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STUDY ON THE VARIATION LAW OF TEMPERATURE FIELD IN THREE-ROLL SKEW ROLLING OF VARIABLE DIAMETER SPECIMEN

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This paper takes the simplified high-speed train hollow axle variable diameter section sample as the research object, uses Simufact.Forming simulation software for simulation, analyze the rolling piece inner variable diameter section, equal diameter section, outer variable diameter section three stages in the forming process of temperature field distribution characteristics and variation, and discusses the causes of temperature field variation.

Keywords: three-roll skew rolling, hollow axle, temperature field, diameter, Finite Element Simulation(FES),

INTRODUCTION

The development of high-speed trains in China is booming, and the hollow axle is the key component of high-speed trains. At present, the mainstream forming process in China and abroad is precision forging, which has the disadvantages of high cost, low material utilization rate, complex forming process and high technical difficulty in producing high-speed axles. China has tried to produce axles by cross wedge rolling, which is difficult to implement due to the shortcomings of large equipment volume and poor mold versatility. The variable roll spacing three-roll skew rolling process can ensure the production efficiency while maintaining the high versatility of the mold. At the same time, due to the process characteristics of local loading, it can save equipment space and realize production automation easily. In addition, the temperature field has a crucial impact on the mechanical properties, dimensional accuracy and stability of rolling process. Therefore, it is necessary to study the temperature field distribution characteristics and variation law.

In 2014, Professor Zbigniew Pater of Lublin University of Technology in Poland innovatively used the variable roll pitch device to make the three-roll skew rolling process produce variable cross-section shaft parts, and concluded that three-roll skew rolling can be used to produce long shaft parts [1]. In 2020, Pater team further tried the simulation of three-roll cross wedge rolling, analyzed and compared the temperature field, stress and strain field and rolling force parameters [2,3]. Xu Chang, Ningbo University, carried out the Finite Element Simulation(FES) of the hollow axle of high-speed train with three-roll skew rolling and the feasibility was verified by preliminary experiments with the existing three-roll skew rolling mill [4,5].

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In summary, there are few studies on the variation law of temperature field in the deformation section of three-roll skew rolling at present, and there is no detailed analysis of the changes in each stage. In this paper, the high-speed railway hollow axle test is divided into three stages, and the temperature field variation law of each stage is described in detail, and the causes of the change are analyzed.

MODEL SIMPLIFICATION

The axle can be segmented along the rolling direction according to the change of section, and each stage is shown in Figure 1.

The study of variable diameter section based on segmentation can simplify the model to the maximum extent, and can significantly reduce the time of finite element simulation. Therefore, the size data of the variable diameter section of the hollow axle of the high-speed train are extracted, and the large size variable diameter section near the two ends of the axle is selected for research. The internal variable diameter section and the external variable diameter section are integrated into a simple hollow rolling piece. The schematic diagram of the test piece is shown in the following Figure 2.

VARIATION LAW OF TEMPERATURE FIELD IN THREE STAGES

During the three-roll skew rolling process, the surface temperature of the high-temperature rolled piece not only has heat exchange when contacting with the roll, but also has heat radiation with the environment. At the same time, the deformation heat is obtained by the transformation of the deformation work of the roll feed. At the same time, the heat exchange is also carried out between the internal part of the rolled piece and the surface at all times. The above factors comprehensively affect the temperature field distribution of the rolled piece, and the

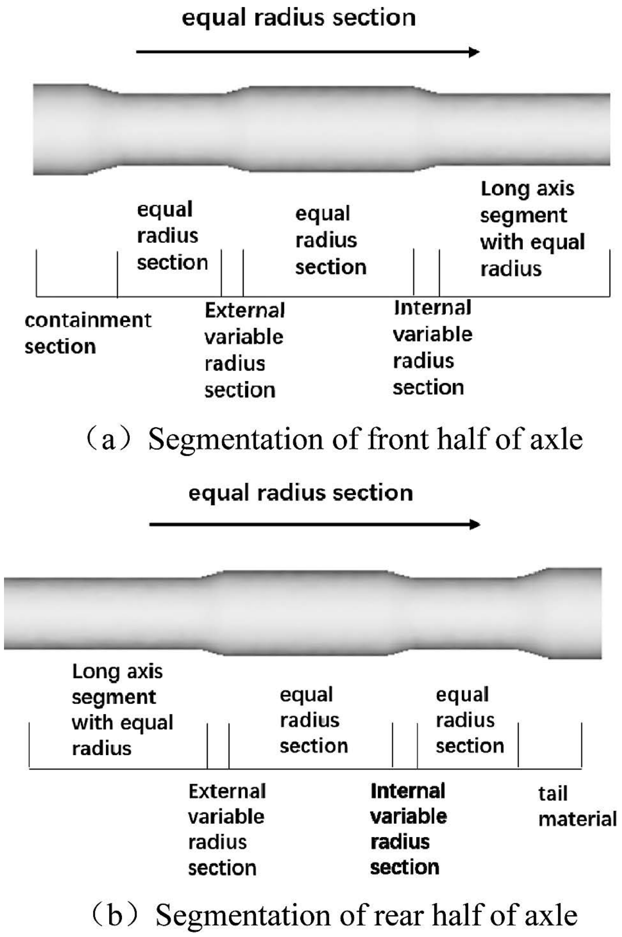

Figure 1 Segmentation of hollow axis

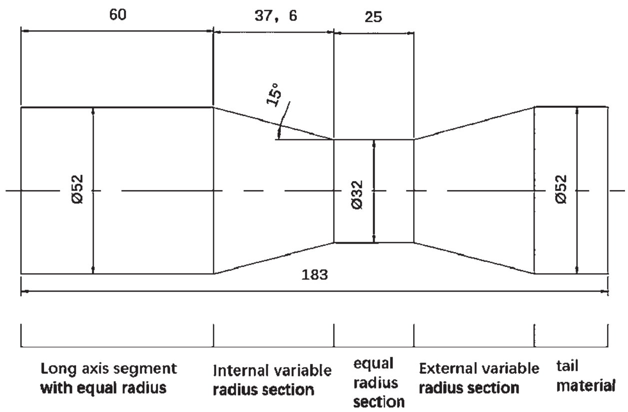

Figure 2 Test piece of hollow axis variable diameter section

temperature distribution also affects the forming quality of the rolled piece and the parameters. So it is necessary to use finite element software to simulate and analyze the rolling situation. The different rolling sections of Figure 2 rolled piece are analyzed as follows.

Rolling temperature field of internal variable diameter section

Figure 3 shows the surface temperature field distribution of the rolled piece and the internal temperature field distribution of the rolled piece. The initial rolling temperature is 1 100 °C, as shown in the first half of Figure 3. There is obvious cooling on the surface of the rolled piece during the rolling process of the inner variable diameter section, which shows that the deformation heat converted by the roll to the work of the rolled piece is less than the sum of the thermal radiation emitted by the surface of the rolled piece to the environment and the heat taken away by the roll surface. Moreover, with the increase of the roll reduction, the surface temperature of the post-processing area of the internal variable diameter section is significantly lower than that of the pre-processing area, and the contact area between the post-processing area roll and the rolled piece is larger than that of the pre-processing area roll and the rolled piece, which indicates that the heat exchange between the roll and the rolled piece takes away a large amount of heat, resulting in significantly lower surface temperature of the post-processing area of the internal variable diameter section than that of the pre-processing area. It can be seen from the lower half of Figure 3 that the radial temperature gradually decreases from inside to outside. The heart slightly lost heat due to thermal radiation, and the temperature did not change significantly. In the radial direction, the closer to the surface, the lower the temperature. This is because the surface and roll take away heat. In the axial direction, the position with the maximum cooling amplitude appears near the end of internal diameter variation, which is the part with the longest contact time between the roll and the rolled piece, so more heat is lost due to the long contact time.

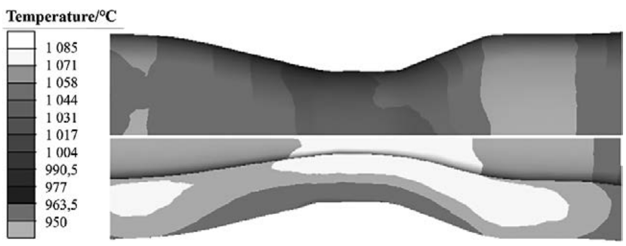

Figure 3 Temperature field distribution in the inward section

Rolling temperature field of equal diameter section

Figure 4 is the surface temperature field distribution and cross-section temperature field distribution when rolling equal diameter section. As shown in the first half of Figure 4, the surface temperature of the rolled piece continues to decrease compared with that of the internal variable diameter section. This is because the roll takes away the surface heat of the rolled piece in the process of forming the equal diameter section, and when the cross-section size is constant, the surface temperature of the region is not much different, which is consistent with the above law. The smaller the cross-section size is, the longer the contact time between the cross-section and the roll is, and the more the heat is taken away. It can be seen from the lower half of Figure 4 that the temperature distribution is more complex than the internal variable diameter section. The temperature on the inner surface of the processed inner variable diameter section decreased, and the highest temperature appeared in the middle of the rolled piece. This was due to that in the rolling process, the thermal radiation on the inner surface and the heat conduction with the air lost part of the heat, resulting in a decrease in the temperature. There is also a similar situation in the equal diameter section, because the heat loss of the inner surface causes local cooling, the highest temperature appears in the center near the inner surface, and the low temperature on the outer surface of the rolled piece transmits inward to form a temperature gradient. From the axial view, the low temperature on the surface of the internal variable diameter section has been transmitted to the interior, and the center temperature is nearly 1 050 °C, while the outer surface temperature of the equal diameter section is lower, but it has not been fully transmitted to the interior. The temperature near the inner surface can still reach 1 070 °C.

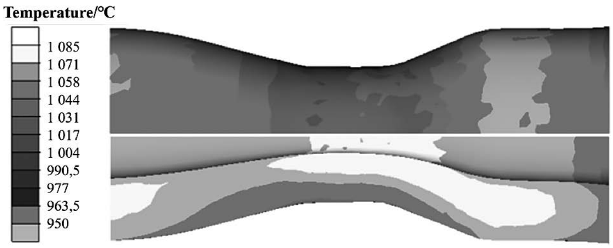

Figure 4 Temperature field distribution in the equal diameter section

Rolling temperature field of external variable diameter section

Figure 5 shows the distribution of surface temperature field and cross section temperature field when rolling external variable diameter section. As shown in the first half of Figure 5, when forming the outer variable diameter section, the surface temperature of the rolled piece is low, which is generally similar to that at the small section of the equal diameter section. The forming of the external variable diameter section is different from that of the internal variable diameter section. The internal variable diameter section is formed by the round chamfer at the tail of the finishing section of the roll, while the external variable diameter section is formed by the inclined roll surface of the roll, and its contact area is much larger than that of the internal variable diameter section, resulting in more heat taken by the roll. Therefore, on the whole, the surface temperature of the external variable diameter section is lower than that of the internal variable diameter section. The lower part of Figure 5 is the temperature field distribution of section. From the radial point of view, except that the outer temperature on the surface is low, there is an obvious temperature gradient in the part which has been processed. The temperature of the center and the inner surface is basically unified. This is because the thickness of the region becomes smaller after plastic deformation, and the internal heat conduction velocity becomes faster. In the external diameter section, the temperature is reduced due to the heat exchange between the outer surface and the roll, and the inner surface also loses part of the temperature due to heat loss. The two surfaces appear relatively low temperature, and the temperature of the core of the rolled piece is high. In the axial direction, the temperature of the processed part tends to be uniform, so the high temperature area exists in the central area of the tail rolled piece. Since the end of the rolled piece is fully exchanged with the ambient heat, even without contact with the roller, the lowest temperature of the rolled piece is close to 900 °C.

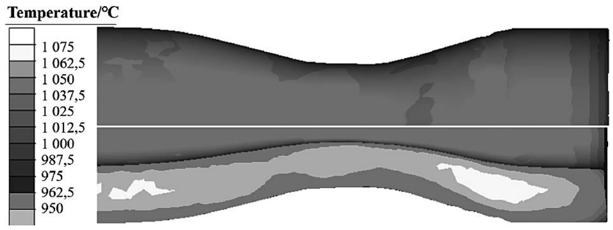

Figure 5 Temperature field distribution in the outward section

CONCLUSIONS

The overall temperature of the rolled piece decreased slightly with the processing. Except for decrease of the temperature of the holding part of the rolled piece and the chuck, the temperature of the contact part with the roller decreases the most, the inner temperature also decreases, and the temperature of the core of the rolled piece is higher. The closer to the roller, the lower the temperature of the rolled piece, and the cooling rate of the rolled piece is the fastest when the large reduction is taken in processing.

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Note: The responsible translator for English language is X.G.Chen, Ningbo, China