Study on the metal flow behaviour of deformation areas of large ring radial-axial rolling process

S X Cheng¹, R J Gu²*, X B Du², G D Shao², D X Yang², B Yang³

¹Hengyang Valin Steel Tube Co. Ltd, Hengyang 421001 China
²China National Heavy Machinery Research Institute Co. Ltd, Xi’an 710032 China
³Xi’an Heavy Engineering Consultant Co. Ltd, Xi’an 710032 China

*jackgu0214@163.com

Abstract. Ring radial-axial rolling technology is the best method to produce high quality large seamless ring. The metal flow behaviour of deformation areas of large ring radial-axial rolling process is studied. It is found that the fishtail pit of up-down surface of the ring section arises after the section passes through radial rolling area and that of in-out surface of the ring section arises after the section passes through axial rolling area. In order to gain better ring section, single radial rolling process is needed to remove the fishtail pit of in-out surface after double radial-axial rolling process. The study is very useful to constitute the process scheme of large ring radial-axial rolling.

1. Introduction

Ring radial-axial rolling (Fig.1) is the continuous local forming process of ring diameter increasing through the continuous local pressing down on ring thickness and height of rollers [1,2]. The formed ring precision by radial-axial rolling is high and the mechanical performance of formed ring fine. The action force of ring radial-axial rolling is much smaller than that of ring whole forging, but the production efficiency of ring radial-axial rolling is much higher than that of ring whole forging. So the technology of ring radial-axial rolling has been the best method to produce high quality large seamless ring [3-4].

Figure 1. Sketch of ring radial-axial rolling.
Some researches on the process of ring rolling have been done, but the research on the process of large ring radial-axial rolling [5-8] is few and is not much satisfied with the factual production. In the previous study [9], the reliable finite element model of large ring radial-axial rolling process is established and the whole deformation rule of large ring radial-axial rolling process is studied. It is found that the deformation of radial-axial rolling ring is created in the radial rolling deformation area and the axial rolling deformation area, the whole deformation feature of the ring depends on the material deformation of radial rolling area and axial rolling area. So, in order to know clearly the deformation behaviour of large ring radial-axial rolling process, it is needed to study deeply the metal flow behaviour of deformation areas.

The metal flow behaviour of deformation areas of large ring radial-axial rolling process is studied in the paper. The strain rule and section shape change of rolling deformation areas is revealed. It is indicated how to constitute the forming process of large ring radial-axial rolling.

2. Metal flow behaviour of radial rolling area

During the forming process of large ring radial-axial rolling, the strain of the section before radial rolling area and that after radial rolling area are shown in Fig. 2 (11 is the thickness direction, 22 the circumference direction and 33 the height direction). It can be found that the deformation of ring section is very inhomogeneous, the deformation value of section corners is large and that of section center small. The deformation value of in ring surface is bigger than that of out ring surface and the biggest deformation locates on the top and bottom of in ring surface. The strain increases after the ring section passes through the radial rolling area, especially the deformation increasing value of section corners is bigger and the biggest deformation increasing value locates on the top and bottom of in ring surface.
Figure 2. Strain of ring section before and after radial rolling area.

The strain of thickness direction is pressure strain, the pressure strain increases after the ring section passes through the radial rolling area and the pressure strain increasing value of in ring surface is bigger. It should be noticed that the thickness direction tension strain of ring section corners becomes the thickness direction pressure strain after the ring section passes through the radial rolling area, which is because that the section thickness decreases. The strain of circumference direction is tension strain, the tension strain increases after the ring section passes through the radial rolling area and the tension strain increasing value of in-out ring surface is bigger, which is because that the section thickness decreases, metal flows towards circumference direction and the ring diameter increases. The strain of height direction is pressure strain, the pressure strain decreases after the ring section passes through the radial rolling area and the pressure strain decreasing value of in-out ring surface is bigger. It should be noticed that the height direction pressure strain of the middle of ring section becomes the height direction tension strain after the ring section passes through the radial rolling area, which is because that the section thickness decreases and the metal flows towards height direction.

The ring section shape changes much in the radial rolling area. There is big fishtail pit on the in-out ring surface when the section is before the radial rolling area. The fishtail pit on the in-out ring surface is rolled to be plat after the ring section passes through the radial rolling area, but the new fishtail pit on the up-down ring surface is created. Fig. 3 compares the height of ring section before and after radial rolling area. It can be found that the height of ring section increases after the ring section passes through the radial rolling area, the height increasing value of in-out ring surface is big and the value of in ring surface is bigger than that of out ring surface. It is because that the thickness of ring section decreases in the radial rolling area and the metal flows towards height direction. Meanwhile, because of the inhomogeneous deformation, the big tension strain increasing value of height direction is created on the in-out ring surface and the increasing value of the in ring surface is biggest.

Figure 3. Height compare of ring section before and after radial rolling area.
3. Metal flow behaviour of axial rolling area

During the forming process of large ring radial-axial rolling, the strain of the section before axial rolling area and that after radial rolling area are shown in Fig. 4 (11 is the thickness direction, 22 the circumference direction and 33 the height direction). It can be found that the deformation of ring section is very inhomogeneous, the deformation value of section corners is large and that of section center small. The deformation value of in ring surface is bigger than that of out ring surface and the biggest deformation locates on the top and bottom of in ring surface. The strain increases after the ring section passes through the axial rolling area, especially the deformation increasing value of section corners is bigger and the biggest deformation increasing value locates on the top and bottom of in ring surface.

The strain of height direction is pressure strain, the pressure strain increases after the ring section passes through the axial rolling area and the pressure strain increasing value of in ring surface is bigger. It should be noticed that the height direction tension strain of the middle of in surface becomes the thickness direction pressure strain after the ring section passes through the axial rolling area, which is because that the section height decreases. The strain of circumference direction is tension strain, the tension strain increases after the ring section passes through the axial rolling area and the tension strain increasing value of in-out ring surface is bigger, which is because that the section height decreases, metal flows towards circumference direction and the ring diameter increases. The strain of thickness direction is pressure strain, the pressure strain decreases after the ring section passes through the axial rolling area and the pressure strain decreasing value of in-out ring surface is bigger. It should be noticed that the thickness direction pressure strain of the section corners becomes the thickness direction tension strain after the ring section passes through the axial rolling area, which is because that the section height decreases and the metal flows towards thickness direction.
The ring section shape changes much in the axial rolling area. There is bigger fishtail pit on the up-down ring surface when the section is before the axial rolling area. The fishtail pit on the up-down ring surface is rolled to be plat after the ring section passes through the axial rolling area, but the new fishtail pit on the in-out ring surface is created. Fig. 5 compares the thickness of ring section before and after axial rolling area. It can be found that the thickness of ring section increases after the ring section passes through the axial rolling area and the height increasing value of up-down ring surface is bigger than that of the middle of the section. It is because that the height of ring section decreases in the axial rolling area and the metal flows towards thickness direction. Meanwhile, because of the inhomogeneous deformation, the big tension strain increasing value of thickness direction is created on the up-down ring surface. The biggest thickness increasing value is not located on the up-down ring surface, which is because of the friction action of up-down axial cone rollers.
4. Effect of metal flow behaviour on formation process

From the above study, the metal flow behaviour of ring radial rolling area and that of ring axial rolling area are completely different. The big fishtail pit on the up-down ring surface is created after the section passes through the radial rolling area and the big fishtail pit on the in-out ring surface is created after the section passes through the axial rolling area. So, the section shape of left part of rolled ring and that of right part are much different. The ring section after ring radial rolling area and before axial rolling area has big fishtail pit on the up-down ring surface, the ring section after ring axial rolling area and before radial rolling area has big fishtail pit on the in-out ring surface.

If the end ring product is gained by machining the radial-axial rolled ring, in order to remove the big fishtail pit on the up-down ring surface and that on the in-out ring surface, both the machining allowance of up-down ring surface and that of in-out ring surface are big, so the ratio of material used is very low. In order to decrease the machining allowance of rolled ring and increase the ratio of material used, the process of single radial rolling should be used to remove the fishtail pit on the in-out ring surface after the process of double radial-axial rolling, by which the rolled ring with homogeneous section shape can be gained. So the reasonable formation process of large ring rolling should include the process of double radial-axial rolling and that of single radial rolling. Meanwhile, in order to remove easily the fishtail pit on the in-out ring surface through single radial rolling and decrease the fishtail pit on the up-down ring surface, the feeding velocity should be low at the end process of radial-axial rolling and the process of single radial rolling. Combining with the previous research achievement of roller feeding scheme, the feeding velocity of roller should decrease gradually during ring rolling process, which can improve the formation quality of rolled ring.

5. Conclusion

The metal flow behaviour of deformation areas of large ring radial-axial rolling process is studied in the paper. It is found that the fishtail pit of up-down surface of the ring section arises after the section passes through radial rolling area and that of in-out surface of the ring section arises after the section passes through axial rolling area. In order to gain better ring section, single radial rolling process is needed to remove the fishtail pit of in-out surface after double radial-axial rolling process. The feeding velocity of roller should decrease gradually during ring rolling process and the feeding velocity should be low at the end process of radial-axial rolling and the process of single radial rolling. The study is very useful to constitute the process scheme of large ring radial-axial rolling.

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