Design and optimization of billet structure about High-speed Rail bearing in cold rolling

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Abstract: Bearing is one of the key parts in high-speed trains. To achieve the high-precision forming of outer ring in bearing for high trail, the paper analyses the sections of the outer ring and deduces the calculating formula for the volume. All of that is based on the basic theory of cold rolling and the principle of volume conversation by the application of the finite element software ABAQUS. According that, the paper designs four typical structure of blank of the outer ring in bearing and then analyses their defects and causing reasons in the process of cold rolling between different structure. Through the analysis, the paper eventually gets the best size of the symmetric blank about outer ring, which lays the theoretical foundation of implementing the high-precision forming of outer ring in bearing for high trail.

Keywords: cold rolling; High-speed Rail bearings; bearing blank; forming quality

1. Introduction

High-speed rail bearing is the key components of high-speed train in running mechanism and is the key material in the construction of the high-speed train. It supports the static and dynamic radial load from the train weight and vehicle load. Besides, it bears the additional unsteady force in axle direction[1-3]. Thus Its reliability has a great affect on the security of train operation.

The rational blank structure will directly determine the quality of high-speed rail and rolling stability of the cold forming[]4-5.Currently the working method for blank from experience not only has the high cost of production, and a long preparation time, but also can not get the Goods in high-precision. Thus structural design of the blank has important theoretical significance and applicable value for the study of parameters in cold rolling process. Based on the principle of constant volume, the paper simulate the rolling process of the billet in four different structures to get the best structure for the bear outer in the high-speed rail through the finite element software ABAQUS.

2 the structural design of blank and the set of program

The diameter of closed hole, formed by the driving roller and core roll in the cold rolling process, gradually expanded. So the unformed piece can be regarded as blank and the optimal shape is various. The outer ring in high-rail bear is symmetry in the axial direction, its size is shown in Fig.1
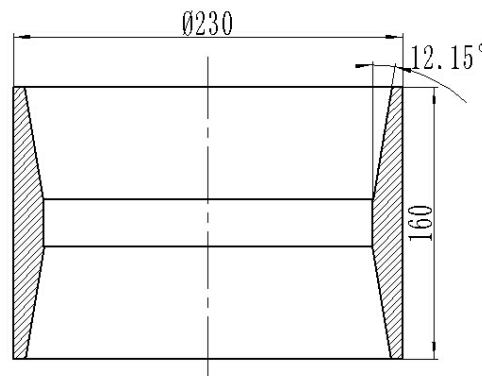

Figure.1 High-Speed Rail bearing outer ring structure size

Thus this paper uses the half model as shown in Fig.2.

$$V_{\text{out er}} = \pi(\frac{R}{2})^2 B_1 - \frac{1}{3}\pi B_2(r_1^2 + r_2^2 + r_1 r_2) - \pi r_2^2 B_3 \tag{1}$$

It can be obtained by the Pythagorean theorem from Eq.(1) that

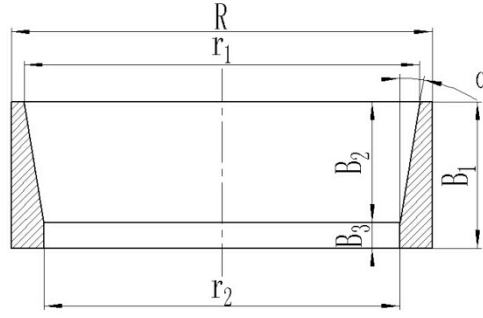$$r_1 = r_2 + \tan\alpha\, B_2 \tag{2}$$

Figure.2 Symmetrical structure size

We can obtain the Eq.(3) from simplify the Eq. (1) and Eq.(2)

$$V_{outer} = \frac{1}{4}\pi R B_1 - \frac{1}{3}\pi B_2 (3r_2^2 + 3r_2 \tan\alpha B_2 + \tan^2\alpha B_2^2) - \pi r_2^2 B_3 \qquad (3)$$

Where R is the outer diameter of the outer ring; B_1 is the width of the outer ring; B_2 is the vertical width of the cant; B_3 is the width of the vertical surface; r_1 is the radius of the up surface; r_2 is the radius of the bottom surface and α is the bevel angle.

It can be obtained from the principle of constant volume

$$V_{outer} = V_{blank} \qquad (4)$$

$$V_{blank} = \frac{1}{4}\pi R B_1 - \frac{1}{3}\pi B_2 (3r_2^2 + 3r_2 \tan\alpha B_2 + \tan^2\alpha B_2^2) - \pi r_2^2 B_3 \qquad (5)$$

Based on the analysis and principle, the paper designs four kinds structural shapes of blank to analyze and compare the finite element simulation of cold rolling about the outer ring of the high-speed rail bear.

The designed options of the blank are as follows:

Option one: the cross-section of blank is rectangular, whose the biggest advantage is convenient to machine and saving the cost. The paper ultimately draw the structure of option one, which is shown in the Fig.3.
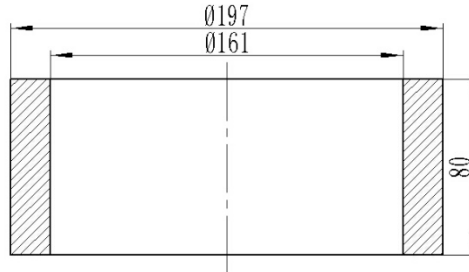

Figure.3 Rectangular section blank

Option two and option three: the cross-sections of blank are both half-cone bevel. According to principle of constant volume and actual production experience, the upper part of the pre-formed of option two is the finished oblique cone, while the taper of option three is different with the finished oblique cone, where the rolling force makes the internal metal flow downward to complete the cold rolling. The structure of option two and option three are separately shown in Fig.4 and Fig.5.

Option four: the cross-section of the blank is identical for finished structure. During the cold rolling, the shape of cross-section don't change while the diameter of the outer ring increases because of the rolling force. The structure of option four is shown in Fig.6.
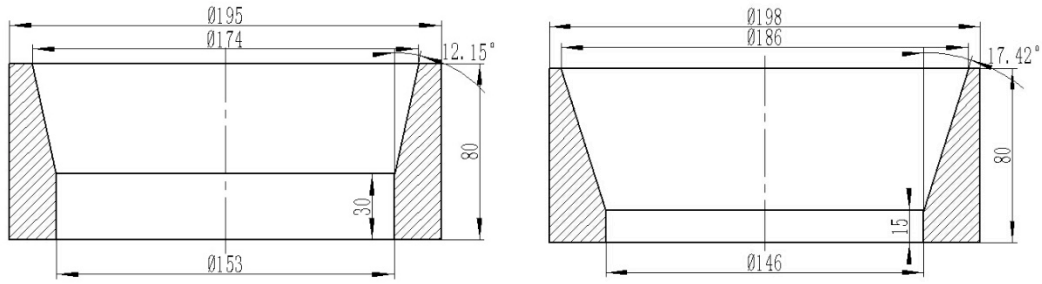
Figure.4 On the half-cone oblique section blank   Figure.5 Under the half-cone oblique section blank
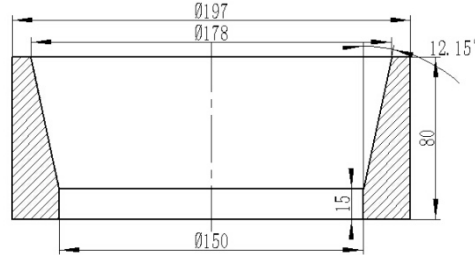

Figure.6 Cone oblique section blank

3 the finite element analysis results of cold rolling about the blank of outer ring in high-speed rail bear

The analysis result of option is shown in Fig.7, the forming quality of option one didn't meet the requirements of finished product. It will produce obviously defect of concave as shown in Fig.7(b) in the simulation of cold rolling, which makes rolling process unstable. It can be obtained that the blank deformed and gradually stick to the outer surface of the core roll by the feed force due to the upper surface of core roll firstly contacting with billets. As shown in Fig.7(a),the rolling force form core roll is perpendicular to oblique cone, which has the downward component in the vertical direction. Thus the internal metal is easily flowing to the place where has no constraints and can't form the shape as designed. The defect of concave resulting from that affects the stability of the cold rolling mill and the forming quality of blank.

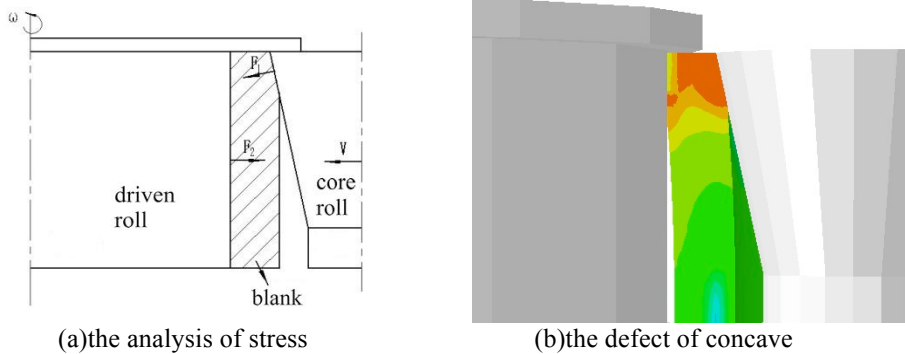(a)the analysis of stress   (b)the defect of concave

Figure.7 Option one

The analysis result of option two is shown in Fig.8, it describes the situation of the forming quality about the blank which owns the section of upper half cone shape. Although option two consume less material during billet machining, but its forming quality didn't meet expectations. It will generate the defect of concave and the defect of filling discontent in cone angle in the cold rolling, which are shown in Fig.8(b) and (c),and makes the rolling process instability. The forming mechanism of concave defects is similar with the option two. The roll of outer ring in high-speed rail bear belongs to cold working and don't have the high thermoplastic as the same as the hot cerclage. The Fig.8(c) shows the structure of blank at 100 step. It is the cone angle of core roller don't completely fit in the blank that leads to defects and affects the forming precision of the outer ring in high-speed rail bear.
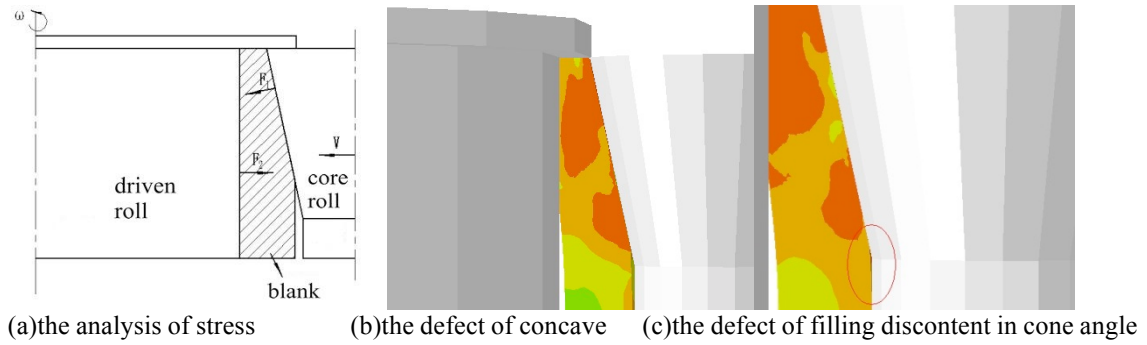
(a)the analysis of stress   (b)the defect of concave   (c)the defect of filling discontent in cone angle

Figure.8 Option two

The analysis result of option is shown in Fig.9.

(a) the analysis of stress in initial cold rolling   (b) the analysis of stress in middle of cold rolling   (c) the defect of tilt
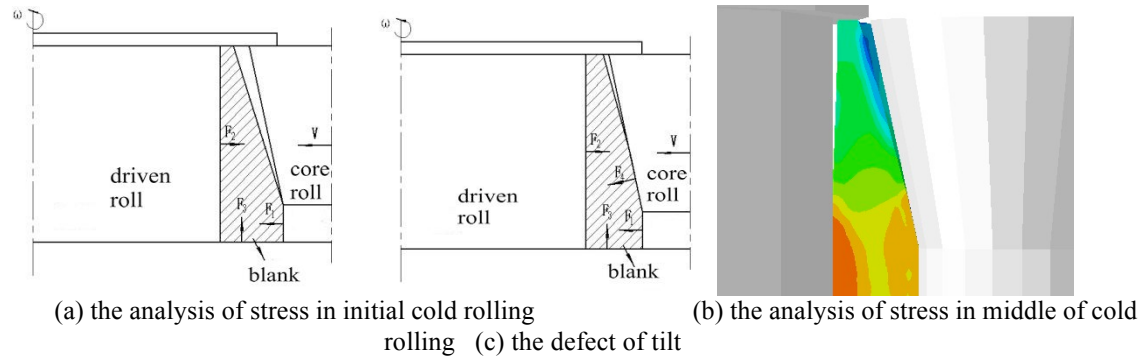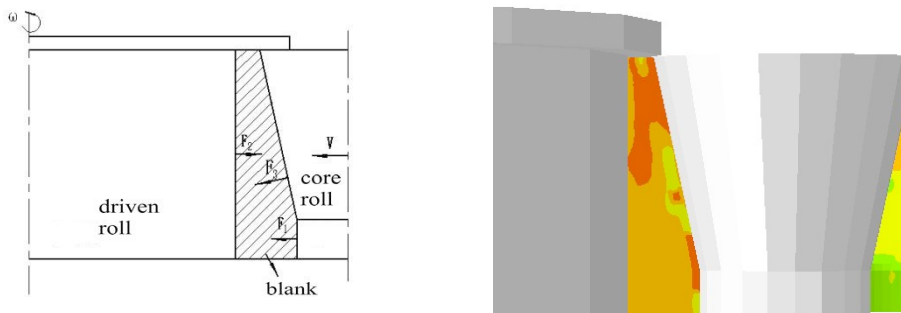
Figure.9 Option three

The Fig.9 shows the situation of forming quality about the option three. The angle of oblique cone in the blank is different from the angle in high-speed rail bear. The vertical plane of blank directly contact with the core roll.As shown in Fig.9(a),core roll firstly contacts with the vertical plane of blank and squeezes the blank in radial direction, which makes the diameter of the blank gradually larger. With cold rolling going on, as shown in the Fig.9(b),blank gradually forms the shape of oblique cone and fits in outer surface of the core roll. In the meanwhile,the situation of force is $F_1 + F_{4x} > F_2$ and The blank is under squeezing in the radial direction. The situation of force is $F_3 > F_{4y}$.In the axial direction,and internal metal accelerate flows to the upper end of the blank where the resistance is smaller.It leads the upper end of the blank to deform in advance and ultimately generates the defect of tilt.

The analysis result of option is shown in Fig.10, it shows the situation of forming quality about the blank with the cone bevel section. The structure is a viable option after considering of the defects of the three options. Fig.10(d) shows that the forming quality of the blank is better after cold rolling .Besides,the process of roll is stable. The inner surface of the preformed blank is identical to the outer surface of the core roll in option four. In the initial cold rolling,as shown in Fig.10(a),the stress is more even and balance than the previous options in radial and axial direction. It doesn't appear that the metal accelerate flow to some direction due to The blank is tightly suppressed by the core roll. Compared with the Fig.10(b),Fig.7(b),Fig.8(c)and Fig.9(c),the defect of concave,filling discontent in cone angle and tilt don't appear in option four,and the forming effect achieves the requirement. Compared with Fig.10(c)and Fig.10(d),it is drawn that the structural size of option four is the best one in above options.
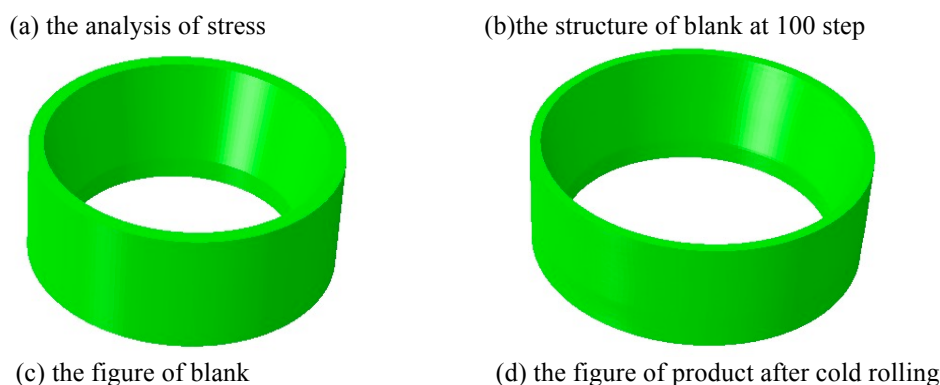
(a) the analysis of stress

(b)the structure of blank at 100 step

(c) the figure of blank

(d) the figure of product after cold rolling

Figure.10 option four

5 conclusion

(1)According to the structure of finished outer ring,the paper analyses that the cross-section of outer ring in high-speed rail bear can be a rectangular or a oblique cone,and derives the volume calculating formula of the outer ring in high-speed rail bear.

(2)The paper designs four typical structure of the blank based on the principle of volume constant,and simulates each structure by applying ABAQUS.Then the paper analyze the various defects and causes in cold rolling through the stress and deformation in the process.As a result,the paper summarizes the advantages and disadvantages of the four structures of the blank,and eventually achieves the best structural size of the outer ring in high-speed rail bear.

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6. References

[1] SUN Zhen-hua,Research and analysis of the High Speed Bearings for Railway Passenger cars in our Country [J].Rolling Stock,2004,42(8):4-9.

[2] HE Qiang,LI An-ling.The Development Trend of High-speed Railway Bearing[J].Journal of Xuzhou Institute of Technology(Natural Sciences Edition),2012,27(1),58-63.

[3] Yang Xiao-wei.The profiles of high-speed railway bearing[J].Bearing,2010,(10),59-61.

[4] SHU Xue-dao,XIAO Min. Blank design and process parameters optimization of high neck flange forming by closed ring rolling[J].Journal of University of Science and Technology Beijing,2012,34(11),1332-1337.

[5] XIAO Min. Research on the Key Technologies of High Neck Flange Forming with Closed Ring rolling Technology[D].Ningbo:a master's degree thesis of Ningbo University,2011.

[6] ZHAO Yu-min.Cold Rolling and Simulation for Step Inner Rings[J].Bearing,2006,(8):13-14.

[7] HUA Lin.the design methods of blank and the forming rules in Ring Rolling [J].Transactions of The Chinese Society of Agricultural Machinery,1994,25(3):92-97.

[8] LI Tian-SHUN.Numerical Simulation of the Concave-section Ring Rolling[D].Jinan:a master's degree thesis of shandong University,2013.

[9] XIAO Min,SHU Xue-DAO.Influence of Blank Shape on Roll Forming of Long Neck Flange[J].Hot working Technology,2010,39(23),120-123.