Q. J. LIAN, X. D. SHU, T. Z. CHEN

ISSN 0543-5846
METABK 61(1) 175-178 (2022)
UDC / UDK 669.15:621.41/518.9:621.771:518.1:536.5:621-49=111

RESEARCH ON TEMPERATURE FIELD AND MICROSTRUCTURE DISTRIBUTION OF CROSS WEDGE ROLLING BASED ON SQUARE BILLET

Received – Primljeno: 2021-04-14
Accepted – Prihvaćeno: 2021-07-25
Original Scientific Paper – Izvorni znanstveni rad

With the deepening and popularization of the cross wedge rolling process, the requirements for the cross wedge rolling blanks have become wider and wider. Relying only on the traditional round blanks will restrict the promotion of the cross wedge rolling process to a certain extent. The emergence of the square billet is a breakthrough in the selection of raw materials, but related research is relatively scarce. Therefore, this paper conducts a finite element simulation for the rolling process of the square billet. Four characteristic points are taken on the longitudinal section of the billet to track the temperature change. Research on the law of field changes. At the same time, the change of the grain size and dynamic recrystallization percentage of the rolled piece during the rolling process is studied. Simulation and experiment are combined to obtain the change rule of the average grain size of the characteristic points of the longitudinal section of the billet with time.

Keywords: alloy steel, square billet, cross wedge rolling, finite element model, temperature field, average grain size

INTRODUCTION

Cross wedge rolling is a new metal near net forming process, which is favored by experts and scholars at home and abroad in recent years [1]. If only relying on the traditional round billet, the promotion of cross wedge rolling process will be limited to a certain extent [2]. Therefore, the selection of square billet for cross wedge rolling is a breakthrough in the selection of raw materials in the traditional cross wedge rolling process. Li Qiaoyun of Beijing University of science and technology proposed the method of making train axle with square billet plate cross wedge rolling, and simulated the forming process based on DEFORM-3D finite element software, and revealed the metal flow law by using the point tracking method [3]. Ma Wenyu of Beijing University of science and technology analyzed the stress and strain distribution of Billet Based on DEFORM-3D numerical simulation software. The effects of billet size, forming angle and broadening angle on rolling force were studied, and the process parameters were set reasonably. By comparing the tangential force, axial force and radial force in the rolling process, the difference between round billet rolling and square billet rolling is obtained [4]. To sum up, the research on billet is relatively less, while the research on Microstructure and temperature field of billet is almost not. Therefore, in this paper, in order to study the microstructure uniformity of the rolled piece, the temperature field variation law and microstructure distribution in the rolling process of square slab are analyzed.

Q. J. Lian, X. D. Shu, T. Z.Chen. Ningbo University, School of Mechanical Engineering and Mechanics, Ningbo, China; X. D. Shu (Email: shuxuedao @nbu.edu.cn)

ESTABLISH THE FINITE ELEMENT MODEL

The finite element model is established by defrom, and the principle of plastic deformation is used to simulate the rolling. The rigid plastic finite element model is shown in Figure 1 and the dimension of parts processed is shown in Figure 2.

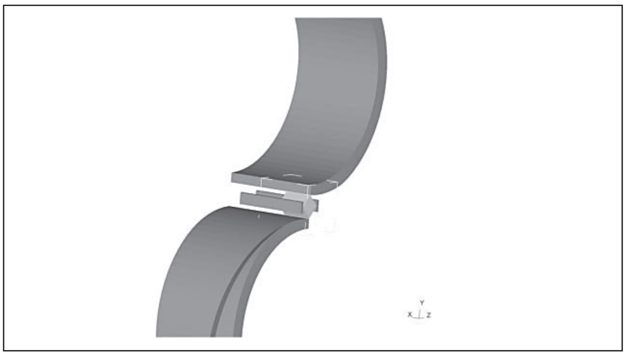


Figure 1 Finite element model of cross wedge rolling

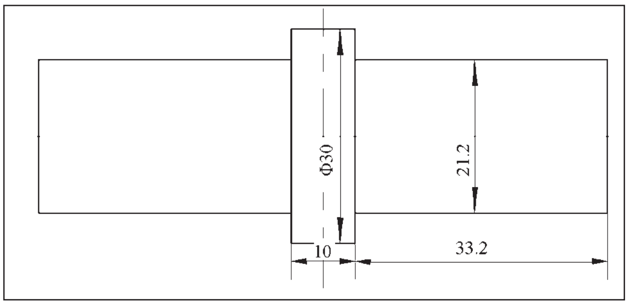


Figure 2 Part size diagram

In order to improve the efficiency of simulation experiment analysis, according to the symmetry of rolled piece and die, the semi simulation analysis is carried out. The material used in the rolling test is 42CrMo with excellent comprehensive properties. The relative tetrahedral mesh is used for mesh generation, and the number of mesh units is 60 The simulation step is set as 0,01, the speed of plate cross wedge rolling template is set as 230 mm / s, the shear friction coefficient between billet and die is 2, and the process parameters are selected as follows: forming angle 32 °,widening angle 7,5 ° and reduction of area 30,17 %.

Variation of temperature field in billet

Four characteristic points are selected on the longitudinal section of the billet for point tracking to intuitively display the temperature change of the longitudinal section of the rolled piece during the rolling process, as shown in Figure 3.

Figure 4 is the curve of temperature changing with time at P1 ~ P4 points on the longitudinal section of billet during rolling. It can be seen from the figure that each curve has two temperature rises and finally tends to be stable.

The temperature of P4 near the middle of the rolled piece rises first, followed by P3, P2 and P1, because the wedge deformation of the rolled piece first occurs above P4, and P1 is the end point of the rolled piece, so the temperature almost does not rise. The results show that the plastic deformation of two wedging metal will make the temperature of characteristic points rise, and the distance of plastic deformation zone will make the temperature drop sharply. P4 point is located in the middle symmetrical step, not in the main deformation area, and the heat dissipation condition of the center is the worst, so the final temperature is the highest; P3 point is also close to the middle of the rolled piece, the heat dissipation condition is poor, and it is most affected by the plastic deformation area, and the temperature changes The results show that the temperature range of P2 is the largest, the temperature range of P2 is larger and the final temperature is the lowest because it is far away from the two deformation zones; the temperature change of P1 is obvious when rolling the second step shaft, but due to the good heat dissipation condition at the end, the influence of plastic deformation is neutralized.

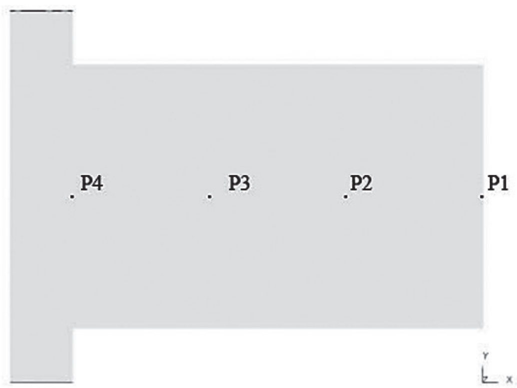
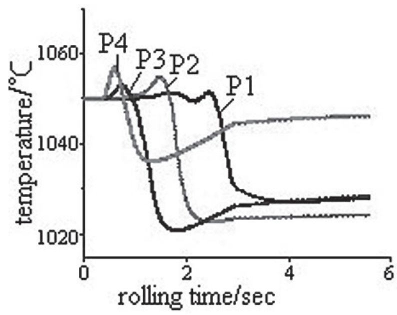
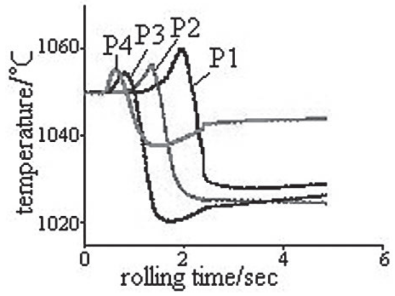


Figure 3 Characteristic points of longitudinal section of square billet



(a) Temperature time curve of characteristic points without wedge



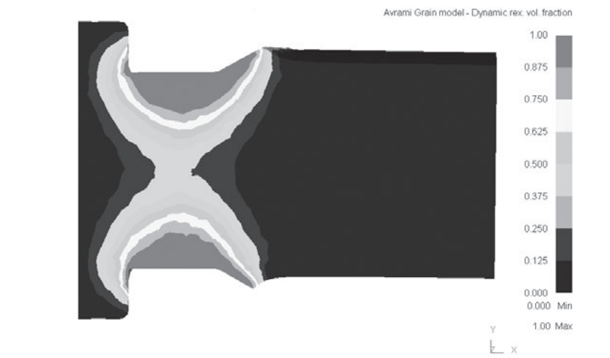
(b) Temperature time curve of characteristic points with wedge

Figure 4 Temperature time curve of characteristic points of square billet longitudinal section

Distribution characteristics of microstructure

Because other stages in the rolling process have little effect on the results, only the stretched pair is simulated. Figure 5 shows the average grain size and dynamic recrystallization volume fraction of the longitudinal section of the billet in the widened section of the stepped axis. The grain refinement degree near the forming wedge is the highest, and the average grain size is the smallest. The further away from the forming wedge, the lower the grain refinement degree, and the grain size of the metal in the core of the wedge does not change. In the same way, the dynamic recrystallization area spreads to the core of the rolled piece in a fan-shaped trend. During the widening period, the deformation of the rolled piece increases, and the deformation gradually penetrates into the center. The material in the core of the rolled piece undergoes plastic deformation, and the strain rate gradually increases, making the rolled piece The internal temperature rises and dynamic recrystallization occurs. When the first rolling of the stepped shaft is completed, the grains in the core of the rolling piece are all refined to below 37,5 μm, the minimum grain size is 1,70 μm, and the dynamic recrystallization volume fraction reaches more than 75 %.

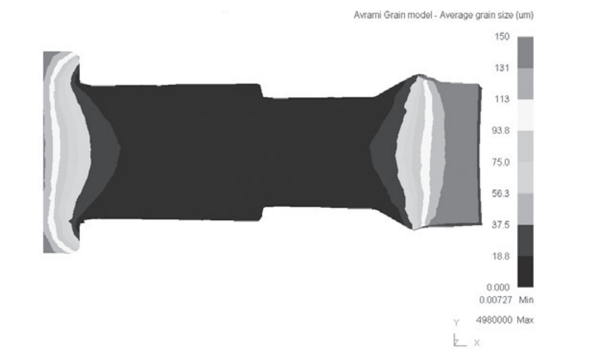
(a) Average grain size of the first wedge broadening section



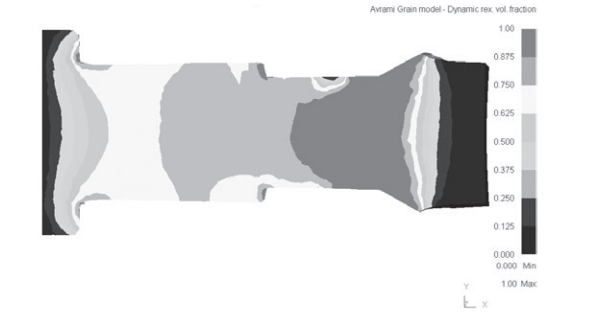
(b) Volume fraction of dynamic recrystallization in the first wedge broadening section

Figure 5 Average grain size and dynamic recrystallization volume fraction of the longitudinal section of the stepped shaft from the first wedge-shaped widening section

Figure 6 shows the average grain size and dynamic recrystallization volume fraction of the longitudinal section of the second wedge widening section of the stepped shaft. The rolling temperature of the second wedge of the stepped shaft is higher, the deformation is greater, the deformation penetrates faster from the surface to the center, the metal grains in the core of the rolling piece are refined, and dynamic recrystallization occurs. However, compared with the outer layer of metal, the degree of grain refinement and dynamic recrystallization of the core metal of the rolled piece cannot completely occur. Because the mold has a retaining wedge, the retaining wedge and the end metal continue to interact, and the deformation of the end surface metal increases. Larger temperature rises quickly, causing the surface metal at the end to take the lead in dynamic recrystallization. However, the core metal at the end of the rolling piece does not interact with the retaining wedge and the temperature is low. Dynamic recrystallization is not easy to occur. This is also the case where the rolling piece produces concave The part of the heart. The surface layer metal undergoes dynamic recrystallization and leads the core metal, so the grain size and grain refinement distribution near the symmetrical step in the middle of the rolling piece and the shaft end are V-shaped. The stepped shaft is basically



(a) Average grain size of the second wedge broadening section



(b) Volume fraction of dynamic recrystallization in the second wedge broadening section

Figure 6 The average grain size and dynamic recrystallization volume fraction of the longitudinal section from the wedging section to the broadening section of the stepped axis

rolled. Except for the larger grain size at the middle symmetrical step and the concave center of the shaft end, the grain size is refined uniformly, and the grain size is below 18,8 μm.

Figure 7 is the curve of average grain size versus time at characteristic points of billet longitudinal section. The trace points of different parts begin to refine the micro grains with the forming sequence, and the metal grains in the two step axis regions are the most completely refined, both below 18 μm. After entering the finishing section, the average grain size of each point increases slightly. The grain size of the metal in the middle symmetrical step and the metal in the center of the shaft end is slightly larger, because the deformation penetration of the metal

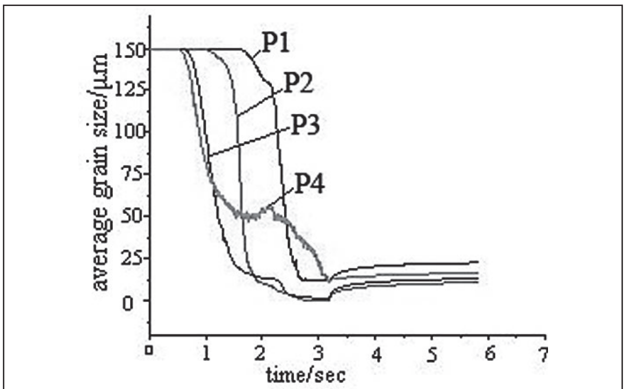
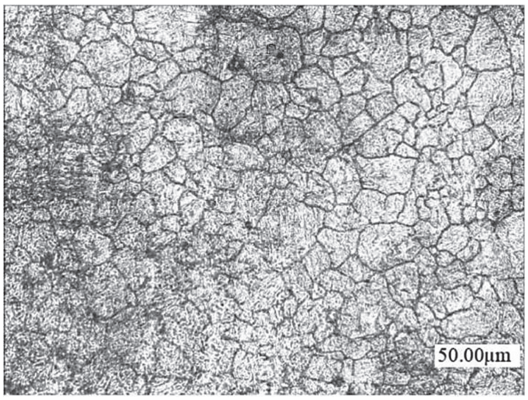
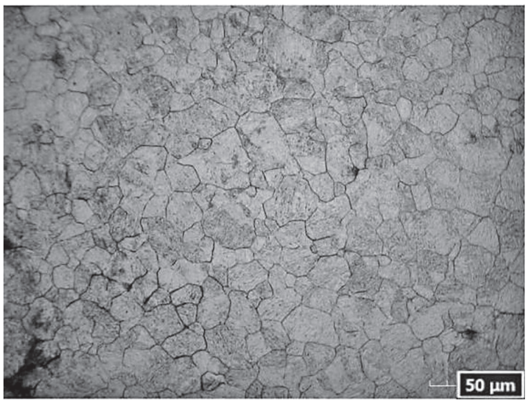


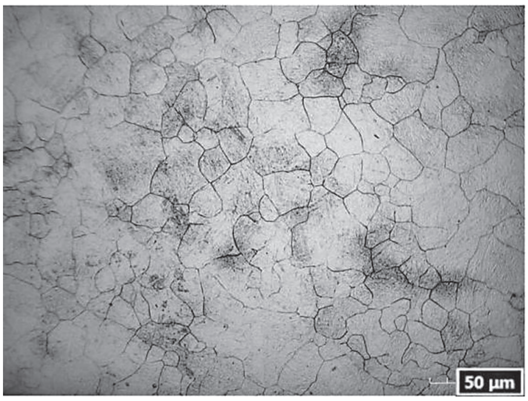
Figure 7 Curve of average grain size time at characteristic points of square billet longitudinal section



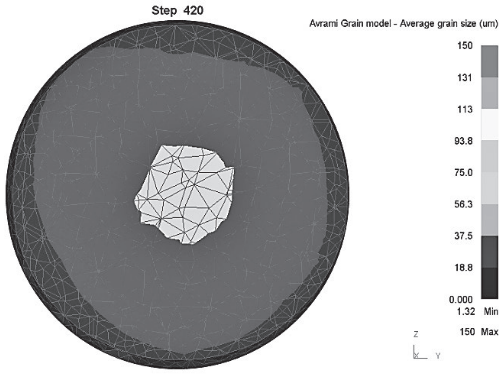
(a) Initial grain size



(b) The external grain size of the cross section of the billet



(c) Internal grain size of billet cross section



(d) Average grain size of billet cross section

Figure 8 Comparison of experimental and simulated grain size

in the formed area is not complete and does not contact with the forming wedge.

Experiment and comparative analysis

The metallographic structure experiment was carried out, and a square section rolled piece with a forming angle of 30° and a spreading angle of 7° was selected as the research object of the metallographic experiment. Cut from the cross-section, wire-cut and sample the core and surface of the cross-section of the rolled shaft section, and perform experiments to observe the icrostructure grain size at the corresponding position with an optical microscope. The average grain size of the surface layer and the core metal of the middle section of the cross-wedge rolled shaft part is measured, as shown in Figure 8.

CONCLUSIONS

Four characteristic points are taken on the longitudinal section of the billet to track the temperature change. The results show that the increase and decrease of temperature are affected by the plastic deformation zone, and the uneven distribution of temperature is also affected by the heat dissipation conditions.

Study the change of the grain size and dynamic recrystallization percentage of the rolled piece during the rolling process, and combine the experiments to verify the reliability of the simulation, and obtain the change rule of the average grain size of the characteristic points of the longitudinal section of the billet with time.

Acknowledgments

This research was supported by the National Natural Science Foundation of China [No.51975301], Project-supported by the National Natural Science Foundation of Zhejiang Province of China [No.LZ17E050001], Ningbo Science and Technology Innovation 2025 Major Project [NO.2020Z110].

REFERENCES

[1] Wang M. T., LI X. T., Du F. S., Current Trends in Cross Wedge Rolling for Part Forming [J]. Journal of the Iron and Steel Institute of Japan, Materials 45 (2005) 11, 1521-1525.

[2] Shu X. D., Rolling near net forming of parts: an advanced forming technology with both theoretical and practical value [J]. Journal of Ningbo University (Science and Engineering Edition), 31 (2018) 1, 1.

[3] Shu C., Wang J.T., Shu X.D., Influencing Factors of Void closure in Skew-Rolled Steel Balls Based on the Floating-Pressure Method[J]. Materials 12 (2019) 9, 1391.

[4] Ma W. Y., Wang B. Y., Zhou J., Analysis of Square Billet Cross Wedge Rolling Process Using Finite Element Method [J]. Mechanics and Materials, 271 (2012) 1, 271-272:406-411.

Note: The responsible translator for English language is Q. J. Lian, Ningbo, China