

11th International Conference on Technology of Plasticity, ICTP 2014, 19-24 October 2014,
Nagoya Congress Center, Nagoya, Japan

Evaluation of deformation behavior of oxide scale in hot rolling process by vacuum hot rolling mill

Takuya Kurotsu^{a,*}, Akio Segawa^b

^a Graduate School, Kanazawa Institute of Technology, 7-1, Ohgigaoka, Nonoichi, Ishikawa, 921-8501, Japan

^b Mechanical Engineering, Kanazawa Institute of Technology, 7-1, Ohgigaoka, Nonoichi, Ishikawa, 921-8501, Japan

Abstract

A method for reproduce the oxide scale in hot rolling is proposed using the vacuum hot rolling mill. This method is possible to control of scale thickness and chemical composition in actual hot rolling process. From results, it is possible to clear the deformation behavior of state generated the oxide scale, oxide scale thickness is thick enough amount of Fe_2O_3 billets. The oxide scale thickness is proportional to the amount of Fe_2O_3 . Some cracks appeared before the roll bite during rolling the oxide scale. Then, peeling or destruction occurred in roll bite for roll exit.

© 2014 Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license

(<http://creativecommons.org/licenses/by-nc-nd/3.0/>).

Selection and peer-review under responsibility of the Department of Materials Science and Engineering, Nagoya University

Keywords : Oxide scale; Vacuum hot rolling mill; Scale transfer method; Deformation behavior; Scale thickness

1. Introduction

Recently, high productivity, high precise, high quality are found to steel materials. There is fear that the oxide scale formed in hot rolling process adverse effects for surface properties of final product. Generally, in hot rolling process, oxide scale generated by re-oxidation after descaling, then it is rolled together with steel plate and causes a surface defect. Until now, some studies on oxide scale by Okada et al. (2003), but are still unknown in detail. In addition, the deformation behavior of oxide scale itself is not clear.

*Corresponding author. Tel.: +81-76-274-9270 ; fax: +81-76-274-9251.

E-mail address: b6300814@planet.kanazawa-it.ac.jp

In this study, the method for reproduce the oxide scale in hot rolling is proposed by Segawa et al. (2007) named Scale Transfer Method using the vacuum hot rolling mill. This method, mother sheet and Fe_2O_3 billets place in vacuum atmosphere, then mother sheet surface is oxidized in the vacuum heating atmosphere, by O_2 dissociated from Fe_2O_3 billets.

This method is possible to control of scale thickness and chemical composition in actual hot rolling process, and to evaluate of deformation behavior of oxide scale itself just after rolling.

2. Scale Transfer Method

2.1. Experiment machine summary

The external appearance of a vacuum hot rolling mill is shown in Fig. 1, and specifications of vacuum hot rolling mill is shown in Table 1. The vacuum hot rolling mill is constructed by a heating zone, a rolling zone, a cooling zone and vacuum pump.

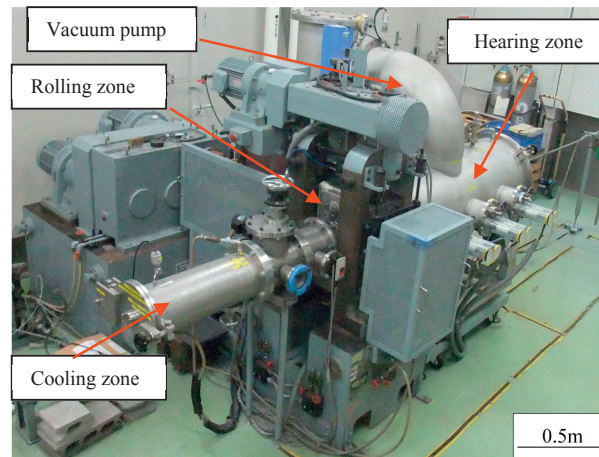


Fig. 1. External appearance of vacuum hot rolling mill.

Table 1. Specifications of vacuum hot rolling mill.

Mill type	2 high mill : $\phi 165 \times 150$
Roll material	2 high roll : SKD61, SiAlON
Rolling speed	2 high mill : max. $10\text{m} \cdot \text{min}^{-1}$
Degree of vacuum	max. $1.33 \times 10^{-3}\text{Pa}$ (10^{-5}Torr)
Rolling load	max. 390kN
Heating temperature	max. 1373K
Functions	Differential roll speed rolling
	Cross rolling (Cross angle : max. $\pm 2\text{deg.}$)
	Grooved rolling

2.2. Experiment summary

Schematic image of Scale Transfer Method is shown in Fig. 2. Detail of this method, mother sheet and Fe_2O_3 billets place in vacuum atmosphere, then mother sheet surface is oxidized in the vacuum heating atmosphere, by O_2 dissociated from Fe_2O_3 billets, then and rolled immediately with state of oxide scale kept.

Results of oxide scale compositions of the mother sheet before and after the experiment detected by X-ray analysis are shown in Table 2. From the results, FeO single layer oxide scale is able to be produced by Scale Transfer Method. Dissociation pressure of each oxide scale is shown in Table 3. Because dissociation pressure of Fe_2O_3 is smaller than degree of vacuum 0.133Pa that is an experiment condition as a reason using Fe_2O_3 . Rolling and experiment conditions are shown in Table 4. Heating temperature is 1273 K near sheet temperature before rolling final process. The oxide scale is controlled by amount of Fe_2O_3 billets.

Recently, the method is using the unit of Fe_2O_3 , although steel sheet with scale used before. It has become possible to control the oxide scale thickness exactly near the secondary scale.

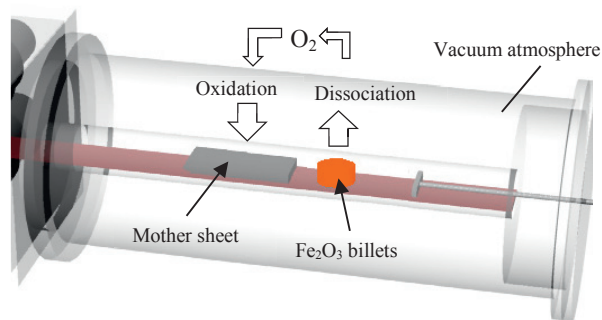


Fig. 2. Schematic image of Scale Transfer Method by using the vacuum hot rolling mill.

Table 2. Results of X-ray analysis.

Mother sheet	Detected compositions of the oxide scale
Before experiment	Fe_2O_3 , Fe_3O_4
After experiment	FeO

Table 3. Dissociation pressure of composition oxide scale.

Oxide scale	Dissociation pressure (Pa)
FeO	1.72×10^{-10}
Fe_3O_4	2.84×10^{-8}
Fe_2O_3	0.172

Table 4. Rolling and experiment conditions.

Mill type	2 high		
Work roll	Material	SKD61	
	Diameter	(mm)	165
	Surface roughness	(μm)	0.35
Rolling speed	($\text{m} \cdot \text{min}^{-1}$)	10	
Degree of vacuum	(Pa)	0.133	
Heating temperature	(K)	1273	
Aging time	(min)	5	
Specimen	Mother sheet size	(mm)	$3.4t \times 50w \times 200l$

Characteristics of vacuum rolling mill are described in the following.

- 1) Degree of vacuum to be able to achieve is a high vacuum level of 1.33×10^{-3} Pa (10^{-5} Torr), and the heating temperature is 1373 K at maximum. An instruction heating system is adopted, and heating in a vacuum atmosphere is possible.
- 2) Comparing with the conventional vacuum rolling mill, a great difference is that only a roll unit for rolling the materials to be processed is installed in a chamber. As a result of this, the pollution in the rolling chamber due to evaporation of a bearing lubricant can be prevented, and the outbreak of impure gas from a housing structure made by casting can be simultaneously restrained. In addition, a capacity to carry out a vacuum operation can be made smaller because of such a structure, and a high vacuum atmosphere can be maintained effectively.
- 3) By changing a bearing part, a cross rolling can be coped with while maintaining a vacuum atmosphere.
- 4) Work rolls in 2 high mill are driven at the upper part and lower part, respectively, and rolling at differential rolling speed can be practiced.
- 5) A material with a maximum size of 50mm in width and 13mm in thickness, 300mm in length can be rolled.

Changes of a degree of vacuum, when the temperature of atmosphere in a heating furnace is 1273 K, are shown in Fig. 3. The vacuum, when the rolling mill turns out a vacuum atmosphere by using jointly both a rotary pump and an oil diffusion pump. When using only the oil rotary pump, the degree of vacuum to be able to attain is about 1.33 Pa (10^{-2} Torr) or so, but using it together with the oil diffusion pump, 1.33×10^{-3} Pa (10^{-5} Torr) can be achieved. The atmosphere becomes a state of high vacuum after one hour later from the start of driving the pumps, and then, another one hour later, the atmosphere temperature becomes 1273 K, the best arrival temperature.

In addition, schematic image of structure in the vacuum hot rolling mill, pass-line, and the rolling method are shown in Fig. 4. A specimen is pushed by push bar, and rolling in rolling zone.

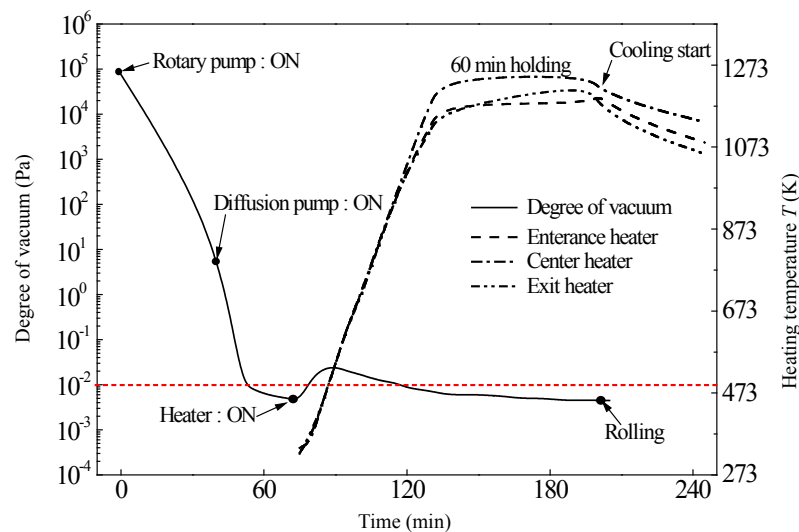


Fig. 3. Characteristics of degree of vacuum and heating temperature.

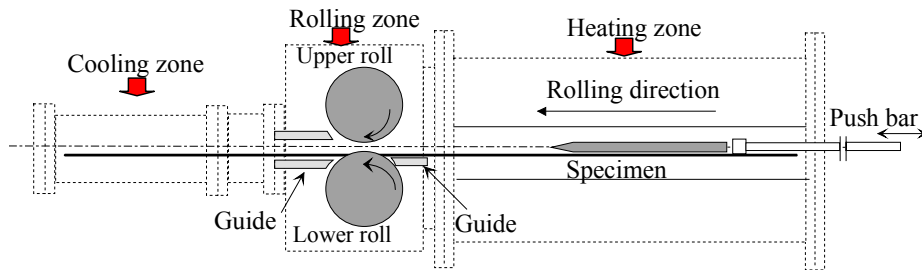


Fig. 4. Schematic image of vacuum hot rolling mill process.

3. Evaluation of deformation behavior of oxide scale by Scale Transfer Method

Evaluation of deformation behavior of the oxide scale production using Scale Transfer Method was cleared. Experiment conditions of each test sheet are shown in Table 5. The thickness of the initial scale is about 10 μ m for each test sheet. In addition, growth the oxide scale is No. 2 and No. 5, No. 6 using Fe₂O₃ billets. There are test sheets rolling with rolling conditions shown in Table 5. After rolling, observed the oxide scale using a scanning electron microscope (SEM).

Table 5. Experiment conditions of each test sheet.

Test sheet No.	1	2	3	4	5	6
Scale thickness (μ m)	10	10	10	10	10	10
Quantity of Fe ₂ O ₃ (g)	0	0.5	0	0	0.5	0.5
Reduction in thickness (%)	0	0	10	40	10	40

Results of cross section observation of each test sheet are shown in Fig. 5. In addition, results of measured average of the scale thickness of each test sheet based on the cross section observation micrograph are shown in Table 6. From Fig. 5 in No. 1 and No. 2 specimens, the oxide scale and steel sheet interface are in an almost flat. No. 3 to No. 6 specimens, the ruggedness is shown on sheet surface after rolling. After rolling, the oxide scale is pushed into a mother sheet surface, and the breaking and cracking occurs in the scale. This is seen conspicuously so as high reduction in thickness. Some cracks are appeared before roll bite during rolling the oxide scale. This is drawn into the roll side at the same time that the oxide scale is rolling it and begins a roll bite, and a crack occurs in a crystal grain boundary. Because crush or flaking and the development that there was occur because of the contact with the roll then, in the thing that is pushed into the steel sheet surface at a stretch when there is it at the time of the rolling, a pit-formed oxide scale bank named scale pit occurs and is guessed with a factor to worsen a steel sheet surface property.

In low reduction in thickness, slight deformation and breaking only occur in the oxide scale and are not pushed into the steel sheet surface. At the high reduction in thickness, the oxide scale deformation it more and it is thought that the steel sheet surface is stormy in what is pushed into a steel sheet.

Deformation produces the oxide scale by rolling it at a high reduction in thickness, and it is thought that a scale wound produces it in what is pushed into the steel sheet surface.

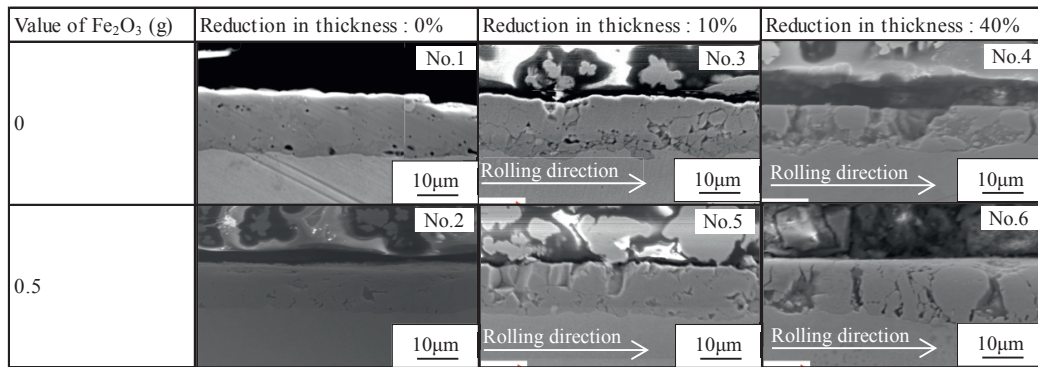


Fig. 5. Results of cross section observation.

Table 6. Average of the scale thickness of each test sheet.

Test sheet No.	1	2	3	4	5	6
Scale thickness of cross-section (μm)	12	13	12	10	13	13

4. Conclusion

In this study, using Scale Transfer Method, evaluation of deformation behavior of oxide scale itself just after rolling. This method, mother sheet and Fe_2O_3 billets place in vacuum atmosphere, then mother sheet surface is oxidized in the vacuum heating atmosphere, by O_2 dissociated from Fe_2O_3 billets. This method is possible to control of scale thickness in actual hot rolling process.

From results of cross section observation after experiment, it is possible to clear the deformation of state generated the oxide scale, the oxide scale thickness is thick enough amount of Fe_2O_3 billets. And oxide scale thickness is proportional to amount of Fe_2O_3 billets. Some cracks are appeared before roll bite during rolling the oxide scale. Then, peeling or destruction is occurred in roll bite for roll exit.

In low reduction in thickness, slight deformation and breaking only occur in the oxide scale and are not pushed into the steel sheet surface. At the high reduction in thickness, the oxide scale deformation it more and it is thought that the steel sheet surface is stormy in what is pushed into a steel sheet.

Deformation produces the oxide scale by rolling it at a high reduction in thickness, and it is thought that a scale wound produces it in what is pushed into the steel sheet surface.

References

- H. Okada, 2003, Deformation of Scale in Hot Strip Rolling, Journal of JSTP, 44, 94-99.
- A. Segawa, T. Taguchi, 2007, Deformation Characteristics of Oxide Scale in Hot Rolling by Scale Transfer Method Using Vacuum Hot Rolling Mill, Materials Science and Technology 2007 Conference and Exhibition proceedings, STEEL, 159-170.