Research on influence of spinning process parameters based on simulation and experiment

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Abstract. In this paper, we focus on the need for the process of spinning manufacturing, the spinning manufacturing simulation of INCONEL718 cylinder part was finished, the scheme consists of two-pass and three wheels spinning, three wheels offset. The FEM (finite element analysis) was used to finish the spinning manufacturing simulation, the stress-strain cloud picture was attained, it takes the wall thickness difference as analysis object, the influence law of spinning wheel feed rate and spinning wheel working angle was analyzed, the spinning manufacturing experiment was done based on the parameters attained by simulation, experimental result coincides with the simulation result. The experimental result shows that the simulation methods and parameters are beneficial to the actual spinning manufacturing.

1. Introduction
Spinning is an advanced forming technology which is no chip of successive partial rotary forming [1-2], it is an important branch of plastic working, it has the advantages of good deformation conditions, small size tolerance, the high material utilization rate, especially in the processing of the large complex thin-walled shell it have obvious advantages[3], by adopting the method of spinning processing parts, through more than once spinning, hot-working, make the spinning blank organization grain refinement, effectively improve the material itself defects such as shrinkage cavity, inclusion and porosity[4], if the unreasonable parameters of spinning process were used, the spinning parts will appear all kinds of flaws[5]. The reasonable process parameters can effectively control deformation of the parts in the process of spinning[6] manufacturing. The method of FEM can be used to analyze the spinning process [7]. This paper mainly aims at spinning forming simulation of INCONEL718 cylinder parts, the FEM method is adopted to simulate the multi-pass spinning forming process of parts and it discusses stress and strain distribution rule in the deformation process, it can provides the basis for the determination of the actual spinning process parameters and optimization. This paper uses the DEFORM-3D software to build INCONEL-718 cylinder parts simulation model, to simulate the spinning forming process and according to the results of simulation to direct and finish the spinning manufacturing experiment, the experimental result shows that the simulation process parameters are beneficial to the actual spinning manufacturing.

2. The Simulation Design
Spinning manufacturing simulation scheme, as shown in figure 1, in the simulation process, a core mould and the blank is fixed, the spinning wheel around the axis of the blank make rotary motion and linear motion. The trajectory of the spinning wheel can be decomposed into two kinds of motion, one
is around the rotation axis Z, the other is along the Z axis linear feed motion, the motion trajectory as shown in figure 2. In the spinning process simulation, in order to simplify the motion and the constraints defined state, it assumes that the blank and core mould are fixed, the spinning wheels around the Z axis (rotating axis) make rotation and axial feed motion along the rough surface, the friction coefficient is set to be 0.1, the friction factor between core mould and blank is set to be 1. To ensure that the simulation is equivalent to the actual spinning process, the contact between blank and core mould is defined to be constraint condition, the X, Y, Z direction of the displacement and rotating speed of the blank are defined as 0.

![Figure 1. Spinning scheme](image1)

![Figure 2. The trajectory of the spinning wheel](image2)

The specific parameters of the simulation analysis are as follows: Blank material: Nickel-based alloy INCONEL-718; Spindle wheel material: H13; Spinning style: forward; Blank dimension: wall thickness 10mm; Spinning passes: two-pass, three wheels spinning; Three wheels offset: 8mm; Core mould temperature: 350°C; The spinning wheel temperature: 200°C; Heating temperature of work piece spinning: 500°C; Spindle speed: 150rpm. The reduction ratio with offset condition as shown in table 1. In order to ensure the effect of the simulation, four simulation schemes with different process parameters were designed as shown in table 2.

### Table 1. Reduction ratio with offset condition, blank wall thickness is 10mm

| Pass | Spinning wheels | Blank wall thickness (mm) | Press amount (mm) | The reduction ratio |
|------|-----------------|----------------------------|-------------------|--------------------|
| 1    | 1               | 10                         | 1.5               | 15%                |
| 1    | 2               | 8.5                        | 1.3               | 15.30%             |
| 1    | 3               | 7.2                        | 1.2               | 16.70%             |
|      | Pass reduction ratio |                   |                   | 40%                |
| 2    | 1               | 6                          | 0.5/1             | 8.3 %/16.7%        |
| 2    | 2               | 5.5                        | 1                 | 18.20%             |
| 2    | 3               | 4.5                        | 1                 | 22.20%             |
|      | Pass reduction ratio |                   |                   | 41.70%             |

### Table 2. Simulation schemes with different process parameters, blank wall thickness 10mm

|                     | Spinning wheel working angle(°) | Spinning wheel working fillet radius R (mm) | Feed rate f (mm/min) |
|---------------------|---------------------------------|---------------------------------------------|----------------------|
| Program 1           | 20°                             | 8                                           | 150                  |
| Program 2           | 30°                             | 8                                           | 150                  |
| Program 3           | 20°                             | 8                                           | 300                  |
| Program 4           | 30°                             | 8                                           | 300                  |
3. **Simulation Result**

Due to the influence of the technological factors on the quality of the spinning products should be complex, the choice of appropriate process parameters is vital to guarantee the formation of the spinning. In order to predict more effectively before spinning manufacturing and process optimization, spinning simulation experiment was carried out in this paper. Through the simulation experiments, we can shorten the new product development cycle, improve the product structure, enhance product quality, increase the understanding of product performance, reduce the development costs of the products, provide technical support for the final process experiment. Among all the process parameters which influence spinning manufacturing, two important parameters are spinning wheel working angle and spinning wheel feed rate. The simulation analysis of spinning manufacturing based on the above two parameters has been carried on in this paper. Take 60% of each pass as the observation point, analyze stress and strain condition generated by different spinning wheel working angle and different spinning wheel feed rate. The result as shown in figure 3, stress and strain result produced by spinning manufacturing when the spinning wheel feed rate is 300 mm/min, spinning wheel working angle is 20° and 30°.

![Figure 3. Stress and strain of spinning](image)

As shown in figure 4, that is the spinning forming section of the cylindrical part, which located in 60% of first pass and the second pass, it can be directly observed from this figure that materials flow...
state after extrusion.

(a) Section state (60% of the first pass)  
(b) Section state (60% of the second pass)

Figure 4. Spinning profile graph

4. Analysis of Simulation Result

When spinning forming of the blank was finished, take section faces which distance should be 20 mm, 40 mm, 60 mm, 80 mm, 100 mm, 120 mm and 140 mm from the top surface as observation point, measuring the wall thickness in +X, -X, +Y, -Y four directions and calculate the wall thickness difference, then compare and analyze the influence rule of spinning wheel working angle and spinning wheel feed rate to the spinning precision. When spinning wheel working angle \( \alpha = 30^\circ \), spinning wheel feed rate \( f \) is 150 mm/min and 300 mm/min respectively, the analyzed influence law of wall thickness difference can be shown in figure 5.

![Figure 5. Influence of spinning wheel feed rate on wall thickness difference](image)

![Figure 6. Influence of spinning wheel feed rate on wall thickness difference](image)

It can be seen from figure 5, when spinning wheel working angle is 30° and spinning wheel feed rate is 150 mm/min, the wall thickness difference is smaller and the spinning manufacturing has better effect. When spinning wheel working angle \( \alpha = 20^\circ \), spinning wheel feed rate \( f \) is 150 mm/min and 300
mm/min respectively, the analyzed influence law of wall thickness difference can be shown in figure 6. It can be seen from figure 6, when spinning wheel working angle is 20° and spinning wheel feed rate is 300 mm/min, the wall thickness difference is smaller and the spinning manufacturing has better effect.

5. Spinning Processing Experiment
In order to improve the spinning manufacturing efficiency and obtain better quality, we use the process parameters got by simulation analysis in actual spinning manufacturing experiment for INCONEL718 cylinder parts, in which spinning wheel working angle $\alpha=20^\circ$, spinning wheel feed rate $f=300$mm/min. Spinning wheel, spinning machine shown in figure 7 (a), (b), the finished cylinder parts as shown in figure 7 (c), (d), the measured result of finished parts shows that actual spinning manufacturing result coincides with the simulation result. The parameters obtained from simulation can be used to direct actual manufacturing.

![Spinning wheel](image1)

(a) Spinning wheel

(b) Spinning machine

(c) Cylinder blank

(d) Finished cylinder parts

**Figure 7.** Spinning wheel, machine, blank and finished spinning parts

6. Conclusion
The main theme of this paper is to find the optimized parameters by using simulation method and use it to direct the actual spinning manufacturing. FEM is adopted to the spinning simulation of INCONEL718 cylinder part, and we get the spinning forming process stress and strain condition, through analyzed the spinning cylindrical wall thickness difference, the influence law of spinning wheel feed rate and spinning wheel working angle on wall thickness was gained, apply the simulation process parameters to actual spinning experiments, the measured result of finished parts indicates that the experimental results accord with the simulation results, The parameters obtained from simulation can be beneficial and used to direct actual spinning manufacturing.

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