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Finite Element Simulation Analysis of Double Nosing Process in the Assembly of Spherical Plain Bearings

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ABRACT: *For spherical bearings, the osculation between inner and outer ring may be too big, too small or uneven after extrusion assembly. Based on the finite element software ABAQUS, according to the actual assembly situation of GE40 series of spherical plain bearings, the two-dimensional axisymmetric elasto-plastic finite element mode is built.. During the research of bearings extrusion deformation process, flow law of metal plastic forming will be concluded, meanwhile the contact stress distribution between the inner and the outer rings. During the research of bearings springback process, osculation will be obtained.*

Keywords: *spherical plain bearings; double nosing; finite element simulation*

I. INTRODUCTION

Spherical plain Bearings consists three main components: inner ring, outer ring and liner. The liner will produce transform film during the bearing motion which can reduce the friction between the inner and outer rings. It is widely used in aerospace, water conservancy and other engineering fields due to the advantages such as higher bearings capacity, higher wear resistance and higher security and reliability, and particularly suitable for applications in aviation, aerospace and other engineering fields where loads are heavy and sliding speeds are relatively slow[1]. For a self-lubricating spherical plain bearing the most important quality indexes are bearing osculation between spherical inner surface of the outer ring and outer surface of the inner ring and the pressure distribution on the liner, which can be used to identify the bearing's application in practical and greatly affect its service life.

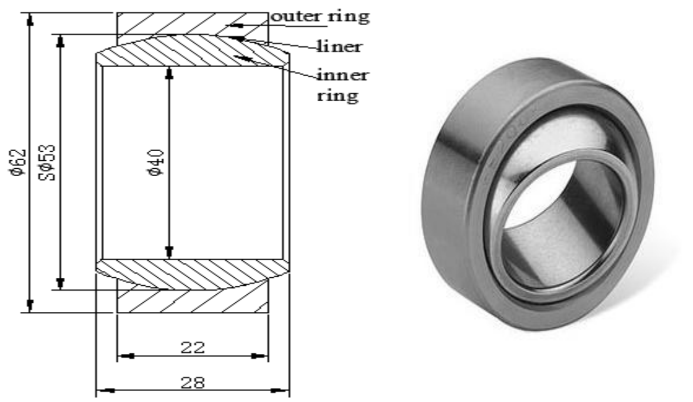


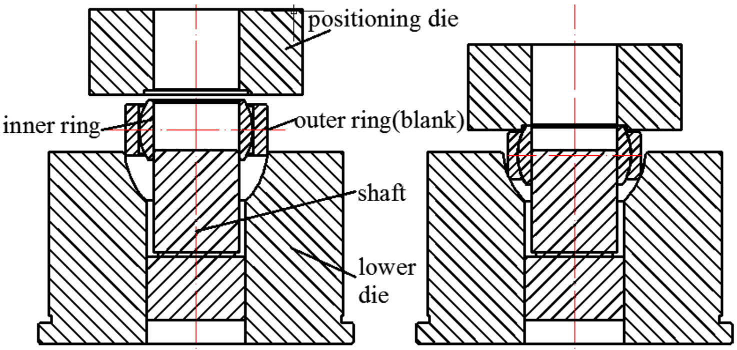
Fig.1 Schematic of spherical plain bearings

II. THE BASIC ASSUMPTIONS AND PRINCIPLES

Spherical plain bearings extrusion assembly process is a complex large elastic-plastic deformation process, the process involves material nonlinearity, geometric nonlinearity and contact nonlinear problem. It is assumed that the material properties and the elastic-plastic deformation process meet the demand of Von Misses yield criterion and Coulomb law of friction. In the elastic stage, stress and strain conform to the Hooke's law. When plastic deformation occurs, stress and strain conform to the Prandtl-Reuss hypothesis.

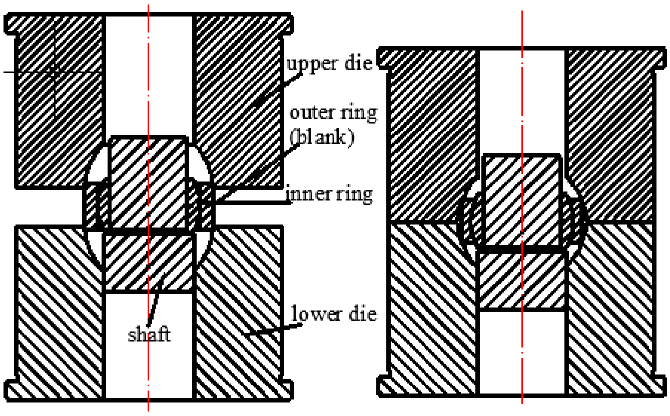
III. THE PRINCIPLES OF BEARINGS EXTRUSION ASSEMBLY

One-way neck forming process is used prior to extrusion assembly to ensure bearing outer ring on the symmetry of the inner ring cross section in the middle is 0.05. In paper[2], Yulin Yang studied the one-way neck forming process for spherical plain bearing and optimum of the necking force in detail. The components of the bearing with outer ring position adjusted are extrusion assembled via double nosing process. In Fig.3, it can be seen that bearing is sandwiched between the upper and lower dies. Under the extrusion process, lower die is fixed, upper die move downward at a certain speed. Upper and lower dies extrude the outer ring together while the inner ring is attached to shaft to keep its translation. After double nosing, outer ring and liner are both shaped to have spherical inner face as designed.



(a)before location **(b)after location**

Fig.2 Schematic of one-way neck forming process



(a)before extrusion **(b)after extrusion**

Fig.3 Schematic of double nosing process

IV. THE MATERIAL PROPERTIES

The effect of liner on the forming process can be ignored because of the material anisotropy and little impact on extrusion process[3].

The material of outer ring is 0Cr17NiCu4Nb meanwhile the material of inner ring is G95Cr18. 0Cr17NiCu4Nb is Martensitic precipitation hardening stainless steel meanwhile G95Cr18 is bearings stainless steel. The material properties of 0Cr17NiCu4Nb and G95Cr18 for the outer and inner rings are shown in Table 1, respectively. The characteristic of 0Cr17NiCu4Nb is that it is easy to adjust the strength level by changes in heat treatment process. Martensite phase transformation and aging treatment of metal forming precipitation hardening phase is the main reinforcement method. The normal stress and strain are obtained by tensile test in lab. The normal stress and strain must be converted to real stress and strain.

Table 1 Material properties

property	G95Cr18	0Cr17NiCu4Nb
Young's modulus (GPa)	210	210
Poisson's ratio	0.3	0.27
Density(Kg/m^3)	7700	7780
Yield strength (MPa)	685	665
Tensile strength (MPa)	885	930

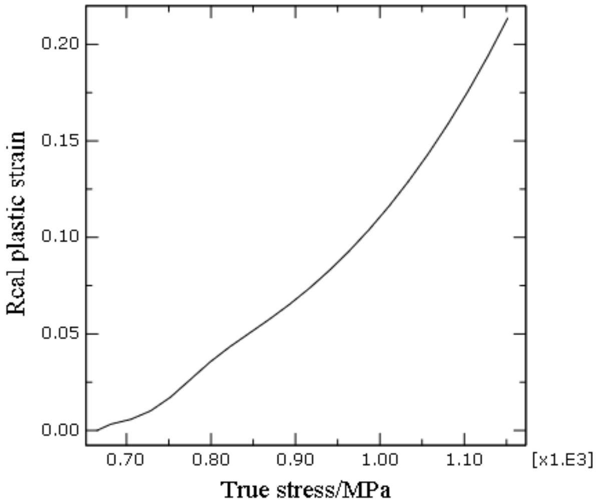


Fig.4 true stress-strain curve

V. THE INFINITE ELEMENT SIMULATION OF THE ASSEMBLY PROCESS

In paper [4], two-dimensional axisymmetric model and three-dimensional model are used respectively, to simulate the extrusion forming and it is concluded that the difference of simulation results is less than 1%.

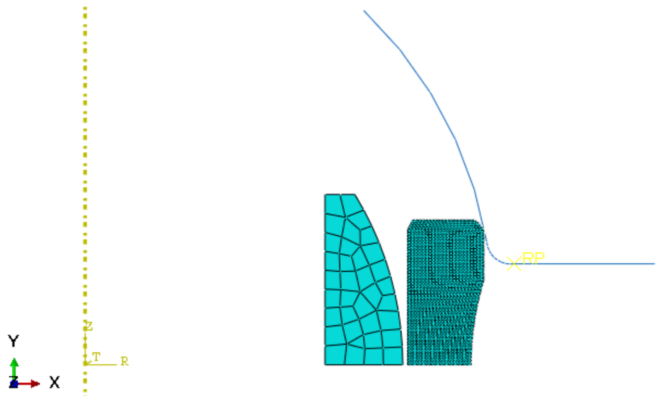


Fig.5 The finite element model of extrusion assembly(shaft hidden)

Two steps are built in this simulation: the extrusion deformation process with upper die, the springback process without upper die. The extrusion assembly of inner and outer rings is analyzed by explicit solver, and the springback process is analyzed by standard solver. The two-dimensional axisymmetric model is built as shown in Fig.5. Explicit solver is used for analysis of extrusion assembly simulation, meanwhile standard solver is used for analysis of springback simulation.

In the whole simulation, upper and lower dies are defined as analytical rigid bodies, while inner ring is defined as elastic deformable body with outer ring defined as elastic-plastic body. To save the CPU computing time in the FEA simulation, the following process parameters are used in Table 2 from the starting state that the upper die touches the blank to the final state that the upper die conforms to the shape of inner ring.

Table 2 The parameters of extrusion process

	mode 1	mode 2	mode 3	mode 4
upper die velocity(mm/s)	33.2	16.6	8.3	4.15
extrusion time(s)	0.5	1	2	4
die displacement(mm)	16.6	16.6	16.6	16.6

Contact definition

According to the actual motion of the bearings during the extrusion assembly process, two contact pairs are built in the simulation. One is between upper die inner surface and outer ring outer surface, the other is between outer ring inner surface and inner ring outer sphere. Contact type meets the coulomb's law of friction:

$$\tau_f = \mu \tau_n \quad (1)$$

Where τ_f is the friction, τ_n is the normal contact stress, μ is the coefficient of friction. The value of μ is set as 0.1 according to the paper [4]. A finite sliding formulation was preferred to a small sliding one for modelling friction. In Abaqus, the penalty method is a version of the Coulomb model in which a small sliding one for modelling friction.

Meshing

Upper die is not meshed due to analytical rigid component. Outer ring involves larger plastic deformation, so ALE adaptive mesh technique is utilized. In order to prevent the penetration between inner and outer rings, the number of outer ring elements must be much larger than the inner ring's. The chosen element family is Explicit axisymmetric stress from which the linear Quad elements of first-order accuracy are selected. The elements type of inner ring and outer ring is 4-node bilinear axisymmetric quadrilateral, reduced integration, hourglass control(CAX4R). The number of elements on inner ring is 35 while the number of elements on outer ring is 1099.

VI. THE ANALYSIS OF THE RESULT

The difference is not obvious on the stress and strain after extrusion，but is obvious on the extrusion force in y axial direction. The extrusion force in y axial direction of four modes between die and blank, between rings are all shown in the Fig 6. Due to uneven deformation in the loading process, in the beginning incremental steps, most of the outer ring is still in the stage of elastic deformation, so the curve drops slowly. Since extrusion pressure is small, the friction has small effects on metal flow, and the ripple of curve is small. As the upper die presses, material of blank is expected to gradually enter a state of compression, more and more material are in plastic deformation. The extrusion force increase rapidly, the pressure of blank also increases, the biggest extrusion force between die and blank, between rings in y axial direction is 716200N and 336300N respectively in mode 4 which whole extrusion time is 4s.

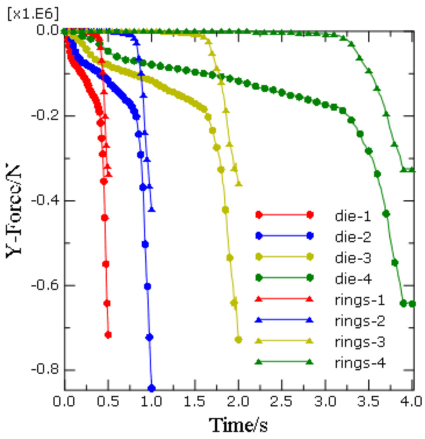


Fig.6 The curve of extrusion force in y axial direction

After the extrusion, from the middle to the top of the outer ring, the normal contact stress distribution between the inner and outer rings are shown in Fig.7. The figure shows that the contact stress of different location is different. Under the influence of die extrusion, contact stress is larger near the top of the outer ring. The longer the die extrudes the outer ring, the smaller the fluctuations of the curve is. It demonstrates that the extrusion of most of the outer ring is uniform when the whole extrusion time is long.

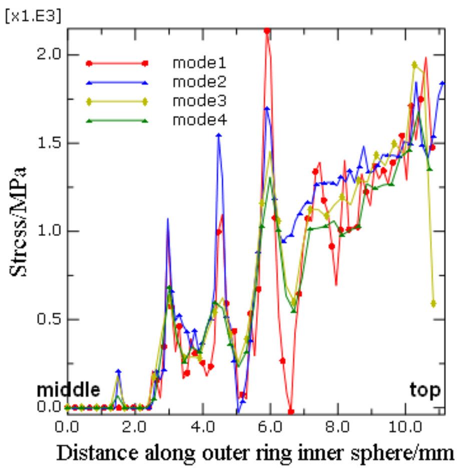


Fig.7 The curve of normal contact stress distribution

The difference of Von misses equivalent stress of inner and outer rings in the four modes stated above is very small, and the difference of the equivalent plastic deformation is also small, so is the difference of the outer ring Von misses equivalent stress after springback. Because there is no failure and stress concentration, stress and strain after extrusion, stress and strain after springback have no effect on judging the bearing extrusion methods, but have an impact on the optimization design of the shape, size and surface roughness of extrusion die. The Von misses equivalent stress of inner and outer rings after extrusion in mode 4 is shown in Fig.8 where the maximum is 1150MPa.The equivalent plastic strain after extrusion in mode 4 is shown in Fig.9 where the maximum is 0.2849. The Von misses equivalent stress after springback in mode 4 is shown in Fig.10 where the maximum is 668MPa.

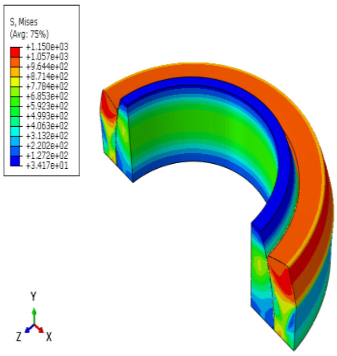


Fig.8 Von misses equivalent stress after extrusion

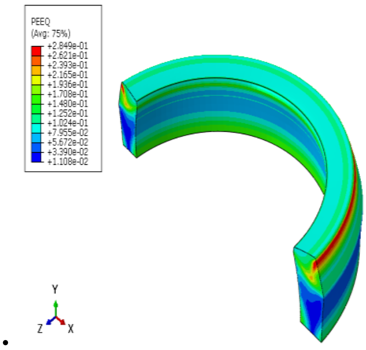


Fig 9 The equivalent plastic strain

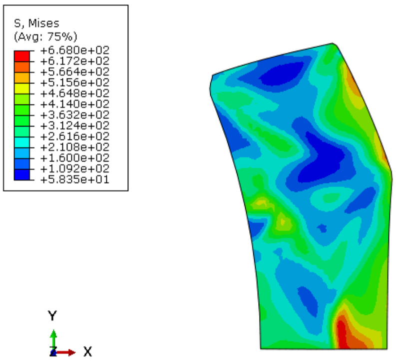


Fig.10 The Von misses equivalent stress after springback

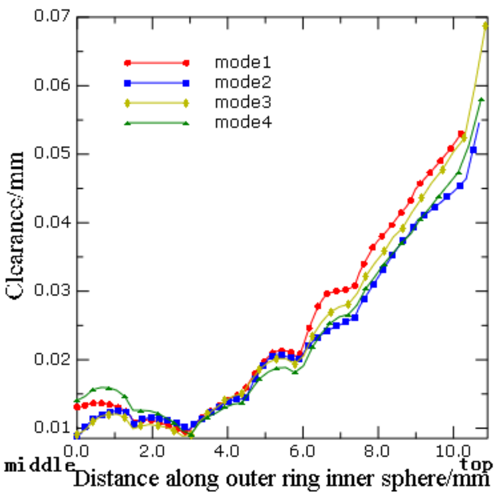


Fig.11 The normal clearance

In the assembly process, the outer ring metal deformation is composed of plastic deformation and elastic deformation. After removal of the die, plastic deformation survives, and elastic deformation completely disappear. In this process, the outside of the outer ring shortens due to elastic recovery while the inner side elongates. Because the elastic deformation on both ends of outer ring is large than the central, the springback amount is also bigger. The normal clearance distribution based on outer ring inner sphere after springback between rings is shown in figure.11. From the Fig.11. ,it can be seen that clearance of different position is different meanwhile the clearance in same position in four modes varies widely. The difference of maximum clearance and minimum changes a lot in 4 extrusion modes due to the extrusion time and speed. The difference of maximum and minimum clearances in 4 modes is 0.04343, 0.04583, 0.05970, 0.04896 respectively. The figure shows that on both ends of the outer ring the clearance is bigger while the minimum clearance appears in the middle. The difference in mode 4 is not the smallest, but the clearance distribution is the most uniform. This will be good for the lubrication film production between inner rings outer sphere and liner inner surface.

VII. CONCLUSION

The product in mode 4 is the best from the difference of clearance, according to the [5], the die extrusion bearing is qualified product which conforms to the actual production requirements. The clearance distribution can be uniform by subsequent turning and rolling. From the force distribution and the normal contact stress distribution, the extrusion product is not optimal, but also by optimizing the mold shape, friction between the contact surfaces can be reduced and friction effects on plastic forming can be weakened.

VIII. ACKNOWLEDGEMENT

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REFERENCE

[1] Xiumei Wang, Shaowei Lv, Chunhui Yang. Numerical investigation on press forming of self-lubricating spherical plain bearings. *International Journal of Materials and Technology, 47*,2013, 46-62

[2] Yulin Yang, Shijun Huang, Chunrong Ma.Study on new neck forming process for spherical plain bearing and optimum of the necking force. *2010 WASE International Conference on Information Engineering,229*,2010, 216-219.

[3] Lianping Wu, Xiaoxiang Yang,. Finite simulation analysis of cold extrusion assembly for spherical plain bearings. *Bearing. 7,* 2014,18-21.

[4] Alex Orsolini, Julian D Booker. Modelling capabilities required for the double nosing process in the assembly of spherical plain bearings. *Journal of Engineering Manufacture, 226(5)*,2012,930-940

[5] American National Standards Institute (ANSI) (2001) SAE AS 81819-2001: Bearing, Plain (Self-Aligning, Sleeve and Thrust), Self-Lubricating, High Speed Oscillation, General Specification for, USA.