The finite element simulation analysis research of 38CrSi cylindrical power spinning

Wei Liang[1,a], Qiongying Lv[2,b,*], Yujuan Zhao[3,c],Yunxia Lv[4,d]

[1,2,3]Changchun University of Science and Technology,

Changchun, Jilin province, China

[4]Changchun Product Quality Technology

Supervision and Inspection Institute

[a]liang811@sina.com, [b]13578868098@163.com, [c]zhaoyujuan4963@163.com, [d]twg_cn@163.com

Keywords: 38CrSi; cylindrical part; power spinning; spinning process parameters.

Abstract. In order to grope for the influence of the main cylindrical spinning process parameters on the spinning process, this paper combines with real tube power spinning process and uses ABAQUS finite element analysis software to simulate the tube power spinning process of 38CrSi steel materials, through the analysis of the stress, strain of the part forming process, analyzes the influence of the thickness reduction and the feed rate to the forming process, and analyzes the variation of the spinning force, finally determines the reasonable main spinning process parameters combination.

0 Introduction

Spinning process is a little, no cutting of advanced manufacturing technology, wherein the cylindrical power spinning technology spinning is commonly used as a method of machining cylindrical parts,the cylindrical parts manufacturing process with low power consumption, high material utilization, and can improve the performance and surface finish, etc, has been widely used in national defense, aerospace and other fields[1,2].

With the rapid development of finite element theory and computer technology, the simulation of the spinning process of the cylindrical parts can be realized by the numerical simulation technology, and understand the spinning forming mechanism and the influence law of main technological parameters, to provide effective reference for spinning solution.Literature[3] using ABAQUS finite element software power spinning of cylindrical parts are simulated and analyzed the feed rate and the reduction ratio of thick wall cylinder parts forming efficiency of elongation.The literature[4] simulation of the cylindrical parts TA2 spinning process, and the spinning forming technology parameters were optimized by the simulation results.

Through finite element analysis software ABAQUS, this paper adopts the power spinning wheel way forward for 38CrSi alloy steel cylindrical spinning process was simulated to explore the thinning rate, feed rate two spinning process parameters influence of its forming process, and sums up the changing regularity of the spin.

1 Simulation modeling and key problems

1.1 Scheme of geometric modeling

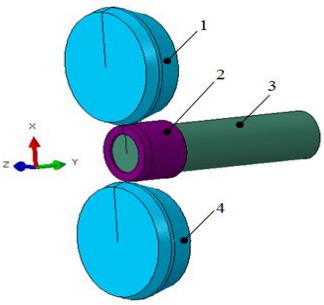
When the cylindrical workpiece actually spun, blank rotate along with the mandrel, two rollers under the certain conditions of reduction to make axial feed movement, forcing the metal to produce tangential, radial and axial flow of elastic-plastic deformation through the gap between roller and mandrel. In order to make possible the simulation model and the actual process of establishing consistent, while shortening the simulation time, the paper made the assumption for the simulation model[5]:(1)Define the blank for elastic-plastic materials;(2) Define the mandrel, roller as the analytical rigid body;(3) Process simulation ignores the influence of roller rotation;(4) Process simulation ignores the influence of temperature;(5) Process simulation ignores the influence of inertia force.

This paper respectively established the roller, the mandrel, the blank geometry model of three components by using ABAQUS software, the basic parameters shown in Table 1.

Table 1. Experimental parameters for simulation

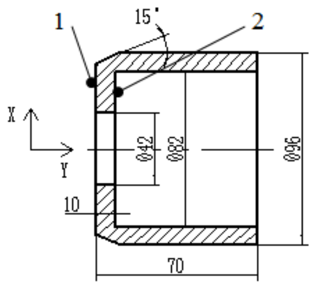
Roller	Diameter	200mm
	Radius of rounded corner	8mm
	Operating angle	20 °
	Receding angle	30 °
Blank	Length	70mm
	Thickness	8mm
	Inside diameter	82mm
	Preformed angle	15 °
Mandrel	Length	350mm
	External diameter	82mm
	Spindle speed	200r/min

The various components of the model in accordance with the actual assembly process, the result shown in Figure 1.



1-Roller; 2-Blank; 3-Mandrel; 4-Roller

Figure 1. The simulation model of assembly drawing



1-Outer end face; 2-Inner end face

Figure 2. Blank size diagram

1.2 Model boundary conditions

Cylinders in combination with the actual spinning process, the blank constraint Y direction outer end and an inner end surface of the workpiece freedom in the simulation model, and the inner end surface of the blank and mandrel end face binding constraints, in order to simplify the management of boundary conditions. Blank diagram is shown in Figure 2. In the model is applied to the mandrel rotation speed around the Y axis, because the binding constraints set between the blank and the mandrel, so that the mandrel can be driven blank rotation. Two rollers to spin the same applied along the Y axis positive feed rate, and by setting the corresponding analysis step to control the length of time the roller feed distance.

1.3 Mesh model

The simulation process, the main object of study is a modification of the process of the cylindrical parts, and therefore have the roller and the mandrel to resolve two rigid when creating a model, it does not require cell division network[6]. In order to prevent serious distortions lead to rough grid failure simulation, so the definition of the ALE adaptive mesh sub-network function, the grid unit selects eight - node linear hexahedron reduced integration with hourglass control unit C3D8R, and finally divided the rough total of 18,900 units.

2 Simulation analysis process

2.1 The influence of thinning rate

According to experience, thinning rate is generally taken 15% to 30%. In this section, we select 15%, 20%, 25% thinning rate, and other major spinning process parameters constant to explore the influence of thinning rate on the spinning process. Radial direction, roller and blank contact area of the equivalent stress shown in Figure 3.

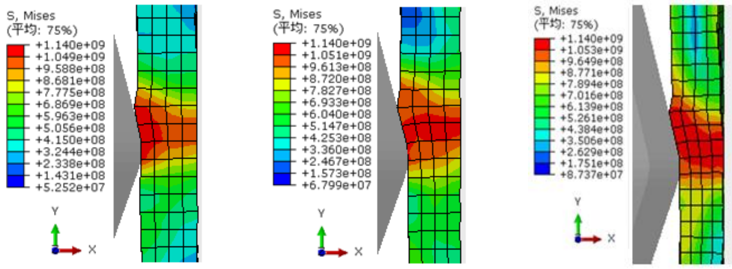


Figure 3. Radial equivalent stress nephogra

The figure shows that the thinning rate of 15%, the plastic deformation occurs mainly in the surface of the cylindrical pieces of rough, plastic deformation is not sufficient. When the reduction rate is 20% and 25%, the stress distribution of the blank in the radial direction is even. The stress of the contact area between the roller and the blank is much larger than the yield stress of the material, so the blank has sufficient plastic deformation. It can be seen, the rotation of the 38CrSi alloy steel cylindrical workpiece, the single pass rate of not less than 20% thinning. When the pass reduction rate is too small, the 38CrSi cylindrical workpiece in the spinning process, the workpiece surface layer of metal materials will have a more pronounced wave-shaped plastic flow, and the workpiece only in the surface of plastic deformation is not sufficient, The value of the thinning rate is too small will reduce the quality of cylindrical parts spinning, forming the workpiece does not make any sense. In addition, the pass thinning rate should not be selected too much, if the thinning rate is large, in the workpiece forming process will lead to a serious accumulation of metal before the roller, affecting the cylindrical part of the spinning forming accuracy.

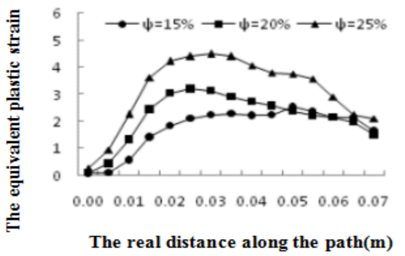


Figure 4. The equivalent plastic strain

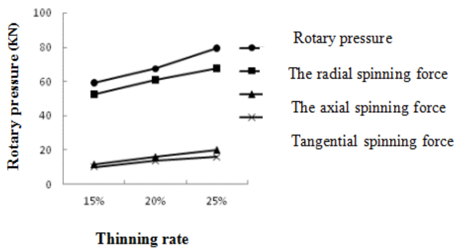


Figure 5. Rotary pressure variation

The equivalent plastic strain curve of the workpiece along the path during the forming process is shown in Fig 4. It can be seen from the figure that the equivalent plastic strain of the workpiece increases with the increase of the spinning thinning rate. When the reduction rate is 15%, the equivalent plastic strain of the workpiece changes smoothly. When the thinning rate is 20% and 25%, the equivalent plastic strain has a tendency to decrease after an extreme value, but the plastic deformation effect of the whole workpiece is 15%.

Under different conditions of thinning rate, the variation of the spinning force during the strong spinning process of the 38CrSi cylinder is shown in Fig 5. As can be seen from the figure, the increase of the workpiece thinning rate, the total spin pressure and radial spin pressure also increased rapidly, axial and tangential spin pressure slightly increased spin pressure to show this trend is due to thinning rate.The increase in the contact area of the blanks of the rotary roller and the cylindrical member increases, and the deformation resistance associated with the deformation rate increases. If the thinning rate is too large, in the spinning process of plastic flow instability in the spinning roller in front of metal accumulation, will lead to greater spin pressure. Through the simulation results in this section and considering the main factors affecting the forming quality of the workpiece and the size of the spinning force, it can be deduced that when the reduction rate is 20%, the rotation of the 38CrSi cylinder is more favorable.

2.2 The influence of feed rate

Spinning cylindrical parts, should be selected according to the process requirements of the size of the feed rate, under normal circumstances, the parameters can be selected for the 0.5~2.0mm/r [7]. In this section, the feed rate is 0.6mm/r, 0.8mm/r, 1.0mm/r, the other main spinning process parameters are invariable to find out the influence of the feed rate on the workpiece spinning process.Radial direction, roller and blank contact area equivalent stress shown in Figure 6.

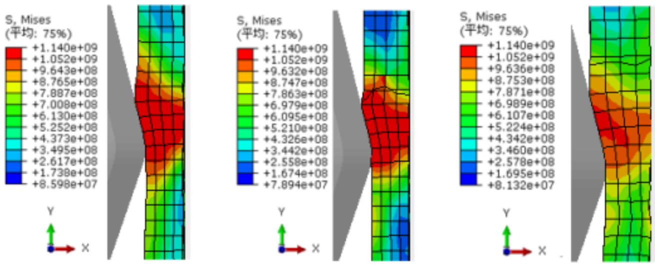


Figure 6. Radial equivalent stress nephogram

Can be seen in the figure 6, the three feed rate conditions in the radial direction of the blanks are more uniform stress distribution, plastic deformation of the workpiece fully. But the feed rate of 0.6mm/r, 38CrSi cylindrical blanks have a relatively large diameter. When the feed rate is 1.0mm/r, the blank in the deformed area behind the roller is stretched in the axial direction (Y direction), resulting in the plastic flow of the blank is not uniform. Increasing the feed rate will increase the radial and axial compressive forces. If the radial compression force is too large, it will cause the plastic deformation of the blank in the radial direction. At this time, the axial force will reach a certain value. The degree of size will be very easy to make the blank in the axial direction of the tensile phenomenon.

If the feed rate is too large, it will lead to deformation of the workpiece on the front roller radial extension of the larger radial, resulting in the radial thickness of the inner and outer metal plastic deformation, The workpiece plastic flow instability[8], when the selected feed rate of 1.5mm/r, the radial direction of the workpiece equivalent stress cloud diagram shown in Figure 7. It can be seen from the figure, in the roller contact with the workpiece area, the workpiece demoulding phenomenon in the roller feed direction, the rear roller has been deformed area has a serious drum package, spinning roller metal material in front of a certain accumulation, As the roller continues to move, a direct result of the interruption of the simulation process. Figure 8 shows the feed rate is greater when the actual spinning cylindrical workpiece fracture diagram, the figure can be seen, the workpiece has a larger diameter at the end, resulting in spinning process instability, leading to spinning the process produces excessive spinning pressure makes the roller at the workpiece fracture. In addition, too large feed rate will also lead to spiral corrugated, seriously reducing the quality of the surface of the cylindrical parts.

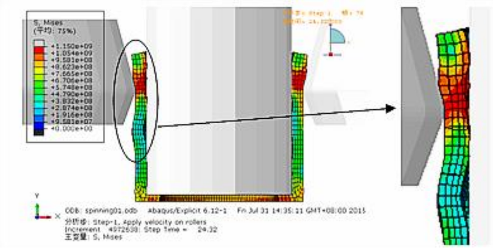


Figure 7. 1.5mm/r equivalent stress nephogram

Figure 8. Cylinder spinning defects

The curve of the equivalent plastic strain along the path is shown in Fig 9. It can be seen from the figure that the equivalent plastic strain change trend and numerical value are basically the same when the feed rate is 0.6mm/r and 0.8mm/r . While the feed rate of 1.0mm/r, the equivalent plastic strain changes in the deformation zone to a larger extreme. This is because the large feed rate causes the rotation of the roller and the cylindrical workpiece blank when the transition is relatively stable, resulting in a large radial deformation of the blank, so the subsequent rotation process, the radial direction of spinning thickness. The larger the non-uniformity, resulting in greater plastic strain, so when the feed rate of 0.6mm/r or 0.8mm/r, 38CrSi cylindrical parts in the rotation process can produce uniform plastic deformation.

The variation of the rotational force of the workpiece under different feed rate conditions is shown in Fig 10. It can be seen from the figure, when the feed rate increases, the total spinning pressure and radial spinning pressure increase during the spinning process, and the axial and tangential rotation pressures do not change much. Through the simulation results in this section and considering the main factors affecting the forming quality of the workpiece and the size of the spinning force, it can be concluded that the rotation of the 38CrSi cylindrical part is more favorable when the feed rate is 0.8mm/r.

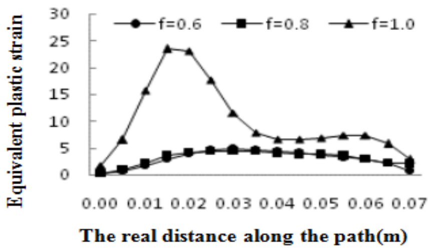


Figure 9. Equivalent plastic strain

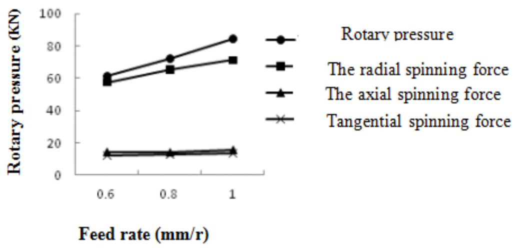


Figure 10. Rotary pressure variation

2.3 Spinning parameters combination

Through the analysis of the simulation results under different reduction rate and feed rate, considering the size of the spinning force in the spinning process, the degree of plastic strain in the spinning process, the plastic flow of the workpiece metal and the avoidance of bulging, etc[9]. The defects of these factors, and finally determine the 38CrSi cylindrical main spinning process parameters for the combination of: thinning rate of 20%, feed rate of 0.8mm/r, roller working angle of 200, roller radius of 8mm, simulation results as shown in Fig 11, there is no accumulation of metal material and bulge defects during the whole forming process. However, at the beginning of the forming process, there is a small extent of expansion and stress concentration, but the plastic deformation of the whole forming process[10]. So it can be predicted that the combination of the main spinning parameters can achieve the smooth spinning process of 38CrSi cylindrical parts, and can satisfy certain forming quality requirements. Therefore, the actual spinning test was carried out under the conditions of the main spinning parameters. The simulation results and the results of the actual single-pass rotation of the 38CrSi cylinder are shown in Fig 12.

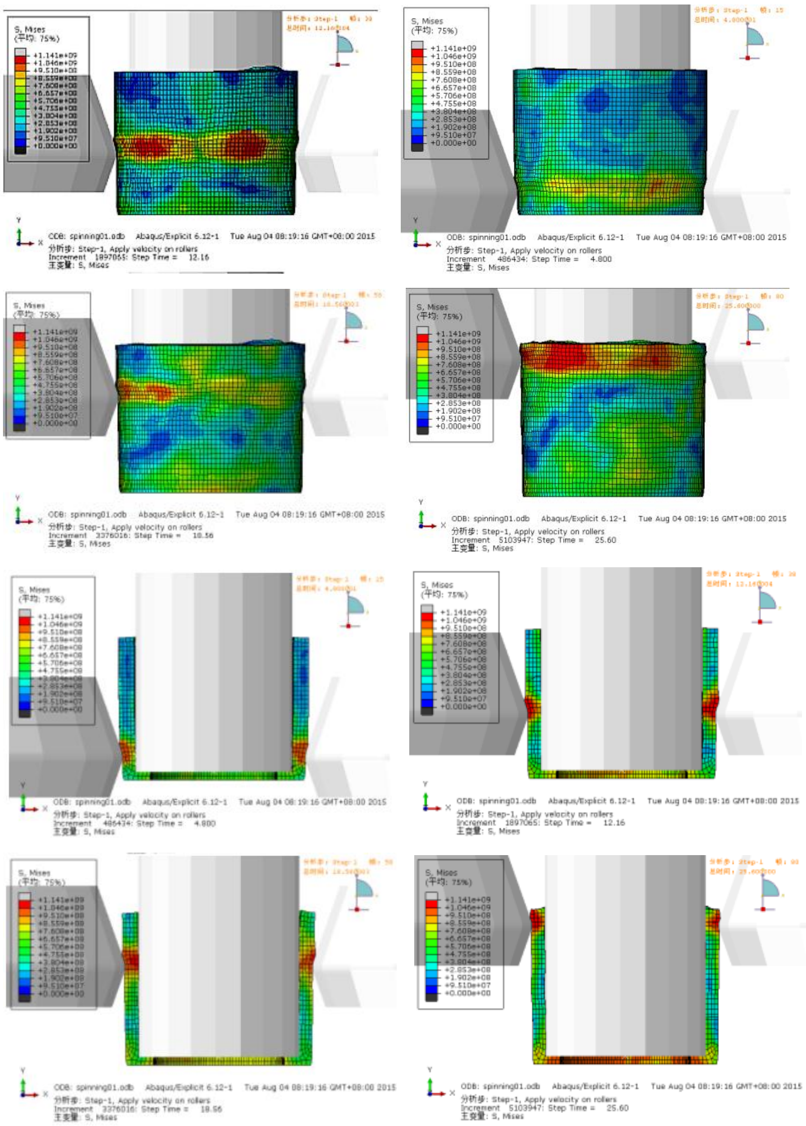


Figure 11. Simulation result

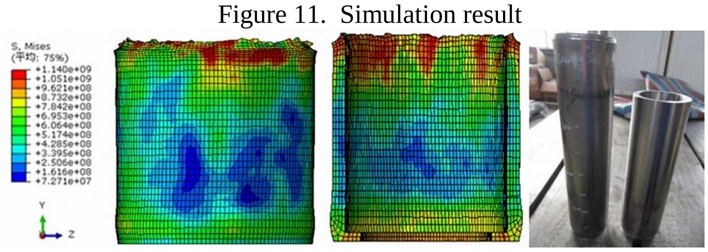


Figure 12. Spinning result

3 Conclusion

1) When the thinning rate is 10%, the surface layer metal material produces obvious wave-shaped plastic flow during the process of rotation of 38CrSi cylindrical parts, and the workpiece only produces insufficient plastic deformation on the surface. When the feed rate is greater than 1.5mm/r,

38CrSi cylindrical parts of the spinning process prone to the accumulation of metal materials, the forming process will have a greater impact.

2) During the forward spinning process of 38CrSi cylindrical parts, the total spinning pressure and the radial spinning pressure increase significantly with the increase of the reduction rate and feed rate, and the axial and tangential pressure increase amplitude is smaller.

3) When the 38CrSi alloy steel cylinder is rotated by the forward strong spinning method, the main spinning process parameters are: the thinning rate is 20%, the feed rate is 0.8mm/r, the working angle of the roller is 200, roller radius of 8mm, the workpiece will form a better quality.

References

[1] Chenghe Wang, Kezhang Liu,Spinning Technology., China Machine PRESS, Beijing, 1986.

[2] Yunhao Zhao, Yanli Li,Spinning Technology and Application., China Machine PRESS, Beijing, 2008.

[3] Guoping Yang, Jie Li, Jianjun Cong,et al, Finite Element Analysis of Influences of Process Parameter and Billet Structure on Tube Elongation Efficiency in Power Spinning, Aerospace Manufacturing Technology. 03(2014) 36-39.

[4] Kun Yang, Jian Li, The Multi-passes Spinning Process of TA2 Tube Based on Finite Element Method, Journal of Plasticity Engineering. 02(2010) 39-44.

[5] Mei Zhan, Shangguan Ma, The treatment of Relative Motion between Mandrel and Roller in Numerical Simulation for Tube Spinning, Journal of Netshape Forming Engineering. 06(2011) 107-111.

[6] Qinxiang Xia, Gangfeng Xiao,et al, A study of manufacturing tubes with nano/ultrafine grain structureby stagger spinning, Materials and Design. 59(2014) 516–523.

[7] Lee KS, Lu L, A study on the flow-forming of cylindrical tubes, J Mater Process Technol. 113(2011) 739–742.

[8] Xinhe Li, XinQuan Yang, Yanfen Wang, Research progress of thin-wall tube spinning ,Forging&Stamping Technology. 01(2011) 7-12.

[9] Fulin Guo, Binbin Zhang, Chenhao Qian,et al, Cylindrical Internal Gear Spinning Forming Technology Research, Metal Working. 09(2011) 54-56.

[10] Xinhe Li, Yanping Liu, Yuesheng Yan,et al, Analysis on Bulging during Flow Forming of Tube with Ultra Thin-wall and Large Diameter,Journal of Plasticity Engineering. 03(2012) 64-70.