Journal of Applied Sciences

ISSN 1812-5654

Journal of Applied Sciences 13 (13): 2474-2478, 2013
ISSN 1812-5654 / DOI: 10.3923/jas.2013.2474.2478

Research on Temperature Field of Hot-rolled H-beam based on FEA Method

Liu Jian, Hou Fu-Zeng, Chen Li-Jun and Yu Xiao-Guang
School of Mechanical Engineering and Automation,
University of Science and Technology Liaoning, Anshan, 114051, China

Abstract: The study uses the FEA software Ansys Workbench to simulate the temperature field under different controlled cooling process of hot rolling H-beam. The aim is to find the better controlled cooling process. Then the temperature field is verified using temperature measuring instrument and the theoretical value and analog value is consistent. It provides the theoretical basis for the further optimization of controlled cooling process.

Key words: The controlled cooling, temperature field, density of water, mechanical properties

INTRODUCTION

At present,most of the mechanical properties of steel materials are obtained by controlled cooling process,the process of controlled cooling is an indispensably important segment in the process of steel production process (Sun and Zhang, 1999; Xie *et al*., 2004). H-beam is an important material in the industrial production whose high quality of the mechanical properties is paid more and more concern and attention. But at present most of the steel can not meet the expected goals in the process of steel hot rolling production. So both the controlled cooling technology of hot rolled steel and performance prognosis have a further space for improvement (Jia *et al*., 2006).

Nowadays,the finite element method is widely used as a basic model in the process of steel controlled cooling. Thus we can quantitatively analyze and study temperature field, stress and strain field of steel in the different cooling solutions and working conditions, in order to accurately predict organizational relative changes and further optimize the process of controlled cooling (Xu, 2007). Zhao and Zhu (Zhao and Zhu, 2001) used heat flow coupling FE method to get steel surface heat flux boundary condition in the pipe laminar cooling zone. They established the FE model to solve the transient temperature field of steel plate. The heat transfer coefficient of water cooling is measured under ideal conditions. It began finite element analysis of steel in recent years. Xu and Wang (Xu and Wang, 2005) conducts math simulation to analyze temperature field changes of H-beam in the cooling process of rolling and after rolling, according to the distribution law of temperature field of h-beam to optimize the controlled cooling parameters. But he ignored the cooling process is impacted by the water current density in the process of simulation. Liu (Liu *et al*., 2008) uses the spray cooling way to analysis the temperature changes and thermal stress of h-beam,which can improve the problem of temperature field uneven distribution under the condition of air cooling and reduce the residual thermal stress of steel. This paper mainly uses the FE software Workbench to simulate the temperature field of h-beam under different process conditions and further verify it through the experiments, which find the best controlled cooling process to further improve the organizational structure of material so that improve the comprehensive mechanical properties.

THE TEMPERATURE FIELD THEORY

According to the law of conservation of energy, we can create heat conduction differential equation (Liu *et al*., 1996):

$$\rho c\dot{T} - \frac{\partial}{\partial x_i}\left(k\frac{\partial T}{\partial x_i}\right) - r_v = 0 \tag{1}$$

where, ρis t he density of the unit volume quality (kg m^3); c is specific heat (J/(kg.°C)); T is temperature (°C); x_i is the displacement (m); r_v is the heat generation rate of unit volume of internal objects (W m^3)

The heat transfer boundary conditions (Liu *et al*., 1996):

$$-k\frac{\partial T}{\partial n} = h(T)(T - T_w) \tag{2}$$

where, T_w is the temperature of the work piece surface (°C); h(T) is the function of concerning temperature; k is the heat transfer coefficient (W/(m.°C)).

Correspoding Author: LIU Jian, School of Mechanical Engineering and Automation,
University of Science and Technology Liaoning, Anshan, 114051, China

Initial conditions (Liu *et al*., 1996):

$$T|_{t=0} = T_0 \quad (3)$$

where, T_0 is the known temperature whose value is constant.

THE BASIC MODEL AND CONTROLLED COOLING SOLUTIONS

The basic model: The paper is based on the three-dimensional h-beam as the research object, the basic size for: H200×200×8×12 (R = 16 mm), the chosen length is 200 mm, meshing is shown in Fig. 1:

The material in the article is Q235 whose chemical composition (mass fraction%) is C 0.18%, Si 0.22%, Mn 0.56%, , P 0.016%, S 0.028% .

When H-beam is in the process of air cooling, the heat exchanges of convection and radiation are taking place with the surrounding air. The experience formula of the integrated heat transfer coefficient in the time of air cooling is following (Gao and Gao, 1989):

$$h = 2.25(T_w - T_c)^{0.25} + 4.6\times10^{-8}(T_w^2 + T_c^2)(T_w + T_c) \quad (4)$$

where, T_w is h-beam temperature (°C); T_c is the environment temperature (°C).

Water cooling heat transfer coefficient is influenced by many factors whose process is complex. There is no unified standard and the empirical formula for it (Y. Nagasaka *et al*., 1993):

$$h = 4.782\times10^5 T_s^{-1.089} W^{0.71} \quad 500°C \le T_s \le 900°C \quad (5)$$

Figure 2 is showed that the integrated heat transfer coefficient of air-cooling and water-cooling process.

Where T_s is steel surface temperature (°C); W is the water current density (L/(m^2.s)).

The main thermal physical parameters of Q235 are shown in Fig. 2:

Controlled cooling scheme

Solution 1: Start from the finishing temperature of 900°C, firstly air cooling is for 5 sec and then water cooling is for 5 sec (water current density is the same as 4.5 L/(m^2.s)), air cooling is for 5s lastly.

Solution 2: Start from the finishing temperature of 900°C, firstly air cooling is for 5 sec and then water cooling is for

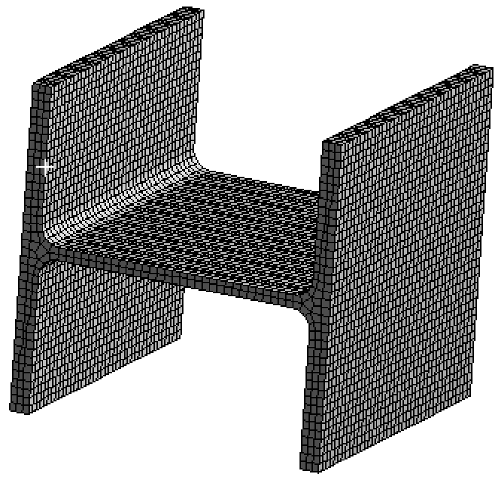

Fig. 1: Meshing

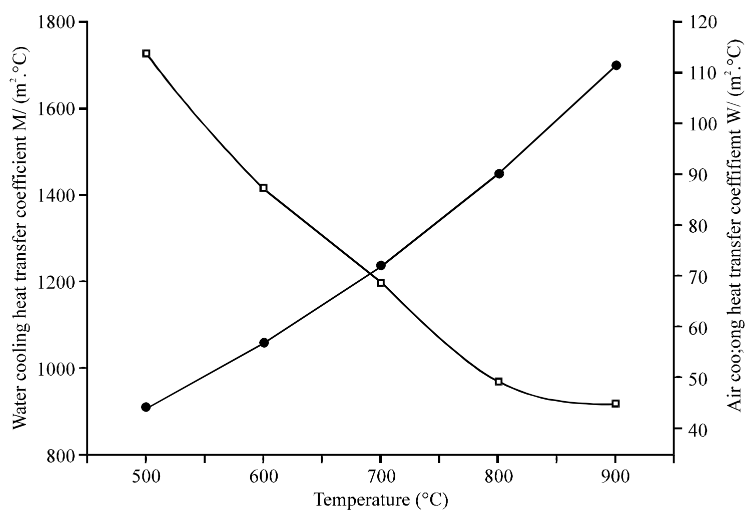

Fig. 2: Air-cooling and water-cooling heat transfer coefficient

5 sec (water current density is the same as 4.5 L/(m^2.s)), air cooling is for 6 sec lastly

Solution 3: Start from the finishing temperature of 900°C, firstly air cooling is for 5 sec and then water cooling is for 7 sec (water current density is the same as 4.5 L/(m^2.s)), air cooling is for 5 sec lastly;

Solution 4: Start from the finishing temperature of 900°C, firstly air cooling is for 5 sec and then water cooling is for 6sec (Current density is different, strong cold of R Angle is 5.5 L/(m^2.s),the web is 3.5 L/(m^2.s) at least, the flange is 4.5 L/(m^2.s)) air cooling is for 5 sec lastly.

THE SIMULATION ANALYSIS RESULTS

At first, the simulation results under different cooling speed (water flow density is identical) are shown in Fig. 3.

Table 1: Thermal physical parameters (Liu *et al*., 2008)

Temperature °C	Density kg m^3	Specific heat J/(kg.°C)	Heat transfer coefficient W/(m.°C)
400	7736	576	43.31
500	7696	615	38.10
600	7659	700	35.68
700	7639	854	31.82
800	7619	806	28.47
900	7600	637	29.90

From the above simulation results: the whole temperature field distribution is similar,the core temperature in the scheme 1 is 739.2°C which value is bigger than Q235 eutectoid point, the scheme is not reasonable. The maximum value in the scheme 2 and 3 is less than the eutectoid point, the scheme is reasonable. Temperature difference is 200.63°C in the scheme 2, which is less than 203.8°C in the scheme 3, so the scheme 2 is more reasonable.

Now the simulation results under different water current density (scheme 2 and 4) are shown in Fig. 4.

We can perceive from the analog results in Fig. 4, the whole distribution of temperature field in two schemes is reasonable, the temperature difference is 127.4°C in the scheme 2, which is bigger than 79°C in the scheme 4. The temperature field distribution is relatively homogeneous and the thermal stress is minimum, which has less effect on the organizational performance. From the above, the controlled cooling process in solution 4 is more reasonable.

THE EXPERIMENTAL VERIFICATION

At first,we insert two sticks of 1.5 mm K thermocouple into H-beam which has already drilled hole (the hole is 1.7 mm, the depth of R Angle is 5 mm, the

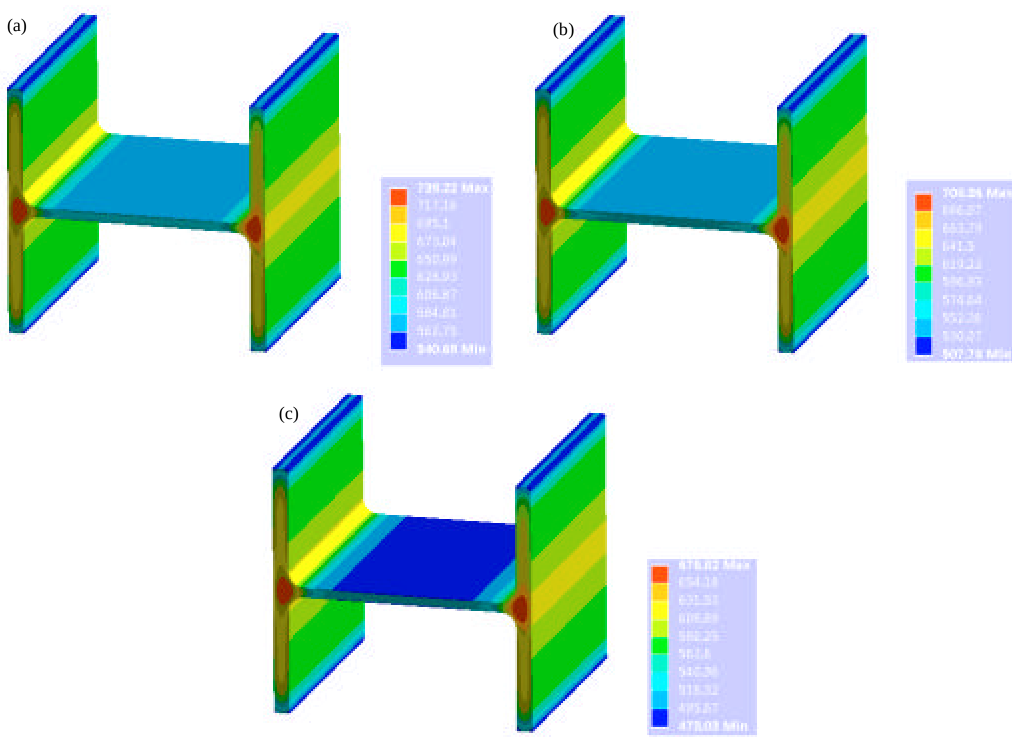

Fig. 3: Simulation results under different cooling speed. (a) Scheem 1 air cooling 5 sec and water cooling 5 sec, (b) Scheem 2 air cooling 5 sec and water cooling 6 sec and (c) Scheem 3 air cooling 5 sec and water cooling 7 sec

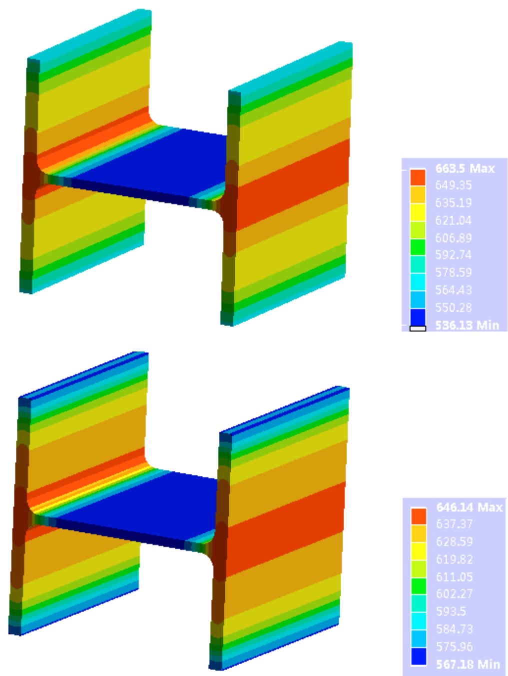

Fig. 4: Simulation results under different current density

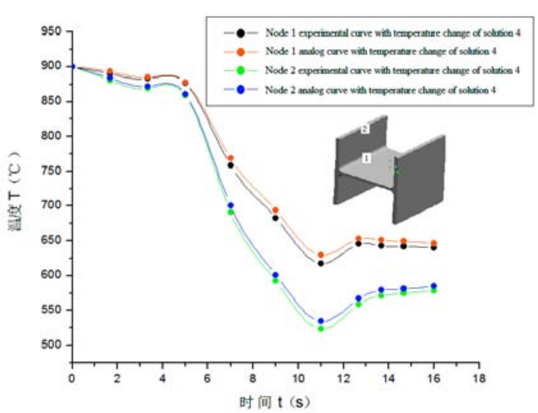

Fig. 5: The curve comparison graph between simulation value and experiment value

depth of flange is 3 mm), the other side of K thermocouple is connected with the paperless recorder which is touch screen (TR-V1001). Then putting the h-beam and K thermocouple into the electric box, they are heated to 900 together. And then do the experiments on the basis of solution 4. Figure 5 is the comparison between the simulation value and experiment value in the solution 4:

We can clearly get that the analog value is consistent with the theoretical value. Temperature drops slowly at the beginning stage of air cooling. Temperature drop is becoming fast at the stage of water cooling, but the temperature difference is increasing at point 1 and 2. Then the temperature difference begins to rebound at the stage of air cooling. Finally, it tends to the basically stable and mechanical performance is improved.

SUMMARY

Through the temperature field simulation and the experimental study of h-beam in this paper, we can get the following conclusion:

- Through the comparison in the different controlled cooling schemes, we have found a better solution. It is from the initial temperature of 900°C, firstly air cooling for 5 sec and then water cooling for 6 sec, lastly air cooling for 5 sec on the rapid cooling scheme, the distribution of the temperature field is more uniform.
- As the temperature of the R Angle drops slowly and web drops quickly, we can cool the different parts under the different water current density. When strong cold of R Angle is 5.5 L/(m^2.s), web is 3.5 L/(m^2.s), the flange is 4.5 L/(m^2.s), the effect is better.
- According to the comparison of experimental value and analog value, the correctness of numerical simulation gets further validation. The optimization of cooling process provides a theoretical basis for the next step.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the financial support of the special fund of Natural Science Foundation of China, Grant No. 51144007.

REFERENCES

Gao, S.Y. and Y. Gao, 1989. The transient temperature distribution in the process of quenching and the mathematical modeling of tissue distribution. J. Dalian Univ. Technol., 29: 183-190.

Jia, Y.P., D. Wu and J. Guo, 2006. The controlled cooling of hot-rolled H-Beam on line. Iron Steel, 41: 45-48.

Liu, Q., Y. Zhang and Q. Qin, 2008. The temperature change and thermal stress analysis in the process of controlled cooling of H-beam. Metall. Equip., 1: 17-20.

Liu, Z., Z.J. Wu and.J.Z. Wu, 1996. The Numerical Simulation in the Process of Heat Treatment. Beijing Science Press, China.

Nagasaka, Y., J.K. Brimacombe, E.B. Hawbolt, I.V. Samarasekera, B. Hernandez-Morales and S.E. Chidiac, 1993. Mathematical model of phase transformations and elastoplastic stress in the water spray quenching of steel bars. Metall. Trans. A, 24: 795-888.

Sun, Z.J. and X.G. Zhang, 1999. Heat treatment of controlled cooling has an influence on the microstructure and mechanical properties of plain carbon steel. Heat Treatment Metals, 1: 9-13.

Xie, S.H., Y. Fan and W.L. Yuan, 2004. The research of the controlled cooling process of hot-rolled H-beam. Steel Rolling, 5: 15-17.

Xu, D.T., 2007. The numerical simulation of temperature field of h-beam in the process of controlled cooling. Steel Rolling, 24: 28-31.

Xu, X.D. and B.X. Wang, 2005. The finite element simulation of controlled cooling of H-beam. J. Iron Steel Res., 17: 30-33.

Zhao, Y.Z. and Q.J. Zhu, 2001. The finite element simulation of medium thick plate in the process of cooling and productive application. Metall. Equip., l2: 12-15.