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DESIGN OF AN ADAPTATION MODEL FOR MODIFICATION OF STRIP'S SPEED IN FINISHING ROLL AREA OF MOBARAKEH STEEL COMPANY

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ABSTRACT

One of the principal laws used in set-point calculation for consecutive rolling stands of hot metal strips, specially rolling speeds, is material flow continuity principle in these stands; the amount of material flow to all stands must be equal. Non-uniform amount of input material to the consecutive rolling stands can cause emergence of extension and /or compression stresses in metal strips between consecutive rolling stands and consequently instability of the rolling process. Several factors can cause overthrowing continuity principle in amount of input material to the rolling stands; because of complexity of the effects of these factors, determining the main cause of overthrowing continuity principle in consecutive rolling stands is very difficult. In this study, an adaptation model has been designed for unification of the amount of input material to the rolling stands. This model, in case of non-uniform amount of input material to the rolling stands, adapts the amount of rolling stands set-points in such a way that material flow continuity principle be reestablished for rolling products. This adaptation model has been used in Mobarake steel company hot rolling area and has produced very beneficial results.

Keywords: *strip's speed; adaptation model; Mobarakeh steel company; finishing roll area; roll speed*

INTRODUCTION

Desired set-points of consecutive hot rolling stands are calculated by complex mathematical models. These models include empirical formulae in accordance with rolling principles and concepts which have been tested in laboratory rolling lines by rolling science researchers, reached and modified and accomplished gradually [1-9].

In the finishing rolling area of Mobarakeh steel company, seven consecutive rolling stands exists whose duties are to gradually decrease the load thickness and to provide the finished strip. To do these, speed and gap of each rolling stands should be set on an appropriate set point.

One of the principles used in calculating rolling stands speed is the material flow continuity in consecutive rolling stands.

Since strip width changes in consecutive rolling stands are slight, according to this principle, width changes in these stands are ignored and it is assumed that the strip width entering consecutive rolling stands is fixed. Also, in accordance to this principle, at the strip entrance to the consecutive rolling stands, product of thickness and to output strip speed in all stands is equal to a constant amount.

If the amount of material entering a rolling stand is more than the amount of material entered the previous rolling stand, a primary extension will be formed between the stands (Figure 1). In this case, desired strip stress will not emerge and there can be lateral movements which may cause instability in rolling conditions.

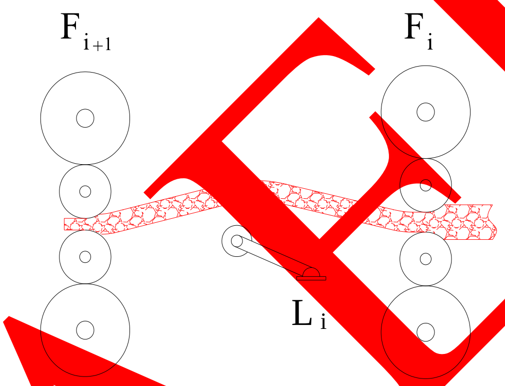

Figure 1. Loop formation between two consecutive stands at the beginning of the rolling.

If the amount of primary extension between stands becomes larger than usual, inconsistency of rolling happens and load surface may strike one of the surrounding equipments and cause instability and stoppage of rolling before the looper is able to modify this extension. This event which is called cobble may cause scrapping of some loads, occurring damaging of rolling equipment and stoppage of production. Also, if in the load entrance to the next rolling strip, the amount of input material to this stand is more than the amount of input material to the previous stand, the load may go through an undesired primary stress, before the looper between these two stands can act to, prevent this.

If difference in amount of the input material to these stands is high, tensile stress is applied to the load; if it is more than yield stress, strip plastic deformation will happen.

Due to plastic deformation caused by high stresses, load width in one segment starts decreasing which is called necking (Fig. 2). Through continuous load rolling, in next rolling stand, the length of the load increases and ultimately, strip width decreases and product becomes damaged.

To prevent these problems, an adaptation model is designed in order that in the case of inconsistency in the input amount of material to the consecutive rolling stands irrespective of cause of the inconsistency, adapts the rolling state in rolling stands in a way that, material flow consistency be reestablished

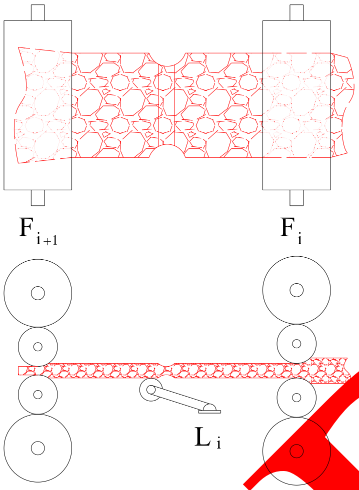

Figure 2. A schematic of slab necking development

CONTROL OF LOOPERS BETWEEN STANDS AND APPLYING CONSTANT EXTENTION

There is a looper between each two consecutive rolling stands whose duty is to control material flow between stands and to apply constant stress in the load. As soon as the load's head enters the next stand, looper is activated and moves quickly to the top to strike the lower surface of the strip and while applying constant stress on the load, sends a speed adaptation message to the previous stand motor to form a load extension between stands.

Formation of extension in the load causes an additional amount of material existing between the consecutive stands, and if due to sudden changes in load thickness or consecutive stands speeds, the material between the two consecutive stands changes, the looper acts to maintain increased material or compensate the decreased material.

Controlling strip extension by looper is done as follows:

When load rolling and in small time cycles, desired strip extension is compared to actual strip extension and based on their difference, an appropriate speed correction is calculated and applied to the stand motor in order to reach the desired strip extension.

The strip extension is a function of looper angle with the horizontal level; therefore, to measure actual strip extension at each moment of time, looper angle is measured by an angle transducer which is installed on looper shaft and actual strip extension is calculated according to the relations:

$$(\Delta L)_i = function(\alpha_i) \qquad (1)$$

ΔL : *Strip extension*

The looper controller is a proportional and integration controller (PI) one, see Figure 3. Thus, to remove actual strip extension fluctuations from desired strip extension, the controller is formed by the following two parts:

1. Proportional parts: this part is utilized for adjustment of strip extension adaptation

$$(\varDelta V)_p = G_p(\varDelta L_d - \varDelta L_a) \tag{2}$$

In the above formula, $(\varDelta V)_p$ is the proportional part, G_p is proportional gain $\varDelta L_p$ is the desired strip extension and $\varDelta L_a$ is the actual strip extension in each moment.

2. Integration part: This proportional part which is the integration controller part output of speed, is ultimate to remove the constant error between desired and actual strip extension. The calculation method of this proportional part is as follows:

$$(\varDelta V)_I = \int_t^{t+\varDelta t} G_I(\varDelta L_d - \varDelta L_a) \cdot dt \tag{3}$$

In the above formula, $(\varDelta V)_I$ is the integration part G_I is the integration gain. The sent proportional part of each lopper to its last strip motor is for controlling amount of material between two consecutive stands which this looper is located in between (stands F_i and F_{i+1}), but with change of speed of the strip preceding the looper (strip F_i), flow of material between this strip and the preceding one changes as well (stands F_i and F_{i-1}).

To neutralize the effect of this unwilling phenomenon, a cascade part is sent to the strip motor preceding this strip. It is equal to:

$$\varDelta V_{i-1} = \frac{V_{i-1}}{V_i} \cdot \varDelta V_i \tag{4}$$

In the above formula, $\varDelta V_i$ is the sent part to strip motor F_i from its looper, $\varDelta V_{i-1}$ Is strip speed F_{i-1}. Therefore, cascade part sent to each strip motor is for controlling material flow between this strip and the consecutive one is equal to:

$$\Delta V_i = (\Delta V_i)_p + (\Delta V_i)_I + \Delta V_{i+1} \tag{5}$$

Which $(\varDelta V_i)_p$ and $(\varDelta V_i)_I$ are proportional gain and integration gain of proportional part sent from looper respectively, L_i and $\varDelta V_{i+1}$ are proportional part sent from looper L_{i+1}.

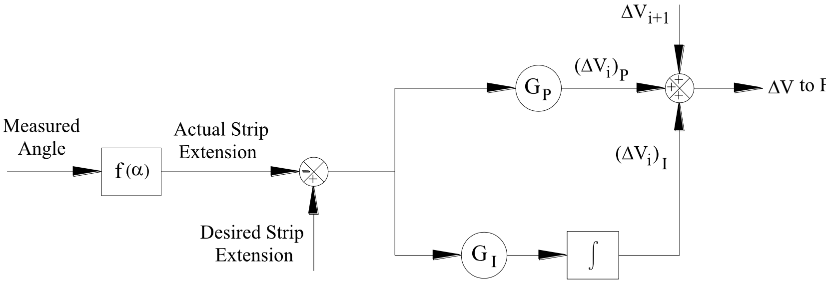

Figure 3. Control loop for material flow in rolling mills.

A lopper's required torque to keep the load up in α angle and applying constant stress in the strip consists of:

$$T_{tot} = T_L + T_S + T_T + T_B \qquad (6)$$

In the above formula T_{tot} is the looper total required torque, T_L is the required torque to tolerate the looper weight, T_S is the required torque to tolerate material weight between the two stands, T_T is the required torque for applying constant stress in the load and T_B is bending torque.

In the case that the input amount of material to F_i is less than the input amount of material to the next rolling stand i.e., stand F_{i+1}, the amount of stress being applied to the load is more than the desired stress and this looper will move down or will stay in its current angle.

In this case looper acts to sent positive correction speeds to the preceding stand, i.e., stand F_i, so that the looper stays in a desired working angle and the desired extension between the stands in formed. The more the variation of input material to stands F_i and F_{i+1} is, the more time looper needs to form the desired extension and the more time correction speed it sends to stand F_i.

In this case, more length of the load will be affected by undesired extension and plastic deformation and as a result more length at finished rolling part strip will have width drop.

Fig. 4 shows the L_4 looper angle, the amount of correction speed sent to rolling stand F_4, stands F_4 and F_5 rolling forces and output strip width of one of hot rolling products.

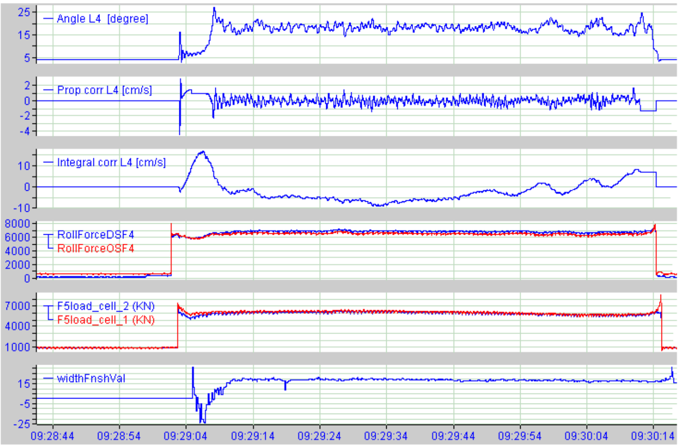

Figure 4. Graphs of undesired tension in bar and slab width reduction.

As it is clear from this figure that, at the beginning of rolling, the input amount of material to rolling stand F_5 is more than input amount of material to rolling stand F_4 and applied stress in the load is more than the desired stress which causes to down falling of rolling forces in these stands.

Applied stress in load is also more than its yield stress which causes load width necking. By sending positive correction speed message by the looper to the rolling stand F_4, the amount of input material to this stand increases and during formation of in-stands desired extension, constant desired stress is applied to the load. Since the amount of applied stress to the load by in stands desired stress force is less than load yield stress, load plastic deformation between two consecutive stands stops and therefore, load width drop stops and finishing output strip width reaches the desired amount.

DESIGNING ADAPTATION MODEL FOR CORRECTION SPEED OF CONSECUTIVE ROLLING STANDS

Several factors can cause overthrowing of the amount of input material continuity to the consecutive rolling, stands at the beginning of the rolling which the most important are:

1. Errors in width and thickness of input load to the rolling stands.
2. Error in calculation of rolling stand’s gap.
3. Error in calculation of rolling stand’s speed.
4. Error in the basis amount (zero) of rolling stand’s gap.
5. Inaccuracy of sensors measuring rolling stand’s gap.
6. Operator’s wrong manual interference during rolling the load.

At the present time, through observing looper states the operator applies speed correction to adapt the rolling stands speed for the next load. Applying corrective speed by operator is effective in removing stress on in-stands extensions; it basically has two fundamental problems, though:

1. Observing loopers operation alone cannot determinate amount of speed correction needed by the stands to remove stress and/or in-stand extensions. Thus, applying correction speed by operator does not have enough accuracy and most of the time cannot contribute to the complete removal of in stands stress and/or extension.

2. With regard to the variations of the conditions of rolling for various products, the amount of speed correction applied by the operator for one product may not be applicable for other products.

Therefore, to overcome the above mentioned problems, an intelligent adaption system is required which through determination of violation of continuity in each of the consecutive rolling stands, adapts the speed and gap set points of this stand for next similar loads in a way that the amount of input material to this stand equals the amount of input material to the previous and next stands.

Regarding the stability and uniformity of rolling conditions, rolling of consecutive similar loads in course of a hot rolling production schedule is the same, unless the production operator interference manually by in rolling situation.

Regarding the nearly similar conditions of rolling of consecutive similar products in a production schedule and looper's duty in forming in-stands extension and controlling amount of passing material from the consecutive rolling stands, if we add to the amount of calculated speed correction by each looper in the first seconds of rolling a product to the speed set point of the corresponding stand of that looper, in rolling the next similar products, the amount of input material to consecutive stands gets on to becoming the same and hence, instands stress and extension in consecutive similar productions disappear and down falling of products width decreases. The suggested model for speed correction of consecutive rolling stands is as follows:

$$(\Delta V)_i = k \cdot (\Delta V)_{L_i} + \frac{V_i}{V_{i+1}} \cdot (\Delta V)_{i+1} \tag{7}$$

In the above formula, $(\Delta V)_i$ is the amount of speed correction of stand F_i for the next similar load, $(\Delta V)_{L_i}$ is the speed correction sent by looper L_i to stand F_i in two seconds, V_i and V_{i+1} are values of set point speeds of stands F_i and F_{i+1}, respectively, $(\Delta V)_{i+1}$ is the amount of speed correction of stand F_{i+1} and k is a constant coefficient whose value is between zero and 1.

Amount of speed correction calculated by the aforementioned adaptation model, influences a stand speed as follows:

$$(V_i)_{new} = \nu_i \cdot (V_i)_{old} \quad , \quad \nu_i = 1 + \frac{(\Delta V)_i}{(V_i)_{old}} \tag{8}$$

where ν_i is called the speed correction coefficient of stand F_i.

RESULTS, DISCUSSION AND CONCLUSION

Fig. 5 represents the speed correction coefficient for one of the Mobarakeh steel company hot rolling stands. This adaptation coefficient has been calculated for hot rolling of similar consecutive productions. As it is clear from the figure, adaptation coefficient has decreased gradually and moves toward one. In other words, through gradual adaptation of the stand speed, the amount of material entering this stand becomes equal to the amount of material entering the next rolling stand and, therefore, this stand does not need speed correction. Thus, theamount of speed correction which is calculated by the suggested adaptation model has decreased to zero.

The aforementioned model has been used for various hot rolling productions and gradual decreasing of extension and primary stress, increasing of rolling production uniformity and increasing of dimensional quality improvement in these productions have been seen in its products.

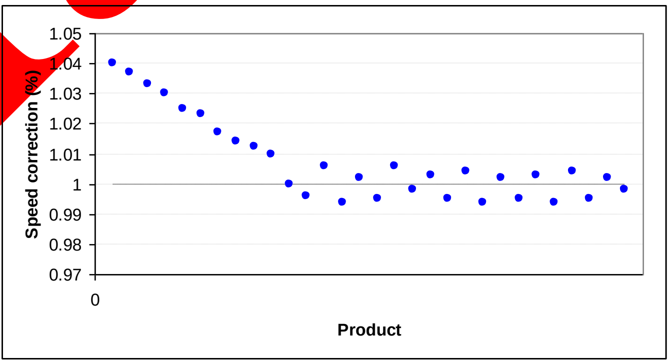

Figure 5. A typical recorded speed correction coefficient.

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