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Effect of Feed Speed on Aluminum Alloy Pipe Neck-Spinning Process and Deformation Analysis Via Simulation

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Abstract. In pipe neck-spinning process, the feed speed has great significant on pipe deformation and smoothly proceeding of spinning. In this paper, the nonlinear finite element software SuperForm is used to simulate the deformation in pipe multi-pass neck-spinning process, the stress distribution inside and outside of the pipe deformation zone, as well as the stress on spinning roller. The results show that, after nine times neck-spinning, the maximum deformation locates in the pipe mouth, and the stress on the outside of the pipe is larger than the inside. With the increasing feeding rate, the thickness of pipe necking deformation zone decreases, while the pipe length is shortened to 4.66mm. The stress in X direction on spinning roller increases with the prolonging of time in the medium term of spinning, but that in Y direction did not changes significantly.

1 Introduction

The Pipe Neck-Spinning process is very important to the quality and forming of pipe [1]. Whether the roller's trail is suitable to the deformation zone, and guarantees the precision of deformation size and successful formation work-piece [2-4]. The metal deformation is complicated in the spinning process, nowadays, the main method of pipe spinning is relying on practical experiments, and it needs much time and cost, meantime, it's so hard to measure the date of strain and stress distribution in practical spinning process, renders the deformation rules of pipe study not clear yet.

While it could be easy and convenient with the software to simulate the pipe spinning process, the process conditions are set initial, and the results shows with many forms [1-4], like stress distribution of the deformation zone and possible exit defects in the spinning

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process, at the same time, it could predict the precision of size, and guiding practical spinning process [7-8]. In this paper, the aluminum alloy neck spinning process is studying, analyze the deformation behaviors and stress distribution, including three directions —— radius, circumference and axis direction which is located on the connect zone of deformation and non-deformation zone in spinning process of pipe.

2 Building Simulation Model

Necking spinning of pipe, and the process has 9 passes spinning. Long axis of the spinning ellipse trail is 208.7 mm, and short axis is changing from 181 mm to 146 mm. Using finite element software SuperForm to simulate and analyze. The material of pipe is 6061 aluminum alloy. Density is 2.9 g/mm3, and elasticity modulus is 68.9 MPa, and Poisson ratio is 0.33.

Meshing it based on the shape of pipe when the pipe bottom is formed. There are 21 240 units meshed before spinning process. Due to take place mesh distort in the spinning process, so it’s would mesh again when the 6th and 9th pass begins. Table 1 is the initial size of the pipe and some spinning process parameters, the length of pipe spinning deformation is 210 mm, wall thickness is 7.5 mm.

Table 1 The Initial Size Of The Pipe And Some Spinning Process Parameters

Size of pipe [mm]	Size of roller [mm]	Velocity of mandrel [$r\cdot min^{-1}$]	Temperature of spinning [^{o}C]
Φ417.5×210×7.5	Φ400×100，R15	200	350

3 Results and Discussion

3.1 Deformation of Pipe on Different Feed Speed

When the spinning process is beginning, the front part radius of the pipe for spinning is 14.6 mm, and the wall thickness of deformation zone is increasing remarkably with spinning direction, at the same time, the length of pipe is increasing by 20 mm. The metal flow direction is similar to spinning moving direction, and because the process has not a mandrel in the pipe, so the deformation resistance is relatively smaller, and on the surface of pipe, it is suffered huge compressive stress, so that metal flow is increasing with deforming process. Fig. 1 is the initial shape of necking spinning process, and it shows that the wall thickness of deformed zone is increasing by 4 mm on the front zone, reach 11.85 mm. With the necking spinning beginning, it is happened that different deformation behaviors on different spinning pass and the metal flow and plastic deformation is more and more big. The mouth of pipe has been form after the 1st pass, as Fig. 2 (b) shows. With spinning proceeding, the deformation of the pipe mouth is more severe. The metal on the deformation is increasing flow to the mouth zone, makes the length of the mouth is prolonging by 20 mm (like Fig. 2 (d) presents).

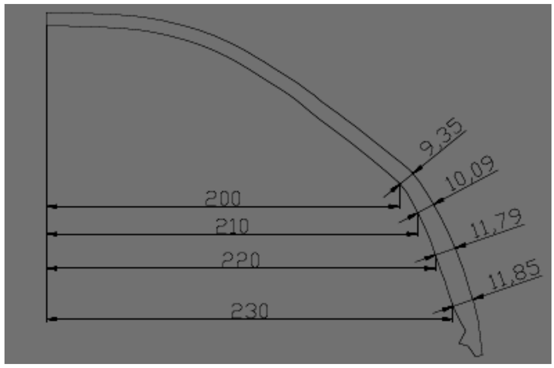
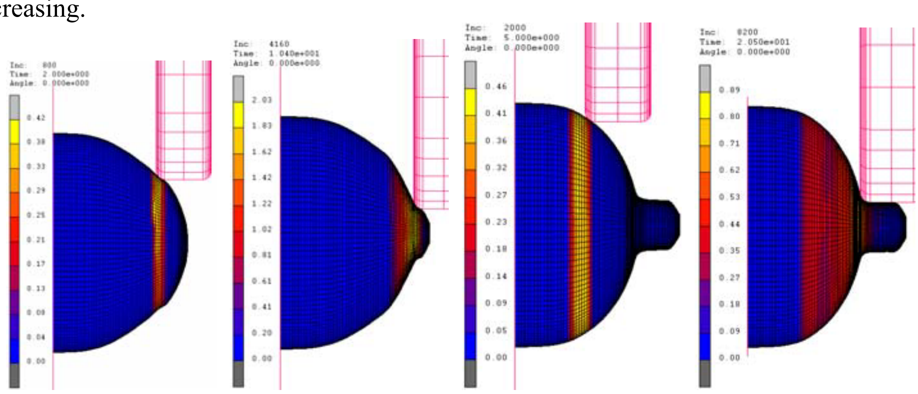


Fig. 1 The cross section deformation before necking spinning process begins

The spinning feed speed is very important to the precision and quality of pipe. It not only affects the deformation behaviors of spinning pipe, but also has an influence on the process environment of spinning, because the spinning work-piece temperature is changing with the feed speed is varies on a large range. When the rate is relatively slow, the deformation of pipe is smaller, too, and the change of deformation zone temperature is small, it makes the mouth zone easy fracture when spinning deformation process. However, while the rate is increasing to higher, the temperature on the pipe surface is very high, so the phase transformation on the deformation zone may be take place, and the pipe is easy over burning. The pipe is undergoing a series of spinning process before necking spinning, but in the necking spinning process, the main deformation zone is the mouth deformed. Due to with feed speed is decreasing; the deformation zone's wall thickness is reducing more. And more passes of spinning could not meet the needs of wall thickness precision. So improving the speed from 600 r/min to 800 r/min, and simulating the process again while the feed speed is 800 r/min, meantime, analyzing the deformation behaviors on the different spinning condition. As states above, the feed speed is important to the size precision. When the rate is improving to 800, the simulation results show that the shape of the pipe deformation mouth zone is not affected, however, the length of the mouth is reduced, and from Fig.3 is found, the corner of the mouth and the pipe arc part is better than in 600 r/min, at the same time, the wall thickness is increasing.



(a) (b) (c) (d)

Fig. 2 The pipe deformation when the 1st pass is going 2 second (a) and 10 second (b) and when the 9th pass is going 3 second (c) and 14 second (d)

The feed speed is improving, render that the connect time between the pipe and the roller is reducing, and the wall thickness's reduction of each second is relatively smaller than before, furthermore, the total reduction in the process is not change, so the deformation is slow down, with time going, the more metal flow to the mouth zone, gently, however, due to the fast rate, the metal flow is more tend to inside, but not moving along the mouth length direction.

3.2 Strain Distribution on Different Feed Speed

The inside and outside part of pipe are suffered different strain in necking spinning process. The simulation results show that the outer part strain is greater remarkably than the inside of pipe. And the strain of corner of the mouth and the pipe arc part is biggest, as Fig. 4 presents, at the same time, the stress of that is biggest, too. However, stress and strain of the front zone of pipe are relatively smaller than other part's, because its deformation is smallest, and it is not suffered stress from the rollers. While in the necking spinning process, the deformation between the mouth and the pipe arc part is different, so simulation result reveals that the mesh is distorted along circumference direction.

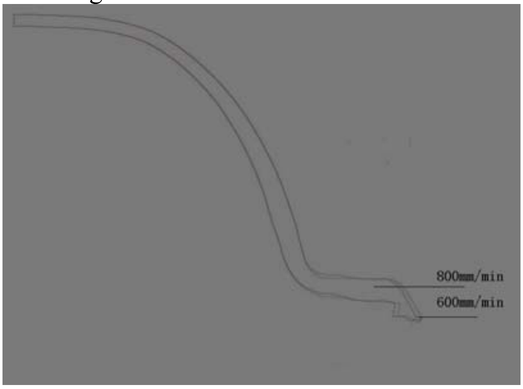


Fig. 3 The cross section deformation under different feed speed of spinning process

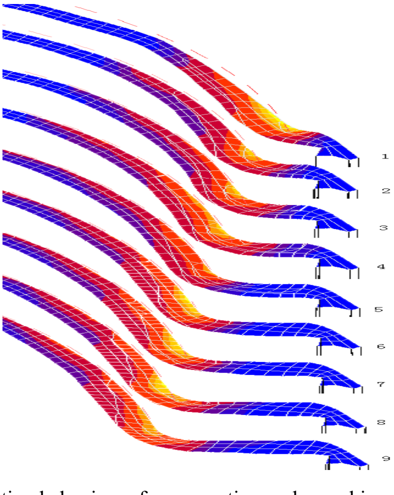
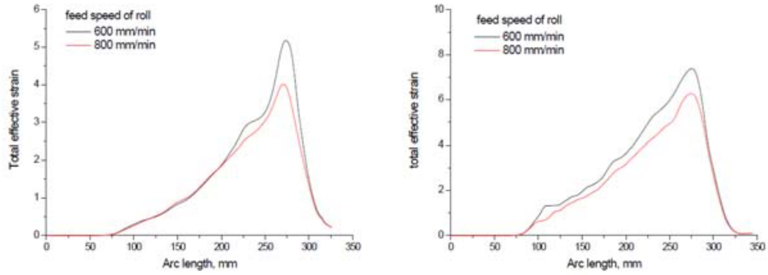


Fig. 4 Deformation behaviors of cross section under necking spinning process.

With feed speed increasing, the strain of the deformation zone along arc length direction is decreasing. Fig. 5 shows the strain distribution along pipe arc length direction. And the peak value is corresponding to the corner; it can be found the stress of the corner is reducing most. Although the points of deformation zone connecting chances with the rollers are increasing under bigger feed speed condition, the each connecting time is less, and the wall thickness's reduction is not change, too. Feed speed increased makes deformation zone wall thickness's reduction is smaller, so the stress of deformation zone is relatively decreasing.



(a) Inside (b) Outside

Fig. 5 Strain distribution under different feed speed in the necking process

The stress of rollers suffered is different from the pipe when the feed speed improving. Fig. 6 is the stress of rollers suffered, and it reveals that at different feed speed condition, the stress changes consistently with time. On the X axis direction, the stress is increasing when feed speed is 800 r/min, however, the stress along Y axis is same as at 600 r/min. On the whole, the effect of feed speed on the rollers is not remarkable.

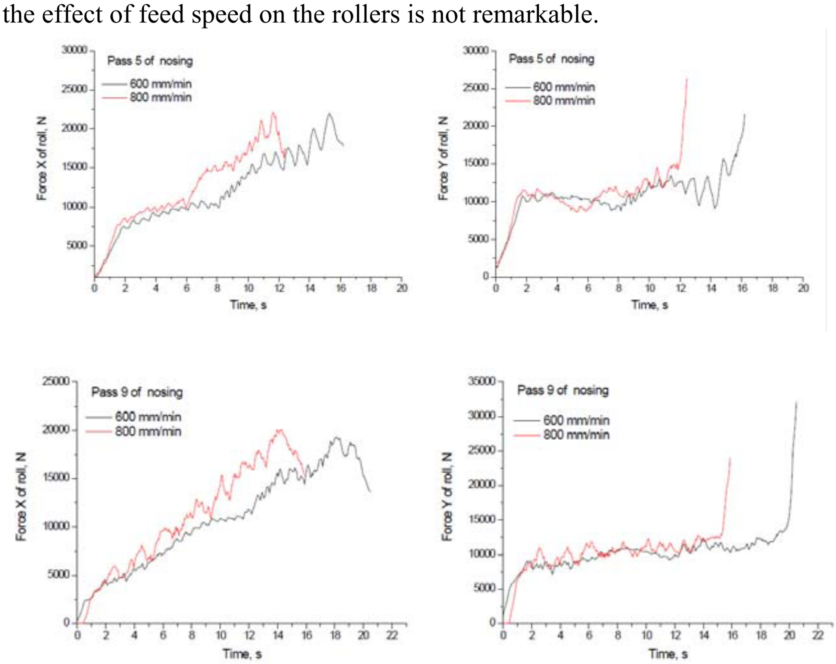


Fig. 6 Stress distribution under different feed speed in necking spinning process

4 Conclusion

(1) According to the spinning deformation process, the spinning roller speeds in each pass are discussed mathematically, and the spinning roller trail of simulation models is

exactly the same with that of process set. The numerical simulation of pipe neck-spinning is successfully implemented.

(2) The size and strain distribution are obtained after spinning in each pass, and the stress on spinning roller is also obtained during spinning process.

(3) The stress in pipe outside is greater remarkably than inside, and the biggest deformation is located on the corner of the mouth formed and the pipe arc part. With feed speed is increasing, the wall thickness is greater than slow feed speed, and the length of the mouth is reduced. The stress at high feed speed is less, therefore, the deformation resistance is decreasing.

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