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Whirlwind Rolling Process of Slender Shaft

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Abstract

In order to solve the problem of slender shaft which is easy bended and deformed for its big slenderness ration and poor rigidity, the method of whirlwind rolling with Tri-tools is designed. This paper introduces the principle and the process of stress analysis. With the help of ABAQUS finite element simulation software, the 3D model of whirling rolling is established. The rolling process is simulated by the software and summarizes the influence of quality factors during the whirlwind rolling process.

Keywords: *Slender shaft, whirlwind rolling, finite element simulation*

1. Introduction

Due to the large length-diameter ratio of slender shaft and rigid is extremely poor, under the effect of the cutting force and gravity, the workpiece will produce bending deformation, increasing the radical error after processing, thereby it affects the slender shaft's machining accuracy. Currently finishing cut of the slender shaft mainly uses turning-grinding and rolling. Turning should make a very strict filtering for machine tools-aids-tools and their cutting parameters. If there is a parameter mishandling, it will affect machining accuracy. Grinding will produce a lot of cutting heat, causing burns on the surface of slender shaft, destructing the surface quality of slender shaft. Rolling processing is mainly used in the conventional single wheel rolling, however, the range of single wheel rolling processing is limited, it only applies to machine the slender shaft which is short and big diameter, for the processing of slender shaft which is large axis-diameter ration, it will generate a greater bending deformation in the effect of stress, it can not obtain the purpose of improving precision through rolling processing. In view of the traditional processing methods can not meet the increasingly stringent processing requirements of modern production, this paper proposes a three wheel whirlwind rolling processing method.

2. The Principle of Three Wheel Whirlwind Rolling Processing

The whirlwind rolling is an advanced chinless finishing cut method. Using a plurality of rollers on the radical surface of slender shaft which exert some pressure, forcing the slender shaft's radical surface to produce elastic-plastic deformation, and achieve smooth cylindrical surface, the purpose of reducing surface roughness. The main factors which cause the machining deformation of slender shaft are from the surface's radial force acting on slender shafts, the using of the balance principle fundamentally resolves the dimension error in processing of slender shaft. The program of whirlwind rolling slender shaft presents in this paper, installing the same three rollers each 120 ° apart in the same plane, comparing with ordinary turning and grinding, three wheel in the whirlwind rolling processing, three rollers play a similar role with positioning of tool post. Therefore, the shaft itself gravity and radial cutting force is no longer the interference factors of machining accuracy, can very well reduce the radial force of slender shaft processing, thus from the root to reduce its bending deformation condition. The whirlwind rolling model of slender shaft makes appropriate simplified in this paper, this significantly reduces the simulation analysis time, and can guarantee the precision of calculations. In this paper, model only selects a section of the slender shaft, because the wheel usually selects the greater hardness of the material, the wheel set for analysis of rigid body.

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With the help of ABAQUS finite element simulation software, the 3D model of whirling rolling is established, as shown in Figure 1.

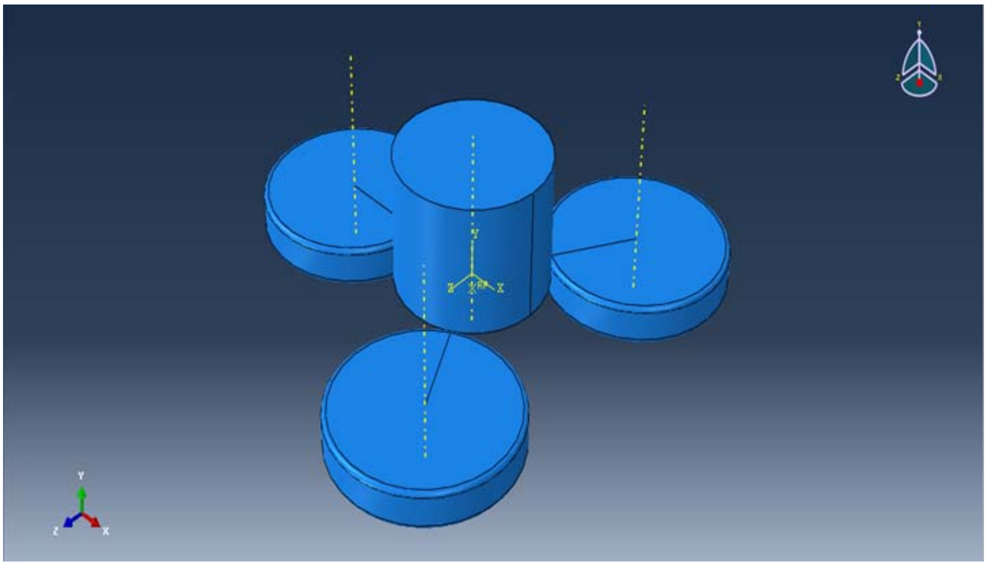

Figure 1. Three-wheel rolling schematic

For the force analysis of three-wheel whirlwind rolling, intercepting cross section of the slender shaft, the model is established by the principle of theoretical mechanics, getting the plane stress diagram as shown in figure 2.

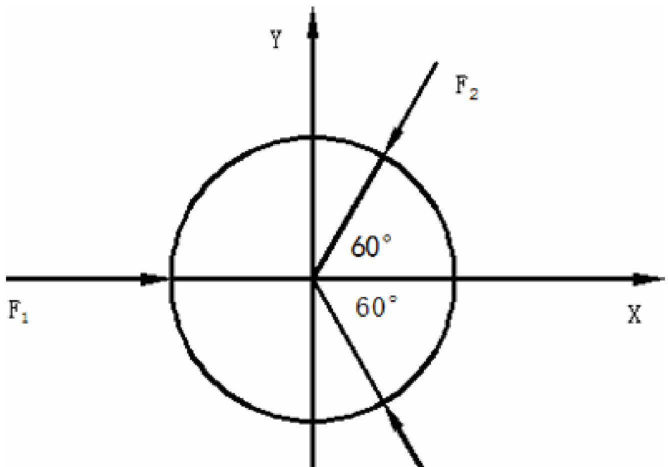

Figure 2. Whirlwind rolling force model

F_1、F_2、F_3 are radial component of the three wheels, acting on the surface of slender shaft. For the analysis of the three radial component (F_1、F_2、F_3) of the slender shaft, it assumes that the slender shaft is rigid and does not take into account internal stress deformation of slender shaft. The center of the slender shaft is the coordinate origin, the horizontal and vertical directions are respectively as the x-axis and the y-axis, establishing the coordinate system. As shown in the above figure, F_2、F_3 will be respectively decomposed into the x-axis, y-axis direction, then:

$$F_{2x} = F_2 \cos 60^\circ \quad F_{2y} = F_2 \sin 60^\circ$$
$$F_{3x} = F_3 \cos 60^\circ \quad F_{3y} = F_3 \sin 60^\circ$$
$$\because F_1 = F_2 = F_3$$

The resultant force in the x-axis: $F_x = F_1 + F_{2x} + F_{3x} = 0$

The resultant force in the y-axis: $F_y = F_{2y} + F_{3y} = 0$

From the previous analysis we can see, the forces in the x-axis and the y-axis direction is zero. From the point of mechanical, the slender shaft achieves a balance through radial force of three directions in the scheme of slender shaft machining, it overcomes the unilateral diameter force of slender shaft that generates a greater bending deformation which can not be processed compared with the conventional single wheel rolling processing, simultaneously this structure also avoids the centrifugal force generated by the rotation caused by the vibration. Comparing with ordinary turning and grinding, three wheels in the whirlwind rolling processing, three rollers play a similar role with positioning of tool post. Therefore, the shaft itself gravity and radial cutting force is no longer the interference factors of machining accuracy, can very well reduce the radial force of slender shaft processing, thus from the root to reduce its bending deformation condition. The three rollers process at the same time, can greatly improve processing efficiency and shorten the processing time, and are no longer limited by the slender shaft's length, this method is more suitable for a number of big slenderness ration of slender shaft processing.

3. Analysis of Simulation Results

3.1. Equivalent Plastic Strains

Rolling simulation of the slender shaft has been completed, entering the function module of post-processing to view response analysis. Figure 3 is the equivalent plastic strain field of the three wheel whirlwind rolling processing of slender shaft.

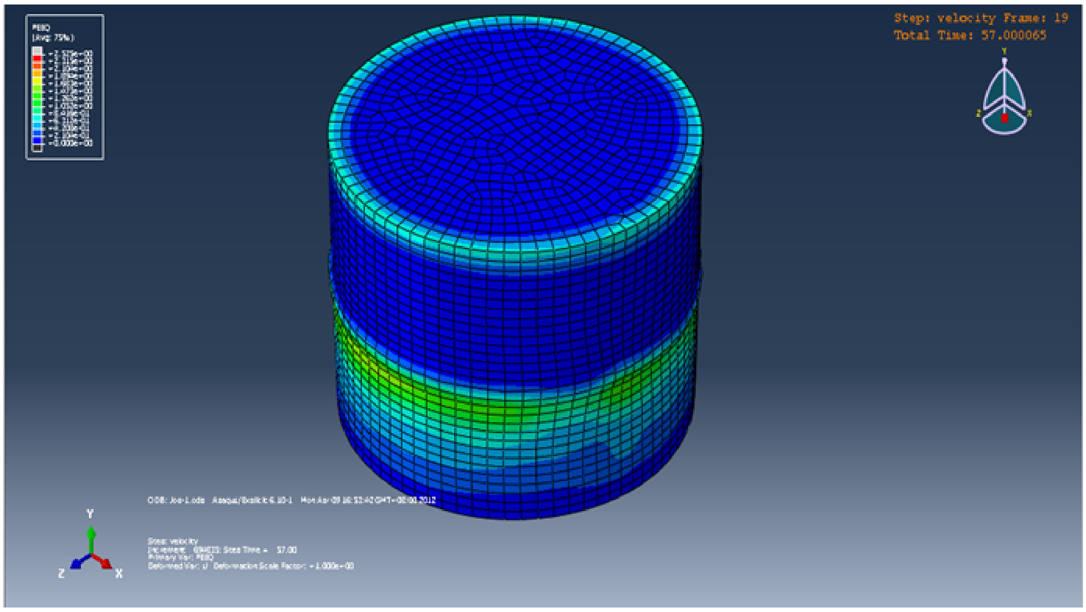

Figure 3. Equivalent plastic strain field

As the contact area of the rollers and slender shaft is relatively large, therefore in the process of rolling, stress is relatively uniform, avoiding the surface of roller and shaft adhesion wear, destructing the quality of processing. In the process of rolling, the equivalent plastic region is relatively wide, the roller rotates for a circle, the contact width of the rollers and slender shaft is relatively large, so we can use a relatively large amount of feed, improving the work efficiency.

3.2. Slender Shaft Surface Strain

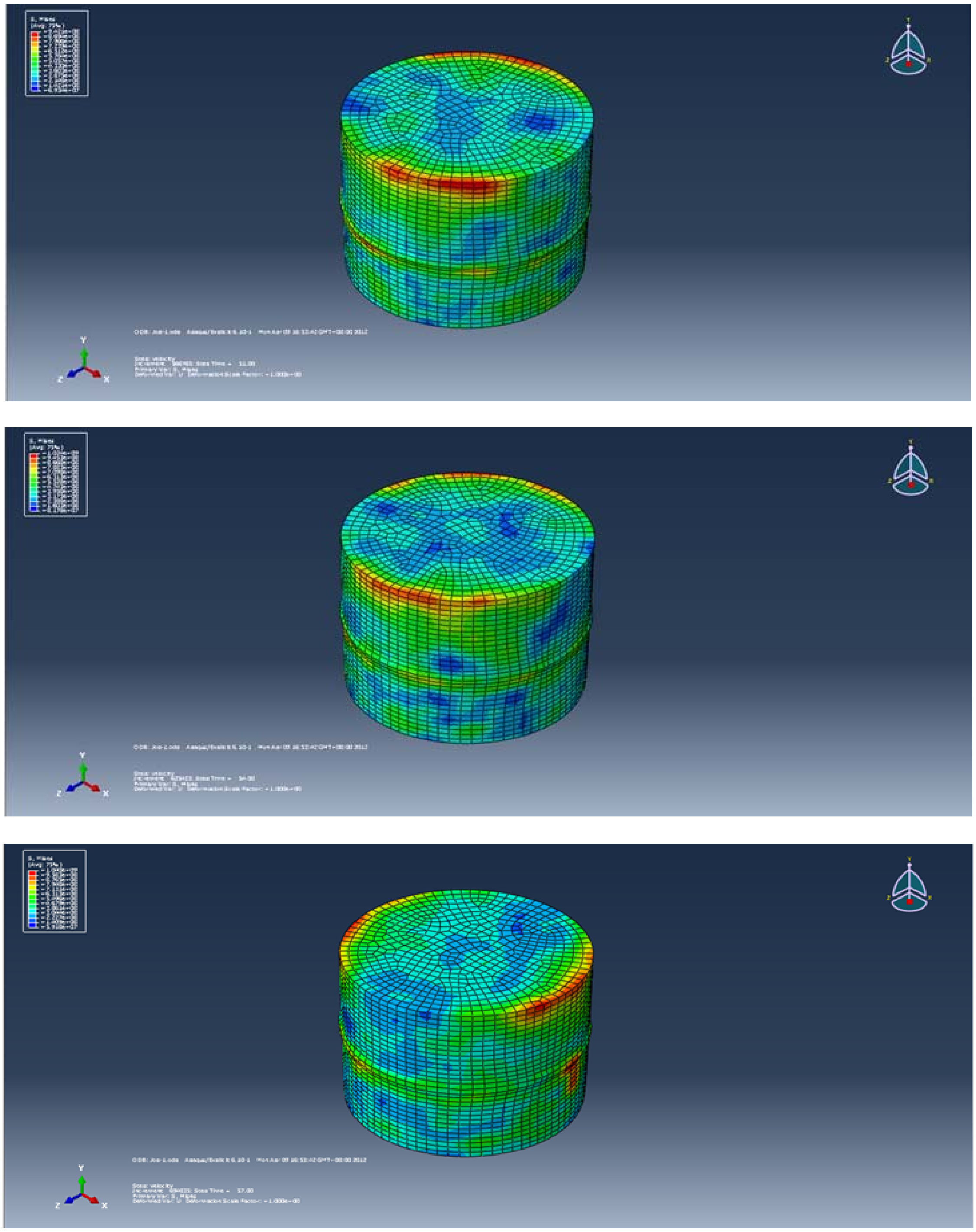

Figure 4. Slender shaft surface deformation diagram

With the process of rolling, the roller feeds along the axial, stretching the surface material of the slender shaft, the resistance of the metal in front of the roller will gradually become larger, when the amount of compression reaches a certain degree, it will remain unchanged. On the function area of the roller, roller radial pressure plays a leading role, for the axial compressive stress of the roller, the resistance of the material along the axial becomes smaller. By the rule of metal flow, the material will flow along the direction of deformation resistance which is small, as shown in figure 4. So the slender shaft can produce axial elongation phenomena for radial compression. Using the reverse rolling processing that is the movement of feed direction from the chuck to the tailstock, the slender shaft suffers tension and is axial elongation. Therefore whirlwind rolling should take one end of the clamping chuck one end of the thimble. The part of thimble should have automatically retractable structures, to ensure that the workpiece when stretchs, not to bend it by the resistance of thimble.

3.3. Whirlwind Rolling Notes

Roller and the workpiece in the rolling processing should try to select the poor miscibility material, in order to avoid adhesion wear between tool and workpiece during rolling processing and destructing of the machining surface. Secondly, the size of rolling magnitude of interference affects the roughness and geometrical accuracy of the slender shaft's surface, therefore it should choose a different amount of compression depending on the material, because when the load is increased to a certain critical value, the wear will increase sharply, and the roughness of the slender shaft's surface is no longer improved, the rolling surface begins to deteriorate and even generates cracks when the pressure of the slender shaft's surface continually increase. Thirdly, the rolling processing cannot impurity inclusions in the rolling tool and the workpiece, otherwise it will affect the rolling, even scratch roller and rolling processing cannot continue. Fourthly, in the rolling processing should avoid midway parking, or rolling tool will leave a circular ring grooves at the workpiece and cannot be eliminated. If you encounter special circumstances must stop, should promptly withdraw rolling indenter. Fifthly, improving the rolling speed may increase the production efficiency because the rolling speed has little effect on the roughness of the slender shaft's surface. Sixthly, the number of rolling should not be too much; otherwise, the roughness of the slender shaft's surface is greater.

4. Conclusion

The three wheel whirlwind rolling processing of slender shaft, the force which is applied to the sensitive direction of the slender shaft is zero, the workpiece is in force equilibrium, theoretically the processing of workpiece does not produce bending deformation. Theoretical analysis shows that it effectively solves the problem of traditional single wheel rolling processing which generates a greater bending deformation, and simulation results show that the surface of slender shaft gets almost equal compressive stress through the three wheel whirlwind rolling processing, thus it greatly reduces the roughness and roundness error of the slender shaft's surface. The whirlwind rolling is not only to improve the wear resistance, corrosion resistance and compliance of the workpiece's surface, and avoid the environmental pollution caused by the grinding, in line with our country's green manufacturing idea. The three roller process at the same time, the production efficiency is greatly improved, the energy consumption is relatively low, meeting the requirements of modern production with high precision, high efficiency, low energy consumption.

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