1-1-2011

Study on oxidation of stainless steels during hot rolling

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Abstract

The oxidation of stainless steels 304 and 304L during hot rolling is studied in this paper. Results show the oxide scale thickness decreases significantly with an increase of reduction, and the oxide scales of both 304 and 304L stainless steels were found more deformable than the steel substrate. Surface roughness shows a complicated transfer during the hot rolling process due to the complexity of oxide scale characteristics. Also, surface roughness decreases with an increase of reduction. The friction coefficient increases with reduction in all cases, and the increase is more significant in the case of the 304 stainless steel than that of 304L stainless steel.

Keywords

stainless, steels, during, study, hot, oxidation, rolling

Disciplines

Engineering | Science and Technology Studies

Publication Details

Jiang, Z. Y., Wei, D. B., Tieu, K., Huang, J. X., Zhang, A. W., Shi, X. & Jiao, S. H. (2011). Study on oxidation of stainless steels during hot rolling. International Journal of Manufacturing, Materials and Mechanical Engineering, 1 (1), 31-42.

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ABSTRACT

The oxidation of stainless steels 304 and 304L during hot rolling is studied in this paper. Results show the oxide scale thickness decreases significantly with an increase of reduction, and the oxide scales of both 304 and 304L stainless steels were found more deformable than the steel substrate. Surface roughness shows a complicated transfer during the hot rolling process due to the complexity of oxide scale characteristics. Also, surface roughness decreases with an increase of reduction. The authors show that the friction coefficient decreases with an increase of oxide scale thickness for stainless steel 304L.

Keywords: *Deformation, Oxidation, Oxide Scale, Stainless Steel, Surface Roughness*

INTRODUCTION

The finishing temperature of hot strip rolling of stainless steels is in a range of 850 - 1100°C, where there is a significant oxidation process, in which oxide scale layers are inevitably formed on the stainless steel surface. In a rolling pass, the oxide scale encounters a complicated stress state which includes: i) normal compressive pressure from the work roll; ii) shearing stress due to the relative speed between the oxide scale and the roll surface, and relative sliding between the oxide scale and the deforming bulk steel; iii) tension in the rolling direction due to the product elongation; and iv) bending stress when the oxide scale and the strip is deformed (Yu & Lenard, 2002)

The deformation of oxide scale plays a key role with regard to the strip surface roughness which has an important influence on the down-stream metal forming and its surface quality, especially for stainless steels. The surface of

DOI: 10.4018/ijmmme.2011010103

the oxide scale is made up of asperities, and when two surfaces are placed in contact, only the tips of the asperities touch. Forces normal to the surface make the asperities deform, and they can weld together at points of contact. Forces parallel to the surfaces are resisted by the shearing strength of these junctions. The oxide scale particles are deeply depressed into the strip surface, and the hot metal is extruded outward to fill the void between the oxide scale particles, thus generate a rougher surface (Jiang et al., 2006). At present, an increasing interest has been shown on the deformation of oxide scale during hot strip rolling (Yu & Lenard, 2002; Munther & Lenard, 1999; Iordanova et al., 2000; Krzyzanowski & Beynon, 1999; Krzyzanowski et al., 2000; Krzyzanowski & Beynon, 2002; Sun et al., 2003; Sun et al., 2004). Li et al. (2000) conducted hot "sandwich" rolling of plain carbon steel, and found that the oxide scale was strongly sensitive to the rolling temperature and reduction, and finite element modelling has been carried out to evaluate the hot ductility of the oxide scale. Suarez et al. (2009) combined previous investigations with their results, and concluded that the thin oxide scale exhibits a plastic behavior at temperatures above 900°C, and a brittle behavior when deformed at temperatures below 700°C, and mixed behavior was observed within this temperature range, as the oxide scale was found to resist limited amounts of deformation.

However, investigation on the deformation and surface roughness behavior of oxide scales during hot strip rolling of stainless steels is limited. Most studies on oxide scale deformation were based on carbon steel which is consisted of wustite, magnetite and hematite. While the two major potential components of a stainless steel oxide scale are the M_2O_3 rhombohedral phase and the M_3O_4 spinel phase (Mark, 2001). In this paper, the oxide scale deformation and the surface roughness transfer of 304 and 304L stainless steels are investigated. The deformation features of the stainless steel surface roughness are also discussed.

EXPERIMENTAL

An electrical furnace was adopted for reheating. Hot rolling tests were carried out on a Hille 100 Experimental Rolling Mill. A computer was used for data collection using Lab Window Software. The rolls are 225mm diameter by 254mm wide, induction hardened to 65 - 70RC up to 2.5mm deep with an initial surface roughness of 0.4μm (R_a) (Sun, 2005). The samples after rolling were put into a cooling box connecting with nitrogen to prevent further oxidation. The surface roughness was measured by the Hommel Tester T1000, the detailed procedures can be found in (Wei et al., 2009a).

RESULTS AND DISCUSSION

Deformation of Oxide Scale Under Various Reductions

The surface morphologies of oxide scale at the lead when the reduction is from 0 to 40% were photographed, as shown in Figure 1. It can be seen that the integrality of oxide scales and the surface finish after cooling increase with an increase of reduction. When the reduction is low, the hot rolled oxide scales were inclined to break after cooling. The bonding between the remained oxide scales and steel substrate is low, and there are a lot of macro cracks. This situation is improved with an increase of reduction. When the reduction is larger than about 20%, there are few macro cracks in the oxide scale, and the oxide scale is intact.

Stainless Steel 304

Figure 2 shows the microstructure of oxide scale of the 304 stainless steel under various reductions when the reheating time is 30min. The thickness of the oxide scale after rolling mainly depends on the reduction rather than the original thickness when the reduction is 20%. The relationship between the oxide scale thickness and reduction can be found from the

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