Study on the Deformation of Large Ring Radial-Axial Rolling Based on the FE Simulation of the Process

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Abstract. Ring radial-axial rolling technology is the best method to produce high quality large seamless ring. The reliable finite element model of large ring radial-axial rolling process is established. Based on the computing result of the FE model, the deformation of large ring radial-axial rolling process is studied. And it is found that the whole deformation feature of the ring depends on the material deformation of radial rolling area and axial rolling area, which is very useful to study deeply the forming process 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, so the machinery allowance is small and the material utilization is high. The metal fiber structure by radial-axial rolling can improve the mechanical performance of formed ring. 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].
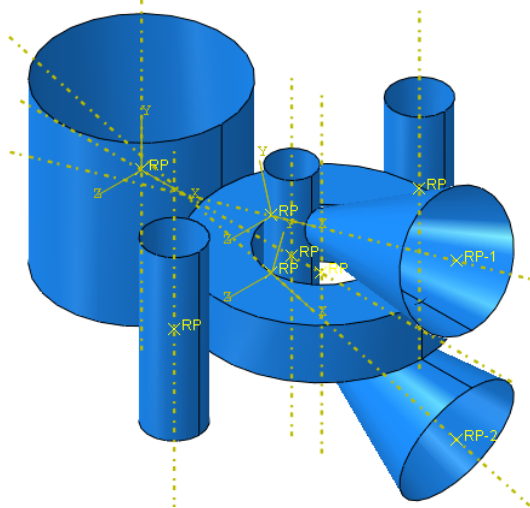

Fig. 1 Sketch of ring radial-axial rolling

The radial-axial rolling process of large ring is a complicated multiple nonlinear process of geometry, material and boundary under the coupling action of multiple fields and multiple factors, so it is difficult to study deeply the process. 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.

The reliable finite element model of large ring radial-axial rolling process is established in the study. With the

model, the process is computed and analyzed, some basic deformation rule of the process is revealed, which is very useful to study deeply the forming process of large ring radial-axial rolling.

2 FE model establishment of large ring radial-axial rolling process

The finite element model of large ring radial-axial rolling process is established on the software platform of ABAQUS in the study. The main work includes the establishment of geometry model, the definition of material property, the application of dynamic explicit algorithm, the setting of contact condition, the meshing of deformation part, the application of load.

During the process of large ring radial-axial rolling, the deformation of rollers is much smaller than that of ring, so the rollers are treated as rigid parts and the ring treated as deformation part in the FE model. The ring material is defined with elastic-plastic constitutive equation. The dynamic explicit algorithm of ABAQUS/Explicit is used to compute the process of large ring radial-axial rolling and the technology of mass scale used to improve the computing efficiency. The contact conditions include the contact of ring and main roller, that of ring and mandrel, that of ring and cone roller, that of ring and two centering rollers. The hexahedron 8 node thermal-force coupling element of first order reduced integration is used to mesh the ring and the ALE technology used to control the mesh distortion.

The loads of all rollers are applied through velocity, angular velocity or displacement condition. Main roller rotates around its center axis with certain angular velocity and mandrel moves towards main roller according to the preset feeding curve. The up cone roller rotates around its center axis and the angular velocity of cone roller is matching with that of main roller. The ring rotating velocity driven by the main roller and that driven by the up cone roller are same. Meanwhile, the up cone roller moves towards the down cone roller according to the preset feeding curve. The backward travel of up cone roller and down cone roller is applied through displacement and the displacement value is the same as

the increasing value of ring diameter. The load of centering rollers is applied through plane displacement and the location of centering rollers can be confirmed with ring diameter and the structure of the centering device.

3 Symmetry of radial-axial rolling ring and improvement of its FE model

With the FE model of large ring radial-axial rolling process, the effective stress and the effective strain of radial-axial rolling ring can be gained as Fig.2 and Fig. 3. It can be found that the stress and the strain of rolling ring are up-down symmetric. During the process of ring radial-axial rolling, axial rolling force and moment are applied through the pressing down and rotating of up cone roller, but the up cone roller and the down cone roller are up-down symmetric with regard to the middle section of rolling ring, so the deformation of rolling ring is also up-down symmetric.

According to the up-down symmetric deformation feature of rolling ring, the FE model of large ring radial-axial rolling process can be improved. In the FE model, the up half of ring blank is used and the symmetric constrain applied on the middle section of the ring blank. The down cone roller can be eliminated and the feeding value of up cone roller is only the half of real feeding value. The improved FE model of large ring radial-axial rolling process is shown as Fig.4 and its computing efficiency is twice of that of initial model.
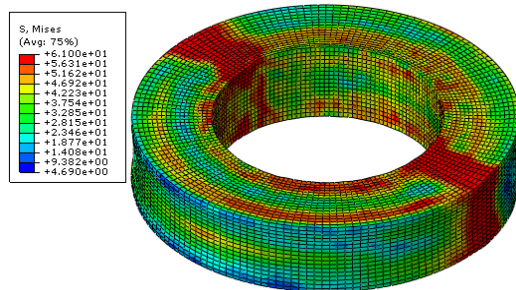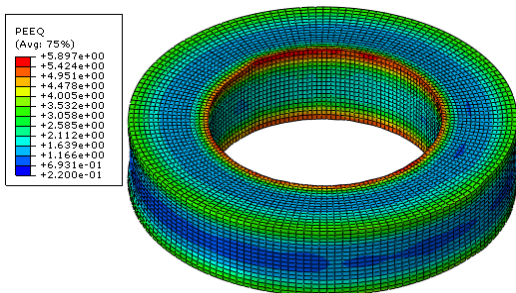

Fig. 2 Effective stress of radial-axial rolling ring

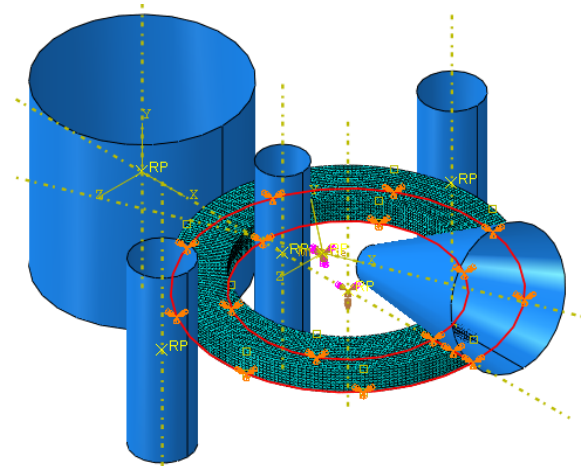**Fig. 3 Effective strain of radial-axial rolling ring**

Fig.4 FE model of radial-axial rolling ring

4 Reliability of the FE model of radial-axial rolling ring process

The reliability of the FE model of radial-axial rolling ring process is validated through experiment. The experiment equipment is the large ring radial-axial rolling mill developed by the authors (Fig.5). The Main technique parameters of the mill are shown in Table 1.

Table 1. Main technique parameters

Technique parameters	Value
Main roller diameter	1600 mm
Mandrel diameter	400 mm
Cone roller angle	32°
Cone roller available length	1300 mm
Main roller rotating angluar velocity	1-2 rad/s
Mandrel maximum feeding velocity	2 mm/s
Up cone roller maximum feeding velocity	2 mm/s
Ring outer diameter	2000-8000 mm
Ring thickness	100-1000 mm
Ring height	100-1000 mm

The compare of FE computing result and experiment result of ring outer diameter is shown as Fig.6. It can be found that the FE computing result and the experiment result of ring outer diameter are almost same, the maximum error between them is smaller than 10%. So the FE model of large ring radial-axial rolling process is reliable.

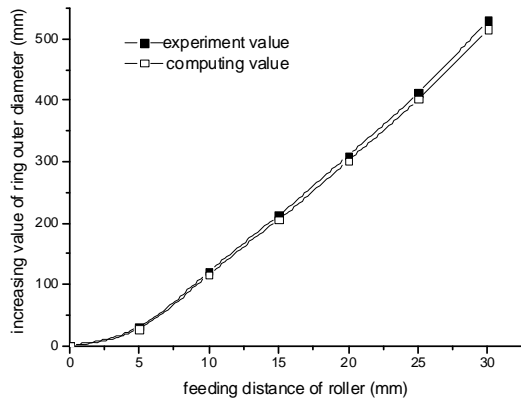**Fig. 5 Experiment mill of large ring radial-axial rolling**

Fig. 6 Simulation value and experiment value of ring diameter increasing

5 Deformation analysis of large ring radial-axial rolling process

With the above FE model, the process of large ring radial-axial rolling is computed, the stress and strain developing rule can be gained. The effective stress and the stress of three cylindrical coordinate directions are shown as Fig.7. The effective strain and the strain of three cylindrical coordinate directions are shown as Fig.8.

Through analyzing the developing rule of the stress and strain during radial-axial rolling ring, it can be found that the ring thickness is decreased under big pressure stress when the material is rotated through the radial rolling deformation area, then the big pressure stress of thickness direction disappears, but the deformation created in the radial rolling deformation area keeps almost invariable before the material is rotated into the axial rolling deformation area. The ring height is decreased under big pressure stress when the material is rotated through the axial rolling deformation area, then the big pressure stress of height direction disappears, but the deformation created in the axial rolling deformation area keeps almost invariable before the material is rotated into the radial rolling deformation area. So 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.
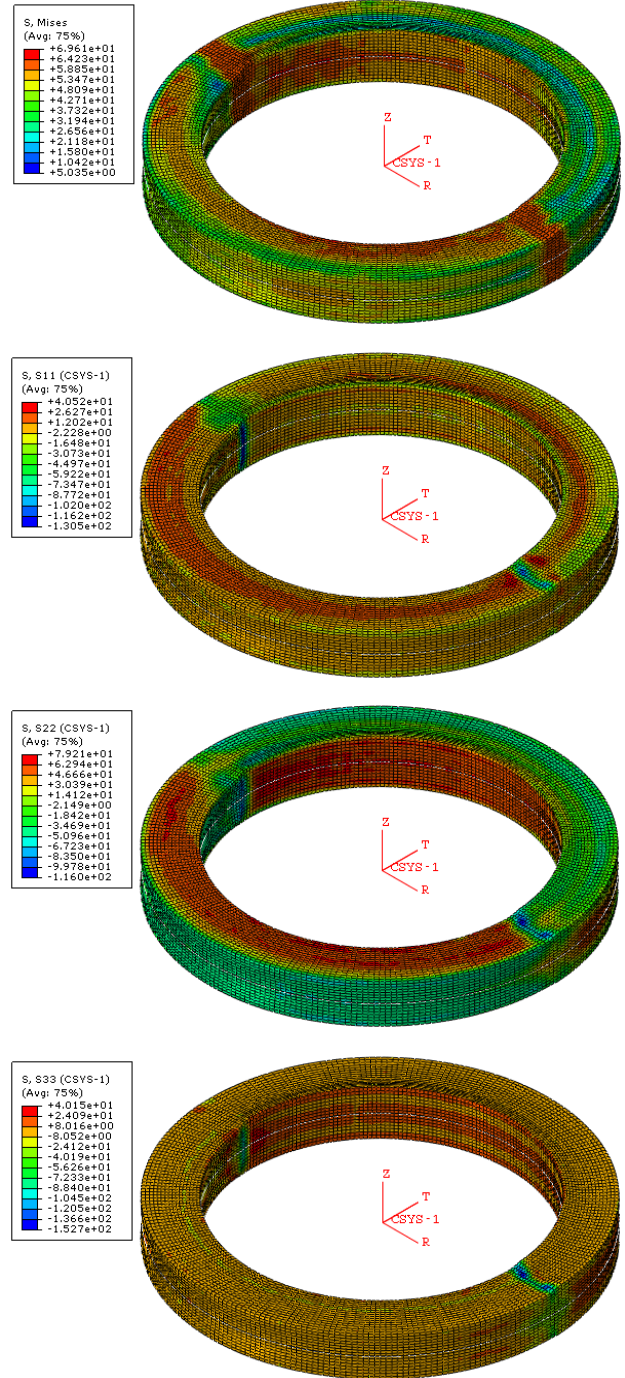

Fig. 7 Stress of radial-axial rolling ring

6 Conclusion

The finite element model of large ring radial-axial rolling process is established on the software platform of ABAQUS in the study. Based on the deformation symmetry of large ring radial-axial rolling process, the FE model is improved. Then the reliability of the FE model is validated through experiment. Based on the computing result of the FE model, the 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

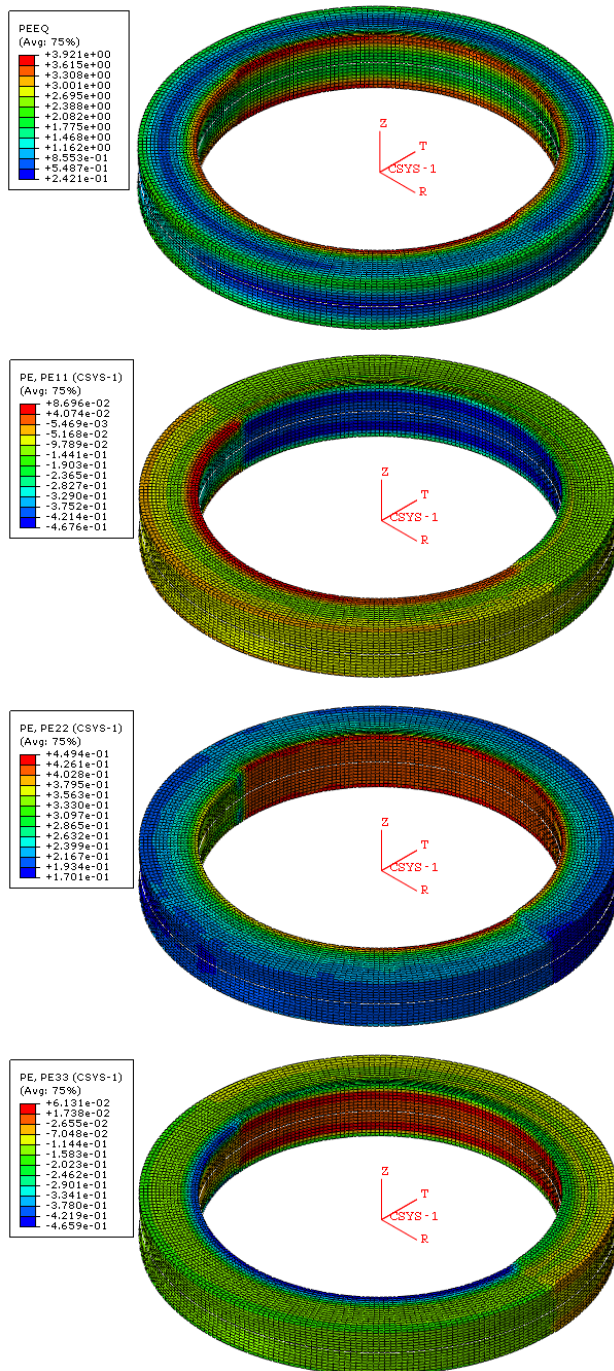feature of the ring depends on the material deformation of radial rolling area and axial rolling area.

Fig. 8 Strain of radial-axial rolling ring

Acknowledgement

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