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DEFORMATION LAW OF AEROSPACE THIN-WALLED THE RODS WITH THREE-ROLL SIZE REDUCTION AND END EXTRUSION THICKENING

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Aiming at the aerospace aircraft tie rod pipe fittings with indented riveted threaded bushing manufacturing, there are problems such as low connection strength, manufacturing cost and high weight, this paper innovates a new process of three-roll reduction and end extrusion thickening to form the aerospace thin-walled tie rods, and adopts the simufact finite element analysis (FEA) software to numerically analyse the forming process of the thin-walled fittings of A6061 aluminium alloy and analyse the equivalent plastic strain distribution, the change rule of the force-energy parameter, as well as the uniformity of the wall thickness in the process of rolling and squeezing, so that we can get the principle of rolling and squeezing forming and deformation rules of the thin-walled tie rods, and the results of the research provide the theoretical foundation for the domestic forming of the thin-walled tie rod pipe fittings.

Key words: aerospace rods; three-roll reduction; extrusion thickening; roll forming

INTRODUCTION

The rod fittings account for about 25 % of the total weight of an aircraft. Aluminium alloys are widely used in aerospace aircraft because of their light weight, corrosion resistance and high strength.Traditional aircraft the rod fittings are limited by the billet wall thickness, when the billet wall thickness is too thin, direct tapping threads will lead to rupture of the fittings, riveted threaded sleeve manufacturing method will result in the aircraft connection of low strength, manufacturing costs and high weight defects.

Domestic and foreign for the use of rolling and extrusion process for the production of aerospace the rod research results are less, Du Bing et al [1] on the tube shrinkage forming process of wrinkle instability theory research, Li Xiaodong et al [2] explore 5A02 aluminium alloy tube extrusion compression notch thickening process of thickening area of the impact of the average wall thickness and the standard deviation of the wall thickness and the formation of the law, Akopyan T K, etc. [3] to explore high-temperature radial shear rolled 7075 Aluminium Alloy The effect of strain and stress distribution in the cross section of processed bars, Ye Bohai et al [4] investigated the effect of wall thickness at the end of three-roll slant rolled thin-walled pipe fittings billet on the force-energy parameter and wall thickening effect, Shu et al [5] discussed the feasibility of various types of slant rolled technology to form a hollow shaft and the key technological issues, which expanded the scope of slant rolled applications.

Although many scholars on the pipe fittings extrusion compression notch and three-roll tilt rolling to reduce the size of a wealth of research, but the pipe notch rolling extrusion forming research is not mature. In this paper, the process of manufacturing aerospace the rod forming principle, analysed the forming process of rolling equivalent plastic strain distribution, force energy parameter change law and rolling wall thickness uniformity.

AIRCRAFT THE RODS THREE-ROLL REDUCTION AND EXTRUSION THICKENING FORMING PRINCIPLE

Rolling extrusion process refers to the billet through the three-roll tilt rolling reduction and end extrusion thickening forming, as shown in Figure 1, the entire rolling extrusion process including billet reduction, end forming, neck forming and end thickening four stages. The billet will be placed in the roll finishing section, through the radial movement of the roll on the billet indentation, and through the chuck axial movement to promote the billet formed out of the end of the thickening volume, followed by axial movement of the chuck and the radial movement of the roll on the billet neck reduction and forming, and finally the chuck will be rolled fixed in the extruder die at the end of the extruder wall thickening using the process of the counter-extrusion.

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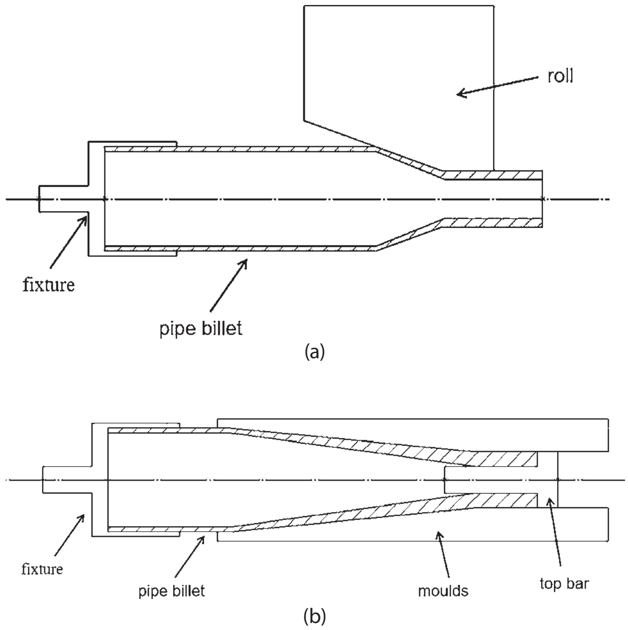

Figure 1 (a) Schematic diagram of neck reduction and (b) End thickening schematic

FE modelling of aerospace the rods by three-roll tilt-roll reduction and extrusion thickening forming

The geometry of the aerospace the rod studied in this paper is shown in Figure 2, the diameter of the billet is 32 mm, the length is 140 mm, the initial wall thickness of the billet is 1.5 mm, and the length of the end of the target tubing after rolling is 17 mm, and the wall thickness is 4.5 mm. In order to verify the feasibility of the process, the use of simufact 16 software on the thin-walled pipe fittings rolling process simulation, in order to improve the efficiency of simulation simulation, according to the principle of rolling symmetry, the simulation process using one half of the thin-walled billet rolling simulation, as shown in Figure 3.

The billet is defined as elastic-plastic body, the material is set as A6061 aluminium alloy, and the material model and parameters are selected from Simufact database. In hot rolling forming, the temperature plays a very important influence on the simulation results, so the temperature of the workpiece is set to 400 °C, and the heat transfer coefficient with the environment adopts the fixed value of 197 w/(m^2-k) of simufact material. Rolls, chucks, mandrels and moulds are defined as rigid bodies, the temperature is 20 °C, and the heat transfer coefficient with the environment is set to 0,2 w/(m^2-k). The speed of the roll is 40 r/min, the roll inclination angle is 8°, the forming angle is 20°, the chuck pushes the end forming speed of 4mm/s, the reduced extrusion forming speed is 4,57 mm/s, and the counter-extrusion top bar speed is 5 mm/s. The speed between the roll and the workpiece is defined as rigid, and the temperature is 20 °C. The friction between the roll and the workpiece is shear friction with a friction coefficient of 0,8, the friction coefficient between the shrinkage mould and the workpiece is 0,4, and the friction coefficients of the rest of the moulds and the workpiece are all 0,2.

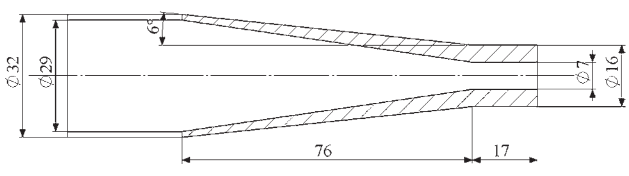

Figure 2 The rod geometry

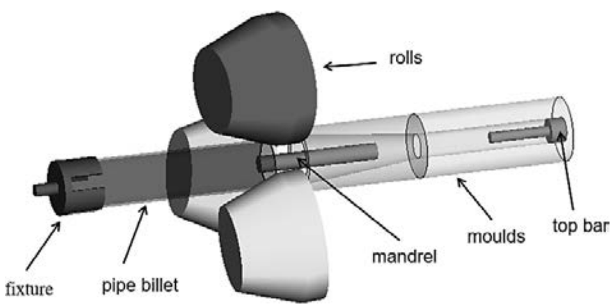

Figure 3 Geometrical model of three-roll slant rolling and extrusion thickening forming

AEROSPACE THIN-WALLED THE RODS WITH THREE-ROLL SIZE REDUCTION AND END EXTRUSION THICKENING DEFORMATION

The FE Simulation of the forming process of thin-walled pipe fittings is shown in Figure 4, which goes through the stages of billet notching, end forming, neck reduction and end thickening. After the cylindrical billet enters the shrinkage stage, the roll with the mandrel to form the inner hole, the neck of the rolled parts can be formed with the radial roll and chuck axial movement, and the traditional mould hot compression shrinkage forming compared to more energy-saving and more efficient.

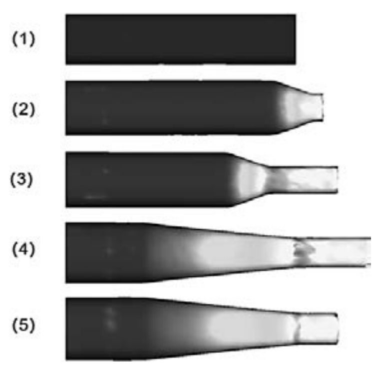

Figure 4 Aerospace the rod forming process

As shown in Figure 5, comparing the forming results with the target forming parts, it can be seen that the end thickening and neck thickening of the rolled parts and the inclination angle meet the expected target. At the same time, the rolled part shrinkage roundness forming quality is high, there is no extrusion wrinkle and neck instability phenomenon, but in the process of counter-extrusion, the end will appear a small amount

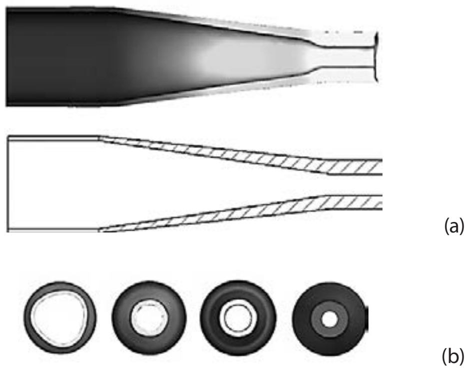

Figure 5 (a) Comparison of Formed Fittings and (b) Thickening Strain Plot for Shrinkage

of flying edge phenomenon. From the final results, the workpiece forming quality is good, no rupture, torsion, collapse and other defects, indicating that the three-roll slant rolling rolling extrusion process for processing such the rod pipe fittings is feasible.

ANALYSIS OF FORCE-ENERGY PARAMETERS

In the process of rolling and squeezing integrated forming, the roll rolling force change curve is shown in Figure 6. When the billet enters the shrinkage forming stage (0 s-7,89 s), the rolls shrinkage forming, the rolling force of the rolls in the range of 0,2-2,6 kN, the rolling force gradually increases. When the piece enters the end forming stage (7,89 s-14,6 s), the roll due to pipe deformation and fixture axial force increases, the rolling force continues to increase, the rolling force of the reduction roll group reached a peak of 4,9 kN; when the piece enters the neck forming stage (14,6 s-30,5 s), the roll reduces the diameter of the neck of the piece and the radial movement of the piece, the piece in the fixture axial force to advance, the roll rolling force in the end forming and neck forming stage of the rapid increase in the rolling force in the end forming and neck forming stage of the roll. Forming and neck forming stage sharply reduced to 2,4 kN, with the reduction of the rolled

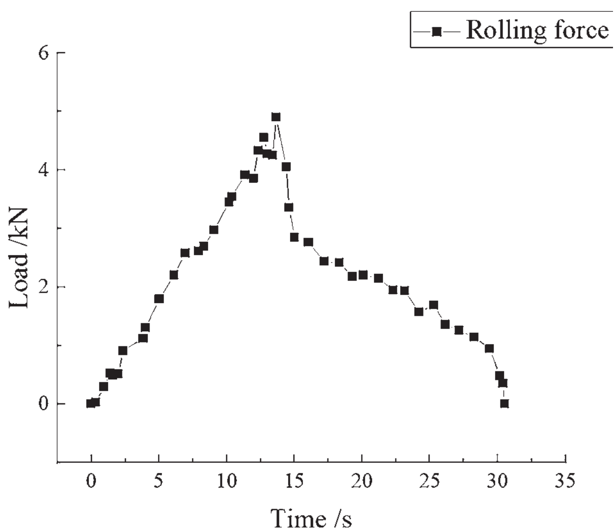

Figure 6 Rolling force

parts, the rolling force of the rolls is gradually reduced, after the completion of rolling, the rolls leave the rolled parts, the rolling force 0.

ANALYSIS OF WALL THICKNESS UNIFORMITY OF PIPE FITTINGS

Now the rolled and extruded the rods as the object of study, respectively, in the neck and end of the region of uniformly selected nodes and analyse their wall thickness changes. As shown in Figure 7, the wall thickness variation rule of the neck and end part of the pipe fitting

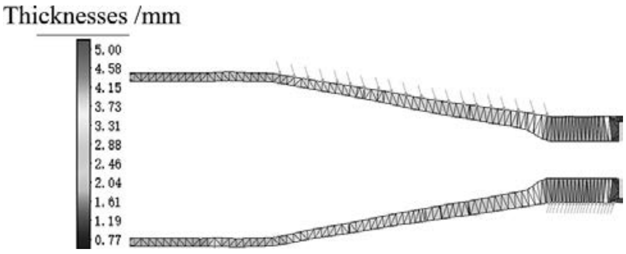

Figure 7 Node Selection

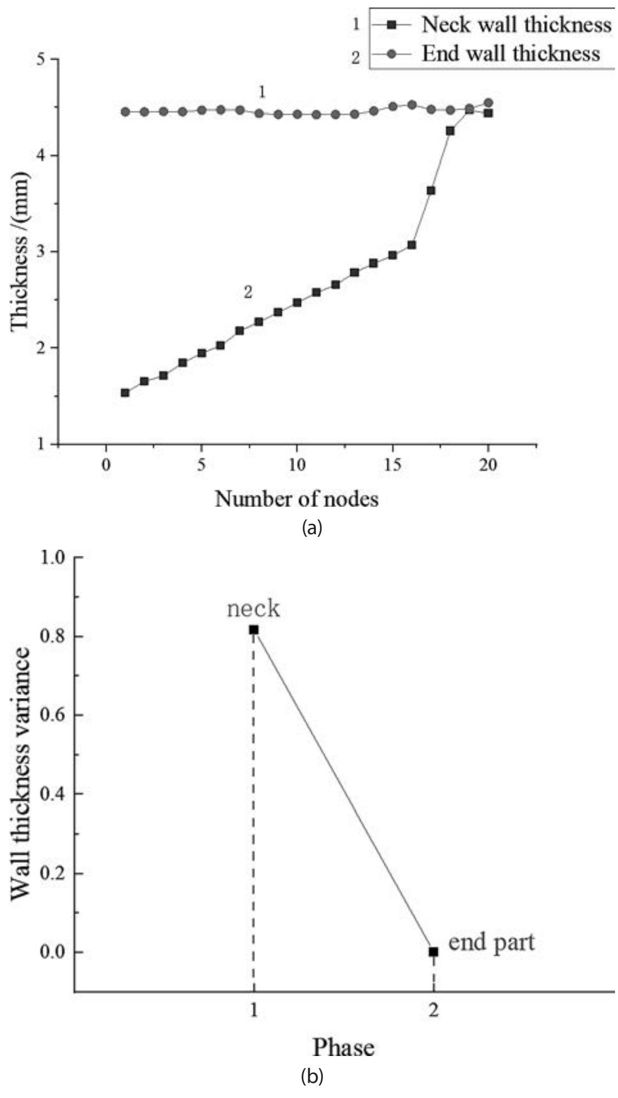

Figure 8 (a) Fitting wall thickness and (b) wall thickness Variance

is studied respectively. The average wall thickness t and wall thickness variance s are introduced respectively to represent the thickening amount of the tubing and the uniformity of the wall thickness, i.e., to calculate the average wall thickness of the two stages and the difference between the wall thickness and the average wall thickness.

$$\bar{t} = \frac{\sum_{i=1}^{m} t_i}{m} \tag{1}$$

$$s = \sqrt{\frac{\sum_{i=1}^{m} \left(t_i - \bar{t}\right)^2}{m}} \tag{2}$$

where m is the number of nodes (m = 20), is the stage node wall thickness, and is the average value of wall thickness at each node.

In the rolling and extrusion forming process, as depicted in Figure 8, the wall thickness and variance undergo two stages. During the neck reduction stage, the fittings' wall thickness increases uniformly. However, at the connection between the neck and the shoulder, the metal flow from counter-extrusion causes an increase in wall thickness. In the end thickening stage, the wall thickness variance becomes smaller, resulting in better uniformity of fittings' wall thickness. This leads to overall higher forming quality. However, due to factors such as extrusion speed and temperature, there may be a slight occurrence of flying edge at the end. This defect can be mitigated by optimizing the process parameters.

CONCLUSIONS

Based on the above study, the following conclusions can be drawn:

- A forming process for neck reduction and end thickening of aerospace the rods is proposed, and the feasibility of the process is analysed by having limited simulation. The plastic forming situation in each stage of the rolling forming process is studied, and the simulation results are compared with the shape and size of the target pipe fittings, indicating that the process has a good forming effect.
- The force-energy parameters of the rolls and top bars in the rolling process and the wall thickness of the formed tubes are analysed, and the forming of the rolled parts and metal flow are analysed to provide reference for the subsequent optimisation of the parameters.
- The deformation law of three-roll size reduction and end extrusion thickening of aerospace thin-walled tie rods is investigated, which lays the foundation for further related research work.

Acknowledgments

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Note: The responsible for English language is Y.S. Chen, Ningbo