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Static Analysis of Bolt Due To Random Vibration Used In Turbine

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Abstract : *In this work computer aided modeling of components of bolted joint and their finite element analysis has been carried out through ANSYS workbench software under definite loading conditions, to obtain different stress and displacement value. These models further find their use in various type of analysis including static and dynamic analysis. The model thus made has been imported in the Ansys Workbench for the analysis using the IGES file format . The spatial variation of total deformation, directional deformation, equivalent stresses and principal stresses .The analysis includes detailed stress analysis of a single lap bolted joint. It has been shown that with increasing pretension the deformation and stresses increase.*

Keywords : *Bolt-Pretension*

I. Introduction

Most of machines and products have various joints such as bolted joint, riveted joint, welded joint etc for effective productivity and maintainability. Bolted joint, one of the joint structures is widely used due to its easiness to install and remove. These joints produce big fastening power with less force and low cost in the production. Bolted joints are one of the most common elements in construction and machine design. They consist of fasteners that capture and join other parts, and are secured with the mating of screw threads.

A turbine is any kind of spinning device that uses the action of a fluid to produce work. Typical fluids are: air, wind, water, steam and helium. Windmills and hydroelectric dams have used turbine action for decades to turn the core of an electrical generator to produce power for both industrial and residential consumption. Simpler turbines are much older, with the first known appearance dating to the time of ancient Greece. In the history of energy conversion, however, the gas turbine is relatively new. The first practical gas turbine used to generate electricity ran at Neuchatel, Switzerland in 1939, and was developed by the Brown Boveri Company. The first gas turbine powered airplane flight also took place in 1939 in Germany, using the gas turbine developed by Hans P. von Ohain. In England, the 1930s' invention and development of the aircraft gas turbine by Frank Whittle resulted in a similar British flight in 1941.

1.1 Types of joints

For the purposes of this guidelines document the different types of joints have been divided into the following five main categories;

1.1.1 Concentric Axially Loaded Joints,
1.1.2 Eccentric Axially Loaded Joint,
1.1.3 Shear Loaded Joints,
1.1.4 Combined Loaded Joints, and
Low Duty Joints.

These are defined by the geometry and system of loading. Due to the different verification procedures "Shear Loaded Joints" and the "Combined Loaded Joints" are further subdivided in to;

1.1.5 Bearing Joints, and
1.1.6 Friction Grip Joints.

The categorisation of joints in this manner is reflected in the structure and format of the document. Within each of the main categories, sub-categories can be identified depending on specific geometrical or loading attributes. Details of the main categories together with examples of typical sub-categories are illustrated in this section. It is intended that this will both indicate the range of joint types covered in the guideline and operate as an index to direct the user to the relevant parts of the document.

1.2Main Joint Categories

The definition for a particular joint configuration depends on the geometry of the clamped parts and fasteners, and the effective loading applied at the fastener (or fastener group). As stated in Section1 it is assumed that the user has knowledge of the system of loads acting on the joint in the vicinity of the fastener(s); these being derived by analysis of the overall structure prior to detailed consideration of joint design. Adequate definition of the applied loading system is essential as this may determine the particular category to which a joint belongs and hence the method of analysis adopted. This is particularly critical when distinguishing between concentric and eccentric axially loaded joints. The selection of the appropriate analysis for the combined loading case is also dependent on adequate specification of the loading system. More complex situations arise where combined loading occurs, typically axial, shear and bending. However, where a single load is dominant in a combined loading case and other load(s) are small it may be possible to assume the joint falls into one of the first three categories outlined below, thereby simplifying the analysis without significant reduction in accuracy. Criteria are included to determine when such an assumption is applicable.

1.2.1Concentric Axially Loaded Joints

The distinguishing feature of this joint category is that the line of action of the applied loading on the joint is parallel to and coincident with the longitudinal axis of the fastener. Therefore, any combination of joint geometry and system of applied loads which conform to this definition may be analysed by the methods and procedures specified for this category.

Examples of joints for this category are illustrated in Figure1 to Figure3. For clarity a single fastener is shown, although in many cases the same analysis may be applied to a group of fastener if they are in a symmetric pattern. However, it should be noted that the effect of flange flexibility can lead to eccentric fastener loads in joints that with symmetric fastener pattern (see Figure3, Joint 17).

1.2.2 Eccentric Axially Loaded Joints

For this joint category the line of action of the applied loading on the joint, whilst being parallel to the fastener longitudinal axis, is not coincident, but offset. The result of this is that a “prying” (or “prising”) action occurs between the clamped parts of the joint such that bending loads are introduced under the bolt head and in the shank. Three fundamental loading case variants can be identified depending on the relative position of the bolt axis, line of action of the applied load, and the joint centroid.

This category of joint and its variants represent a large proportion of the joints encountered in practice. The main examples of these are illustrated in Figure1 to Figure3. For clarity a single fastener is shown, although in practice this may be a group.

1.2.3Shear Loaded Joints

The principle feature of this joint category is that the line of action of the applied loading on the joints is in the plane of the clamped parts immediately adjacent to the fastener, and therefore normal to the fastener longitudinal axis. The forces need not be coplanar if the joint is of the non-symmetrical or single lap shear type. Joints of this type may be further subdivided into friction grip or bearing categories, depending on whether load is transferred through the joint by friction at the faying surfaces or by transverse shear in the fastener(s). Examples of joints in this category are illustrated in Figure1 to Figure3. For clarity a single fastener is shown, although in practice this may be a group if the joint has multiple fasteners.

1.2.4Combined Loaded Joints

The essential feature of this joint category is that more than one system of loads act on the joint relative to the fastener axis. In the most general case features of all the preceding categories will be combined. Examples of joints for this category are illustrated in Figure1 to Figure3. For simplicity a single fastener can often be considered, although in practice the same may be a group if the joint has multiple fasteners.

During the design process, joints initially being placed in the (most general) category of combined loaded joints may be reclassified into a sub-category, for the purpose of analysis. This guideline does not provide specific criteria for determining when this simplification can be assumed. Rather, the appropriate analysis method should be determined using engineering judgment considering the relative magnitudes of the shear and axial loads, the configuration of the joint and any other relevant attributes of the design.

1.2.5Low Duty Joints

Joints in this category have loadings and configurations that fit into one of the preceding categories, however they form a unique category since they have small external loading with respect to the fastener strength. In many cases this will be readily apparent due to the particular application, e.g. hold-downs, access panel attachments, etc. Some example diagrams of joints that frequently fall into this category are shown in Figure1 to Figure 3.

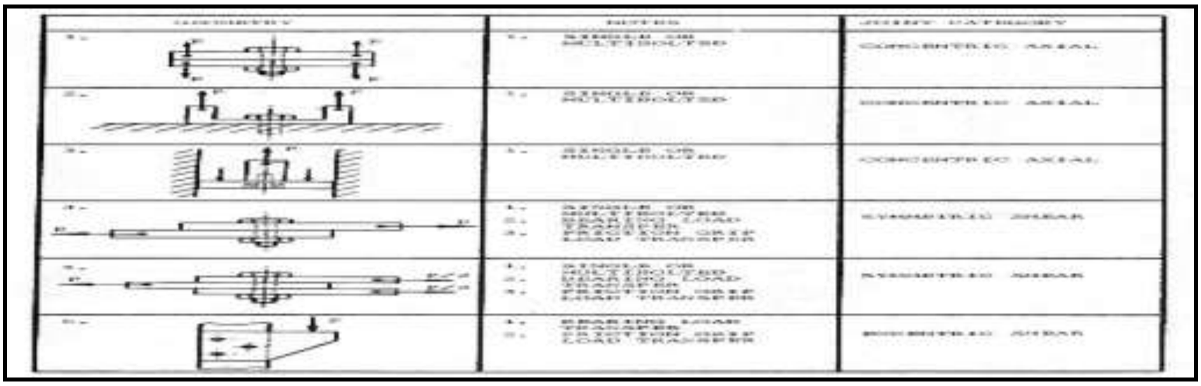
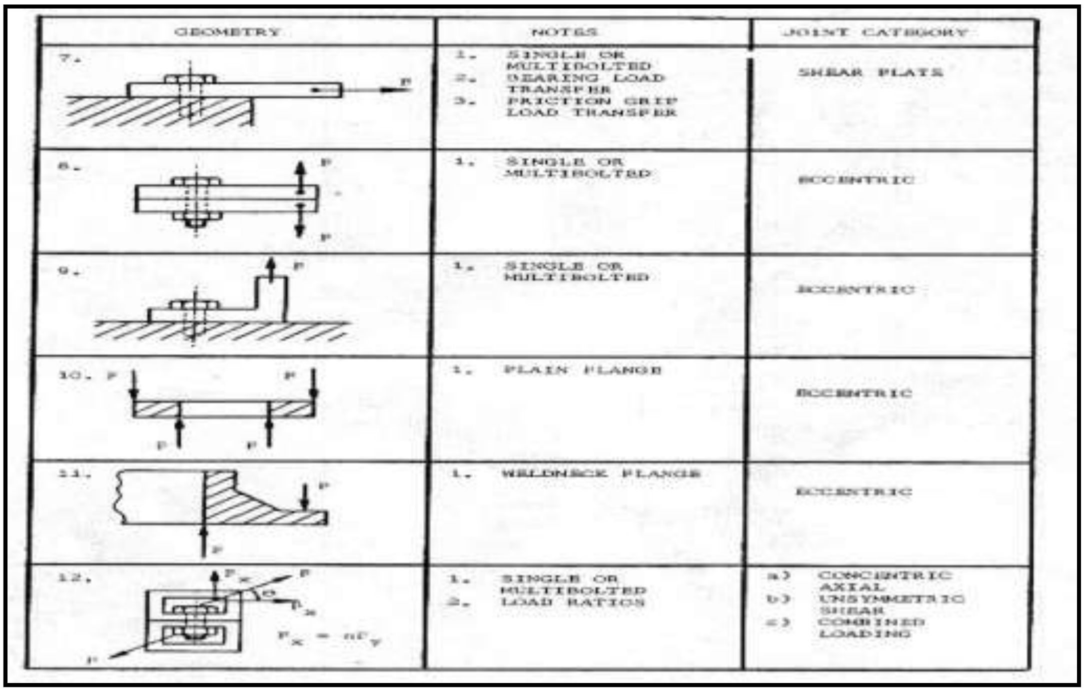
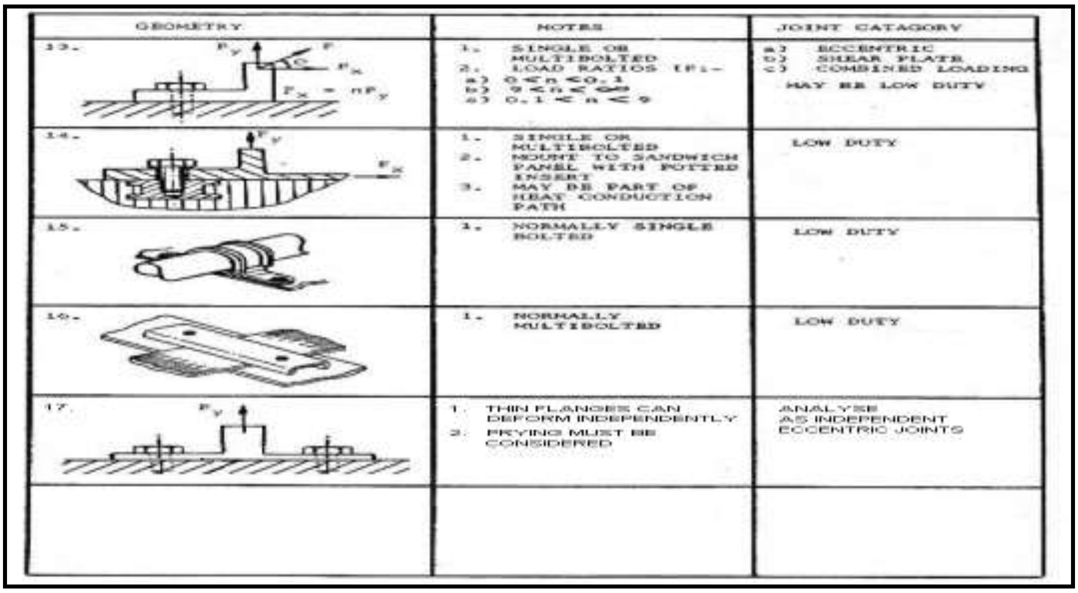


Fig. 1



GEOMETRY	NOTES	JOINT CATEGORY
7. F	1. SINGLE OR MULTIBOLTED 2. BEARING LOAD TRANSFER 3. FRICTION GRIP LOAD TRANSFER	SHEAR PLATE
8. F F	1. SINGLE OR MULTIBOLTED	ECCENTRIC
9. F	1. SINGLE OR MULTIBOLTED	ECCENTRIC
10. F F F F	1. PLAIN FLANGE	ECCENTRIC
11. F F	1. WELDNECK FLANGE	ECCENTRIC
12. F_y F F_x $F_x = nF_y$ F	1. SINGLE OR MULTIBOLTED 2. LOAD RATIOS	a) CONCENTRIC AXIAL b) UNSYMMETRIC SHEAR c) COMBINED LOADING

Fig.2



GEOMETRY	NOTES	JOINT CATAGORY
13. F_y F F_x $F_x = nF_y$	1. SINGLE OR MULTIBOLTED 2. LOAD RATIOS (F:- a) $0 < n < 0.1$ b) $9 < n \leq \infty$ c) $0.1 < n < 9$	a) ECCENTRIC b) SHEAR PLATE c) COMBINED LOADING MAY BE LOW DUTY
14. F_y F_x	1. SINGLE OR MULTIBOLTED 2. MOUNT TO SANDWICH PANEL WITH POTTED INSERT 3. MAY BE PART OF HEAT CONDUCTION PATH	LOW DUTY
15.	1. NORMALLY SINGLE BOLTED	LOW DUTY
16.	1. NORMALLY MULTIBOLTED	LOW DUTY
17. F_y	1. THIN FLANGES CAN DEFORM INDEPENDENTLY 2. PRYING MUST BE CONSIDERED	ANALYSE AS INDEPENDENT ECCENTRIC JOINTS

Fig.3

II. Problem Statement

2.1 Practically very engineering product with every degree of complexity uses threaded fasteners a key advantage of threaded fasteners over the majority of other joining methods is that they can be disassembled and re used. This feature is often the reason why threaded fasteners are used in preference to other joining methods and they often pay a vital role in maintaining the products structural integrity. However, they are also a significant source of problems in machinery and other assembly's .The reasons for such problems are due in part to them unintentionally self -loosening.
2.2 The pre load is the initial clamp forces imparted into a joint by tighten a fastener. The vast majority of joints rely upon this pre load for their structural integrity .The pre load acts on the fastener threads creates a torque in the circumferential direction which is registered by friction. Self loosening of fasteners leads to a reduction and sometimes the elevation of this pre load which is frequently leads to joint failure.
2.3 Most bolted joints especially the ones associated with machinery, are subjected to significant vibration labels during their life span. Rotating or reciprocating machines such as gas, steam turbine, electric motors and IC engines are subjected to vibration of relatively high frequencies; gyratory crushers, jackhammers and so forth are subjected to medium frequencies vibration.

III. Objectives

3.1The aim of this study is to find a constructive way to protect a bolted connection from self-loosening.
3.2To study the effect and design bolt to sustain for the vibrations.

IV. Literature Review

A. Nomesh Kumar, P.V.G. Brahamanandam and B.V. Papa Rao "3-D Finite Element Analysis of Bolted Flange Joint of Pressure Vessel" In his paper it was studied that, the stresses in the bolts of the bolted flange joint of 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: (a). to maintain the structural integrity of the joint itself, and (b). to prevent the leakage through the gasket preloaded by bolts. 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.

B. Gowri Srinivasan & Terry F. Lehnhoff "Bolt Head Fillet Stress Concentration Factor Cylindrical Pressure Vessels"

In this paper it is found that, linear three-dimensional finite element analysis (FEA) was performed on bolted pressure vessel joints to determine maximum stresses and stress concentration factors in the bolt head fillet as a result of the prying action. The three-dimensional finite element models consisted of a segment of the flanges containing one bolt, using cyclic symmetry boundary conditions. The maximum stress in the bolt as well as the stress concentration factors in the bolt head fillet increase with an increase in bolt circle diameter for a given outer flange dimension. Keeping the bolt circle diameter constant, bolt stress and stress concentration factors inthe bolt head fillet decrease with increase in outer flange diameter. The maximum stresses in the bolt were also calculated according to the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code and the Verein Deutscher Ingenieur (VDI) guidelines and compared to the results observed through finite element analysis. The stresses obtained through FEA were larger than those predicted by the ASME and VDI methods by a factor that ranged between 2.96 to 3.41 (ASME) and 2.76 to 3.63 (VDI).

C. S.H. Ju, C.Y. Fan, & G.H. Wub "3-dimensional finite elements of steel bolted connections"

In this paper it was found that, the three-dimensional (3D) elasto-plastic finite element method is used to study the structural behaviour of the butt-type steel bolted joint. The numerical results are compared with

AISC specification data. The similarity was found to be satisfactory despite the complication of stress and strain fields during the loading stages. When the steel reaches the nonlinear behaviour, the bolt nominal forces obtained from the finite element analyses are almost linearly proportional to the bolt number arranged in the connection. Moreover, the bolt failure is marginally dependent on the plate thickness that dominates the magnitude of the bending effect. For the cracked plate in a bolted-joint structure, the relationship between KI and the applied load is near linear, in which the nonlinear part is only about one tenth of the total relationship. This means that the linear elastic fracture mechanics can still be applied to the bolted joint problem for the major part of the loading, even through this problem reveals highly nonlinear structural behaviour.

D. Iuliana PISCAN, Nicolae PREDINCEA & Nicolae POP "FINITE ELEMENT ANALYSIS OF BOLTED JOINT"

In this paper it was found that, this paper presents a theoretical model and a simulation analysis of bolted joint deformations. The bolt pretension force, friction coefficient and contact stiffness factor are considered as parameters which are influencing the joint deformation. The bolted joint is modelled using CATIA software and imported in ANSYS WORKBENCH. The finite element analysis procedure required in ANSYS WORKBENCH simulation is presented as a predefined process to obtain accurate results.

E. Ali Najafi, Mohit Garg and Frank Abdi "Failure Analysis of Composite Bolted Joints in Tension"

In this paper it is found that, the failure of preloaded cross-ply laminated composite has been studied through finite element simulation embedded in Progressive Failure Analysis (PFA). Two modelling strategies including low- and high-fidelity models have been considered for this investigation. The high-fidelity FE model consists of fixture components (bolts and washers). It has been shown that both low- and high-fidelity FE models are capable of predicting the experimentally observed failure modes of bolted joints that depends on the geometric parameters with reasonable accuracy. Two catastrophic failure loads, net-tension and shear out can be predicted using both low- and high-fidelity model while the failure load of bearing mode can only be predicted via high-fidelity model that considers the applied preload of the bolt. However, the overall stiffness in the actual experiment is lower than that of predicted via finite element simulation.

F. ZHANG Yongjie and SUN Qin "Joint Stiffness Analysis of Sheared Bolt with Preload"

In this paper it is found that, nonlinear contact arithmetic of ANSYS system is employed for simulating hole-edge stress of sheared bolt. The preload of sheared bolt is caused by cool method. In this paper, an evaluation formula of bolt joint stiffness is presented to obtain relative curves between bolt joint stiffness and thickness of lapped plates. Some reliable conclusions are shown for simplifying computation of lapped bolt from complex structure.

Bolted joints are probably the best choice to apply a desired clamp load to assemble a joint, with the option to disassemble if and when necessary [1]. The threaded fastener (nut and bolt) has played a significant role in the industrial revolution even though the exact date of its conception is not known. The concept of a helical thread was first introduced by Archimedes in the 3rd century B.C. Some archeologists argue that the threaded fastener was in existence even before Archimedes at the "Hanging Gardens of Babylon". It is accepted that the common forms of threaded fastener assemblies have been in existence for at least 500 years [3]. History of evolution of screw fasteners dates back to few thousand years ago. It is learnt that screw fasteners were used in the Tigris–Euphrates region in around 1,000 B.C., mainly, for the purpose of water supply. The plate shaped cross-section of the screw thread was then used. The People of Greece were also supposed to use screws to press olives. Leonardo da Vinci is credited for creating and sketching different ideas leading to implementation of important usage of screw threads [1].

This work includes the numerical studies in static analysis of single lap bolted joint. The model has been developed in the CAD software. Stress analysis has been carried out using finite element method. Static analysis is a multi-discipline Computer Aided Engineering (CAE) tool that analyzes the physical behavior of a model to better understand and improve the mechanical performance of a design[2]. It can be used to directly calculate stresses, deflections and thus to predict the behavior of the design in the real world. for analyzing the problem, various elements were modeled using Pro-Engineer 4.0. These solid models are imported in ANSYS workbench for meshing, and the meshed model was subjected to boundary condition as loads and constraints. Then a deck is generated for solver and template is solved using ANSYS workbench.

V. Finite Element Analysis

Plate=300x50x8mm & Eccentricity(e) = 174mm

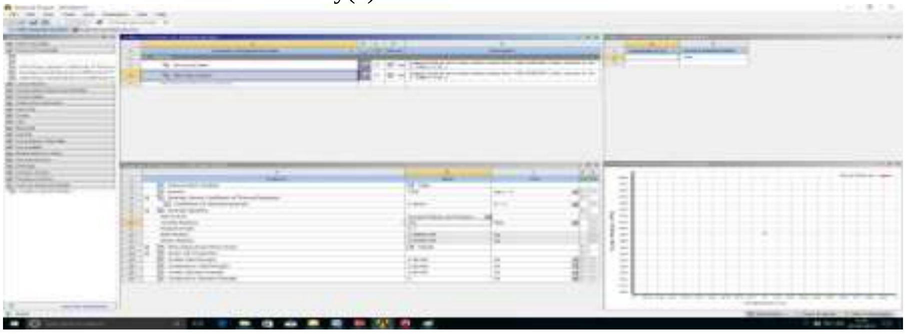


Fig.4- Material Properties

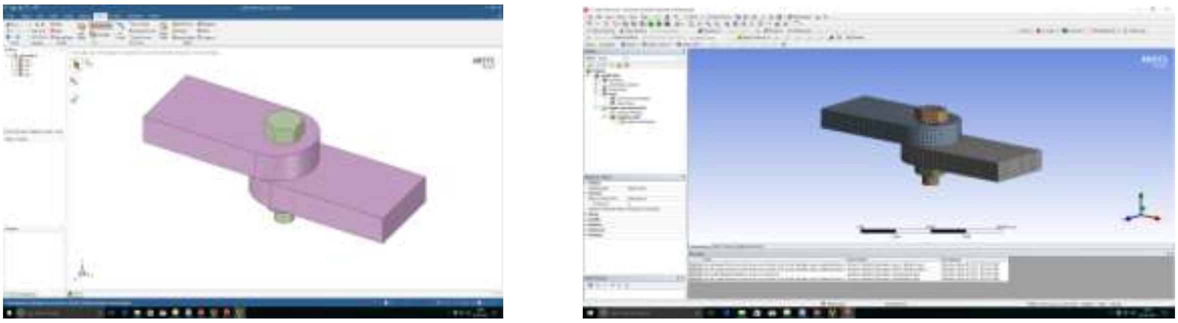


Fig 4. Meshing of lap joint

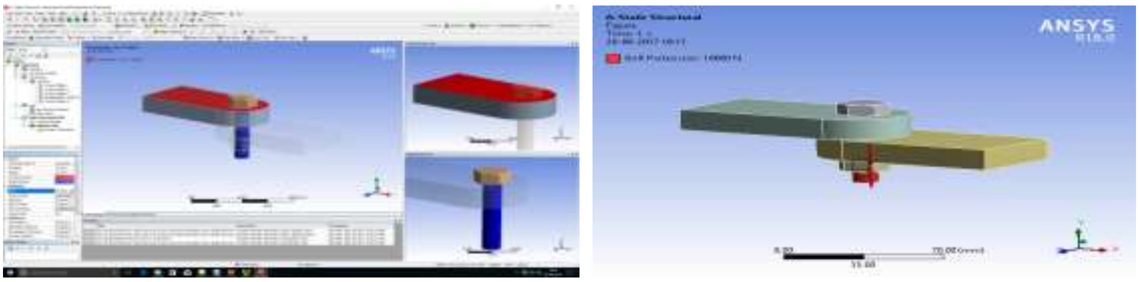


Fig.5 Boundry condition -Bolt Pretension

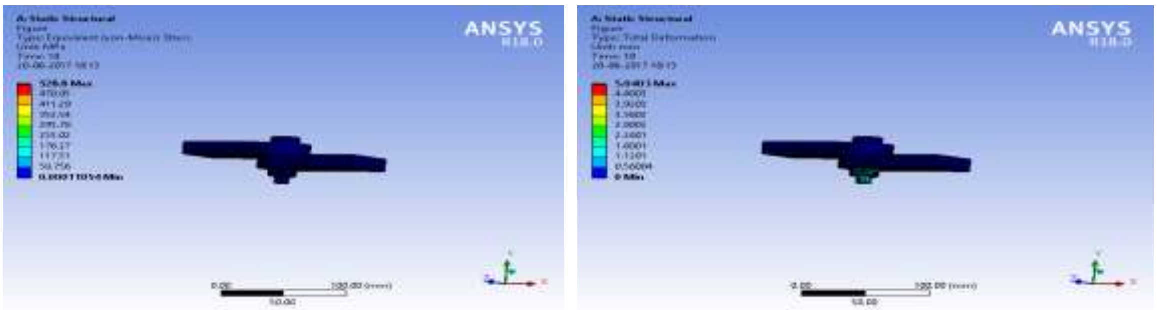


Fig.6- Von Mises Stress and Total Deformation in whole Lap Joint

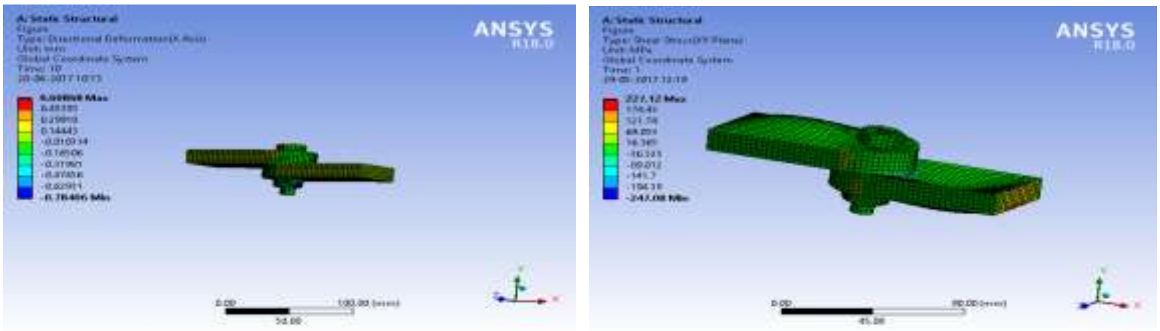


Fig7-20 Directional Deformation in X – Direction

VI. Result

PARAMETERS	FEA
BOLT PRETENTION IN KN	4.328
TENSILE STRENGTH IN BOLT & STRESSES IN MPA	528.8
DEFORMATION IN X- DIRECTION IN MM	0.60868
TOTAL DEFORMATION IN MM	5.0403
SHEAR STRESS IN MPA	227

Table.1-Result

Model prepared for analysis	t (mm)	d (mm)	P_i (N)	τ_{max} (MPa)
Symmetrical bolted joint	11	12	9940	227
Unsymmetrical bolted joint	11	12	9940	250

TABLE.2- ANALYTICALLY DETERMINED STRESSES FOR ALL MODELS UNDER ANALYSIS

VII. Conclusion

The discussion and conclusion on the basis of result is presented in this section. We are considering symmetrical model as solution basis because circular flange of turbine housing assembly shares the strength equally with respect to lap joint, hence symmetry is maintain. The experimental determination of breaking strength of symmetrical eccentric loaded bolted joint revealed the breaking stress is 253 MPa. The FE analysis of symmetrical eccentric loaded bolted joint for the same geometry revealed the maximum shear stress is in the range of 121 MPa to 227 MPa

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