Model development of work roll wear in hot strip mill

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Abstract. This paper, based on the analysis of the main factors(specific roll force, mean roll surface temperature, irregular edge wear and contact arc length) affecting roll wear, designed a new work roll wear model, the test data shows that the model can more accurately reflect the work roll wear, can be on-line prediction of work roll wear. The roll wear curve, including constant wear and irregular edge wear, presents a box shape, and the reasons also are showed in this paper. The top roll wear and bottom roll wear in the same mill are inconsistent, and the reasons are also analysed in this paper. Results show that the construction of the work roll mathematical model accords with the general law of work roll wear and tear; it can more accurately forecast roll wear online.

1. Introduction
In the hot rolling, physical models for rolling mills have been intensively developed in recent years. Work roll wear not only worsens the strip shape, and also declines the performance of mills on shape control. As many factors affect work roll wear in the hot rolling and these factors influence each other, quantifying the impact of these factors on roll wear is important and difficulty [1, 2]. According to a literature study presented in a PhD thesis by Meng 1994 at least 182 wear equations have been published [3]. Referring to Meng, available equations are so confusing that just few designers can use any of them to predict product lifetime with confidence [4]. Thus it is not strange that the author has found just a few models of interest in the year of 2003. However the works by Archard [5, 6] shall especially be mentioned. Most models are empirical and only few influential parameters are taken into account.

In this paper, the main aim of the work is to find an empirical work roll wear model structure suitable for hot strip roll finishing mills. On the basis of this structure a new model is developed that takes more influential parameters into consideration than the presently used on-line model. The equation includes the influence of specific roll force, mean roll surface temperature, irregular edge wear, the number of roll rotation and contact arc length. The roll wear curve, including constant wear and irregular edge wear, presents a box shape, and the reasons also are showed in this paper. Analyzed the influence factors of roller wear is inconsistent in the same roll. Results show that the construction of the work roll mathematical model accords with the general law of work roll wear and tear, it can more accurately forecast roll wear online.
2. Mill Configuration

Fig. 1 shows the arrangement of typical tandem hot mill. Slabs for strip rolling are heated to a temperature of 1250 °C in walking beam or pusher-type reheating furnaces. After descaling, the slabs are rolled in a roughing mill to a thickness of about 20 to 30 mm using 5 or 7 passes. The width of the work piece is adjusted in a vertical edger.

After that the work piece is rolled down to a strip of about 1.5-16.0 mm thickness, using a four-stand computer controlled finishing mill. The transverse thickness profile of the strip is maintained by controlling the shape and axial displacement of the work-rolls. The control system is based on mathematical models. It provides real time data in various rolling stages and controls the process. From the last stand, the strip continues to the cooling zone where it is chilled from about 800 °C to about 600 °C. Then the strip is coiled. The maximum weight of a coil is approximately 30 tones. If required, the strip can be skin pass rolled at room temperature to improve its properties.

3. Model Development

A flow diagram for the wear model is shown in Fig. 2. One of the important factors affecting roll wear is the roll force. To develop a wear model, it is therefore important to develop a roll force model, which calculates the rolling force at each finishing stand during rolling. Strip temperature, strip width, strip thickness, roll diameter and chemical composition are the factors to calculate the roll force. Except the roll force, mean roll surface temperature, irregular edge wear, contact arc length and work roll revolutions also influence the wear of work roll.

The work roll wear function is a high order polynomial function as the wear rate at the strip edges is more pronounced than at the strip centre. The roll wear term is a profile over the strip width zone of the work rolls calculated from the number of work roll revolutions made. The number of work roll revolutions $N_i$ is defined as:
Where, $V_{pl}$ is the stand work roll peripheral speed, $m/s$; $t$ is the time since last calculation, $s$; $R_{Wi}$ is the work roll radius, $m$. In calculating the wear profile, the work roll is segmented into thin discs across the work roll face length. The work roll wear is calculated for each disc. For $(2N_{w}+1)$ discs across the strip width, the dimensionless disc position $X_{j}$ is:

$$X_{j} = \frac{j}{N_{w}}, -N_{w} \leq j \leq N_{w}$$

The work roll incremental wear due to the last $N_{i}$ roll revolutions $\Delta y_{Wij}$ is defined as:

$$\Delta y_{Wij} = -(k_{wW1i} + k_{wW2i}P_{i}^{k_{wW1}})(1 + k_{wW4i}X_{j}^{k_{wW1}})(1 + k_{wW6i} \theta_{Ri})(1 + k_{wW7i}L)$$

Where, $P_{i}$ is the specific roll force, $KN/mm$; $\theta_{Ri}$ is the mean roll surface temperature, $^\circ C$; $L$ is the contact arc length, $mm$; $k_{wW1i}$ is the related parameters.

That is, the wear is a function of specific roll force, mean roll surface temperature and contact arc length. The total wear for each disc $j$ and stand $i$ is obtained by summing the individual roll wear increments.

$$y_{Wij} = \sum_{0}^{N_{i}} \Delta y_{Wij}$$

4. Experimental Procedures

Using the above mathematical model, in a programming language C++ offline simulation program, calculating the work roll wear of a rolling cycle, and the actual situation of the roll wear are measured with high precision grinding machine. The calculation scheme of work roll wear is shown in Fig.3.

Figure 3. Model calculation scheme
The measuring direction is along the roll driven side to operation side, and the roll is divided into 21 sections, using the actual production data of Qian-Gang 2250mm HSM in March 2016, after a rolling cycle the F4 work roll wear calculation results are shown in Fig.4. From Fig 4, we can see the deviation between calculated value and the actual value is not big, so the model can be used for online prediction of roll wear. The actual roll wear contour approximate box, including the middle constant wear and the edge irregular wear, the reason is the roll pressure distribution difference at various points. Both sides roll wear relatively central roll wear is bigger; this is because the strip edge temperature is lower and the existence of edge thinning. We also can see that the mean value of top roll wear is greater than the mean value of bottom roll wear in the same mill. The area and pressure between strip and top roll is bigger because of mill loop, so the top work roll wear is serious, and the oxidation iron retention on the strip surface also increases the top roll wear.

**Figure 4.** The calculated roll wear and measured roll wear of top work roll

### 5. Conclusion

A wear model was developed to predict the roll wear profile at different stands of a finishing mill. The wear behavior of finishing mill (stands F4) work rolls was analyzed experimentally. A box type wear pattern with sloping wall was observed. Comparatively higher irregularity was observed for stand F4. Agreement between the predicted and actual wear values for the top and bottom rolls for all four schedules was in general within 6.5%. The computational time required for the overall simulation was within reasonable limits. This model can therefore be used as an efficient online roll wear prediction method for the finishing mill stands of a hot strip mill.

### Acknowledgments

This work was financially supported by Beijing postdoctoral research fund 2015 ZZ-152.

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