STUDY OF THE PICKLABILITY OF 1.8 mm HOT-ROLLED STEEL STRIP IN HYDROCHLORIC ACID

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Abstract — **After the hot rolling process the steel strip remains covered with an oxide layer (scale) which must be removed previous to the cold rolling process. The scale removal through the pickling process by hydrochloric acid (HCl) depends on both the scale structure and the conditions of the pickling bath (temperature, acid concentration, and dissolved iron concentration). This work is focused on picklability (decapability) studies accomplished in laboratory on hot-rolled steel strip, 1.8 mm thickness. The oxide amount was determined by weight difference of samples with and without acid pickling. The scale was characterized by X-ray Diffraction (XRD) and Scanning Electron Microscopy (SEM). The pickling or descaling time (t_d) was determined using different bath conditions. Pickling kinetic studies were carried out being the pickled fraction (α) determined as a function of the immersion time. Expressions were obtained, allowing descaling time estimation under various pickling bath conditions. These expressions were used to estimate the maximum operation line speed that assures a complete descaling.**

Keywords — **Pickling, hydrochloric acid, oxide scale, hot-rolled strip, descaling.**

I. INTRODUCTION

During hot rolling process an oxide layer (scale) is formed on the surface of the steel. The aim of this process is to reduce steel slab thickness, typically from 230 mm, to strip products with thickness ranging from 1.2 to 12 mm. Usually, the steel strip temperature at the end of the hot rolling process (Finishing Temperature, FT) varies from 820 to 910°C, with an average of 870°C for strip having a thickness of 1.8 mm. Oxide scale formed at these temperatures is composed of three well defined layers (iron oxides), namely: a thick wüstite (approximate composition FeO) layer adjacent to the steel, then an intermediate magnetite (Fe_3O_4) layer, and finally a thin outermost hematite (Fe_2O_3) layer (Blazevic, 1987; Blazevic, 1996; Chen and Yuen, 2000a; Goode *et al.*, 1996; Hudson, 1991; Lecourt, 1996; Malik and White, 1981; Wei, 1990).

Following the finishing mill, the strip is quickly cooled by water spray on the run-out table and coiled at a temperature between 500-760°C. In this case, the coiling temperature (CT) is nearly 630°C. Finally, the steel coil is cooled to room temperature by natural convection. While the strip is being cooled, the scale keeps growing, if there is oxygen supply. The same three layer structure is maintained until a temperature of 570°C is reached. However, when temperature drops below 570°C, wüstite becomes unstable and decomposes, leading to a mixture of iron and magnetite via a eutectoid reaction:

$$4\,FeO \rightarrow Fe + Fe_3O_4 \qquad (1)$$

Depending on the temperature and the cooling rate, different oxide scale structure may build up within the original wüstite layer. At slow cooling rates, wüstite has enough time to decompose completely, forming a finely disperse iron phase into magnetite, whereas at very rapid cooling rates the eutectoid transformation may be incomplete. Intermediate cooling rates lead to domains of undecomposed wüstite into the iron-magnetite matrix (Blazevic, 1987; Blazevic, 1996; Chen and Yuen, 2000a; Goode *et al.*, 1996; Hudson, 1991; Lecourt, 1996; Wei, 1990; Yamaguchi *et al.*, 1994). Besides, the cooling rates could be quite different depending on the locations in the coil (Chen and Yuen, 2000b).

In brief, the scale structure will be influenced by different processing parameters, such as the finishing and coiling temperatures, the cooling rate, and the conditions under which the coils are stored. Therefore, the scale structure will not be uniform throughout the coils, and variations are observed both across the width and along the length of the strip (Chen and Yuen, 2000a; Lecourt, 1996).

The scale must be removed previous to the cold rolling process, since it may produce operative problems and qualitative defects in the material. Effective scale removal is essential for the success, not only of cold rolling, but also of the subsequent annealing and coating operations (Lecourt, 1996). In order to get rid of these oxides, the steel strip is submitted to a critical process called pickling. The continuos pickling process consists in the immersion of steel strip in a series of tanks containing a hydrochloric (HCl) or sulphuric acid (H_2SO_4) hot aqueous solution. Hydrochloric acid is the most used acid. The choice between these two acids is complex and will not be considered in detail. However, it should be mentioned that hydrochloric acid shows a faster pickling rate than sulphuric acid, shortening the process time.