MODELLING AND SIMULATION OF THE HEAT TRANSFER ALONG A COLD ROLLING SYSTEM

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Abstract— In the industry of flat rolled sheet product, strip crown and shape has been one of the most important factors for quality assurance, productivity improvement, cost effectiveness, and customer satisfaction. The transient work roll profile influences load distribution and imprints an undesirable profile on rolled strip. Precise prediction of the work roll thermal profile facilitates adjustment of crown control devices for crown compensation and shape correction.

Many studies, including numerical methods, statistical equations, and analytical solutions are proposed in the literature. This article proposes a semi-analytical solution for the work roll subjected to predict transient thermal profiles of work rolls with multiple cooling/heating zones. It was derived from the heat balance equation using the finite difference method and Runge-Kutta method that are two semi-recursive analytical solutions, developed to update, the work roll temperature distribution within a very short computing time. The model suggested is used for the numerical simulations in rolling. In this paper, presenting the equations describing a system part is interesting. An evaluation of this work is made through discussing the results and finally, some prospects are evoked.

Keywords— Modelling, cold rolling, thermal profile, work roll, heat exchange.

I. INTRODUCTION

In rolling process, large amount of heat generated in the roll bite transfers to work rolls and strip (Rabbah and Bensassi, 2007b). Work rolls are cooled by cooling medium in both entry and exit sides of the mill. Transient cooling behavior of the roll affects temperature distribution and thermal profile.

The strip deformation is caused by several factors; of which we quote the irregular distribution of the liquid rate flow along the rolls. A direct consequence of this phenomenon is the non-homogeneous temperature profile, which causes a dilation of the work rolls in various points (Rabbah and Bensassi, 2007a). One of the effects of this dilation is the strip shape disturbance at the exit of the roller (Rabbah and Bensassi, 2006). To remedy this problem, we are compelled to study the rolls behavior affected by the temperature distribution and thermal profile.

The shape quality of the cold-rolled strips is very important. Temperature rolling is also used to improve the surface quality of the strip and the flatness properties. To optimize these final properties of cold-rolled steel, the elongation of each strip product must be strictly controlled. Therefore, it is particularly necessary to control the cooling headers system, and thereafter, to realize the desired thermal profile.

Many studies have been published to predict thermal profiles based on finite difference methods (Ginzburg, 1993; Poplawski and Seccombe, 1979; Yarita et al., 1979; Kawanami et al., 1985; Tooru et al., 1975; Ben-non, 1985) and even simple closed-form formulations (Yasuda et al., 1987). Pallone has, for the first time, derived equations of temperature distributions in work rolls with two cooling/heating zones using Laplace transform and Cauchy’s residue theory (Pallone, 1983). Even if the model was later verified by Somers et al. (1984); the usage of the model, however, should be limited only for the same width continuous rolling since only two heat transfer zones were considered in the derivation.

The model was later expanded by Guo (1993b) to accept the time discrete multiple zone cooling/heating boundary condition. This modification was adopted for various strip widths and cooling control zones and making it possible for the model to be used in the on-line control. This expanded model showed some disadvantages such as the required large computing time and memory storage. To cope with insufficiency, Guo (1993a) further converted these equations into recursive equations and introduced a hybrid method for fast computation and small memory storage. The model was verified to obtain an empirical heat equation using Powell’s method and three measured work roll profiles from a production hot strip mill (Guo et al., 1993).

This article proposes a semi-analytical solution to solve temperature field of the work roll which is subjected to various cooling and heating boundary conditions. The model is particularly adapted to the cold rolling system operation in very low thickness, in order to predict the shape of a strip. The governing basic equations and the boundary conditions associated will also be presented. The various methods of the resolution of the heat equation are quoted in the fourth part. The article ends in an interpretation with an evaluation of the results.