Abstract

Efficiency of back up rolls depends mostly on two parameters – length of campaign and dressing amount after the campaign. The longer the campaign (in terms of rolled tones) is, the higher the dressing amount. To solve this task properly it is necessary to know the distribution of accumulated damage in the working layer of the roll caused by previous campaigns and by loads (separating force and bending) during present campaign respecting changing conditions of material properties (hardness) through radius of the roll. To find an optimum dressing amount an algorithm has been developed and specialized computer program will be presented, that takes real measured loads during the backup roll campaign, calculates fatigue damage in the roll and suggests relevant dressing amount. This can help to prolong service life of rolls, minimize the risk of spalls and reach maximum efficiency in terms of rolled tones/km per roll.

Keywords: Backup roll; Service life; Dressing amount; Fatigue of rolls.
1 INTRODUCTION

Efficiency of utilization of back up rolls depends mostly on the campaign length and subsequent dressing amount. The longer the campaign, the higher should be the dressing amount. But the campaign could not be prolonged too much, because this can cause spalls on the surface of the roll. Very short campaign on the other hand is expensive, because part of the costs of the roll change is constant, independent of the campaign length. Each campaign may be different in terms of loads and generates different degradation of the surface layer of the roll. It makes the situation more complicated. But it is obvious that an optimum must exist for each roll, ensuring lowest cost of the roll per ton/km with acceptably low danger of spalling or other damages.

2 CONCEPT

Before solving the optimization task mentioned above (minimum cost) it is necessary to be able to simulate the degradation process of the roll surface layer in dependence of varying parameters during the campaign. Knowing the degradation (called accumulated damage) it is possible to calculate suitable dressing amount to avoid spalls or other damages in the following campaign.

Into the Control System of the mill new models have been implemented (Figure 1):

- Roll stack deflection model **Erro! Fonte de referência não encontrada.** which calculates distribution of hertz contact pressure between work roll and backup roll generated by each strip during backup roll campaign.
- Roll wear model (present Level 2 model) delivers topical wear profile of both rolls after each strip.
- Model of thermal camber (present Level 2 model) delivers thermal shape of both rolls.
- Cyclic stress model (new model) composes all stresses (contact, bending and resident stresses) and transfers them into cyclic loading.
- Fatigue module **Erro! Fonte de referência não encontrada.** (new model) calculates for each strip a differential of accumulated damage in surface layer of backup rolls.

![Figure 1. Scheme of models – Modifications of Mill Control System and Roll Supervisor.](image)
The accumulated damage in the backup rolls is checked after each strip and if it exceeds a pre-set value, the operator (technologist) is informed. Accumulated damage is stored in a database when the backup rolls are changed and sent to Roll Supervisor a module working separately in roll shop on PC. The Roll Supervisor besides a wide range of visualisations offers calculation of dressing amount according to several criteria.

3 BACKGROUND THEORY

3.1 Contact (Hertzian) Stress

The contact pressure distribution is calculated for the contact line between backup roll and work roll using simplified spring beam model RollFlex [3]. The rolls are modelled by beams connected by nonlinear springs (Figure 2).

![Figure 2. Simplified spring beam model for calculation of Hertz contact load.](image)

According to Hertz theory maximum HMH stress can be found under the surface. The depth of stress peak depends on diameter of the rolls, specific contact force and mechanical properties of roll materials. In common backup rolls for hot strip mills it varies from 3 to 9 mm. In this depth the first microcracks originate and they can growth up to the surface and form spalls [4].

3.2 Calculation of Accumulated Damage

The calculation of damaged layer is done according the following scheme (Figure 4):

![Figure 3. Hertzian stress in rolls.](image)

From all stress components HMH maximum and minimum stress for each revolution of the roll is calculated. Resultant cyclic loading is transformed to symmetrical one and fatigue strength curve is constructed using Smiths diagram and material parameters of the roll. Miner’s rule enables to evaluate various loadings and calculate accumulated fatigue damage:

\[
AD = \sum_{i=1}^{k} \frac{n_i}{N_i} \tag{1}
\]

AD ... accumulated fatigue damage,
N_i ... maximum number of loading cycles for stress Level 1 (N_i = crack),
n_i ... number of loading cycles for stress Level 1,
i ... index of the stress level,
k ... number of stress levels,
stress 1,2 ... value of equivalent cyclic stress.

The calculated accumulated damage in surface layer after rolling of several strips can be seen in Figure 6. Maximum values can be observed in the beginning of taper on backup roll.

### 3.2 Estimation of Grinding Amount [5]

As described before, the grinding amount and the length of backup roll campaign are in relation. In most mills the period of the backup roll change (backup roll campaign) is constant. If the loads are lower for various reasons (lower mill performance, different product mix, unexpected shutdown etc.) the grinding amount can be smaller. In opposite case of excessive performance of the mill the grinding amount should be higher or even the length of campaign should be shortened.

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There are several methods, how the dressing amount can be calculated:

- Based on calculation of accumulated damage (fatigue approach):
  Under the assumption that the next campaign generates the same loads resulting in the same differential of accumulated damage as the previous one, we just search for the dressing that will create the same maximum value of accumulated damage as in previous campaign.

- Based on previous grindings (empirical):
  This method is based on regression analysis. We know the history of dressings and know the corresponding length of campaigns (tons/km). Supposing dressing amount grows with quadrat of the length of the campaign, it is simple to find coefficient for this relation by e.g. least square method.

Figure 7. Accumulated damage considering removal of dressing amount

4 BACKUP ROLL SUPERVISOR

Backup Roll Supervisor is a database oriented programme, working on PC in roll shop. It keeps all information about particular backup rolls:

- Roll producer,
- Chemical composition,
- Mechanical properties of rolls,
- Data about campaigns (number of campaigns, rolled tons/km, dressing after campaign, etc.),
- Measured hardness before/after dressing,
- Measured data/damages (Lismar),
- Calculated accumulated damage in rolls,
- Price and other costs of the rolls.

Data is organised in two levels, level of all rolls and level particular roll (Figure 8). Many of the data can be displayed in graphs e.g. tons/c per campaign (Figure 9).
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Figure 8. Data of particular roll

Figure 9. An example of graph – tons per campaign

Very interesting is a distribution of accumulated damage in the roll barrel (Figure 10). Roll surface is 0 and the damage is calculated up to 50 mm under the surface. There is no concentration near the edges of the roll that means the taper on the rolls are designed properly.

Dressing amount versus length of campaign can be displayed for previous campaigns. Using regression, statistical dressing amount can be calculated for each roll, group of rolls or roll producer (Figure 11).

If the price of the roll and other costs related to roll exchange and roll grinding are known, it is possible to calculate price related to the length of campaign (Figure 12).

All those parameters help the technologist to understand influence of various parameters on service life of rolls, how to avoid spalling and how to use the rolls more effectively.

5 CONCLUSION

The described system is used for optimization of backup roll performance in twin Steckel reversing Hot Strip Mill 1700. The dressing amount is calculated after each campaign and later, during grinding the computed dressing amount is compared with nondescriptive testing by Lismar. There have been optimized tapers of backup roll barrel in the past [6]. New forms of tapers and positive grinding of backup rolls have been introduced. All those measures have brought better backup roll performance and longer service life.

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REFERENCES


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