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Investigation on the self loosening behavior of hexagonal nut and nylock nut in curvic coupling under transverse loading

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ABSTRACT: *Failure of fasteners is due to dynamic loads generally due to fatigue or self-loosening. Even partial loosening can reduce the fasteners preload and thereby increase the dynamic loads acting on the fasteners loading to increase of fatigue failure. Nylock nut has property to prevents the self loosening under vibration Such failure can be catastrophic in safety application. In this project self loosening of bolts in curvic coupling is analyzed for standard hexagonal nut and nylock nut by applying cyclic transverse load on disc after the preload of bolt. Using ANSYS AND PRO-E 3D model for curvic coupling and thread is established to study the details of self loosening mechanism of bolt in standard hex nut and nylock nut.*
Keywords- *Bolt loosening, Curvic coupling, Finite element analysis, Nut rotation, Nylock nut*

I. Introduction

The preload of bolt in curvic coupling is a key factor for the assembly design of curvic coupling. Most machines and structures are assemblies of simpler components. Fastening and joining technology used to assemble the components is a key feature of practically all modern machines. Threaded fasteners are commonly used in assemblies due to the advantages they over, such as the ability to develop a clamping force, and the ease of disassembly for maintenance and repair. Clamping force in a bolt is commonly developed by turning the engaged nut such that it moves against a clamped component and causes an axial elongation in the bolt.

The resulting clamping force is a function of the joint stiffness and the bolt axial elongation. It has been widely observed that fasteners turn loose when subjected to dynamic loads in the form of shock, vibration or cyclic thermal loading. This reduces the clamping force and leads to joint failure. Such failures result in higher maintenance expense, costly downtime in machines, and can be catastrophic in safety critical applications.. This work is aimed at obtaining a complete understanding of bolt loosening mechanism with standard hexagonal nut and nylock nut in curvic coupling under dynamic torque loads using a three-dimensional FE model explained in relation to the contact state on the thread, the curvic and the bearing surfaces[1-5].

The curvic coupling is an important component in gas turbine widely used in the aero-engine and electric power generation industry to drive rotating equipment and safely transfer high torque without relying on friction between the contacting surfaces of the curvic couplings. Its advantages such as reliable positioning, precise centering, excellent structure stability, strong loading and bearing ability, meeting the requirements of strength, vibration, and fatigue life definitely make the curvic couplings used more and more widely in the high speed rotating machine for torque transmission.

II. Finite element modeling

A three-dimensional FE model is established with the software packages PRO-E wildfire5 and ANSYS 14.5 workbench. The material in modeling is isotropic. The Young's modulus and Poisson's ratio for all components are 209 GPa and 0.3, respectively. The FE analysis is assumed to be elastic. In this way, it is possible to construct finite element models of bolt and nut in curvic coupling with high accuracy and computation efficiency. The whole finite element model is created that would be able to satisfy the requirement for this work, shown in Fig.1. It can be found that the curvic coupling is comprised of two discs and six bolts the exploded view is shown in fig.2 and there are twenty-four curvics in each disc. In order to loosen the bolts in curvic coupling in simulation, a torque load should be applied on one disc, and another disc should be fixed at the end of the shaft.

In this paper, the thread friction, the underhead friction and the curvic bearing friction are the critical parameters influencing the self-loosening behavior of bolt. The fig .1 shows the dimensions of curvic coupling.

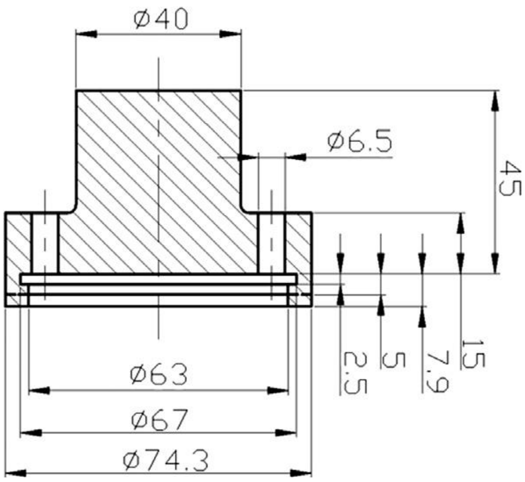

Fig. 1 Dimensions of curvic coupling

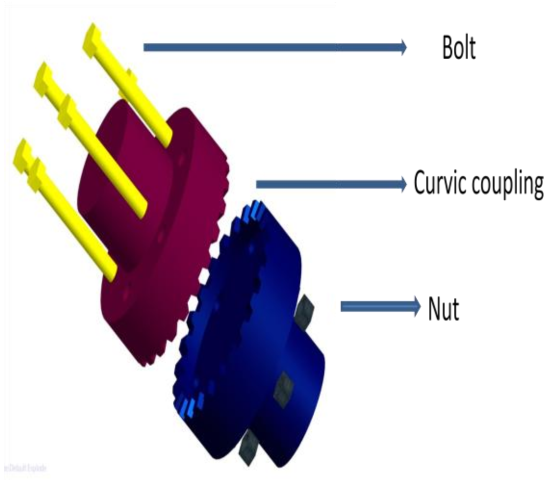

Fig. 2 Exploded view of curvic coupling

Boundary condition of the complete assembly is shown in the fig.3. During analysis one end of the coupling is fixed and other end has torque applied at 5000 Nmm. The bolts are pretension at force of 2290 N.

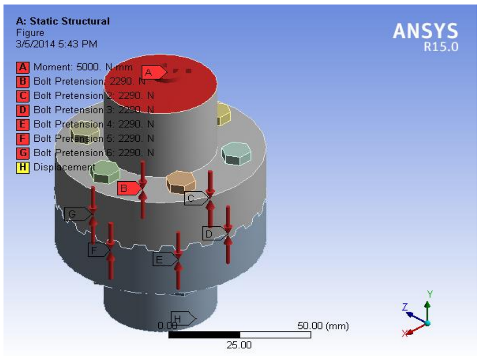

Fig. 3 Boundary condition

III. Contact status analyses under cyclic loading

The slip–stick status or localized slip of contact surface is the critical factor to determine the loosening process of bolt in curvic coupling, which could be depicted by a proportional coefficient □ that is a relationship ratio between the tangential stress □ and the contact pressure p, and can be expressed as follows:

$$\square = \frac{\mathrm{Fs}}{\mathrm{Fn}} = \frac{\square}{\mathrm{P}} \qquad (1)$$

where Fs is the magnitude of frictional shear force per contact element; Fn is the magnitude of frictional normal force per contact element. If the proportional coefficient □ is significantly less than the friction coefficient of the corresponding contact surface, it means that the contact status is stick. However, the contact status can be thought to be complete slip when □ is equal or close to the friction coefficient. In addition, □ is impossible to be larger than the friction coefficient of contact surface in theory.

1.1 Finite element analysis for Hexagonal nut

Using ANSYS software normal stress and shear stress is analyzed for standard hexagonal nut.

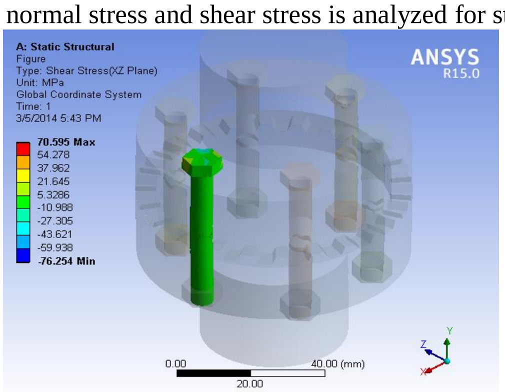

Fig. 4 Shear stress for coupling using ANSYS

From fig .4 shear stress analysis result, the shear stress is 70.595 MPa

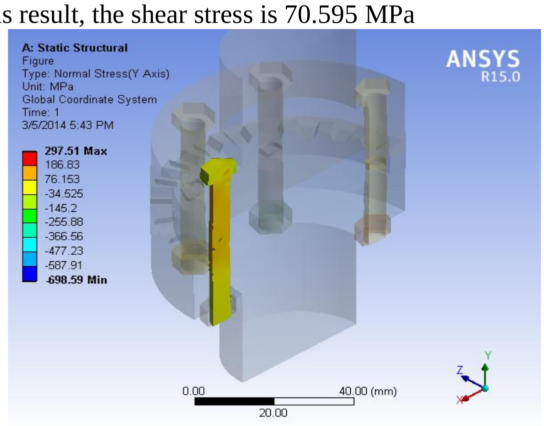

Fig .5 Normal stress for bolt in coupling using ANSYS

From fig .5 normal stress analysis result, the normal stress is 297.51 MPa

Using the equation (1), the slip-stick status will be found by using following data's from the analysis result

$$\square = \frac{\square}{\mathrm{P}} = \frac{70.595}{297.51} = 0.24$$

From the analysis, proportional coefficient is close to 0.3. Therefore, slip will be taking place at contact status in standard hexagonal nut.

1.2 Finite element analysis for nylock nut

Using ANSYS software normal stress and shear stress is analyzed for nylock nut

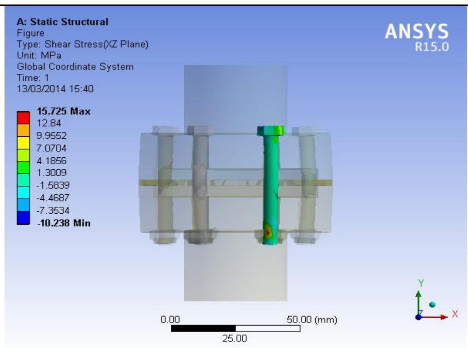

Fig. 6 Shear stress for bolt in coupling using ANSYS

From fig .6 shear stress analysis result, the shear stress is 15.725 MPa

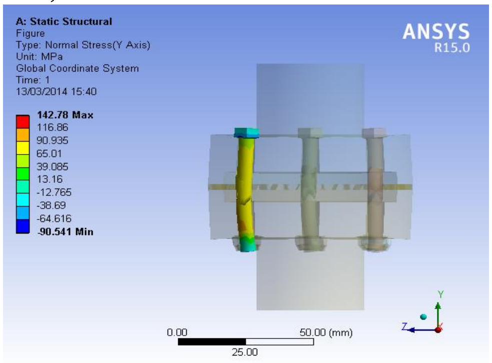

Fig. 7 Normal stress for bolt coupling using ANSYS

From fig .7 normal stress analysis result, the normal stress is 142.78 MPa

Using the equation (1), the slip-stick status will be found by using following data's from the analysis result

$\square = \frac{\square}{P} = \frac{15.725}{142.78}$=0.11

From the analysis, proportional coefficient 0.11 is very less than 0.3. Therefore, stick will be taking place at contact status in standard hexagonal nut.

IV. Conclusion

The current investigation is focused on the prevention of self loosening of bolt and nut in curvic coupling under cyclic transverse loading.

By using hexagonal nut there is slip in contact status due to cyclic loading. When hexagonal nut is replaced by nylock nut there is stick in contact status because there is increase in coefficient of friction between bolt and nylock nut due presence of nylon in nut.

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