JOURNAL OF IRON AND STEEL RESEARCH, INTERNATIONAL. 2014, 21(12): 1104-1110

3D Thermo-mechanical Coupled Simulation of Whole Rolling Process for 60 kg/m Heavy Rail

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Abstract: 3D thermo-mechanical coupled simulation of whole rolling process for 60 kg/m heavy rail was accomplished by FEM method. The finite element model, physical parameters of U75V and parameter setting of simulation were introduced in detail. The whole rolling process of 60 kg/m heavy rail was divided into 27 time cells to simulate respectively, and the model rebuilding and temperature inheritance method in intermediate pass were proceeded. Then, based on simulation results, the workpiece deformation result, metal flow, stress and strain of 60 kg/m heavy rail for typical passes were obtained. The temperature variation curves of whole rolling process for section key points of 60 kg/m heavy rail were plotted, and the temperature falling law of whole rolling process for 60 kg/m heavy rail was studied. In addition, temperature distribution of 60 kg/m heavy rail after whole rolling process was analyzed, and the results showed that temperature was highest at center of rail head and lowest at fringe of rail base. Moreover, the simulation results and measured results of rolling force for 60 kg/m heavy rail were compared, and the regularity was in good agreement.

Key words: heavy rail; thermo-mechanical coupled simulation; metal flow; stress; strain; temperature; rolling force

With the leaping development of railway transportation, railway technology in the world is moving towards the direction of automation traction, high speed and heavy axle load. Therefore, the requirement for rail performance is higher, and stricter production process and control technology are objectively needed[1,2]. Parameters affect and restrict each other in the rolling process of rail, so the process control is complex and the requirement for operation is strict. When certain production problems occur, a lot of time is spent in finding out it. Besides, it is very difficult to study new production line, new products and new technology.

With the rapid development of computer technology, numerical simulation method has become an important tool for rolling theory research. It could not only predict the final results but also simulate and show the changes of certain process. Nowadays, the numerical simulation of rolling process is becoming more and more widely: 3D thermal mechanical coupled simulation of whole rolling process for H-beam was carried out by Zhu et al[3-5]. The elastic-plastic finite element simulation of whole rolling process for universal rolling 60 kg/m high-precision heavy rail was accomplished by Wang et al.[6,7] using explicit finite element software. The reduction rate and stress field in the heavy rail rolled with hat pass and cutting-in pass from continuously cast blank were analyzed by Wu et al.[8]. Besides, the finite element simulation, optimization and stress analysis on blooming and rolling heavy rail were conducted by Chen et al.[9,10]. The temperature distribution and deformation of heavy rail in cooling process was simulated by Basu et al.[11,12] using ANSYS. In addition, the numerical simulation of full-universal passing process for 60 kg/m heavy rail was studied by Zhu and Yuan[13]. And the high precision heavy rail rolled with the full-universal finish pass was simulated by Zhou et al.[14,15] using ANSYS/LS-DYNA.

3D thermo-mechanical coupled simulation of whole rolling process for 60 kg/m heavy rail was accomplished by software ANSYS/LS-DYNA. The

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numerical simulation model, material model, model rebuilding and temperature inheritance method were introduced in detail. And simulation results of workpiece deformation, metal flow, stress and strain, temperature and rolling force for whole rolling process of 60 kg/m heavy rail were analyzed.

1 Numerical Simulation Model and Model Rebuilding Method

1.1 Numerical simulation model

In 3D thermo-mechanical coupled simulation of whole rolling process for 60 kg/m heavy rail, models of roller and workpiece were built by software ANSYS/LS-DYNA, and then were meshed using SOLID164 element (eight nodes hexahedron element). The fourth pass model of break-down rolling process is shown in Fig. 1. Because of complex section shape and uneven deformation of 60 kg/m heavy rail in rolling process, guides should be installed before and after roller to guarantee stable deformation of workpiece. The model of universal rollers and guides is shown in Fig. 2.

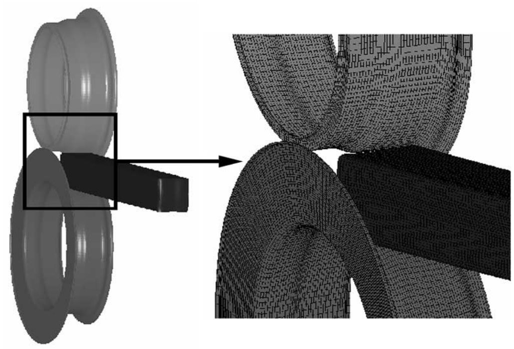


Fig. 1 Fourth pass model of break-down rolling process

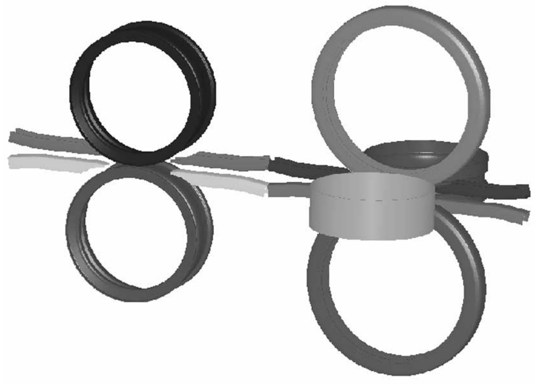
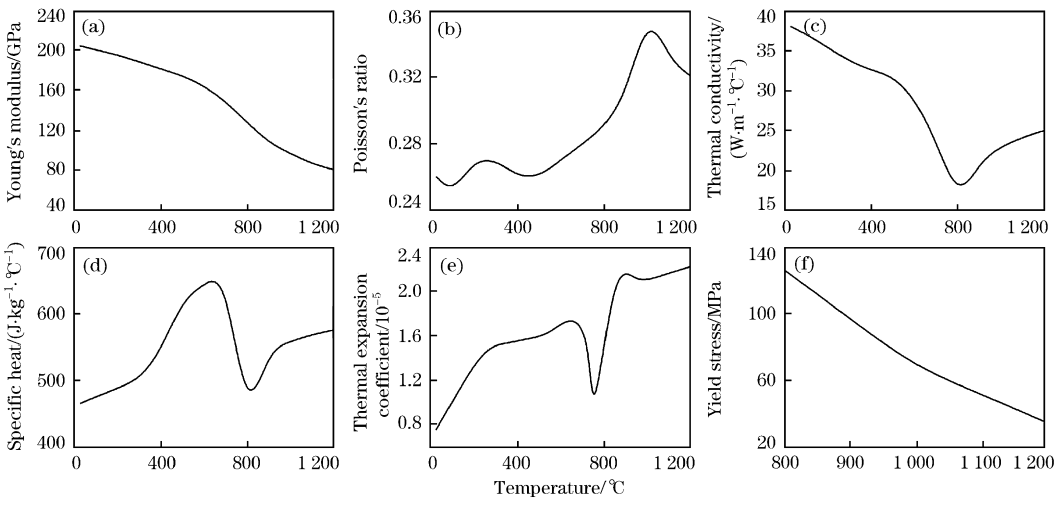


Fig. 2 Model of universal rollers and guides

The material of 60 kg/m heavy rail was U75V in this study. According to experimental data, its physical parameters are plotted in Fig. 3, and the density of U75V is 7721 kg/m^3. In the simulation of whole rolling process for 60 kg/m heavy rail, rollers were treated as rigid body and were face-to-face contacting with workpiece. The Coulomb friction was adopted, and dynamic friction coefficient between roller and workpiece was set to 0.35. In addition, the initial temperature of workpiece was set to 1180 ℃, and the temperature of roller was set to a constant value which was 300 ℃. Besides, the effective coefficient of plastic work converting into heat was set to 0.9. And heat exchange between roller and workpiece was mainly heat conduction. There were two boundary conditions between workpiece surface and surrounding environment which were convection and radiation, and they were all automatically converted to heat conduction in deformation zone.



(a) Young's modulus; (b) Poisson's ratio; (c) Thermal conductivity; (d) Specific heat; (e) Thermal expansion coefficient; (f) Yield stress.

Fig. 3 Change of physical parameters of U75V with temperature