Advanced Science and Technology Letters
Vol.41 (Mechanical Engineering 2013), pp.26-29
http://dx.doi.org/10.14257/astl.2013.41.07

HSS work roll wear prediction model for non-oriented electrical steel strip in hot rolling

Cao Jian-guo[1,1], Cao Jian-yong[1], Li Hong-bo[1], Dong Qiang[1],Wen Dun[2], Zhou Yun-song[2], Yan Tan-li[2], Lai Jin-quan[2]

[1] National Engineering Research Center of Flat Rolling Equipment, School of Mechanical Engineering, University of Science and Technology Beijing, Beijing 100083, China
[2] Wuhan Iron & Steel (Group) Corp., Wuhan 430083, Hubei, China

Abstract. Based on measured data of HSS (high-speed steel) and HCr (high-chromium iron) work rolls applied in 1580mm HSM (hot strip mills) with mass production of electrical steel strip, an HSS work roll wear prediction model in upstream stands for non-oriented electrical steel strip rolling was established by genetic algorithm. The accuracy of the model was verified and could guide practical production.

Keywords: hot rolling; wear; non-oriented electrical steel; mathematic model; genetic algorithm

1 Introduction

When manufacturing electrical steel strip, the work rolls have more severe and non-uniform work roll wear and higher quality demand than that of most of other hot rolling products. The research on roll wear mechanism achieved higher accuracy of roll wear prediction model. Nakanishi et al. [1] gave a partial wear formula to calculate the local wear near the strip edge. Shao et al. [2] established a work roll wear prediction model which took lubrication into account and estimated the key parameters using simulated annealing genetic algorithms. Cao et al. [3] established a work roll wear prediction model grounded on the rolling characteristics of non-oriented electrical steel.

In recent years, HSS work roll was widely applied in electrical steel strip production line due to its outstanding red-hardness, wear-resistance of high temperature and anti-roughness, making great performance in lowering roll consumption and improving strip profile quality. However, there was no HSS work roll wear prediction model in electrical steel rolling published yet. In this paper, an HSS work roll wear prediction model for non-oriented electrical steel rolling process is established based on data collection and analysis.

---

[1] Corresponding author. Tel.: +86 10 62334709; fax: +86 10 62329145.
E-mail address: geocao@ustb.edu.cn (J.-g. Cao).

Project supported by the Specialized Research Fund for the Doctoral Program of Higher Education of China (Grant No. 20120006110015).

ISSN: 2287-1233 ASTL

2 HSS and HCr work roll wear measurement and analysis

In order to study HSS and HCr work roll wear patterns, the production data and wear contours of HSS work roll and HCr work roll after rolling electrical steel strip were collected. Figure 1 shows the comparison of wear contours of HSS and HCr work rolls. Through the analysis of the data, it is found that work roll wear in stand F3 has the following characteristics:

1) Comparing with carbon steel rolling, electrical steel rolling results to greater roll wear up to 2 or 3 times and more severe non-uniform wear.

2) HSS work roll wear amount is about 30μm averagely after rolling a strip campaign while HCr work roll loses about 150μm which is 5 times as that of HSS work roll.

3) The HSS and HCr work rolls are similar in wear form which is mainly“U” groove-type overall wear contour with slight cat-ears local wear near both ends.

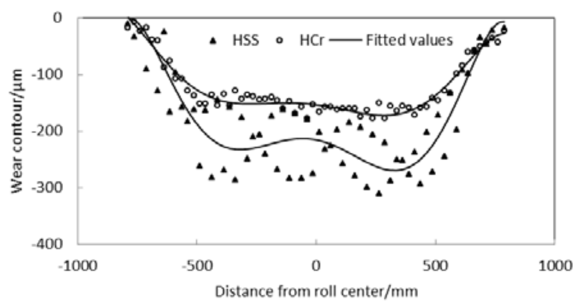

Fig. 1. Measured Wear contours of HSS and HCr work rolls of stand F3 after rolling electrical steel strips in HSM
HSS: HSS work roll wear contour after rolling 7 campaigns of strips
HCr: HCr work roll wear contour after rolling 1 campaign of strips

3 The HSS work roll wear prediction model in upstream stands

Based on the massive data analysis of work roll wear contours of stand F3 in 1580mm HSM, the wear contour of work roll is defined as shown in Figure 2 [4].

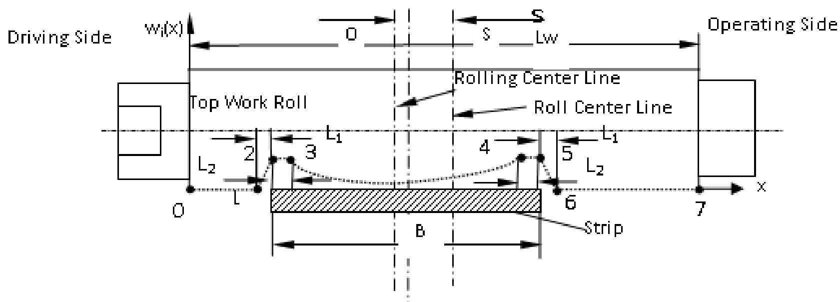

Fig. 2. The work roll wear contour after rolling a strip

Since the wear contour of HSS work roll is considered similar to the HCr work roll, according to the HCr work roll wear prediction model in paper [4], the HSS work roll wear prediction model is established by modifying the HCr model with coefficients w_0, w_1 and w_2.

Thus, the wear amount of the *j*-th slice after HSS work roll finishes rolling the *i*-th strip as followed.

$$Wx_{ij}=w_0 k_0 L_Z (F_R/BL_D)^{K_1} L_D (1+k_2 f(x))/D_W \ . \tag{1}$$

The axial non-uniform wear function *f(x)* for HSS work roll is as follows.

$$f(x)=\begin{cases} 0 & x\in(0,x_1) \\ w_1(x-a)(a_0+a_2+a_4) & x\in(x_1,x_2) \\ w_1(a_0+a_2+a_4) & x\in(x_2,x_3) \\ w_2\left(a_0+a_2\left(\frac{x-b}{0.5B}-1\right)^2+a_4\left(\frac{x-b}{0.5B}-1\right)^4\right) & x\in(x_3,x_4) \\ w_1(a_0+a_2+a_4) & x\in(x_4,x_5) \\ w_1(c-x)(a_0+a_2+a_4) & x\in(x_5,x_6) \\ 0 & x\in(x_6,x_7) \end{cases} . \tag{2}$$

Where coefficient w_0 is comprehensive modification coefficient. relevant to the density, hardness, strength, elastic modulus of HSS work roll and so on. Coefficients w_1 and w_2 are axial non-uniform wear modification coefficients, where w_1 modifies the edge part of work roll and w_2 modifies the middle part.

After rolling a campaign of strips the wear amount of the *j*-th slice is:

$$C_{wj}=\sum_{i=1}^{n_w} W_{x_{ij}} \ . \tag{3}$$

Where n_w is the number of rolling strips contained in a campaign.

4 Determination of model parameters and model validation

The prerequisite of the model accuracy is to look for a global optimization method which is adaptable and less demanding. The genetic algorithm, excelling at large-scale parallel processing and complex problems, can solve the parameter optimization problem of wear prediction model [5, 6].

The modification coefficient intervals are: w_0∈0.3, 1.2), w_1∈（0.1, 0.8）, w_2∈（0.1, 0.8）, while the optimization results are: w_0=0.401, w_1=0.139, w_2=0.559.

Figure 3 is the comparison of measured roll wear values and predicted values calculated by the model showing high precision in predicting work roll wear distribution and can be used to guide the rolling process.

The method to establish the HSS model also provides a foundation to study the application of HSS work roll in the downstream stands and to explore the potential integrated fusion effect of HSS work roll and other profile and flatness control technologies, such as the long-stroke work roll shifting system [1], and the hydraulic work roll heavy bending device, lubrication rolling [2], ASR (asymmetry self-compensating work rolls) [4], VCR (varying contact backup rolls) [7].

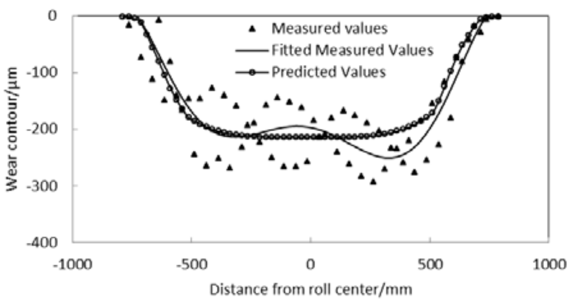

Fig. 3. Measured roll wear values and predicted values calculated by the HSS model for stand F3 in HSM

5 Conclusion

HSS work roll has excellent performance in rolling electrical steel, which causes severe and non-uniform work roll wear. Based on the collecting production data of non-oriented electrical steel rolling, the HSS work roll wear prediction models is established for upstream stands in 1580mm HSM by genetic algorithm. The model shows high precision and can be applied to guide production.

References

1. Nakanishi T, Sugiyama T, Iida Y, et al. Application of Work Roll Shift Mill HCW-MILL to Hot Strip and Plate Rolling [J] . Hitachi review, 1985, 34(4): 153-160.
2. Shao J, He A R, Yang Q, et al. Work Roll Wear Prediction Model Taking in Account Lubrication in Hot Rolling [J]. China Mechanical Engineering, 2009, 20 (3) ：361~364.
3. Cao J G, Zhang J, Gan J B, et al. Work Roll Wear Prediction Model of Non-oriented Electrical Steel Sheets in Hot Strip Mills [J] . Journal of University of Science and Technology Beijing, 2006, 28(3)：286~289.
4. Cao J G, Liu S J, Zhang J, et al. ASR Work Roll Shifting Strategy for Schedule-free Rolling in Hot Wide Strip Mills[J]. Journal of Materials Processing Technology, 2011, 211(11): 1768~1775.
5. Poursina M, Dehkordi N T, Fattahi A, et al. Application of Genetic Algorithms to Optimization of Rolling Schedules Based on Damage mechanics [J]. Simulation Modelling Practice and Theory, 2012, 22：61~73.
6. He A R, Zhang Q D, Xu J W, et al. Genetic Algorithms of Work Roll Wear Model for Hot Rolling [J]. Iron and Steel, 2000, 35(2) ：56~59.
7. Cao J G, Zhang J, Kong N, et al. (2010). Finite Element Analysis of Strip and Rolling Mills, Finite Element Analysis, David Moratal (Ed.), ISBN: 978-953-307-123-7, InTech :561-587

