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RESEARCH PAPER

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STRESS ANALYSIS OF COLD ROLLED STEEL SHEET BASED ON ABAQUS

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Abstract: Stress is one of the key factors affecting cold rolling effect. In order to determine the influence of process parameters on cold rolling stress of wear-resistant steel, finite element analysis software ABAQUS was used to analyze the rolling process. In the analysis process, the solver adopts explicit dynamic scheme, and the research method is a single variable method. The stress variation characteristics are calculated under different tension and friction coefficient before and after rolling. According to the analysis results, the stress is related to the tension. The stress increases first and then decreases with the rolling direction. The cold rolling stress can be significantly increased when the friction coefficient increases to a certain value.

Keywords: stress, finite element, friction coefficient, cold rolling

I. INTRODUCTION

Wear-resistant steel has been widely used in the industrial field. Cold rolling is one of the most important processing methods. It has been paid more and more attention in the manufacturing industry. Residual stress in cold rolling process is the main obstacle to the process plan, which has a direct relationship with the process parameters. It is called the research hotspot in the current mechanical processing industry [3]. Generally speaking, rolling force and friction coefficient are the most important factors affecting the forming effect of wear-resistant steel in cold rolling process. Therefore, in rolling process, it is necessary to adjust the appropriate tension parameters and matching friction coefficient. Otherwise, in cold rolling process, it is prone to the differential deformation of the edge, even pressure leakage and damage. Legal issues [4].

In order to obtain the effect of process parameters on the stress characteristics of wear-resistant steel during cold rolling, the finite element numerical simulation method is used to calculate the stress changes under different conditions, which provides an important basis for the improvement of processing technology.

II. FINITE ELEMENT ANALYSIS OF COLD ROLLING PROCESS

A. Numerical simulation scheme

Finite element analysis is one of the indispensable methods in engineering analysis. It can accurately simulate different types of working conditions and multi-physical fields. In this paper, ABAQUS software is used to carry out finite element analysis of cold rolling process. ABAQUS is one of the most widely used and mature numerical simulation software at present. It is developed by HKS Company in the United States. It has remarkable advantages in non-linear materials and models, boundary debugging, structural mechanics, etc. It has been recognized in mechanical engineering, construction engineering, water and hydropower, automobile manufacturing and other fields.

ABAQUS has powerful solver, which can realize static implicit and dynamic explicit calculation of different models. It integrates abundant element types and can effectively ensure the reliability and accuracy of numerical simulation analysis of cold rolling. ABAQUS provides users with a wide range of functions and is very simple to use. A large number of complex problems can be easily simulated by different combinations of option blocks. For example, the simulation of complex multi-component problems is by combining the selection blocks that define the geometric dimensions of each component with the corresponding selection blocks of material properties. In most simulations, even for highly nonlinear problems, users only need to provide some engineering data, such as geometry, material properties, boundary conditions and load conditions. In a non-linear analysis, ABAQUS can automatically select the corresponding load increment and convergence limit. Not only can he choose the appropriate parameters, but also he can continuously adjust the parameters to ensure that the accurate solution can be obtained effectively in the analysis process. Users can control the numerical results well by defining parameters accurately. ABAQUS has two main solver modules, ABAQUS/Standard and ABAQUS/Explicit. ABAQUS also includes a graphical user interface that fully supports the solver, namely the pre-and post-processing module of human-computer interaction, ABAQUS/CAE. ABAQUS also provides special modules to solve some special problems.

B. Establishment of Model Assembly

ABAQUS/Standard is the default solver in software. Its solution algorithm is universal. The content of ABAQUS/Standard analysis is from static linear to complex dynamic, and even non-linear multi-coupled physical field operations. In the aspect of mesh generation, the software can analyze the large deformation of thin-walled parts through adaptive mesh function. The adaptive mesh is more flexible in the analysis of display problems, and can effectively solve some difficult convergence problems, such as nonlinear transient dynamics problems, fully coupled thermodynamic analysis problems and so on. In contact setting, the dynamic collision problem can be simulated by the definition of contact conditions. In this paper, ABAQUS is used to simulate the thermal structure coupling process of ventilation disc. The calculation of friction heat generation, heat transfer and radiation between ventilation disc and brake pad can not only ensure the convergence of calculation, but also optimize the structural parameters of the model.

Because the model of cold rolling process is relatively simple, the model is built directly in ABAQUS/CAE, and the corresponding material properties are given. When a component is created, the software automatically generates an independent coordinate system to facilitate the creation of the final assembly within the Assembly function module. Because the model belongs to the typical large deformation, the display dynamics analysis method is adopted.

In the construction of assembly model, firstly, the wear-resistant steel plate model is tangent to the roll based on rotation and motion control; secondly, a dynamic reference point is created at the center of mass of the roll, and the coordinates of the dynamic reference point can be obtained by calculating the translation required when the reduction rate is 19%. According to the size of the model, the biting distance is set.

C. Boundary Conditions Setting

The key problem of cold rolling analysis is contact setting, which is also the main factor affecting the convergence and reliability of calculation. From the point of view of mechanics, deformation and contact problems are typical complex non-linear problems. It is necessary to ensure the contact of multiple objects in each time step and avoid the penetration between contact surfaces. From a mathematical point of view, the main constraints to ensure non-penetration are Lagrange multiplier method, penalty function method [7] and direct constraints method. According to the deformation of wear-resistant steel, penalty function method is adopted. Penalty function method can magnify the influence of errors when checking the penetration, and ultimately make the model not convergent, thus ensuring the contact of the contact surface, which is often used in display dynamics.

In ABAQUS software, contact is mainly controlled by the function module of Interaction. Because the contact properties of different materials are different, Penalty function can be used to define the effect of contact surface, including friction coefficient. According to the cold rolling process, the deformation of the idler cannot be considered in the whole analysis process, so it is set as a rigid body, which is set by Rigid Constraint, as shown in Fig.1.

For unit types, ABAQUS provides a variety of types to choose from. According to the type of analysis, the structure element of C3D8R (eight-node linear hexahedron element, reduced integral) type can be used to deal with non-geometric boundary problems effectively. Compared with other element types, the eight-node element can effectively reduce the error under large deformation conditions. In addition, the type of eight-node element has an obvious effect on the accuracy of interpolation calculation in the element, which can deal with complex curve calculation. In order to ensure the accuracy of calculation, the mesh size should be reduced as much as possible under the allowable conditions, and the final mesh generation results of the model can be obtained as shown in Fig.2.

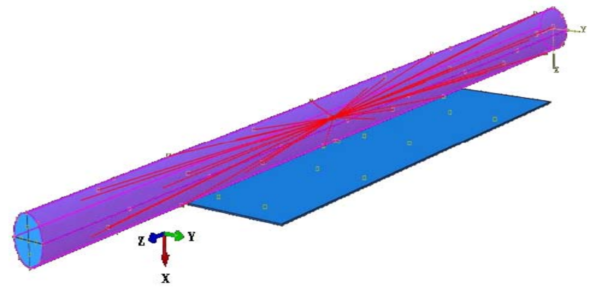

Fig. 1 Rigid Body Constraints

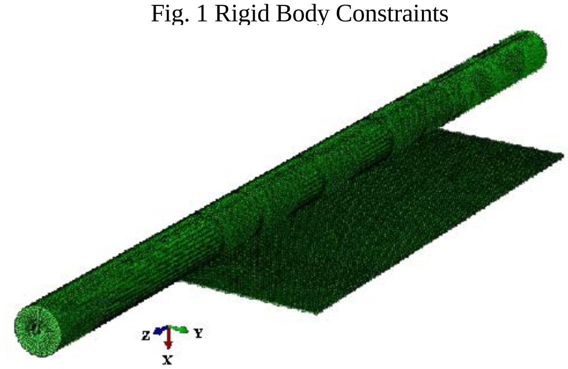

Fig.2 The meshing results of model

D. Visualization analysis

Through the corresponding settings, including the establishment of assembly model, the definition of material attributes, the setting of contact boundary, the submission of work interface, the creation of operation model, and so on, the visual simulation results can be obtained through continuous iteration. As shown in Fig. 3 and Fig. 4, the equivalent stress diagrams of wear-resistant steel sheets in the range of biting stage and stabilization stage are obtained respectively. As can be seen from the figure, the stress gradually diffuses with the increase of contact time. The analysis results can be applied to the study under different process parameters.

After cold rolling, there will be obvious residual stress on the surface of the wear-resistant steel plate, in which the outer surface is compressive stress, while the inner surface is tensile stress. This characteristic is related to the physical properties and loading of the metal itself, especially under different tension conditions, the magnitude of residual stress is significantly different. Under higher tension conditions, the residual stress will increase obviously and fluctuate greatly. It can be seen that excessive tension can directly lead to the imbalance of plastic deformation and eventually cause the wavy defects on both sides of the cold rolled workpiece. Generally speaking, the stress changes in the middle position are relatively uniform and the stress values are relatively small, but the thickness of the steel plate has a greater impact.

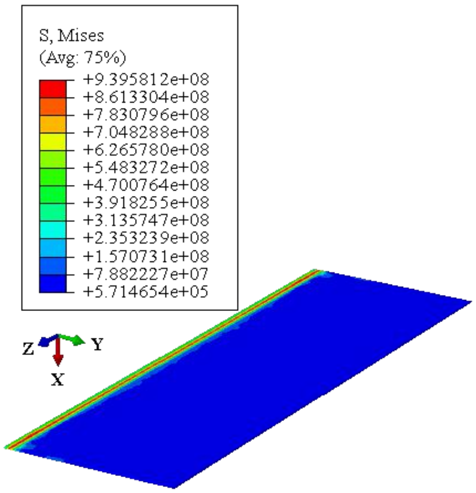

Fig. 3 Stress nephogram in biting stage

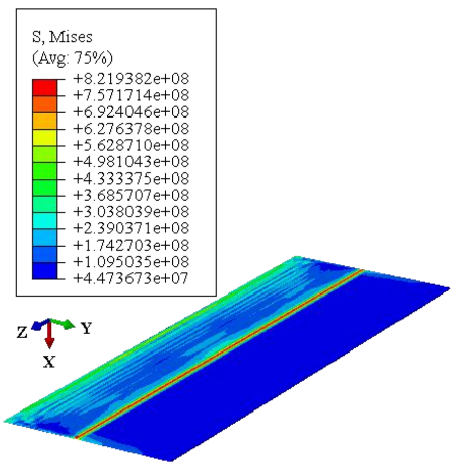

Fig. 4 Stress nephogram in stable stage

III. Effect of Different Technological Parameters

A. *Different front tension*

In order to ensure the reliability of the relationship between process parameters and stress changes, a single variable method is needed, that is, only one variable is changed for analysis. Under different pre-tension (95MPa~145MPa), the stress variation curves under specific rolling direction can be obtained as shown in Fig. 5. It can be seen that when the current tension is 95 MPa, the maximum stress value on the wear-resistant steel plate is 560 MPa; the stress value first decreases and increases with the increase of rolling distance. In a word, more balanced and lower residual stress can be obtained under the pre-tension condition of 115 MPa. Different pre-tension has obvious influence on the stress distribution, especially on the inflection point of stress change. When the front tension is 135 MPa, the inflection point of stress change will appear at the front end of rolling direction.

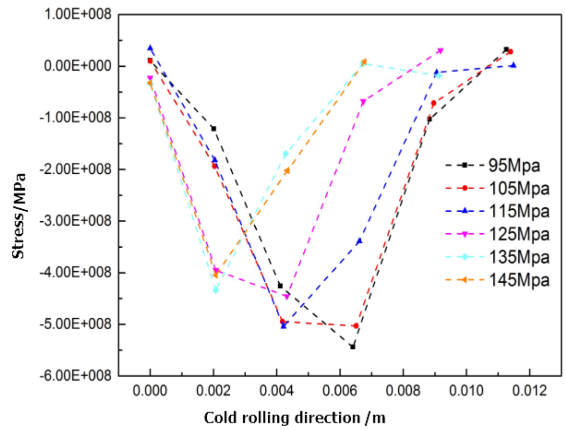

Fig.5 Stress changes under different front-tension conditions

B. *Different post tension*

Keeping the other parameters unchanged, the stress curves were calculated under the condition of 45 MPa ~ 95 MPa post tension, and finally the stress curves were obtained as shown in Fig. 6. It can be seen from the figure that the maximum stress on the wear-resistant steel plate is 540 MPa when the post-tension value is 45 MPa; with the increase of the post-tension, the stress value decreases gradually; during the cold rolling process, the residual stress under different post-tension conditions has little difference. Compared with the front tension, the influence of the post tension on the stress change is relatively small. For example, the post tension cannot change the inflection point of the stress change significantly, and the influence of the post tension on the stress value at the far end can be neglected.

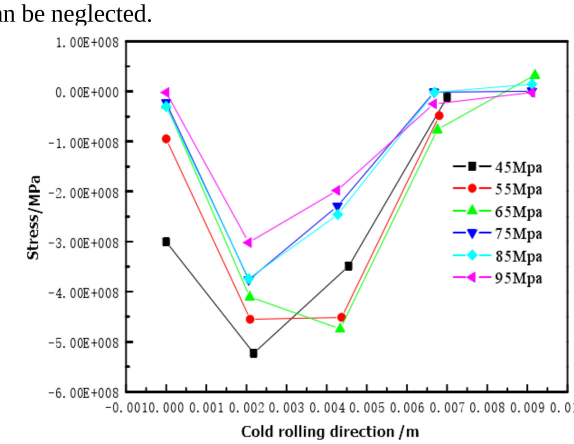

Fig.6 Stress changes under different post-tension conditions

C. *Different friction coefficients*

Under the condition of only changing the friction coefficient (0.06~0.10), the stress variation curve is shown in Fig. 7. It can be seen that when the friction coefficient is 0.06 and 0.08, the difference of stress value is not great, but it is quite different from that when the friction coefficient is 0.1. Generally speaking, with the increase of friction coefficient, the stress value tends to increase and change. This is because the lubrication between the contact pairs decreases, so that the contact pressure increases. Friction coefficient is also easy to adjust in practical engineering applications, especially in cold rolling die processing, the method of coating lubrication material is generally used to reduce friction coefficient, and ultimately achieve the effect of reducing residual stress.

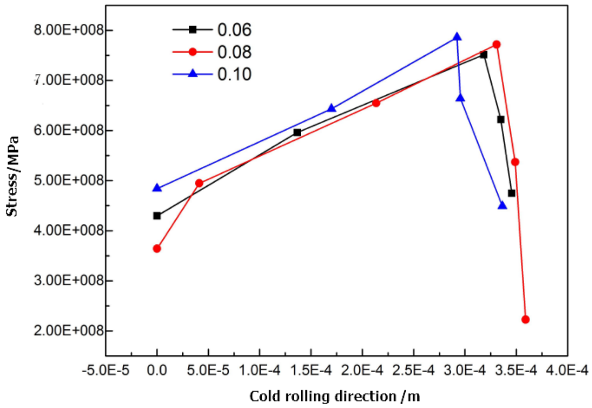

Fig.7 Stress variation under different friction coefficients

IV. CONCLUSION

The influence of the tension before and after the idler on the cold rolling stress of the wear-resistant steel sheet is very significant. This is because the tension before and after the idler obviously changes the stress of the steel sheet in the cold rolling process, and the normal bearing capacity of the steel sheet changes greatly. The change of friction coefficient on cold rolling pressure is mainly reflected in friction factor. With the increase of friction coefficient, tangential contact force increases. In the actual cold rolling process, there are many factors of stress and cold rolling stress, and the optimal process parameters are difficult to determine. But the finite element simulation based on ABAQUS in this paper can provide an important basis for the optimization of some process parameters.

V. ACKNOWLEDGEMENT

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VI. REFERENCES

[1] H. Xiuhua. “Microstructure and properties of wear-resistant steel Mn13 hot-rolled sheet,” Metal heat Treatment, vol.32, pp.206-209, October 2015.

[2] L. Liu-min, H. Guiyun. “Effect of cold rolling deformation on the structure and properties of Mn13 wear resistant steel,” Computer Simulation, vol.33, pp. 234-237, August 2016.

[3] L. Hongsheng. “Development of DC03+C590 cold-rolled steel strip for automobile sealing strip,” Computer Simulation, vol. 31, pp. 407-411, January 2014.

[4] L. Qiaohua. “Cause analysis and improvement of hollow shaft damage of cold rolling coiler,” Journal of Automotive Engineering, vol. 01, pp. 464-468, April 2014.

[5] Q. Canwen. “Multi-physical field coupling study of gasoline engine seal performance based on finite element analysis,” Lubrication and Sealing, vol.3, pp. 45-47, June 2018.

[6] Z. Zhiguo, P. Yugang. “Research on explicit dynamic analysis method based on ABAQUS,” Mechanical Design and Manufacturing, vol.24, pp.208-215, July 2015.

[7] W. Kesheng, Z. Leiqiang. “A new exact penalty function method for solving inequality constraints,” Computer Simulation, vol.28, pp.342-347, April 2013.

