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Numerical Simulation of Interference Assembly of Shaft and Sleeve

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***Abstract*— In this paper, the stress and deformation of the sleeve and shaft after interference fit were investigated by finite element model. Effects of interference and sleeve's thickness on the stress and deformation of the sleeve were studied. The results show that the maximum von Mises stress, contact stress, shear stress and deformation of the sleeve appears on the two ends. The contact pressure distribution is W-shape. The maximum von Mises stress of the shaft appears in the center. The maximum von Mises stress, contact stress, shear stress and deformation of the sleeve increase with the increasing of the interference. The maximum contact stress and shear stress increase with the increasing of the wall thickness, but the deformation decreases. With the increasing of the wall thickness, von Mises stress in the middle part of the sleeve decreases, but the stresses on the two ends increase.**

***Index Terms*—interference fit, shaft, sleeve, finite element method, stress.**

I. INTRODUCTION

Interference fit is a one of the most common connection way [1]. It relies on the interference between the containing component and contained component. This connection method has many advantages, such as simple structure, good centering, large bearing capacity, less weaken on the shaft [2]. But the dimensional accuracy of the fit surface should be higher, and the installation and disassembly processes are difficult. Interference fit of shaft and sleeve is the one of the most commonly used artifacts in mechanical structure [3]. Fig.1 shows the schematic diagram of interference fit of shaft and sleeve. In the working status, the interference fit structure has to bear tensile force, compression force, bending moment and torque. If the assembly quality is bad, the interference fit structure is prone to failure with a short service life [4]. So, mechanical behavior of the interference fit structure of shaft and sleeve should be studied. In this paper, the stress and deformation of the sleeve after interference fit were investigated by finite element model. And effects of interference and sleeve's thickness on the stress and deformation of the sleeve were studied.

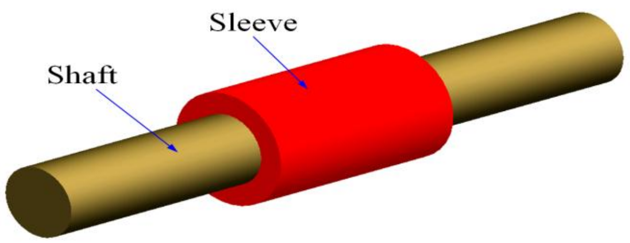

Fig.1 Schematic diagram of interference fit

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II. FINITE ELEMENT MODEL

Considering the symmetry of bearing and structure, the two-dimensional axisymmetric finite element model is established, as shown in Fig.2. The radius of the shaft is 0.15m, length of the shaft is 1.5m. The outer radius of the sleeve is 0.25m, wall thickness is 0.1m and the length is 0.5m. The tetrahedron element mesh is used to mesh the models.

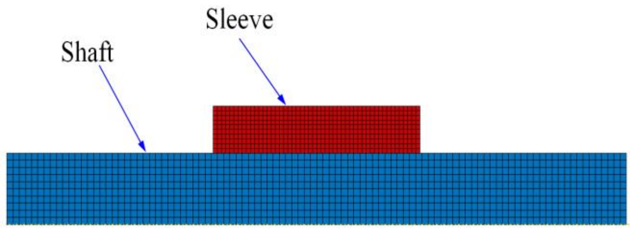

Fig.2 Finite element model

The materials of the shaft and sleeve are the same, and the elasticity modulus is 206GPa, Poisson's ratio is 0.3, and the density is 7800kg/m^3. The fiction coefficient between the outer surface of the shaft and the inner surface of the sleeve is 0.2.

III. SIMULATION RESULTS

When the interference is 0.5mm, the von Mises stresses of the shaft and sleeve are shows in Fig.3. Von Mises stress of the sleeve is bigger than the shaft. The stress of the inner surface of the sleeve is even along the axial direction. But there are two stress concentration phenomenon at both ends. The maximum stress is 660.6MPa. Along the radius direction of the sleeve, the von Mises stress decreases. The maximum von Mises stress of the shaft is not on the outer surface, but it appears in the center of the shaft. It means that there is a singular for the interference fit structure.

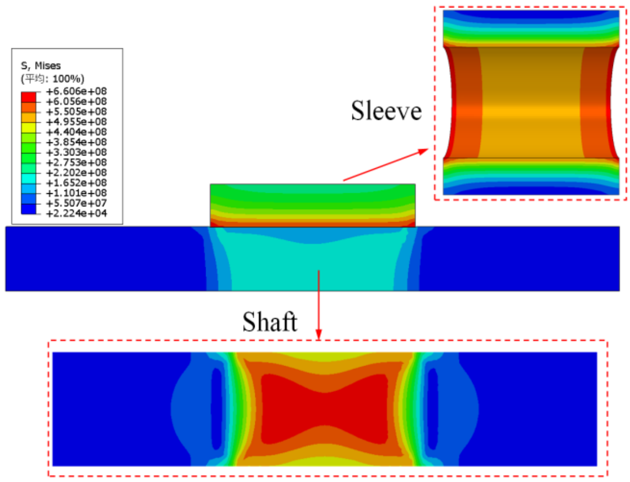

Fig.3 Von Mises stress of the shaft and sleeve

Fig.5 shows the shear stress of the shaft and sleeve after interference fit. The maximum shear stress appears on the two ends of the sleeve and shaft. This is because the dramatic change of geometric structure. Crack is prone to appear on the two locations. Under the action of high frequency load and high load, the crack will further expand, eventually lead to fracture of the shaft.

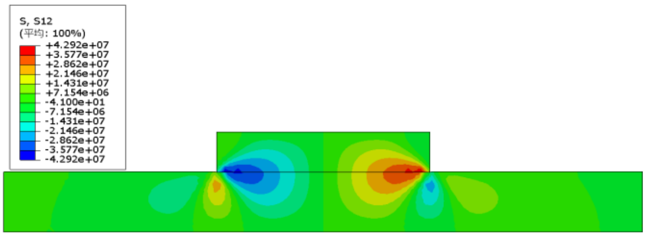

Fig.4 Shear stress of the shaft and sleeve

Fig.5 shows the deformation of the shaft and sleeve. The deformation distribution is symmetrical along the geometric center for the structure symmetry. The maximum deformation of the sleeve are on the two ends.

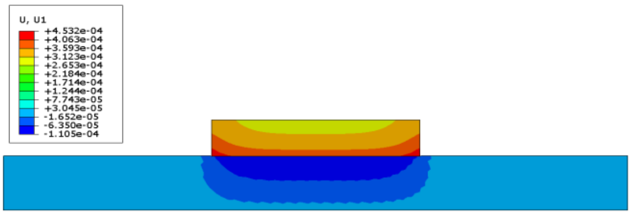

Fig.5 Deformation of the shaft and sleeve

Contact pressure of the shaft and sleeve is one of the important parameters affecting fretting fatigue life. It determines the micro initial contact area, size of the stress field and other parameters. Contact stress distribution of the sleeve is shown in Fig.6. Contact pressure between the sleeve and shaft along the axial distribution is uneven. The contact pressure distribution is W-shape. The stress is big in the end and small in the middle.

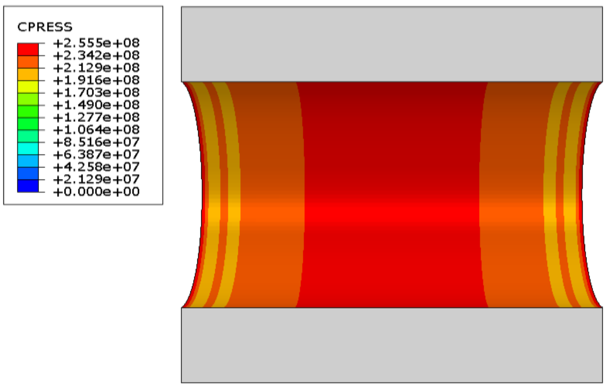

Fig.6 Contact stress distribution of the sleeve

IV. Effect of Interference

Fig.7 shows the von Mises stress of the sleeve under different interferences. Von Mises stress of the sleeve increases with the increasing of the interference. Stress distribution of the middle part is even, but the stress on both end are bigger. So, the stress concentration phenomenon is more serious on the two end of sleeve.

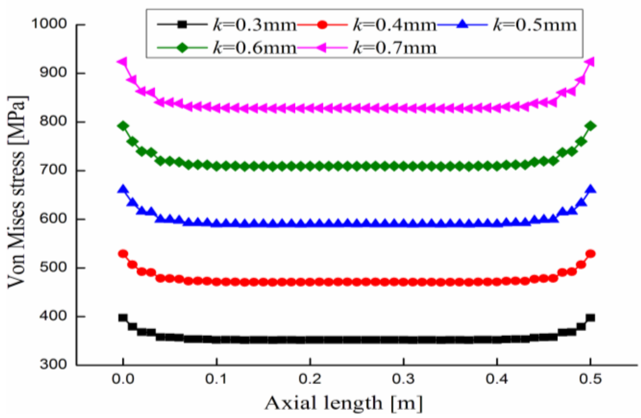

Fig.7 Von Mises stress of the sleeve under different interferences

Fig.8 shows the contact stresses of the sleeve under different interferences. Contact stress distribution of the sleeve under different interferences are similar. The contact stress distribution is W-shape. Contact stress concentration phenomenon appears on the two end of sleeve. The contact stress increases with the increasing of the interference. The bigger the interference, the stress concentration phenomenon is more serious.

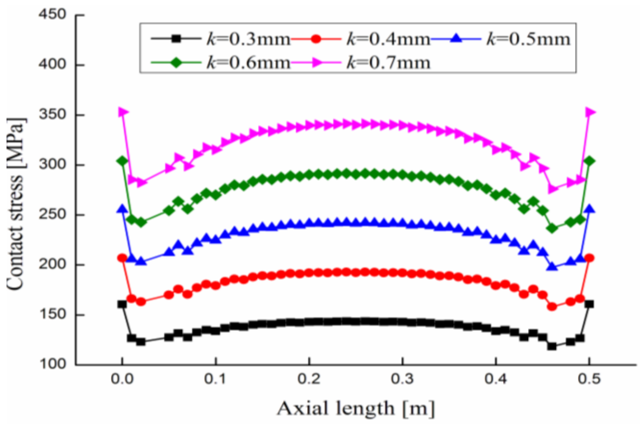

Fig.8 Contact stress of the sleeve under different interferences

Table 1 shows the maximum stress and deformation of the sleeve under different interferences. The maximum von Mises stress, contact stress, shear stress and deformation increase with the increasing of the interference. Therefore, the interference between the shaft and sleeve should be selected. If the interference is too small, the action of interference fit will not occurs. If the interference is too big, the stress concentration phenomenon is serious, and then parts will be damaged.

Table 1 Maximum stress and deformation corresponding to interference

k [mm]	Von Mises stress[MPa]	Contact stress[MPa]	Shear stress[MPa]	Deformation [mm]
0.3	397.5	160.8	23.4	0.271
0.4	529.1	207.1	33.9	0.362
0.5	660.6	255.5	42.9	0.453
0.6	792.2	304.1	51.5	0.544
0.7	923.8	353.0	60.1	0.635

V. EFFECT OF SLEEVE'S THICKNESS

Wall thickness of the sleeve affects the interference fit of the shaft and sleeve. Fig.9 shows the von Mises stress of the sleeve under different wall thicknesses. Von Mises stress in the middle part of the sleeve decreases with the increasing of the wall thickness. But von Mises stress on the two ends of the sleeve increase with the increasing of the wall thickness. So, the stress concentration phenomenon is more serious when the wall thickness is bigger.

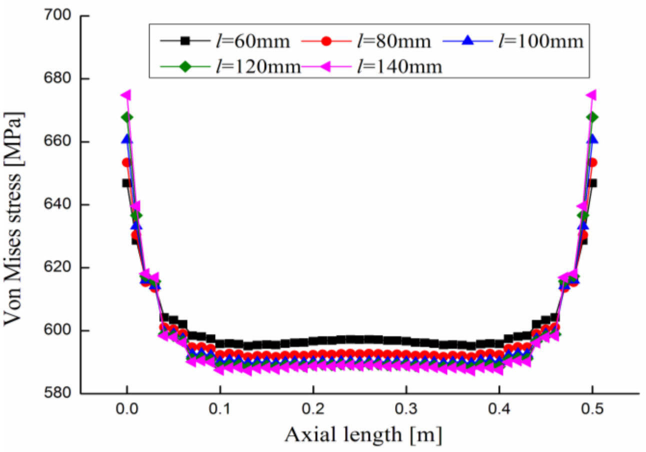

Fig.9 Von Mises stress of the sleeve under different thicknesses

Fig.10 shows the contact stresses of the sleeve under different wall thickness. Contact stress distribution of the sleeve under different wall thicknesses are similar. The contact stress distribution is W-shape. Contact stress concentration phenomenon appears on the two end of sleeve. The contact stress increases with the increasing of the wall thickness, but the change rate decreases.

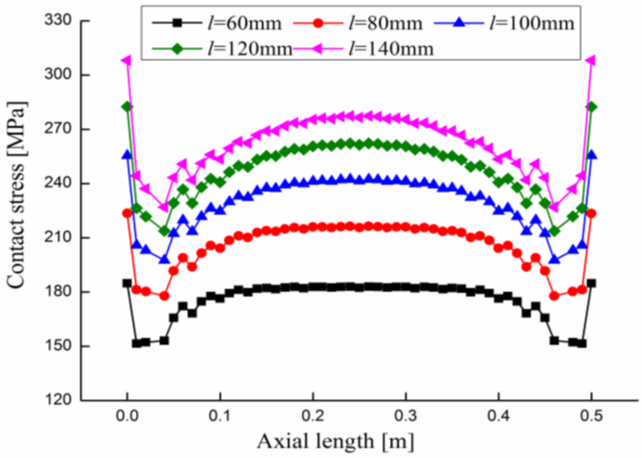

Fig.10 Contact stress of the sleeve under different thicknesses

Table 2 shows the maximum stress and deformation of the sleeve under different wall thicknesses. The maximum von Mises stress, contact stress and shear stress increase with the increasing of the wall thickness. But the deformation of the sleeve decreases with the increasing of the wall thickness. Therefore, if the wall thickness is too big, the stress concentration phenomenon is serious, and then parts will be damaged.

Table 2 Maximum stress and deformation corresponding to thickness

l [mm]	Von Mises stress[MPa]	Contact stress[MPa]	Shear stress[MPa]	Deformation [mm]
60	646.8	184.9	31.64	0.465
80	653.4	223.5	37.79	0.459
100	660.6	255.5	42.92	0.453
120	667.8	282.5	46.49	0.449
140	674.8	308.1	47.72	0.444

VI. CONCLUSION

(1) For the interference fit structure of the shaft and sleeve, von Mises stress of the sleeve is bigger than the shaft. The maximum von Mises stress, contact stress, shear stress and deformation of the sleeve appears on the two ends. The contact pressure distribution is W-shape. The maximum von Mises stress of the shaft is not on the outer surface, but it appears in the center of the shaft.

(2) The maximum von Mises stress, contact stress, shear stress and deformation of the sleeve increase with the increasing of the interference. Von Mises stress in the middle part of the sleeve decreases with the increasing of the wall thickness, while the von Mises stress on the two ends of the sleeve increase. The maximum contact stress and shear stress increase with the increasing of the wall thickness. But the deformation of the sleeve decreases with the increasing of the wall thickness.

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