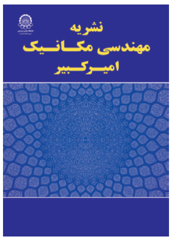

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Investigation on the Effect of Pressure and Radius of Contact Surface Curvature on the Friction Coefficient in Contact Surfaces of Interference Fit Joints

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ABSTRACT: Interference fit joints are widely used to produce tight joints. Interference fit joints could be applied under dynamics and statics design loads, successfully. Interference fit joints are always imperfect and also affected by some parameters which directly affect the operation of these joints. For instance, the contact surface of every manufactured joint part is not a perfect cylinder and always there are some form defects. The variation of these parameters could affect the performance and strength of interference joints, so these parameters should be considered. Some effective parameters on the strength of interference fit joints are friction coefficient, roughness, materials properties, dimensions and geometric irregularities of contact surfaces. In this study, the effect of diameter of shaft and interference value variation on the friction coefficient in contact surface and strength of joints are investigated. Finite element results are interacted with experimental ones to estimate friction coefficients. Also, factorial method, which is a statistical method for design of experiments, is used to analyze the effects of pressure, which is vary by variation of interference, and radius of contact surface curvature on friction coefficient and strength of joints. Results indicate that the friction coefficient changes with diameter of interference surface, inversely and increase of interference and consequently, pressure leads to growth of friction coefficient.

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1- Introduction

Todays, interference fit joints have a high degree of importance in the industry and the application of this type of joints are growing. These joints are easily balanced through the rotating structure and can easily be used in conjunction with the rotating machines. Interference joints can also be used to repair rotary parts and to restore damaged surfaces in rotating machines [1]. examined the effects of form defects in the contact surface of interference fit joints on the strength properties of them, and Sogalad et al. [2] investigated the bearing load capacity of interference fit joints, considering of form defects by means of finite element method. Also, Boutoutaou et al. [3] considered rough contact surfaces using the elastic contact model and Fourier analysis of micro curvature in contact surface. So, it is clear that the finite element method is the proper tools to analyze interference joints.

The common method of estimating of stress field at the interference fit joints is Lamé method [4]. In most of the previous researches, a default value was applied for friction coefficient for further investigations. Seifi and Abbasi [5] presented a method to estimate the friction coefficient in the contact surface of the interference fit joints; The estimated friction coefficient is depended on the geometry of the contact surface.

In this research, it is tried to analyze the effect of pressure and shaft diameter on the friction coefficient in the interference fit joints using Finite Element Analysis (FEA) and experimental results. Also, the interaction of investigated parameters on friction is analyzed statistically. The friction coefficient was derived by Seifi and Abbasi [5] method.

2- Methodology

In this study shaft and the bush connection are considered, that are widely used in the industry. AISI 4140 steel was used to manufacture shafts. The shaft parts were made using turning operations in two 30 and 15 mm diameters and 30 and 13 mm in length, respectively. For each diameter, two shafts specimens are prepared with an interference diameter of 0.02 mm and 0.03 mm. The inner ring of roller bearings with designation numbers NA6906 and NA4902 are used to create interference joints. The dimensions of these rings are 30 mm and 15 mm for internal diameters, respectively, and 35 mm and 20 mm outer diameters respectively. Bushes dimensions are precise but form defects were observed in the shafts. So, accurate optic scanner was used to extract actual geometry of shafts. In next step, using ABAQUS software, the exact models of the shaft were joined with the perfect cylindrical model of the bush and analyzed for further Finite Element (FE) investigations. In order to apply the material properties in the software, the tensile tests were performed on standard samples made from shaft and bush materials and the properties of the materials were extracted and applied to the software. Also, roughness was measured by a portable device.

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To assemble the joint parts, without damaging the interference surfaces, the shafts were cooled down by liquid Nitrogen and the bushes were heated in an industrial oven, and finally, the parts were assembled without applying external force.

After that, a designed fixture with the universal testing machine was used to extract shafts from bushes and push out forces were measured. These forces are called extraction strength.

Based on the method proposed by Seifi and Abbasi [5] to extract friction coefficient it is necessary to calculate the normal force on the interference surface using finite element analysis. The value of this force can be derived from the following equation:

$$F_N = \int \sigma_r dA \tag{1}$$

Since the amount of extraction strength in the finite element analysis is obtained from the following equation:

$$ES = \mu \times F_N = \mu \int \sigma_r dA \tag{2}$$

By dividing the extraction strength by default friction coefficient, the value of normal force can be obtained. Finite element model for 4 specimens was constructed and extraction strength and normal force were derived from FE model.

3- Results and Discussion

It is clear that by dividing the empirical extraction strength by the FE normal force a new estimation of the friction coefficient will be yielded. This estimation could be corrected through the repetition of FE analysis with improved values of the friction coefficient. The repetition process continues until the convergence to the certain value of friction coefficient. Using this method, four friction coefficients were obtained for samples with different diameters and different interferences. Table 1 illustrated the experimental extraction strength values, the initial finite element extraction strengths, the FE normal force, the pressure at the interference surface and the estimated friction coefficient.

In the next step, using Taguchi method, the effect of interference and diameter on the experimental extraction strength and the friction coefficient of the interference surface can be statistically analyzed.

Table 1. Comparison of numerical and experimental results of extraction strength and estimated friction coefficient of shaft

	Part A	Part C	Part E	Part G
Shaft Diameter(mm)	15	15	30	30
interference value (μm)	15	10	15	10
Experimental Extraction Strength (N)	43733	23329	62228	28279
FE Extraction Strength (N)	11237.42	7472.25	16697.09	10473.94
Normal Force (N)	56187.11	37361.23	83485.44	52369.69
FE Pressure (Mpa)	59.12	30.65	21.09	10.77
Estimated Friction Coefficient	0.775	0.622	0.743	0.538

Zero value of P-values indicates that the selected parameters have a significant effect on the pressures and friction coefficients. Also, the relationship between the diameters and the amount of interference and the extraction strength obtained from the factorial analysis was presented as follows:

$$ES = 9439 - 1632 \times D + 1015613\delta + 192294D\delta \tag{3}$$

Using statistical analysis, the proposed relationship between the amount of friction coefficient and the two parameters of diameter and interference is presented as follows:

$$f = 0.504 - 0.01253D + 20.20\delta + 0.6933D\delta \tag{4}$$

The Eq. (3) were validated by predicting the results of an experimental extraction strength test. The predicted value from the equation for a part with 30 mm diameter and the 20 μm radial interference was equal to 966167.66N, and the experimental result was 91508 N. The relative error of statistical prediction of the experimental test was around 5.09%, which is acceptable.

4- Conclusion

1. Generally, for interference fit joints that have the same surface roughness, it is clear that by increasing the interference, the pressure in the interference surface and the extraction strength will increase. Also, it is concluded that the extraction strength is grown by increasing the diameter of the shaft. On the other hand, it is illustrated that the increase in diameter results in the reduction of friction coefficient. Another important point is that increasing the interference and consequently pressure will result in the friction coefficient growth. Also, it is seen that the variation in the pressure is not as effective as diameters on the variation of friction coefficient.
2. Also, using a factorial analysis, it was clear that the parameters of the radius of the contact surface (diameter) and the pressure (interference) have a significant effect on the friction coefficient and the extraction force.
3. Finally, the results of this study can be summarized in the direct relationship between pressure and friction coefficient at the interference surface of the interference fit joints and, of course, the inverse relationship between radius of the interference surface and the friction coefficient of in the interference surface.

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