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ISSN 0543-5846
METABK 58(3-4) 228-230 (2019)
UDC – UDK 621-41/531.42:621.5/621-58:536.416/621.785:518.5=111

THE INFLUENTIAL FACTOR STUDIES ON THE COOLING RATE OF ROLLER QUENCHING FOR ULTRA-HEAVY PLATE

Received – Primljeno: 2018-11-16
Accepted – Prihvaćeno: 2019-03-02
Original Scientific Paper – Izvorni znanstveni rad

In this paper, the gradient temperature rolling (GTR) method is used to establish the 12-pass rolling model by Deform-3D finite element (FE) software. The variation of temperature field and strain field of ultra-heavy plate slab under different conditions is systematically studied. The result shows that the more the number of water cooling between the passes during the rolling process, the greater the deformation of the core of slab, and the one of plate rolling with large temperature difference does not appear on near surface but gradually moves to the central part of the plate as cooling times increase.

Key words: ultra-heavy plate; cooling rate; quenching; strain effective field; finite element simulation.

INTRODUCTION

Ultra-thick plate plays a very important role in offshore platform steel. Its comprehensive performance will directly affect the construction of offshore platform. Because of the harsh environment of offshore platform steel, it is necessary for offshore platform steel to have high strength, thick specification, good low-temperature flexibility and high corrosion resistance when working in severe oceans such as waves, tidal storms and cold current ice. How to improve the quality of super thick plate has always been the focus of production. Ultra-thick slab has the characteristics of large size and single weight, which leads to segregation of Mn, Nb, H and other elements in the slab and difficult control of S, P and other elements, resulting in intergranular cracking, pore, hydrogen embrittlement and other defects [1-3]. due to the limitation of compression ratio in the rolling process, the deformation cannot penetrate the center of the steel plate, and the deformation of the extra-thick plate from the surface to the center decreases gradually, resulting in the rolling cannot significantly improve the core structure and heal the defect [4-6]. With the development of computer, the simulation of metal forming process by finite element method has become an important means to solve these problems and has been widely used [7-9]. Studies have shown that it is possible to weld the core pores when the conventional rolling method of a 400 mm thick blank has a reduction ratio of more than 30 %, and the core crack can be closed when the 140 mm thick blank reduction rate requires 14 % [10]. Therefore, the conventional method of rolling is difficult to close the shrinkage and segregation existing in the core of the large casting billet, and the toughness of the steel sheet is lowered [11,12]. Recently, researchers have used differential temperature rolling technology to roll ultra-thick plates and achieved favorable results [12-15].

In this paper, FEM was used to investigate the generation rules of the temperature field and the performance of deformation in thickness direction of ultra-heavy plate, which provides theoretical support for the development of rational control and control cooling process

Experimental procedure

The three-dimensional model of slab, roll and push plate is established by Creo 3.0 software, and the STL file is imported into deform-3D software, the continuous casting slab is 300 mm thick, 260 mm wide, and 600 mm long; diameter of work roll is 1 100 mm, length of work roll is 600 mm. Because of slab and roll symmetry with respect to both horizontal and vertical planes passing through slab center of gravity, only a quarter of the physical model is simulated as shown in Figure 1.

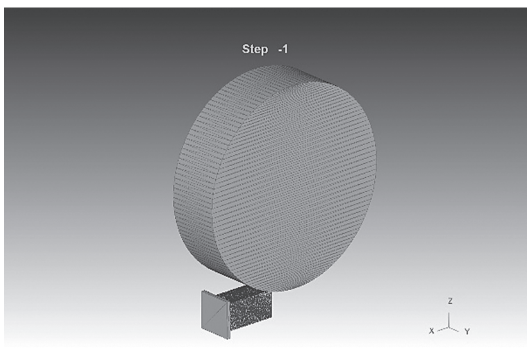

Figure 1 The model of simulation

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Table 1 **The chemical composition of experimental steel / mass,%**

C	Si	Mn	P	S
0,08	0,35	1,50	0,018	0,003
Cu	Cr	Ni	Nb	Ti
0,25	——	0,36	0,04	0,012

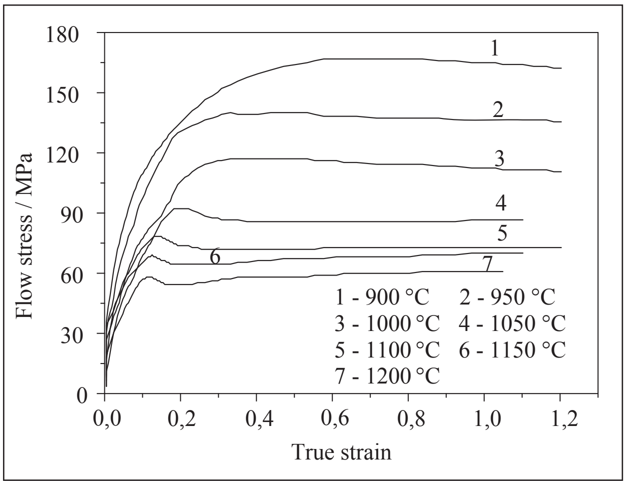

Figure 2 Stress-strain curves at different temperatures

The simulated mesh is automatically re-divided by grid to ensure the simulation is correct. A rigid material model was used for work roll, and its deformation was neglected. The chemical composition of experimental steel used in this study is given in Table 1. The Flow stress-true strain curves (Figure 2) of materials under deformation temperature obtained from thermal compression tests of metal cylinder specimens are imported into Deform-3D software.

According to the experimental setup in FE analysis samples temperature was initially set at 1 200 °C and rolled to a final thickness of 90 mm, environment temperature was set at 20 °C and a heat convection coefficient equal to 20 W/ m^2·°C was chosen.in order to model friction between rolls and workpiece, the shear friction model was utilized. Since experimental tests were performed without lubrication, a shear friction factor equal to 0,7 was chosen in order to reproduce the high friction conditions between rolls and samples.

Experimental results and analysis

A 12-pass rolling simulation experiment was carried out, which was divided into four cases, and the rolling schedule as shown in Table 2. The cooling scheme was shown in Table 3.

Figure 3 (a) is temperature curve of the slab for cooling process of case 4. It can be seen from the figure that the surface temperature of the slab is cooled to 498 °C and the temperature difference of the core (1 224 °C) is 726 °C after water cooling. Figure 3 (b) is the temperature variation curve of the rolled piece along the thickness direction after 12 passes of rolling under different water-cooling systems. It can be seen from the figure that the temperature difference between the surface layer and the core in-

Table 2 Rolling Process

Items	Pass					
	1	2	3	4	5	6
H/mm	300	270	235	200	170	145
h/mm	270	235	200	170	145	125
Δ*h*/mm	30	35	35	30	25	20
Items	7	8	9	10	11	12
H/mm	125	110	104	100	96	92,5
h/mm	110	104	100	96	92,5	90
Δ*h*/mm	15	6	4	4	3,5	2,5

H is the thickness before the rolling pass, h is the thickness after the rolling pass, Δ*h* is the reduction.

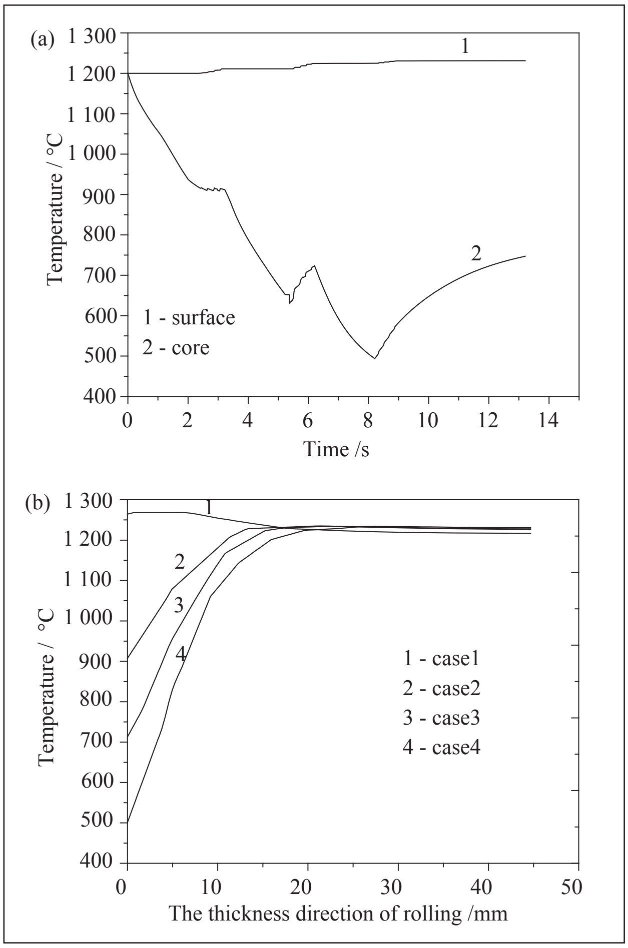

Figure 3 Temperature curve of ultra-heavy rolling. (a) cooling process of case 4 for rolling, (b) temperature distribution across the slab after rolling.

Table 3 **Cooling Process**

Cooling process	Before Rolling	After 4th pass	After 8th pass	After Rolling
Case1	No	No	No	No
Case2	Water cooling	No	No	No
Case3	Water cooling	Water cooling	No	No
Case4	Water cooling	Water cooling	Water cooling	No

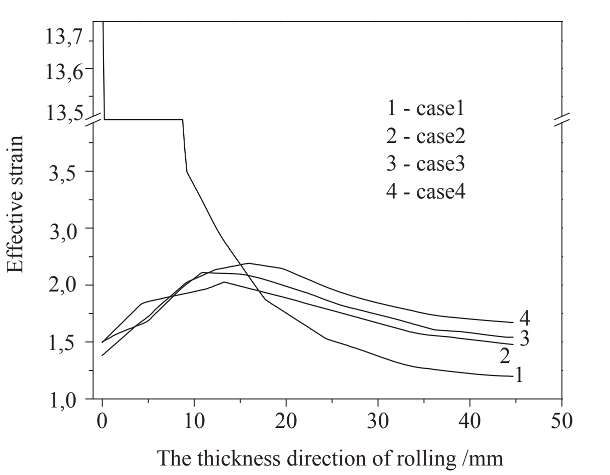

Figure 4 Distribution of total effective strain along the thickness direction of rolling

creases with the increase of the number of cooling times, and the difference is 357, 542 and 749 °C respectively.

Figure 4 is a diagram showing the total effective strain distribution along the thickness direction of the slab during the rolling process. It can be seen from the figure that the equivalent stress of the super thick slab is rapidly decreased from the surface along the thickness direction after isothermal rolling (case 1). However, in the three water cooling processes of case 2, case 3 and case 4, the equivalent deformation in the thickness direction first increases and then decreases, that is, the maximum is about 1/3 of the thickness from the surface. In addition, case 2, case 3, and case 4 GTR increased the core equivalent strain by 20,2 %, 24,2 %, and 30,4 %, respectively, compared with UTR (case1); the ratio of the maximum to the minimum effective strain is reduced from air cooling (case 1) 11,2 to water cooling (case 2, case 3, case 4) 1,4, 1,57 and 1,32, respectively, which means that GTR not only significantly improves the deep penetration of thick plate rolling, but also greatly improves the uniformity of deformation, which is beneficial to improve the uniformity of the quality of slab.

SUMMARY

The effective strain of isothermal-rolling occurs mainly on the near surface of ultra-heavy plate, but the one of plate rolling with large temperature difference does not appear on near surface but gradually moves to the central part of the plate as cooling times increase.

GTR can improve deformation uniformity and core deformation of slab. The simulation experiment of different GTR is comprehensively compared. The results show that the GTR with case 4 water cooling scheme has the best effect.

Acknowledgments

This work was financially supported by Opening Fund for National Key Laboratory of Metallic Materials for Marine Equipment and Application (SKLMEA-K201801), Liaoning Province Natural Science Fund Project (201602385), 2017 Provincial Key Laboratory Opening Project of Liaoning University of Science and Technology (USTLKFSY201709), Liaoning Provincial Department of Education Innovation Team Project (LT2016003)

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Note: Q.H.XIAO is responsible for English language, Liaoning, China