Research on the Influence of Main Spinning Process Parameters on the Forming Quality of 20 Steel by Strong Spinning

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Abstract—With the continuous development of spinning technology, more and more products are processed by spinning. Every time spinning a new product, it is necessary to reset the spinning process parameters, which are usually determined by spinning process test. If the influence of spinning process parameters on the forming quality can be grasped, it can help the rapid setting and optimization of spinning schemes. In this paper, through a large number of spinning process tests, the effects of spindle speed and feed rate on the strength of 20 steel were analyzed, including the defects such as corrugation, cracking, and diameter expansion, as well as the spinning force, roundness and nominal diameter tolerance. The research results of this paper have certain scientific significance for the reasonable setting of process parameters of 20 steel, and provide theoretical basis for the optimization of spinning process parameters.

1. INTRODUCTION
Cylindrical spinning is an advanced processing technology which integrates the characteristics of forging, extrusion and stretching. With the continuous development of spinning technology, more and more products are processed by spinning[1-3]. Each time spinning a new product, it is necessary to reset the spinning process parameters, which are usually determined by spinning process test[4-6]. Each new product needs at least 8 trials of spinning process test to determine its final spinning process scheme. This method not only causes material waste, but also delays production time. In this paper, nine sets of spinning process tests were carried out on 20 steel. Under the condition of only changing the spindle speed and feed rate, the effects of these two spinning process parameters on corrugation, cracking, expanding, spinning pressure, roundness and nominal diameter tolerance were explored. The research results of this paper have certain scientific significance for the reasonable setting of process parameters of 20 steel.

2. TEST PLAN
20 steel has good toughness and strength. The final dimension of the blank used in this test is $\phi$ 185mm×20mm×155mm. Spinning process test was carried out on QX62 double-wheel strong spinning machine produced by a research institute in Changchun. In order to carry out comparative analysis, according to the main factors affecting the processing quality, nine groups of spinning process parameters were set to evaluate the forming quality of 20 steel.
schemes are set for the experimental blank, with the fixed thinning amount of 5%, the fixed working angle of the spinning wheel and the cold spinning, and the lubrication of molybdenum dichloride, which only changes the spindle speed and feed rate, as shown in Table 1.

| Schemes   | Spindle speed | Feed rate  |
|-----------|---------------|------------|
| Scheme 1  | 100rpm        | 50mm/min   |
| Scheme 2  | 100rpm        | 100mm/min  |
| Scheme 3  | 100rpm        | 150mm/min  |
| Scheme 4  | 150rpm        | 50mm/min   |
| Scheme 5  | 150rpm        | 100mm/min  |
| Scheme 6  | 150rpm        | 150mm/min  |
| Scheme 7  | 200rpm        | 50mm/min   |
| Scheme 8  | 200rpm        | 100mm/min  |
| Scheme 9  | 200rpm        | 150mm/min  |

The spinning process test was performed according to the spinning process scheme 1 to 9, and the obtained spinning products are shown in Figure 1.

3. CORRUGATION AND CRACKING DEFECT ANALYSIS

In the whole process of spinning, there are two parts: tensile stress area and compressive stress area. Some fine cracks are prone to occur on the surface of the spin-formed product under tensile stress, and the surface of the product under compressive stress is prone to bulge, which is the accumulation of metal materials in front of the spinning wheel. Under normal circumstances, as long as the spinning process parameters are set reasonably, this metal accumulation phenomenon will begin to occur during the spin-up phase and maintain a stable state throughout the spinning process. And this metal accumulation phenomenon will not have any effect on the normal spinning of the products. However, if a serious metal accumulation phenomenon occurs during the spinning process, the deformation and instability of the spinning product will be caused, and cracking and corrugation will occur when the situation is serious. There are two main factors affecting the metal accumulation in front of the spinner,
namely the thinning rate and the feed rate. In this paper, because the thinning rate is fixed, this article only discusses the effect of the feed amount on the metal accumulation in front of the wheel.

When the working angle of the spinning wheel and the thickness reduction are fixed, the metal accumulation coefficient is 0.12 when the feed rate is 0.67mm/r. The metal accumulation in front of the spinning wheel is obvious. When the feed rate is 1mm/R, the coefficient of metal accumulation degree is 0.15. The metal accumulation in front of the spinning wheel is relatively small, and there is no gradual accumulation. When the feed rate is 1.5mm/r, the coefficient of metal accumulation degree is 0.26. The deformation of the whole blank is relatively stable, and its spinning quality is the best.

Figure 2 shows the relationship between the feed rate and the metal accumulation coefficient. It can be seen from the figure that with the increase of the feed rate, the metal accumulation coefficient is also increasing. When the feed rate exceeds a certain value, the metal accumulation in front of the spinning wheel will be too large, which will lead to instability or even fracture.

4. DIAMETER EXPANSION DEFECT ANALYSIS
The phenomenon of diameter expansion of cylindrical parts during strong spinning is due to the fact that not only the axial flow but also the tangential flow of the metal occurs during the cylindrical spinning of the blank, which leads to the expansion of the diameter of the spinning product. The size of the expanded diameter of the spinning product will mainly affect the diameter accuracy, roundness and straightness of the spinning product.

The influence curve of the feed rate on the diameter expansion is shown in Figure 3. With the increase of feed rate, the corresponding expanding diameter is smaller and smaller. The reason is that in the case of larger feed rate, the metal flow is mainly concentrated in the axial direction, while the flow in the tangential direction is relatively small.

5. INFLUENCE OF SPINNING PARAMETERS ON SPINNING FORCE
Take scheme 5 as an example to explore the variation law of spinning force. The spinning force-time curve measured by spinning process in scheme 5 is shown in Figure 4. A is an axial force, b is a radial force, and c is a tangential force. It can be seen from the figure that in the spinning stage, the spinning pressure rises rapidly. Due to the metal accumulation in front of the spinning wheel, there will be a peak value of the spinning force in the initial stage. Then, with the stability of the metal accumulation in
front of the spinning wheel, the spinning force falls back and gradually keeps stable. Finally, at the end of the spinning stage, the spinning force disappears rapidly.

5.1. Effect of feed rate on spinning force
The selected spindle speed is 150rpm, and the feed rates of 50mm / min, 100mm / min, and 150mm / min are applied to study the effect of different feed rates on the spinning force. The experimental results are shown in Figure 5 as the effect of feed rate on the radial force. Figure 6 shows the effect of the feed rate on the axial force.

When the feed rate of the spinning wheel is 50 mm / min, the maximum values of the radial, axial and tangential spinning forces are 31.33KN, 14.68KN and 0.30KN respectively. When the feed rate of the spinning wheel is 100 mm / min, the maximum values of the radial, axial and tangential spinning pressures are 44.25KN, 20.64KN and 0.66KN. When the feed rate of the spinning wheel is 150 mm / min, the maximum values of the radial, axial and tangential spinning forces are 54.29KN, 25.37KN and 1.92KN. It can be seen that with the increase of feed rate, the spinning pressure in three directions increases gradually, because the deformation speed of the blank is affected. In a very short time, there are more and more metals deforming under the extrusion of the spinning wheel, that is to say, the deformation speed of the blank increases in unit time, which is the reason for the increase of the spinning force in three directions.

5.2. The influence of spindle speed on spinning force
The feed rate of the spinning wheel is selected as 50 mm / min and 100 mm / min, and the spindle speed of 100 rpm and 200 rpm are applied respectively to study the effect of different spindle speed on the
spinning force. The feed rate of the selected wheel is 0.5mm/r, and the experimental results are shown in Figure 7.

![Spinning force curve](image)

**Figure 7. The spinning force curve**

When the feed rate of the spinning wheel is 0.5mm/r and the spindle speed is 100rmp, the maximum values of the radial, axial and tangential spinning forces are 37.47KN, 17.65KN and 0.93KN respectively. When the spindle speed is 200 rmp, the maximum values of radial, axial and tangential spinning forces are 38.39KN, 17.97KN and 0.95KN respectively.

The feed rate of the spinning wheel is 100 mm / min and 150 mm / min, and the spindle speeds of 100 rmp and 150 rmp are applied respectively to study the effect of different spindle speeds on the spinning force. It is equivalent to the feed rate of the selected wheel is 1.0mm/r, and the experimental results are shown in Figure 8.

![Spinning force curve](image)

**Figure 8. The spinning force curve**

When the feed rate of the spinning wheel is 1.0mm/r and the spindle speed is 100rmp, the maximum values of the radial, axial and tangential spinning pressures are 52.23KN, 23.25KN and 1.84KN respectively. When the spindle speed is 150rmp, the maximum values of radial, axial and tangential spinning pressures are 54.29KN, 25.37KN and 1.92KN respectively. It can be seen that with the increase of feed ratio, the spinning force in the three directions gradually increases. With the increase of spindle speed, the volume of metal involved in plastic deformation increases in a short time, that is to say, the metal involved in plastic deformation increases in a unit time. This means that the speed of metal deformation increases in unit time, which is the reason why the spinning force increases gradually in three directions.

### 6. INFLUENCE OF FEED RATE ON ROUNDNESS AND NOMINAL DIAMETER TOLERANCE

The factors that have the greatest influence on roundness, straightness, and wall thickness deviation are the thinning rate and feed rate. Since the thinning rate in this paper is fixed, only the effects of the feed rate on its roundness and nominal diameter tolerance are studied. The effect of feed rate on roundness is shown in Figure 9.
It can be found from the figure that as the feed rate gradually increases, the roundness of its spinning products gradually decreases, and when the feed rate reaches 0.75mm/\(r\), the ovality of its spinning products gradually increase. This is because in the case of a large feed rate, the spinning product is easier to stick, and the better the effect of the die, the smaller the roundness of the spinned product. However, when the feed rate is greater than a certain value, the metal flow in front of the wheel is not smooth, and metal accumulation are easily formed in front of the wheel. And the uniformity of deformation begins to get worse, so the ovality of the spinning products begins to increase. Similarly, the feed rate is also an important influence factor of the nominal diameter tolerance, and the influence is shown in Figure 10.

It can be found from the figure that with the continuous increase of the feed rate, the nominal diameter tolerance of the spinning products is getting smaller and smaller. When the feed rate reaches 0.67 mm/\(r\), the nominal diameter tolerance appears to be the smallest. As the feed rate continues to increase, the nominal diameter tolerance increases. The reason is the same as the effect of the feed rate on the roundness. Under the condition of a large feed rate, the spinning product is easier to be stuck, the better the die casting effect, the smaller the nominal diameter tolerance of the spinning product. However, when the feed rate is greater than a certain value, metal accumulation are easily formed in front of the wheel because the metal flow in front of the wheel is not smooth. The uniformity of the deformation began to deteriorate, so that the nominal diameter tolerance of the spinning products began to increase.

7. Conclusion
This paper takes the 20-steel cylindrical workpiece as a research object, analyzes the causes of the defects in each process scheme, and the influence of the main process parameters on the spinning force, stress, strain, roundness, nominal diameter tolerance. It provides a theoretical basis for the optimization of spinning parameters.

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