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RESEARCH ON COLD ROLLING OF 41Cr4/20NiCrMo7 BIMETAL COMPOSITE BEARING RING

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In order to improve the service life of bearing rings, a new method of cold rolling bimetal composite bearing rings was proposed in this paper.With Abaqus software,a finite element simulation model of the cold rolling of bimetal composite bearing rings was established. The law of the radial stress distribution, the diameter growth and the deformation of plastic zone during the cold rolling of bimetal composite bearing rings were analyzed. The results of these analyzes are helpful to study the deformation characteristics of the cold rolling of bimetal composite bearing rings. The results show that the bimetal composite bearing ring interface is well bonded and no segregation occurs during the process of cold rolling.

Key words: cold rolling, alloy steels,bearing ring,bimetal composite, finite element simulation

Bearing as the most basic and widely used parts in equipment manufacturing industry, the reliability of its quality and service life will directly impact on the safety and the use of machine.At present,high-chromium bearing steel, with high hardness,good wear resistance and lack of toughness, is the most commonly used material of bearing rings. It is easy to break the bearing ring during high load and high impact, and seriously threaten equipment safety.

In order to solve the problem that is single material of the bearing rings cannot meet the practical application ,the performance requirements of different materials in different working parts of the bearing rings were analysed, then materials were targeted. Using tough, impact-resistant 20NiCrMo7 carburizing bearing steel as the rolling surface of bearing ring, and high strength, good processing properties 41Cr4 as substrate material, these two materials was combined as bimetal composite. Then use cold rolling forming process, which is a unique no metal fiber cutting forming process, to form bimetallic composite bearing rings. This innovative research has great significance in improving the reliability and service life of the bearing rings.

A lot of research has been done, which were based on the performance advantages in the bimetallic composite materials. G. X. Huang, W. F. Peng et al. analyzed 42CrMo / Q235 laminated shaft cross-wedge-rolling forming and found that the existence of different materials laminated shaft interface [1]. CG Kang et al.verified the pull-forming of Al / Cu laminated rods by finite element simulation and experiments [2]. Ahmet Durgutlu et al. explored the microstructure and mechanical properties of Cu / stainless steel composites by explosive compound [3].

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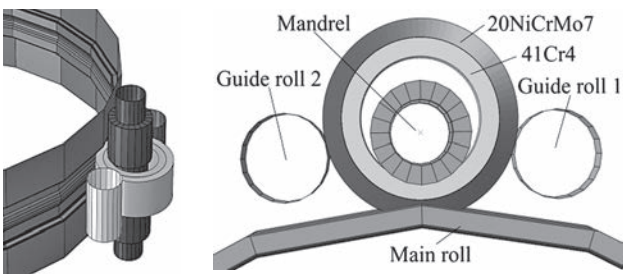
Establishment of cold rolling finite element model

Cold rolling technology with its high utilization of materials, good forming quality, high efficiency, etc., has gradually become the main method of production of bearing rings [4]. The bimetallic composite bearing rings finite element model was established by ABAQUS software as shown in Figure 1.

The biggest difference between different types of materials cold rolling model and the other models is that the blank is made of two kinds of materials, The grid of the substrate and cladding materials were divided, which was selected as C3D8R (hexahedral reduction grid). As the cold ring rolling is a large deformation process and easy to produce grid distortion to reduce the accuracy of calculation or even non-convergence, thus adaptive grid technology (ALE) was used to reduce grid distortion in this paper. Main parameters of Finite element simulation were set as shown in Table 1.



(a) Axonometric drawing (b) Top view

Figure 1 cold rolling Finite element model

Table 1 Main process parameters

Parameter	Value
Rotation speed of main roller	21rad/s
Feed speed of mandrel roller	0,6mm/s
Mass Scale factor	50
Friction coefficient	0,35

Research on law of radial stress

The process of cold rolling of bimetallic deep groove ball bearing ring is nonlinear and complicated three-dimensional elastic-plastic deformation. The forming process is mainly divided into three stages: a) the stage of biting compression; b)the stage of stable rolling; c) stage of entire round. The ring is profiled perpendicular to the Z axis in the Abaqus software aftertreatment module. The stress field distribution at different stages of the profile between the driving roller and the core roll gap was obtained. The radial stress distribution cloud chart of compression and deformation stage, steady rolling stage and the entire round stage as shown in Figure 2 (a), (b) and (c).

As shown in Figure 2(a), the ring is in compressive deformation stage, the contact area between the blank and the mold is compressive stress, and the extreme value appears in the contact area between the cladding material and the driving roller groove ball, and the value is -1,24GPa. At the end of the blank, there is obvious stress difference between the substrate and the cladding material, and the compressive stress of the substrate is obviously larger than that of the cladding material. From Figure 2(b) and Figure 2(c), it can be seen that as

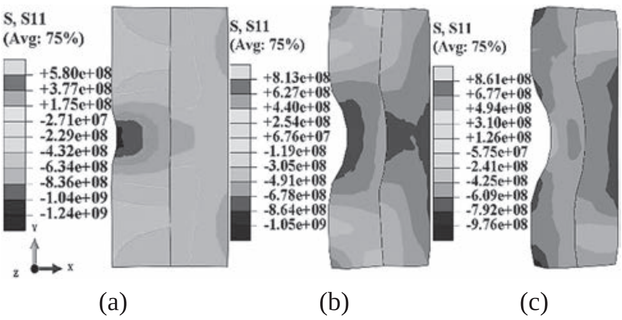


Figure 2 Radial stress distribution at different rolling stages

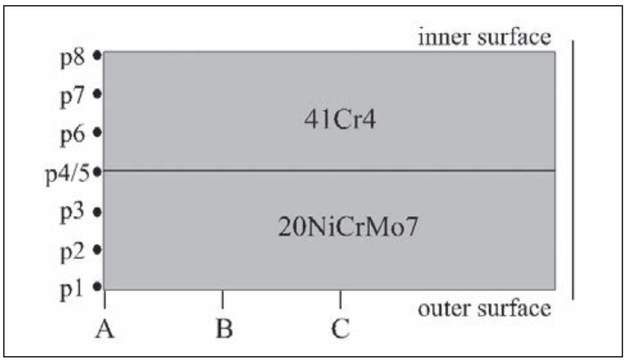


Figure 3 Node selection diagram

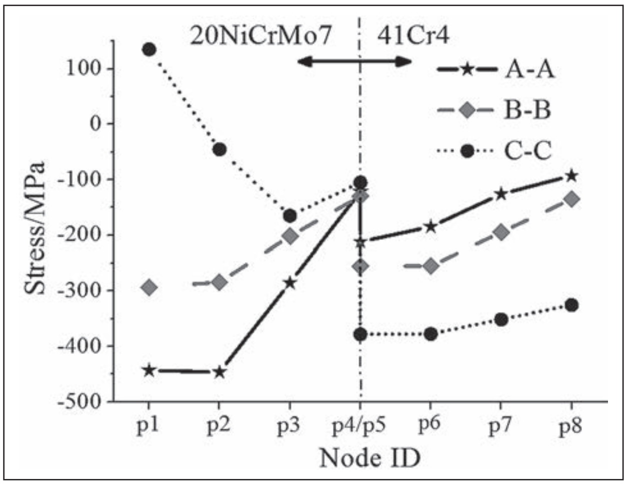


Figure 4 Radial stress distribution of nodes with different sections

the cold rolling progresses, the wall thickness of the ring decreases and the compressive stress area becomes larger and the overall stress distribution becomes more uniform. The stress at the interface between the substrate and the cladding distribute discontinuous. It shows that in the whole process of cold rolling, although the interface between the ring base material and the cladding material hinders the transmission of stress, the overall distribution is compressive stress, and the substrate compressive stress value is greater than the cladding material, these indicating that the interface does not occur detached.

As shown in Figure 3, three sections A, B and C are selected along the axial direction of the blank, and eight tracing points (P4 and P5 are selected at the interface) are equally spaced along cross-section,in order to further analyze the stress distribution.

As shown in Figure 4, single material layer of section A and B, the compressive stress value decreases along the radial direction. In the outer material, the stress of A section is larger than the B section, whereas in the inner lining material the stress in the outer layer is less than the B section. In the C section, along the radial direction, the stress decreases from the tensile stress until the P2 point becomes the compressive strain, then the general trend is the same as the A, B section.

The closer the cross-section of the substrate to the end surface is, the smaller the compressive stress value is and the closer the node to the driving roller is, the larger the stress value is. The regularity of section A and B is the same, but there is no obvious regularity in section C, which coursed by the uneven force since the driving roller groove ball only contacts with the cladding material at the beginning of rolling, the mandrel roller is in contact with the whole substrate.In the overall ring, except the P1 node in C section for the tensile stress, the rest of the track point radial stress are compressive stress. When compressive stress is present at the interface, it is beneficial to increase the bonding strength of the bimetallic composite interface.

Study on the regularity of ring diameter growth

In the forming process of bimetallic composite, assume the substrate and cladding material as two independent rings in rolling process, and ignore the axial width in the ring rolling, with the same volume principle of plastic deformation, the following formula can get:

$$\frac{\pi}{4}(D_0-d_0)^2=\frac{\pi}{4}(D-d)^2 \tag{1}$$

$$d = D - 2H \tag{2}$$

$$d_0 = D_0 - H_0 \tag{3}$$

The simultaneous equations 1,2,3 give:

$$D=\frac{D_0+d_0}{2}\frac{H_0}{H}+H \tag{4}$$

$$d=\frac{D_0+d_0}{2}\frac{H_0}{H}-H \tag{5}$$

$$H = H_0 - Vt \tag{6}$$

On the formula 4 and 5 on the derivation of time, ring diameter expansion rate can be obtained:

$$V_D=(\frac{D_0+d_0}{2}\frac{H_0}{H^2}-1)V \tag{7}$$

$$V_d=(\frac{D_0+d_0}{2}\frac{H_0}{H^2}+1)V \tag{8}$$

When the feed rate of the coring roller is 0,6mm/s, the outer diameter of the cladding is 31,5mm, the inner diameter is 25,5 mm, the outer diameter of the substrate is 25,5 mm and the inner diameter is 19,5 mm. Substituting these into equations 4, 5 and 6, the relationship between the outside diameter of the substrate material and the inside diameter of the cladding material with respect to time can be drawn, as shown in Figure 5.

From Figure 5, during the rolling process of the bimetallic composite ring, the inner diameter of cladding material expanded faster than the outer diameter of the substrate, and the inner diameter of the cladding material and the initial diameter of the outer diameter of the substrate were always synchronized during the actual rolling process. This indicates that the outer ring of the substrate has been closely adhered to the inner ring of the cladding material during the cold rolling of the bimetallic composite and exerts a certain pressure on it. This is advantageous for the rolling.

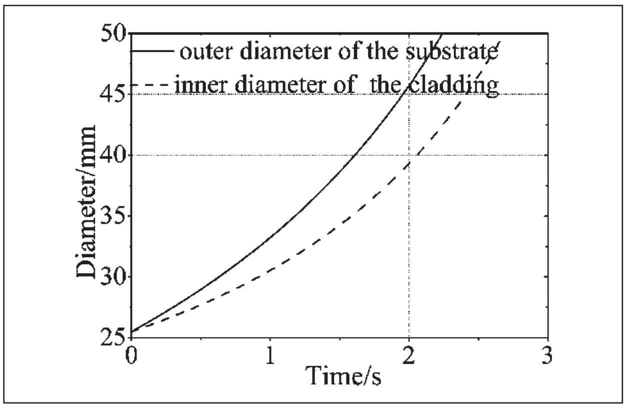


Figure 5 Contrast of diameter growth

Research on law of rolling deformation

The cold rolling of ring is asynchronous rolling. The deformation zone is always located in a gap localized area between the drive roller and the mandrel roller during the forming of the ring, alternating with the rotation of the ring. Circumferential elongation of material in the deformation zone will cause uneven stress and strain of the whole ring. And this uneven stress and strain will form a plastic hinge at the opposite end of the deformation zone [5].

The emerge of plastic hinges will bring_an effect on the ring rolling process. The appearance of plastic hinge makes the ring become oval. which easy to make the two layers of material separation near the plastic hinge area.

Fourteen node were equidistant selected along the axial in interface which was shown in Figure 6 as the abscissa, and the radial stress steady rolling stage as the vertical axis. The stress distribution diagram shown in Figure 7. It can be seen from the figures that the overall trend of the cladding material and the substrate in the two zones is the same, but the magnitude of the stress in the deformation zone is obviously larger than that in the plastic hinge. This is due to the cladding material contact with the drive roller and the substrate contact with the mandrel roller in the deformation zone, the stress is mainly concentrated in the deformation zone.

Compare Figures7(a) and 7(b).It can be found when the substrate is under compressive stress, the cladding

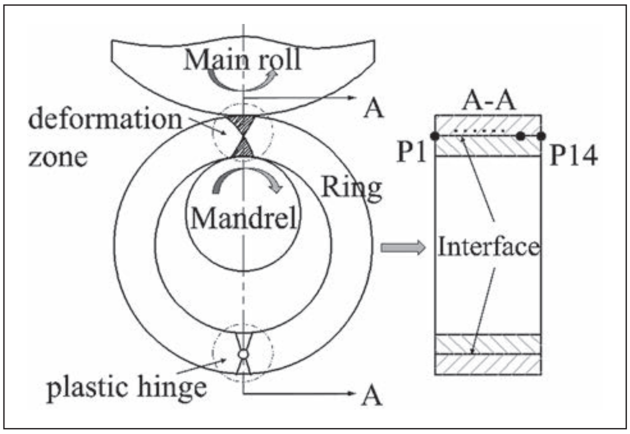
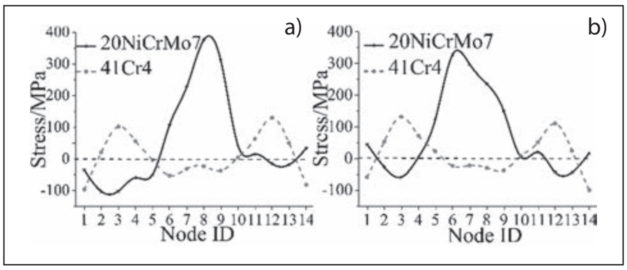


Figure 6 The distribution of deformation zone of cold ring rolling



(a) deformation zone (b) plastic hinge

Figure 7 Interface surface node stress distribution material is tensile strain by comparing the stress distribution between the cladding material and the substrate material.And the stress difference between the cladding material and the substrate is the largest at node 5 to node 9 which is the contact area between the ring cladding and the driving roller groove ball, and also it's the biggest deformation area. Therefore, the strain force of cladding material is larger, while the substrate stress is smaller, it shows that the bonding of interface between substrate and cladding material is good.

CONCLUSIONS

(1) In the process of ring cold rolling,the Ring is subjected to compressive stress in the deformation zone.which is conducive to increasing the bonding strength of the bimetallic composite interface.

(2) During the entire process of ring cold rolling, the diameter expansion rate of outer ring of substrate is always greater than the inner ring of cladding diameter. The bimetallic composite ring cold rolling was ensured progresses smoothly from the forming mechanism.

(3) The stress distribution diagram of deformation zone and plastic hinge region is compared. It can be found that the overall stress tendency of plastic hinge is similar to the deformation zone by comparing the stress distribution between deformation zone and plastic hinge, and the interface of the cladding material is mainly compressive stress, which indicates that in the whole area of the cold rolling of bimetallic composite bearing ring will not appear interface detachment.

Acknowledgements

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Note: The responsible translator for the English language is Q. Q. Yan, Ningbo, China