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A REVIEW ON DESIGN AND ANALYSIS OF KEYLESS POWER TRANSMISSION BY SHAFT LOCKING DEVICE – SHRINK DISC

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Abstract— Ina keyed shaft/hub connections, problems of fretting corrosion and backlash occurs due to slippage of keys during impact and shock loads. The solution to these problem is elimination of key by using keyless power transmission device to transmit torque. This papers reviews shrink disc as a keyless power transmission device to transmit power between shaft and hub. Shrink disc as a locking device uses interference fit to transmit torque or axial force. In this paper, review of design of these interference fit carried out by different authors by different methods like traditional method (Lame's equation, compound cylinder theory) and numerical method is carried out. Also the comparison between these methods have been carried out. Also, design of shrink disc based on reliability and dynamic reliability has been reviewed. In this review paper, torque transmission capacity and contact stress analysis of shrink disc compiled by different authors is carried out.

Keywords— Keyless power transmission, Shrink disc, Interference fit, contact pressure, contact stress,

I. INTRODUCTION

For a long time, Interference fit between components has been used to achieve require power transmission. Interference connection has several advantages like simple structure, high load-carrying capacity, excellent concentricity, etc. as compared to mechanical transmission through keys, pins, and screws. It plays a significant role in engineering applications such as heavy machinery, lifting machinery, ships, locomotives, and general machinery.

Shrink disc as a keyless power transmission device uses mechanical interference fit to transmit torque between shaft/hub. Shrink Discs rely on the proven wedge principle to create a keyless, mechanical interference fit by converting locking screw tension into radial contact pressures on shaft and hub[1]. To calculate contact pressure between mating surfaces of shaft/hub connections, Thick wall cylinder theory and Lame equation is used considering impact of amount of interference.

When positioned around the hub, there is only one interface transmitting the loads that gives the shrink disc method different advantages such as the possibility of very concentric and well balanced connections suitable to high speed applications. Shrink discs overcome the disadvantages of traditional shrink fits, such as complicated calculations, close machining tolerance, fine surface finishes and considerable effort with mounting and removal.

The shrink disc consists of two outer rings with tapered bores and a mating tapered inner ring. By tightening locking screws the outer rings are drawn together compressing the inner ring and applying pressure to the outside of the hub clamping it to the shaft. These radial contact pressures in turn accomplish the following [2]:

1. Contract the inner ring and hub to close the clearance between shaft and hub bore.
2. Generate a defined shaft/hub contact pressure for a high capacity mechanical interference fit.

This frictional bond transmits torque, bending and/or thrust loads directly from the hub to the shaft; the shrink disc itself does not carry any torque or thrust load. A typical shrink disc and working of shrink disc is shown in figure below.

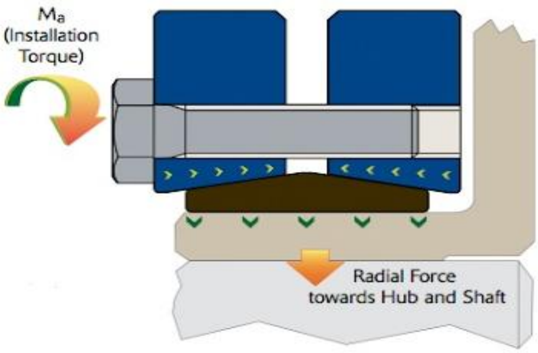


Fig. 1 Working principle of shrink disc [2]

II. Literature Review

Y. Zhang, B. McClain, X.D. Fang [3] designed ring gear-wheel interference fit connections by using traditional method and finite element method. Traditional thick wall cylinder theory gave poor results of interference stresses and deformation due to complex geometry of assembly. Then results were obtained from finite element method which gave more accurate results than traditional method [4] Finite element method considered stresses in axial direction, which were not considered in traditional method. They also introduced factors for assuring component strength and factor of safety for assuring no slipping on mating surface provides a new method for determining the quality of interference fits. These two factors in combination with finite element method gave more reliable and precise method for design of interference fit.

Jian Shen, Dong Che [5] carried out finite element analysis of shaft-sleeve geometry to carry out stress analysis and to determine the influence of primary factors like shaft diameter, wall thickness, mating length and interference on stress. Based on symmetry characteristics of the structure, a 1/4 finite element model was generated. In the orthogonal experiment analysis, type of element used was Solid 185, which is used for the 3-D modelling of solid structures. Results of finite element analysis were compared with theoretical results. They concluded that the interference was most significant factor affecting the stress. With increasing value of interference, contact stress also increases. The order of influencing factor was as follows:

Interference > Shaft diameter > Mating length > Wall thickness

F Ozturk [6] carried out finite element analysis of two-disk shrink fit assembly to determine the effect of interference on contact pressure. The pair of material used was steel-steel and steel-aluminium, in which one is solid shaft assembly and one was hollow shaft assembly. They concluded that, there was a non-uniform stress distribution in hollow shaft and a uniform stress distribution in solid shaft. Also for outer disk, there was non-uniform stress distribution.

From the extension of two disc shrink fit assembly, Fahrettin ÖZTÜRK, Tse-Chien WOO [7] considered three disc shrink fit assembly (solid shaft-sleeve-holder) to determine effects of interference on interfacial pressure. From the finite element analysis, interfacial pressure for different interference were determined. Results shows that the interfacial pressure between sleeve and holder was higher than between solid shaft and sleeve for the same value of interference. Also from the stress analysis, they concluded that peak value of stress was at inner radius of holder. Also uniform stress distribution for shaft and non-uniform distribution in sleeve and holder was observed.

As contact analysis of two or more bodies is difficult due to non-linear behaviour. To overcome this difficulty, Pauli Pederson [8] tried to simplify analysis of axisymmetric problem. He determined two different point of view as classical plane analysis and design of shrink fit surface. The first method determines the shape of a shrink fit surface that will result in a prescribed distribution of contact pressure due to the shrink fit. For the two parts to be shrink fitted, traditional finite element analysis gave the results. The second method determines the distribution of contact pressure that will result from a prescribed shrink fit surface by using super element technique which gives the result without iteration and incrementation.

Jianmei Wang, Ke Ning [9] considered shrink disc of a wind turbine as a research object to design it on bases of reliability and quality because it transmit high torques and is subjected to complex impact loads. By considering the geometry relationship of interference fit of multi-layer cylinder, a matrix equation of combined pressure and interference was derived. Firstly, the reliability model was established on the basis of pressure-strength model, and the formula of reliability sensitivity was derived. The reliability-based robust design (RBRD) model was built in terms of the minimum principle on the square sum of reliability sensitivity and the minimum reliability principle, and the dynamic reliability model was developed on the basis of reliability model, load model, and residual strength model. The dynamic reliability-based robust design (DRBRD) model was obtained from Dynamic reliability sensitivity formula. Based on RBRD and DRBRD methods, the effects of various influencing factors like coefficient of friction, assembly clearance, and yield strength on the reliability of WTSD were analysed. They concluded that RBRD method can improve the reliability of shrink disc by 47.6% as compared to traditional method of design.

During the actual working condition of shrink disc, to ensure the reliability of shrink disc Wang Jianmei, Kang Jianfeng [10] gave more accurate design method of shrink disc and method for precise calculation of contact pressure on the mating surfaces with interference fit. The design of shrink disc was carried out by combining thick-wall cylinder theory and Lame's equation by considering effect of fit clearance. Also Abaqus software used for simulation of results. They also concluded that the simulation result was more accurate and precise ac compared to traditional method. Also, the test was carried out to determine whether shrink disc can bear load in actual condition or not. The test platform of shrink is shown in figure. The bolts were tightened by using torque wrench and hydraulic jack acts on the support bar to simulate the rated torque. From the test results, they concluded that shrink disc can transmit the required torque in actual loading condition.

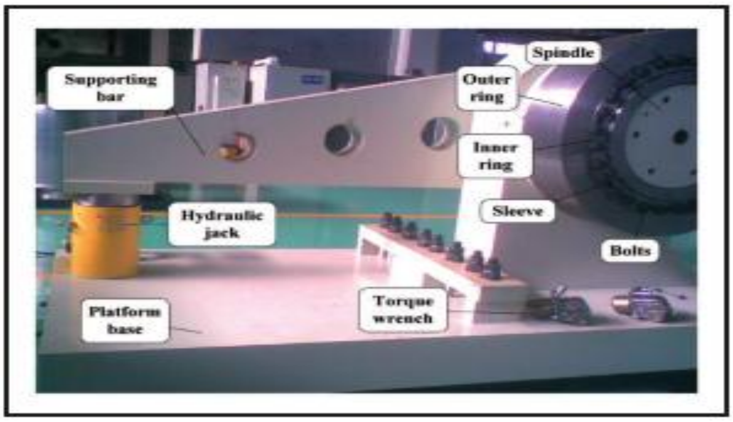
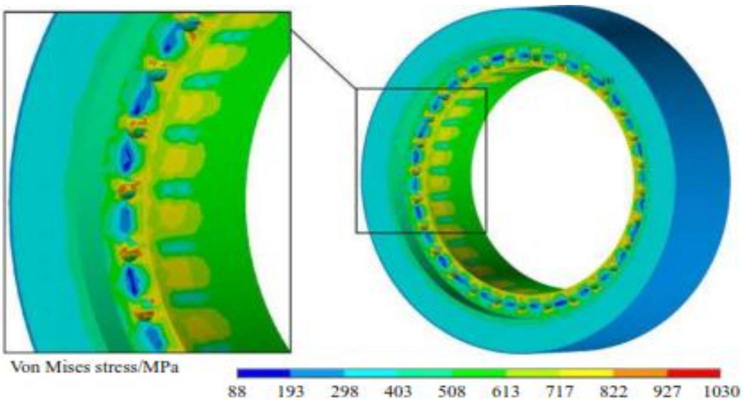


Fig. 2 Test platform of Shrink Disc[10]

K.H. Yu, Xi Yang [11] carried out torque capacity and contact stress analysis to predict the effectiveness of the shrink disc by numerical and experimental methods. They used universal testing machine to determine the stress-strain curve of material of components of shrink disc. From the numerical result, they concluded that there was no plastic deformation at interference surfaces, also the maximum equivalent strain occurs on the inner ring. Also stresses in the outer ring was decreasing with radius increment and stress concentration was found at the location of holes. They also carried out test to experimentally verify the torque transmission capacity of shrink disc. From the test, they concluded that the difference in numerical and experimental result was about 3.3%



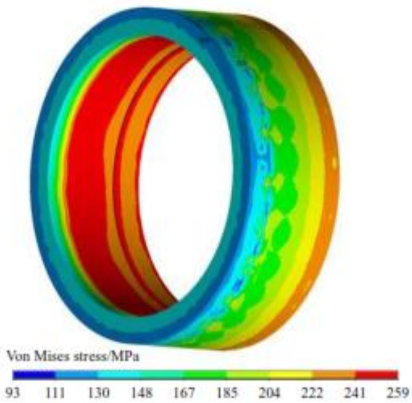


Fig. 3 Von Mises stress contours of outer ring [11] Fig. 4 Von Mises stress contours of shaft sleeve [11]

III. CONCLUSION

Mechanical interference fit is widely used in application where large torque is required to be transmitted due to its advantages over keyed connections. The design of keyless power transmission device is based on the theory of compound cylinders based on thick-wall cylinder theory and Lame's equation. Computer based analysis in software like ANSYS and Abaqus is used to carry out numerical analysis of contact stresses and contact pressures between mating surfaces. Numerical results give better design as compared to traditional design method. Also, for reliability check of shrink disc during working condition, reliability based robust design and dynamic reliability based robust design can be carried out. Reliability based robust design method used to design shrink disc can give better reliability during actual working condition.

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