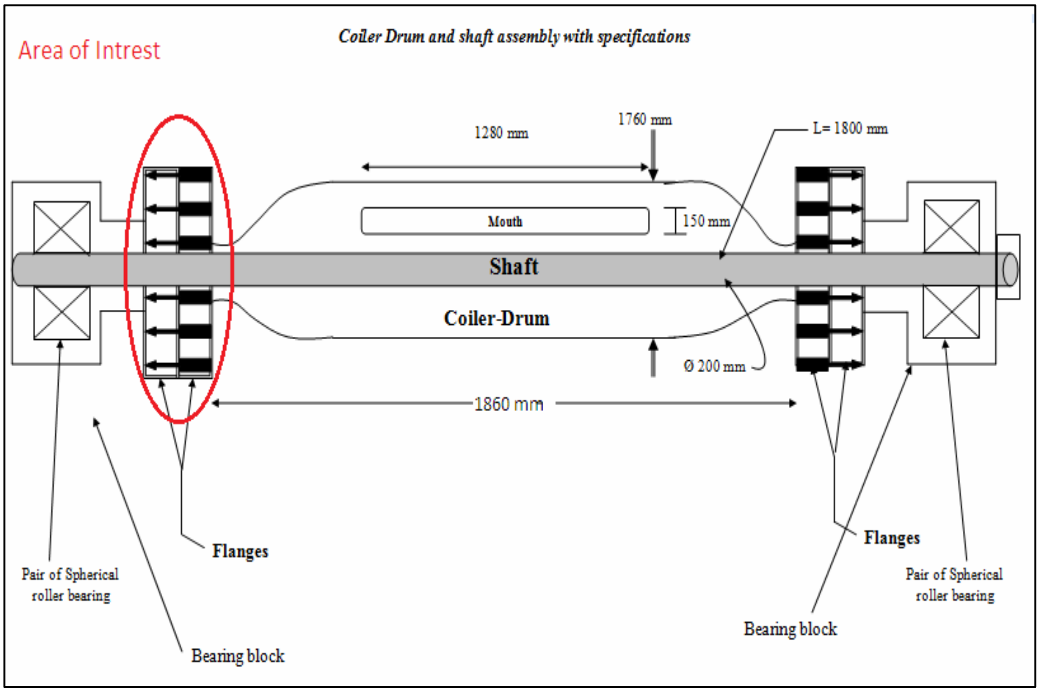

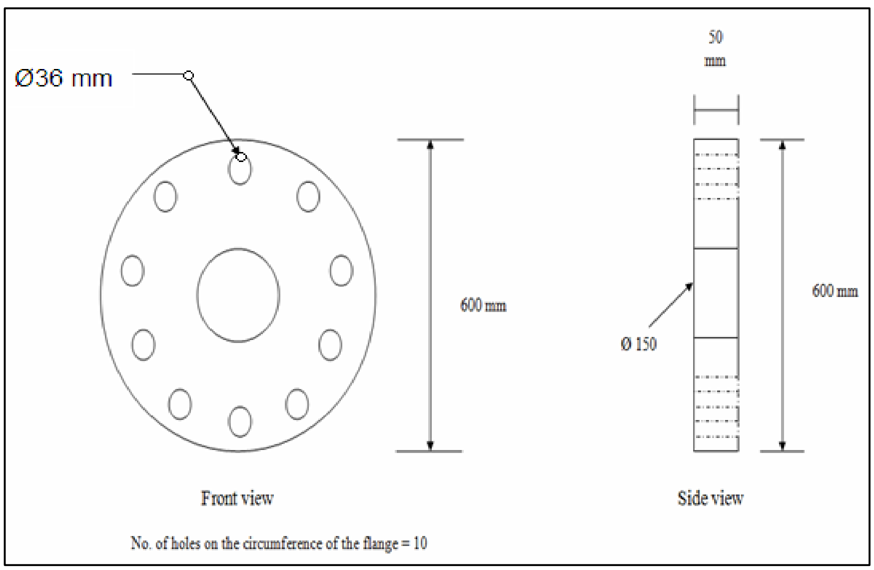

Fig No. 02-Specifications of Flange

II. PROBLEM IDENTIFICATION

A. PROBLEM ORIGIN: REVERSIBLE FINISHING MILL (STECKEL FURNACE)

The coiler-drum is an essential component of steckel mill reversing hot strip rolling process. A steckel mill produces hot rolled strip steel from cast slab which are heated before being converted via roughing to the transfer bar of which the thickness is subsequently reduced (up to 1.8 mm) to the desired gauge by means of a reverse rolling process performed by the steckel mill. Coiler drums are located inside two steckel furnaces which are positioned on the both sides of the mill stand. As the strip thickness is reduced during each pass, length increases. In order to obtain high rolling speed and retain temperature, the strip is successively coiled and uncoiled, under tension onto and from the heated coiler drum during processing. Since from the installation of Reversible finishing mill both the Down Coilers have maximum capacity of 18 tons, i.e. D.C-I and D.C-2. After the shutdown of D.C-I, D.C-3 was

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installed which was having the maximum capacity of 22 tons. Since the net load is increased by 4 tons the factor of safety is not sufficient to avoid frequency of failure of flange joint which increased subsequently. Thus, the frequency of failure of flange joint increases after the incorporation of D.C-3 as production capacity increases by 4 ton causes breakdowns as there is breakdown maintenance approach. Bolted flange joint is made up of Coiler Drum Shaft's fixed flange fastened with on-board bearing flange by Nuts-bolts. As the magnitude of load changes with respect to time thus causes whirling & positive bending moment of the shaft. Relative stresses have been increased. Along with the high temperature about 9500c, thermal stress plays important role in failure of flange joint. Due to high temperature and load, the stresses are induced per cycle inside the bolt via flanges causes shearing of bolt head. Moreover, a bolted joint is one of the joining techniques employed to hold two or more parts together by the help of nut and bolt to form an assembly in mechanical structures. The flange joint consist of two flanges joined with 10 Nut-bolts. The model of coiler drum is given clear idea about the specifications of system. In the joint, one of the flange and head of bolts are having direct exposure to the high temperature maintained at 9500c inside the Steckel Mill. This causes thermal stress into the flange and bolts. As bolts and flange are subjected to load and temperature, resulting into cyclic fatigue and shearing of bolt head.

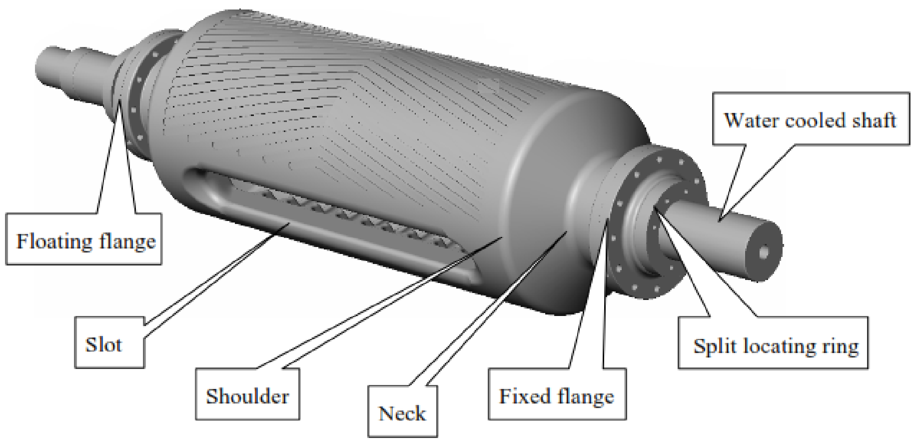

Fig.No.03 Model of Coiler Drum

III. LITERATURE REVIEW

In this work, literature and research papers have been be referred. This chapter will discuss the coiling process in steckel mill with particular attention to the steckel mill method of production, especially the working of steckel mill and the coiler drum. The present chapter reveals that the study that held previously to mitigate the induces stress, in order to do this, a complex set of design parameters involving the characteristics of the bolt, nut, and mating materials must be arranged such that the resistance to loosening is optimized and less shear of the material is to be occur. The relevant literature on bolted flange joint failures has been reviewed and the material used in manufacture of flange of coiler drum and bolts has been investigated, together with its associated literature. The chapter will be concluded with an introductory discussion on Finite Element Analysis.

Most integrated steel mills incorporate a hot rolling mill. The purpose of the hot rolling mill is to convert cast slabs into hot rolled steel, usually by means of a rolling operation, which may involve either hot tandem or hot reverse rolling. The steckel mill is a single 4-high reversing mill stand. On the ingoing and outgoing sides of the mill stand there are two gas-fired hot coiling steckel furnaces with heated coiler drums onto which the coil is coiled during each successive pass. When the desired steel gauge is reached, after three, five or seven passes, it runs out of the mill stand, via roller tables to the down coiler. The strip steel is then cooled from a last pass temperature of 9500c to the required final coiling temperature, which typically ranges between 6000c and 7000c by a laminar flow water spray system situated between the mill stand and the down coiler and coiled into the final coil format down coiler. The steckel mill generally consists of reversing four-high mill stand is a single 4-high reversing mill stand with two gas fired steckel furnace. Slabs are heated before being converted, via roughing, to the required transfer bar gauge and width. The transfer bar is then cropped and de-scaled before the gauge is reduced subsequently in the steckel mill by means of a reverse rolling process. The strip is successively coiled and uncoiled from the heated coiler drums positioned inside the steckel furnace on both sides of the mill stand. Since some steckel mill installations do not have a dedicated roughing mill stand, the roughing operation is

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carried out by means of repeated reversing of the mill until the required coiling gauge, which is below 25 mm, is reached; only then thus coiling commence during subsequent passes. Once the required final gauge has been reached, the strip is water cooled and finally coiled.

A fastener may experience either static loading or fatigue loading. Static loading may be tension, shear, bending, or torsion. These static loading conditions may occur in combination. One example of fatigue loading is vibration. In addition to overload and fatigue, some other common reasons for fastener failures include environmental issues, manufacturing discrepancies, and improper use or incorrect installation. [7] Fatigue is one of the most common failure modes for threaded fasteners. Fretting failures may result from small movements between adjacent surfaces. Additionally, atmospheric corrosion, liquid immersion corrosion, galvanic corrosion, crevice corrosion, stress corrosion cracking, and hydrogen damage may contribute to fastener failure Material selection, heat treatment, cutting or rolling threads, manufacturing, assembly, and design are some of the factors that affect fastener failures. Failure analysis can determine the cause of the fastener failure and determine the primary or contributing causes of fastener failure. [7]

A bolted joint is one of the joining techniques employed to hold two or more parts together by the help of nut and bolt to form an assembly in mechanical structures [1]. The bolted flange joint consist of two flanges and these two flanges are connected together by nut-bolts. Here in this project, bolted flange joint is the focus of the investigation. Flange joints may fail due to because of high temperature and load. An example of such a study is the research literature shared by Aidy Ali, Ting Wei Yao, Nuraini Abdul Aziz, Muhammad Yunin Hassan and Barkawi Sahari [1]. The aim of this premier was to analyze single lap bolted joint under bending loads. The experimental work has been carried out. A three-dimensional finite element model of a bolted joint has been developed using MSC Patran and MSC Nastran FEM commercial package. In the simulation, different methods in modelling the contact between the joint, which affects the efficiency of the models were detailed. Experimental work was then conducted to measure strains and deformations of the specimens for validation of the developed numerical model. A four-point bending load type of testing was used in both simulation and experiment works. [1]

A three-dimensional finite element analysis was used to examine the stress distribution of a single lap bolted joint and comparisons were made to the experimental results. These comparisons include surface strain and joint displacement measurement. The result obtained from the simulation analysis shows agreement with experiment analysis and validation of the bolt model was confirmed for an applied load less than 7 KN. A finite element method has been successfully developed and it can be applied for the prediction of other material, load and size of geometry in four-point bending of a single lap bolted joint. The critical area could be predicted from the simulation analysis and it could save cost of carrying out experimental work. The FEM gives good control of experimental techniques, confirming, complementing and refining the specimen design before commencing experiment tests. [1]

Jeong Kim, Joo-Cheol Yoon , Beom-Soo Kang [2] had investigated a modelling technique of the structure with bolted joints, four kinds of finite element models are introduced; a solid bolt model, a coupled bolt model, a spider bolt model, and a no-bolt model. All the proposed models take into account pretension effect and contact behaviour between flanges to be joined. Among these models, the solid bolt model, which is modelled by using 3D solid elements and surface-to-surface contact elements between head/ nut and the flange interfaces, provides the best accurate responses compared with the experimental results. In addition, the coupled bolt model, which couples degree of freedom between the head/nut and the flange, shows the best effectiveness and usefulness in view of computational time and memory usage. Finally, the bolt model proposed in this study is adopted for a structural analysis of a large marine diesel engine consisting of several parts which are connected by long stay bolts. [2]. in this research literature, four kinds of the bolt models were suggested as a finite element modelling technique for the structure with a bolted joint. In addition, through a comparison with simple static experiment and modal test results, the effectiveness and usefulness of the bolt models were confirmed. The conclusions are summarized as the followings.

In order to generate a finite element model for the structure with a bolted joint, a solid bolt model, coupled bolt model, spider bolt model, and no-bolt model were suggested. Among them, the solid bolt model could most accurately predict the physical behaviour of the structure.

In the case of shear loading, since the contact characteristic between interfaces is predominant, distinction with a difference in stress distribution, especially neighbouring the bolted joint, is expected according to the bolt models.

From the result of static analysis, the coupled bolt model and the spider bolt model can save 62% and 49% of the computational time, and 21% and 19% of the memory usage compared to the solid bolt model. Therefore, in view of effectiveness and usefulness, the coupled bolt model is also recommended [2].

Nomesh Kumar, P.V.G. Brahamanandam and B.V. Papa Rao [3] investigated the stresses in the bolts of the bolted flange joint of

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the pressure vessel so that bolts/studs should not be failed during proof pressure test. Bolted flange joints perform a very important structural role in the closure of flanges in a pressure vessel. It has two important functions:

To maintain the structural integrity of the joint itself, and

To prevent the leakage through the gasket preloaded by bolts.

One flange is having a groove for the gasket, and other flange is flat connected by a number of bolts/studs. The preload on the bolts is extremely important for the successful performance of the joint. The preload must be sufficiently large to seat the gasket and at the same time not excessive enough to crush it. The flange stiffness in conjunction with the bolt preload provides the necessary surface and the compressive force to prevent the leakage of the gases contained in the pressure vessel. The gas pressure tends to reduce the bolt preload, which reduces gasket compression and tends to separate the flange faces. Due to flange opening, bending has been noticed in the bolt. Hence the bolts/studs should be designed to withstand against preload, internal pressure load and bending moment. Due to existence of Preload, internal pressure and bending moment at a time, the bolt behaviour is nonlinear which cannot not be evaluated by simple mathematical formulas. 3-Dimensional finite element analysis approach is only the technique which shows some satisfactory result. The 3-dimensional cyclic analysis has given the value of axial forces and stress induced due to these axial forces. It also has given the value of bending moment on each bolt/stud. This bending moment divided by the sectional modulus of the stud to obtain bending stresses in the bolt/stud. The total stresses in each bolt/ stud is the sum of axial stress and bending stress. The deflection of bolt due to internal pressure is obtained in FEA. The total stresses and bending stresses in the bolt/stud pressure is also obtained in FEA. The axial stress in the bolt/stud due to pretension, the contact gap and stresses in flange [3].

Stress analysis of nut-bolt connections by altering Nut thread form, literature shared by B. KENNY & E. A. PATTERSON [4]. In this research, six photo elastic frozen stress models of IS0 nut-bolt connections loaded in pure tension were studied. Four of these models had modifications to the threads at the load bearing end of the nut. These modifications included tapered truncation of the thread crests and taper of the whole thread form for a portion of the nut length. The maximum stress in the bolt always occurred within one pitch of the load bearing face of the nut. Truncating threads increased the maximum bolt stresses. Tapering the whole thread form reduced the maximum stress and produced a more uniform load distribution in the bolt. The conditions at the load bearing face of the nut were found to influence the load distribution in the bolt threads more than the stress concentrations in the bolt. The use of a steel-Araldite contact at the load bearing face of a frozen stress model of a threaded connection affects the position of the maximum stress concentrations in the roots of the bolt thread. In addition, the position and magnitude of the maximum thread load is also different to the case when an Araldite-Araldite loaded contact surface is used. In a conventional nut-bolt connection the local variations in the normalized tensile stress in the bolt roots are directly related to the asymmetry of the thread load distribution. However, when the nut-bolt connection is modified the distribution of local maxima and minima in the stresses become more complex. Truncating the tips of the threads increases the maximum normalized tensile stress and, therefore, will be detrimental to the strength of the bolt. Tapering the entire thread form for three threads starting at the load bearing face of the nut, produces a more uniform load distribution and significantly reduces the maximum normalized tensile stress.[4]

Another literature that came across during survey is shared by N.G. Pai, D.P. Hess [6]. In this literature investigation result of a study on failure of threaded fasteners by vibration induced loosening caused due to dynamic shear loads. Previous experimental work has revealed that fastener loosening occurs as a result of complete or localized slip at the thread and head contact surfaces. A three-dimensional finite element (FE) model is used to study details of four different loosening processes that are characterized by either complete or localized slip at the head and thread contacts. The FE model is found to be capable of adequately modelling factors that influence slip and predicting the different loosening processes. Primary factors that influence slip at fastener contacts are discussed. The results show that loosening can occur at relatively low shear loads due to the process of localized slip. The finite element model presented is capable of predicting the four different loosening processes observed experimentally. The FE results capture the essential features displayed by the experimental data. Several factors influence loosening at different stages of loading, and the final outcome is a result of their non-linear interactions. The FE model includes the primary factors that cause loosening, and provides a powerful tool for evaluation of the details of fastener loosening. The loosening process caused by localized slip can occur at significantly lower shear force than loosening caused by complete slip, and therefore is critical in joint design [6].

Research article W R Broughton and G Hinopoulos [8] argues the evaluation of effect of moisture, specimen geometry and adhered properties on the behaviour of the single-lap joint. A finite element analysis was used to establish the effects of these parameters on the joint stiffness and stress distribution within the adhesive layer. The report also includes an evaluation of the perforated single-lap joint, assumed to promote accelerated ageing by shortening the diffusion path of moisture. A series of stress and deformation analyses using finite element analysis (FEA) has been conducted on the single-lap configuration for this purpose. The analyses were based on experimental data obtained from data generated within the DTI funded ADH and PAJ programs. The effect of moisture on the joint performance was investigated using a sequentially coupled mechanical-diffusion finite element model that incorporated continuously varying adhesive material properties. The numerical predictions revealed that the stress distributions become more uniform along the adhesive layer with increasing moisture content. Peel stresses at the ends of the bonded area also decrease with increasing moisture content. The introduction of holes decreases the time taken for the moisture content in the adhesive layer to reach saturation, although increasing the size of the holes and reducing the bonded area only has a marginal effect on the joint performance. The parametric studies on the specimen geometry revealed that stress distributions are sensitive to changes in adhered material properties, adhered and adhesive thickness and the applied load. In general, stresses were reduced when changes to the joint resulted in smaller joint displacement or an increase in ability of the adhesive layer to plastically deform Finite element analysis has been employed to perform a series of non-linear stress analyses of the single-lap shear joint under tensile load. The analysis involved two-dimensional modelling of parametric effects on the stress and strain distributions within the adhesive layer. Parametric studies revealed the stress and strain distributions are sensitive to adhered material properties, adhered thickness, adhesive thickness and applied load. The analyses also showed that peel stresses tend to be higher than shear stresses for most practical test geometries. In general, maximum stresses at the ends of the overlap were reduced by increasing the joint stiffness (i.e. increasing tensile modulus of the adhered or increasing the adhered thickness) or by increasing the adhesive thickness. Subsequently, the “apparent” shear strength should increase. Although, titanium alloy joints have a lower stiffness than an equivalent joint fabricated from mild steel, the joints proved stronger because titanium has far higher yield strength than the mild steel [8].

B. Sergeev, E. Madenci, D.R. Ambur [12] concerns the effect of bolt spacing and degree of anisotropy on the bolt load distribution and nature of the failure mechanism. Bolt loads and failure prediction are determined using a solution method that treats the contact stresses and contact region as unknowns. Utilizing the boundary collocation technique, this method provides the non-linear solution while capturing the effects of geometry under general loading conditions. The nature of the failure mechanism is established by using the maximum strain criterion. Comparison of the predictions with experimental results reveals their close agreement [12]. Failure loads for two laminate lay-ups with fastener diameter specified and varying spacing obtained. There is no notable interaction among the stress concentrators for the case of distantly placed fasteners, and the relationship between bolt spacing and failure load is approximately linear. As the fastener positions are closer to each other and the high stress areas near the fastener holes merge, the joint strength starts to decrease [12].

IV. FAILURE OF BOLT IN FLANGE JOINT

Sometimes, the bolts are used to prevent the relative movement of two or more parts, as in case of flange coupling, and then the shear stress is induced in the bolts. The shear stresses should be avoided as far as possible. It should be noted that when the bolts are subjected to direct shearing loads, they should be located in such way that the shearing load comes upon the body (i.e. shank) of the bolt and not upon the threaded portion. In some cases, the bolts may be relieved of shear load by using shear pins. When a number of bolts are used to share the shearing load, the finishing bolts should be fitted to the reamed holes.

Let,
D= Major diameter of the bolt
Dc = Core diameter of bolt
p= pitch of bolt
n= Number of bolts = 10
τ = Shear stress
For M36 x 4 with p= 4 mm
D = 36 mm
Dc =31.093 mm
Shearing load carried by the bolt,
$P=\pi/4 \times Dc^2 \times \tau \times n$
$110000 = \pi/4\ (31.093)^2 \times \tau \times 10$
τ = 14.487 N/mm2
τ = 14.487/125 N/mm2per mm length of bolt

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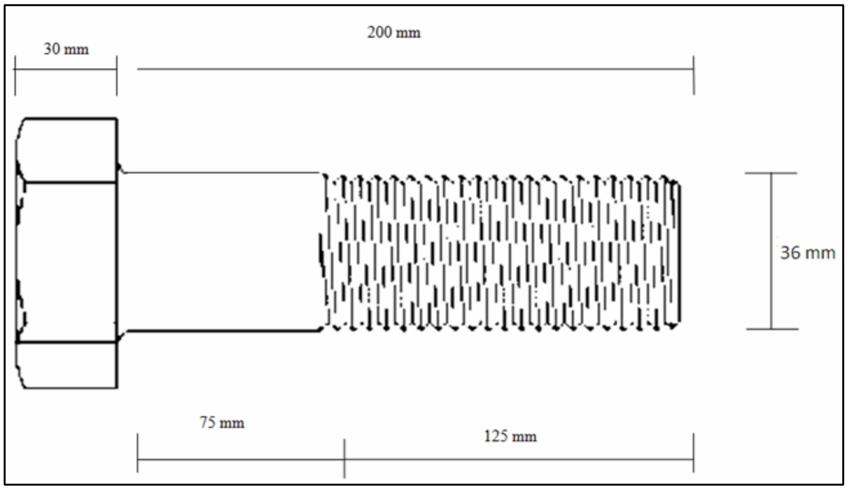
τ = 0.1158 N/mm2per mm length of bolt



FigNo.04- Dimensions of bolts

For M36 x 3 with p=3 mm

D = 36 mm

Dc = 32.219 mm

τ = 13.408 N/mm2

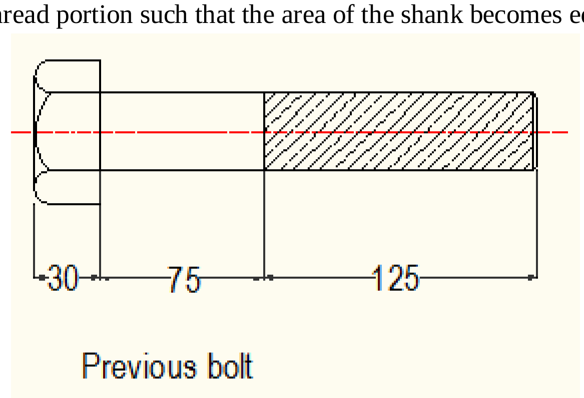
τ = 13.408/125 N/mm2per mm length of bolt

where the length under shear = 125 mm

τ = 0.1073 N/mm2per mm length of bolt

A. *Bolts Of Uniform Strength*

Mainly the load applied to the bolt acts on the weakest part of the bolt i.e. cross sectional area at the threaded portion. In other word , the stress in the threaded will be higher than that in the shank .Hence a great portion of the energy will be absorbed at the region of the threaded part which may fracture the threaded portion because of its small length. In this method ,an axial hole is drilled through the head as far as the thread portion such that the area of the shank becomes equal to the root area of the thread.



Let,

D = Diameter of the hole.

Do = Outer diameter of the thread

Dc = Core diameter of the thread.

Using this method we get,

π/4 x D2 = π/4 x (Do2 – Dc2)

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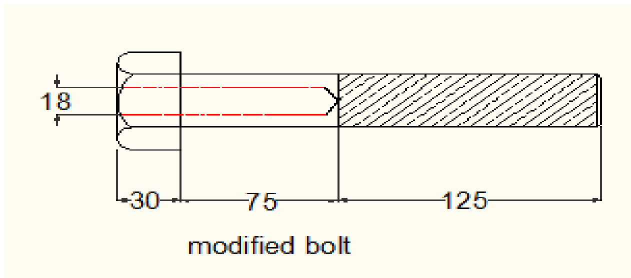
D2 = Do2 – Dc2
D = √(Do2 – Dc2)
= √(362-31.0932)
= 18.1445 mm

Considering shank portion under shear, the shear stress using bolt of uniform strength method is given by relation,

P=π/4 x (Do2- D2) x τ x n
110000 = τ x π/4 x (362-18.14452) x 10
τ = 14.487 N/mm2
τ = 14.487/(125+75) N/mm2per mm length of bolt
where the length under shear = 125+75 = 200 mm
τ = 0.072 N/mm2per mm length of bolt

From this we find that after using the method of bolts of uniform strength, the maximum shear stress induced in bolts remains same for the total length, but it is reduced per mm length of bolt



V. CONCLUSION

The purpose of this investigation is to investigate the stress affected zone over the bolted flange joint model in the specified operating conditions. The failure of bolts in flange joint of coiler drum of steckel furnace is mainly due to the shear stress induced in the bolts. The shear stress induced can be reduced slightly by using M36 x 3 bolt instead of M36 x 4.Also using the method of bolt of uniform strength the maximum shear stress is not reduced but the length of bolt under shear is increased which in turn causes the shear stress per unit length to reduce.

The purpose of this study was to investigate the reasons for bolted flange joint failure and to devise and propose solutions that would mitigate the frequency of failure and would increase the lifespan of the bolted flange joint. This chapter summarizes and concludes this research. The recommendations given are based on the results of all investigative measures that were employed, namely the literature survey, analysis of existing model & analysis of design evolution.

VI. FUTURE SCOPE OF STUDY

Following analysis can be done in future so as to reduce the stress allocation over the stress affected zone resulting into the lesser breakdowns.

FEA can be done by changing material of bolts.

Thermal analysis of coiler drum can be done so as to examine the conduction and convection rate.

Finite element analysis can be done after doing some heat treatments on the flange and bolts.

REFERENCES

[1] Aidy Ali, Ting Wei Yao, Nuraini Abdul Aziz, Muhammad Yunin Hassan and Barkawi Sahari, “Simulation and Experimental Work of Single lap bolted joint tested in Bending ”, Suranaree J. Science Technology. Vol. 14 No. 4; October-December 2007.

[2] Nomesh Kumar, P.V.G. Brahamanandam and B.V. Papa Rao “3-D Finite Element Analysis of Bolted Flange Joint of Pressure Vessel ” ,MIT International Journal of Mechanical Engineering Vol. 1, No. 1, Jan 2011, pp 35-40, ISSN No. 2230 – 7699.

[3] Jeong Kim, Joo-Cheol Yoon, Beom-Soo Kang, “Finite element analysis and modeling of structure with bolted joints”, Applied Mathematical Modeling 31 (2007) 895–911.

[4] B. Kenny, E. A. Patterson, “Stress analysis of some nut-bolt connections with modifications to the nut thread form”, Journal of Stress Analysis, Vol 20 No. 1 1985

[5] Gert J.M. Hamman, “An investigation of Steckel mill coiler drum failure mechanisms, University of Johansburg”, Nov 2006.

[6] N.G. Pai, D.P. Hess, “Three-dimensional finite element analysis of threaded fastener loosening due to dynamic shear load”, Engineering Failure

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Analysis 9 (2002) 383–402

[7] A Technical White Paper, “Investigating Material and Component Failure, Failure and Root Cause Analysis by TCR Engineering”, Written by TCR Engineering Services Technical Team published July 2004.

[8] W. R. Broughton and G. Hinopoulos, “Evaluation of the Single-Lap Joint Using Finite Element Analysis, Project PAJ3” - Combined Cyclic Loading and Hostile Environments, Dec-1999.

[9] Jordan Christopher Baker, “Analysis of Bolting in Flanged Connections”, Rensselaer Polytechnic Institute Hartford, Connecticut, April, 2009.

[10] A Textbook on. “Design of Machine Elements”, Third edition-2010, Tata Mc graw Hill, pg. 220- 221

[11] A manual on “High Tensile Cast Steel”, by Bolher Uddeholm, Australia (www.buau.com.au).

[12] B. Sergeev, E. Madenci, D.R. Ambur, “Infuence of bolt spacing and degree of anisotropy in single-lap joints”, Computers and Structures 76 (2000) 89 - 103.

[13] A textbook on, “Fundamentals of CAD/CAM/CIM” First edition, Katson books, pg. 220-261.

[14] A Design Databook on “ Design Data for Machine Elements” by B.D.Shiwalkar, Central Techno Publications (ISBN 81-89178-05-9), Pg. 1, 2

[15] www.lloyds.com/HRM.

[16] Kovács, N., Calado, L., and Dunai, L. (2004).Behavior of bolted composite joints: experimental study. Construction Steel Research, 60(3-5):725-738.

[17] Krishnamurthy N, Krishna VR. Behavior of splice–flange connections with multiple bolt rows. Report submitted to the Metal Building Manufacturers Association; February 1981.

[18] D. Lehmann, Nonlinar axis force and bending moment distribution in bolt clamped L-flange, Stahlbau 9 (2003) 653-663 (in German).

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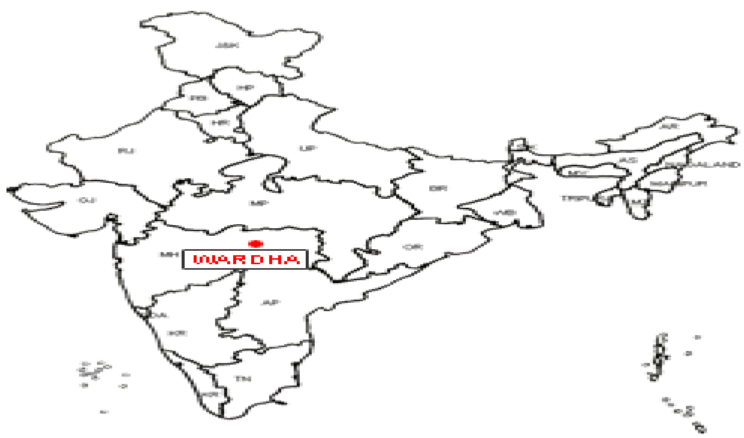
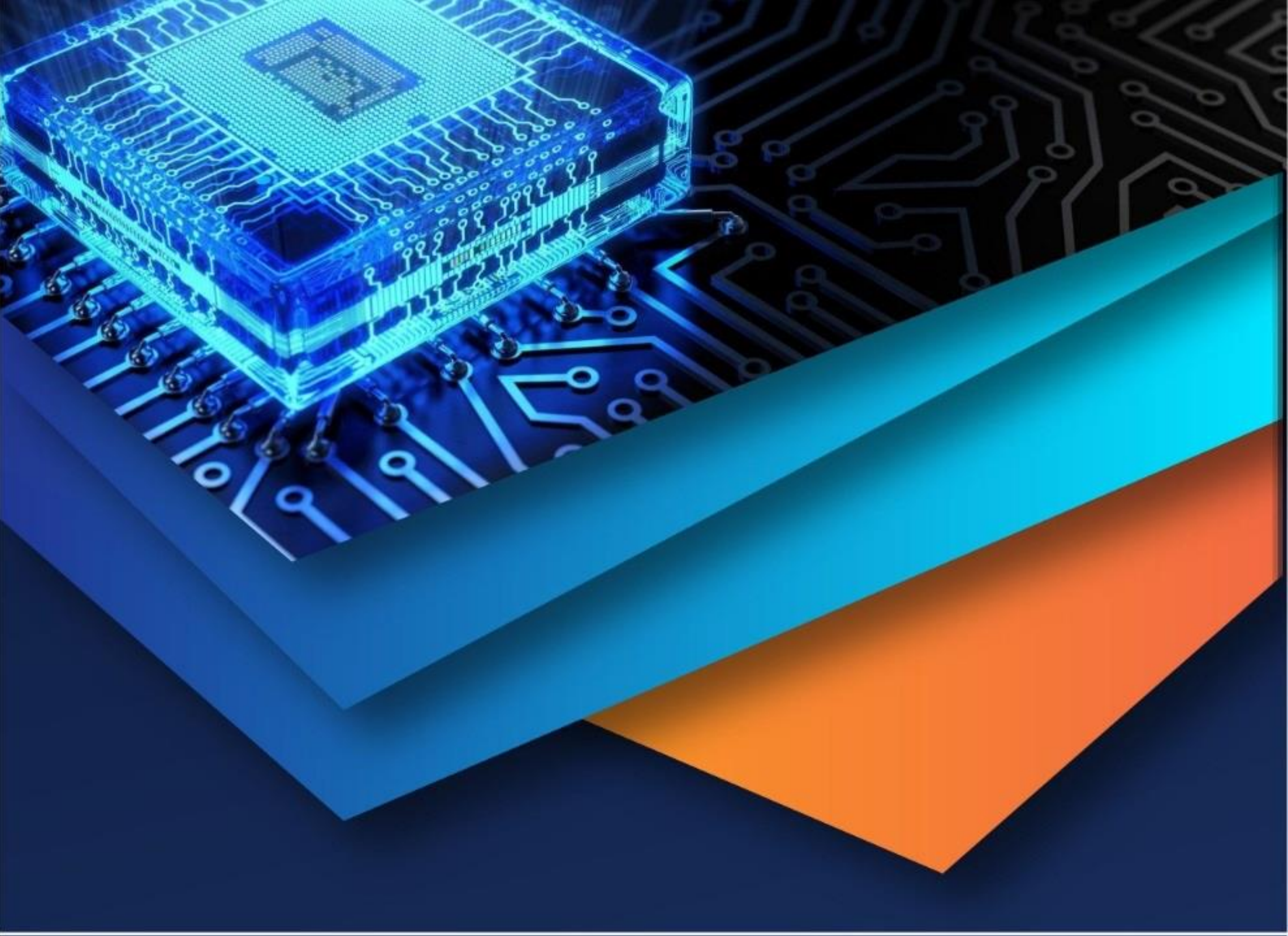
APPENDIX-1

Lloyds Steel Plant

Photo No.01: Lloyd’s Steel plant, Wardha [15]
[Courtesy: www.Lloyds.com]

Location





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