ISSN 1983-4764

COMPUTER AIDED UTILIZATION OF BACKUP ROLLS*

Daniel Hajduk[1]
Pavel Šimeček[1]
Jan Vahalík[2]

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] *ITA Ltd., Ostrava, Czech Republic.*
[2] *ArcelorMittal Ostrava, Ostrava, Czech Republic.*

* *Technical contribution to the 51st Rolling Seminar – Processes, Rolled and Coated Products, October 28th to 31st, 2014, Foz do Iguaçu, PR, Brazil.*

ISSN 1983-4764

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.

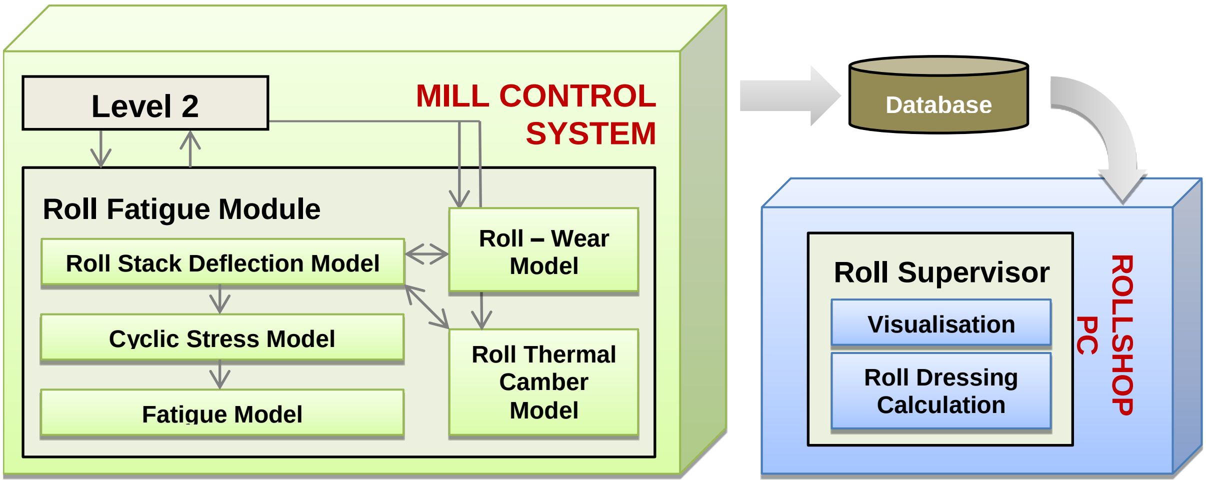

Figure 1. Scheme of models – Modifications of Mill Control System and Roll Supervisor.

* *Technical contribution to the 51st Rolling Seminar – Processes, Rolled and Coated Products, October 28th to 31st, 2014, Foz do Iguaçu, PR, Brazil.*

ISSN 1983-4764

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).

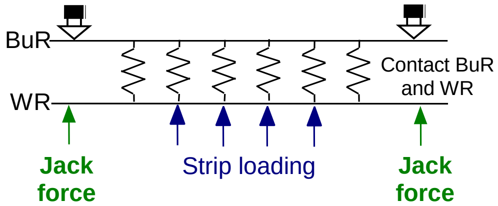

Figure 2. Simplified spring beam model for calculation of Hertz contact load.

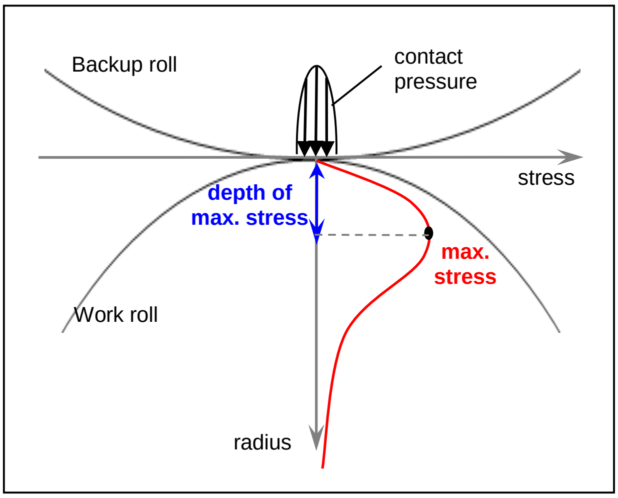

Figure 3. Hertzian stress in rolls.

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):

* *Technical contribution to the 51st Rolling Seminar – Processes, Rolled and Coated Products, October 28th to 31st, 2014, Foz do Iguaçu, PR, Brazil.*

ISSN 1983-4764

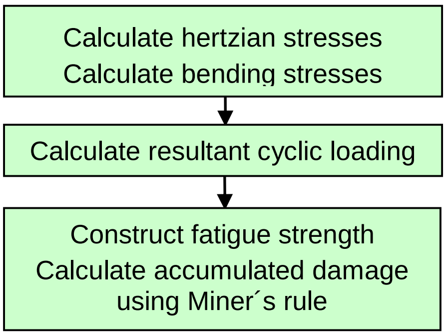

Figure 4. Calculation algorithm of damaged layer

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.

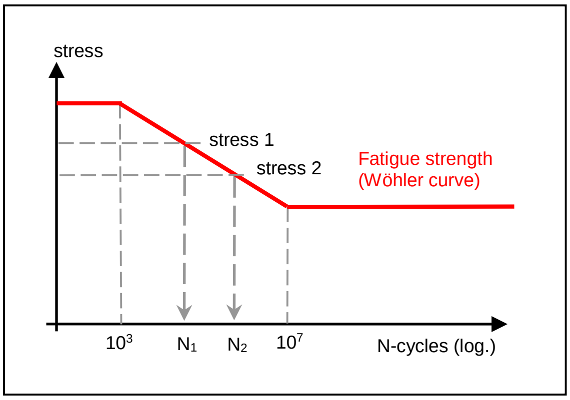

Figure 5. Calculation by Miner´s rule

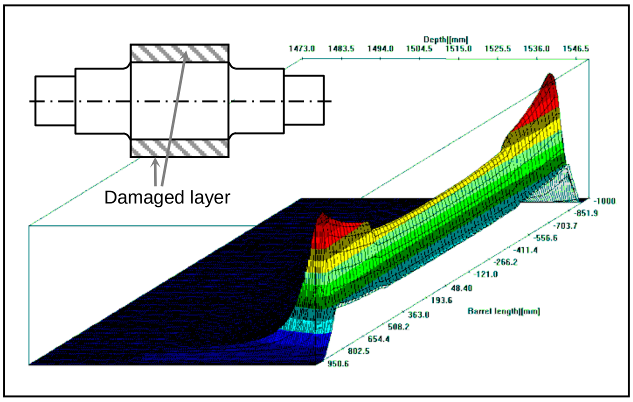

Figure 6. An example of accumulated damage

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.

* *Technical contribution to the 51st Rolling Seminar – Processes, Rolled and Coated Products, October 28th to 31st, 2014, Foz do Iguaçu, PR, Brazil.*

ISSN 1983-4764

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.

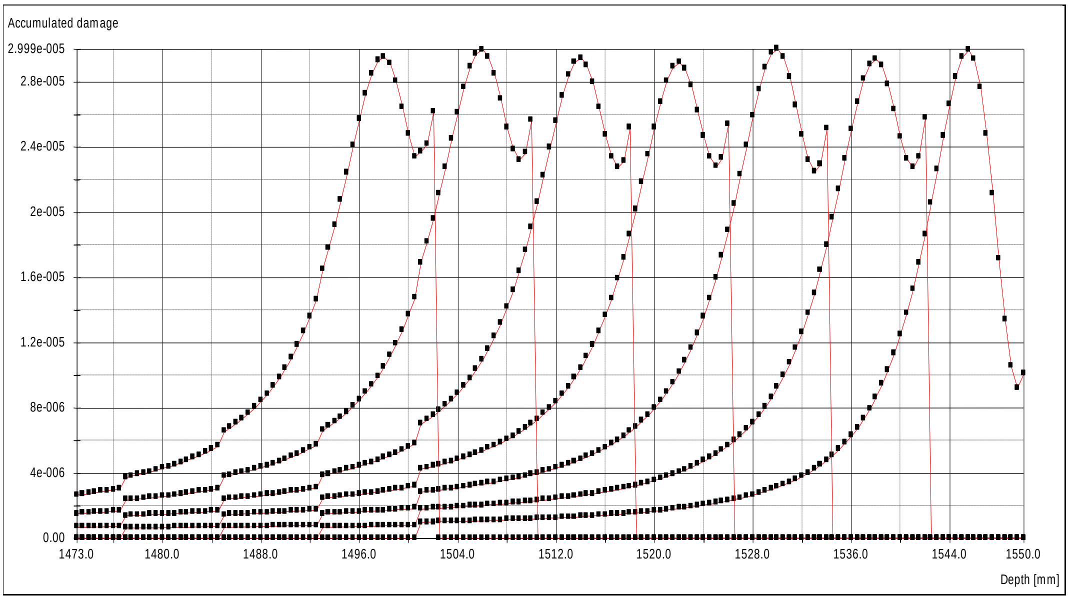

Figure 7. Accumulated damage considering removal of dressing amount

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).

* *Technical contribution to the 51st Rolling Seminar – Processes, Rolled and Coated Products, October 28th to 31st, 2014, Foz do Iguaçu, PR, Brazil.*

ISSN 1983-4764

Campaign	Stand	Campaign Start	Tons/c	Tons	Kms/c	Kms	Barrel Diameter [mm]	Dressing [mm]	Rolled thickness 1.5-2.0 [mm]	Rolled thickness 2.1-5.0 [mm]	Rolled thickness 5.1-13.0 [mm]	Contact	Contact	Middle Force	Middle Pressure	Calculated Dressing	Calculated AD Shift	Dressing Recommende [Km]	Dressing Recommende [Tons]	AD
Sums			13259.0		5565.7(			86.08								0.00		73.84	68.02	
1	2H	2009-01-0...	36213	36213.1	2070	2072.6	1740.11	3.130000	8.7	64.4	22.5	494757.06	0.00	0.00	0.00	0.00	0.00	3.59	4.03	N/A
2	2H	2009-04-0...	19191	55404.1	1120	3193.0	1736.98	0.440000	4.6	65.8	29.3	283071.00	0.00	0.00	0.00	0.00	0.00	1.05	1.13	N/A
3	2H	2009-04-2...	1378	56783.0	43	3236.7	1736.54	2.060000	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	N/A
4	1H	2009-06-3...	21137	77920.8	1291	4528.1	1734.48	2.080000	9.7	62.1	27.5	311233.00	0.00	0.00	0.00	0.00	0.00	1.40	1.37	N/A
5	1S	2009-08-1...	22404	10032...	1188	5716.2	1732.40	3.400000	7.4	63.9	27.9	472177.00	0.00	0.00	0.00	0.00	0.00	1.18	1.54	N/A
6	1S	2009-10-0...	46760	14708...	2435	8152.1	1729.00	4.120000	6.4	51.6	41.9	667772.03	0.00	0.00	0.00	0.00	0.00	4.97	6.73	N/A
7	1S	2009-11-3...	9087	15617...	422	8574.6	1724.88	4.090000	10.0	62.3	24.8	544188.03	0.00	0.00	0.00	0.00	0.00	0.15	0.25	A
8	1H	2010-01-2...	32331	18850...	2002	10577.4	1720.79	2.630000	11.0	62.6	25.6	492756.01	0.00	0.00	0.00	0.00	0.00	3.36	3.22	N/A
9	1H	2010-03-2...	32498	22100...	2111	12688.6	1718.16	1.960000	15.6	60.9	22.8	477161.06	0.00	0.00	0.00	0.00	0.00	3.73	3.25	A
10	1S	2010-05-2...	23202	24420...	1378	14066.6	1716.20	2.490000	8.3	58.2	32.1	344386.00	0.00	0.00	0.00	0.00	0.00	1.59	1.66	N/A
11	1H	2010-08-1...	13441	25764...	2095	16161.6	1713.71	1.840000	9.8	54.9	28.2	538885.01	0.00	0.00	0.00	0.00	0.00	3.67	0.56	N/A
12	1S	2010-10-2...	33934	29158...	2184	18345.8	1711.87	3.350000	16.5	61.7	21.5	517315.05	0.00	0.00	0.00	0.00	0.00	3.99	3.54	N/A
13	1S	2011-01-0...	42744	33432...	2363	20709.2	1708.52	2.080000	9.0	59.3	30.1	616606.01	0.00	0.00	0.00	0.00	0.00	4.68	5.62	N/A
14	1S	2011-03-1...	37382	37170...	2341	23050.7	1706.44	5.430000	12.0	64.7	21.5	552897.05	0.00	0.00	0.00	0.00	0.00	4.59	4.30	N/A
15	2H	2011-06-0...	42048	41375...	2811	25862.4	1701.01	11.630000	20.5	52.3	24.0	639970.08	0.00	0.00	0.00	0.00	0.00	6.62	5.44	N/A
16	2H	2011-08-0...	33598	44735...	2090	27953.2	1689.38	2.440000	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	3.66	3.47	N/A
17	2H	2011-11-1...	32015	47936...	1943	29897.1	1686.94	2.380000	10.6	65.8	21.3	460161.07	0.00	0.00	0.00	0.00	0.00	3.16	3.15	N/A
18	2H	2012-01-2...	33512	51288...	2474	32371.9	1684.56	4.560000	9.4	54.9	30.7	625695.12	0.00	0.00	0.00	0.00	0.00	5.13	3.45	N/A

Figure 8. Data of particular roll

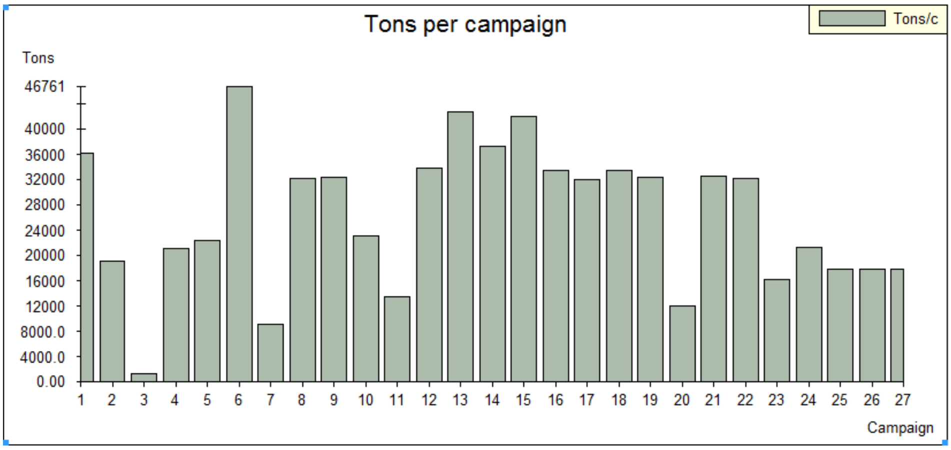

Figure 9. An example of graph – tons per campaign

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.

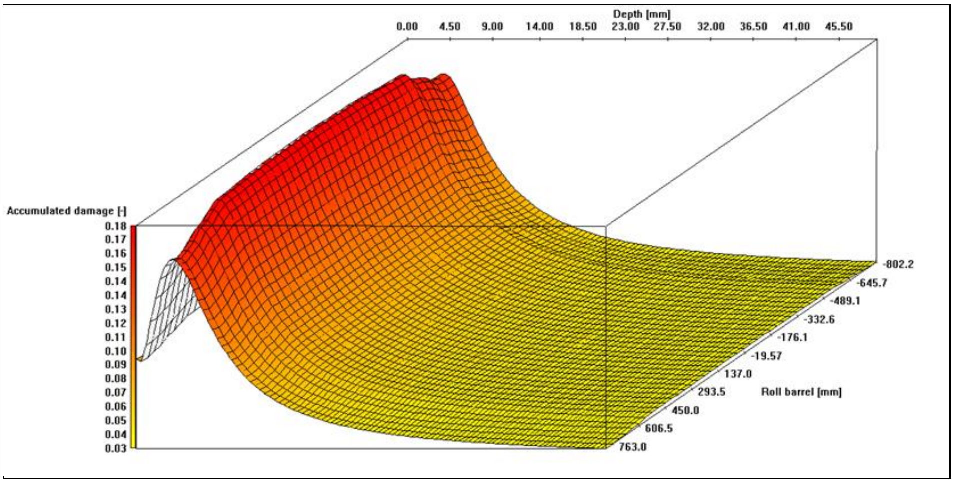

Figure 10. Relative accumulated damage in the roll

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).

* *Technical contribution to the 51st Rolling Seminar – Processes, Rolled and Coated Products, October 28th to 31st, 2014, Foz do Iguaçu, PR, Brazil.*

ISSN 1983-4764

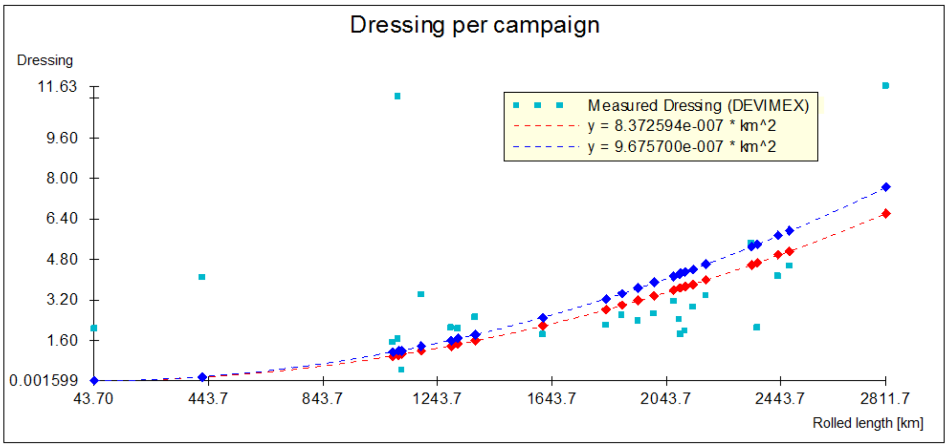

Figure 11. Dressing amount versus length of campaign

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).

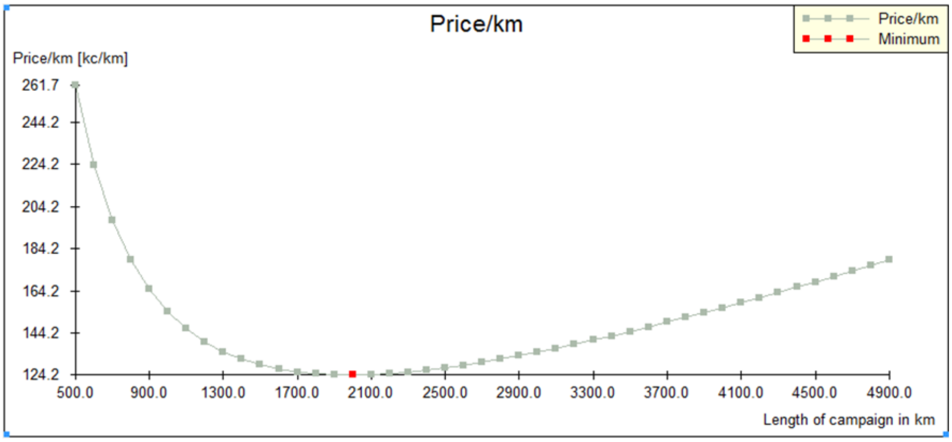

Figure 12. Roll cost in CZK per km versus the length of campaign

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 nondescructive 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.

Acknowledgments

This paper was supported from budget chapter of Ministry of Industry and Trade, Czech Republic within the program TIP – the project FR-TI 3/053.

---

* *Technical contribution to the 51st Rolling Seminar – Processes, Rolled and Coated Products, October 28th to 31st, 2014, Foz do Iguaçu, PR, Brazil.*

ISSN 1983-4764

REFERENCES

1 Decultieux F, Hoffman M, Adams T. Backup Roll Chamfer Design, Profile and Maintenance. Material Science & Technology; 2004.

2 Hajduk D, Cornelio GT, Bernardes FG. Computer modelling for better BuR performance. Proceedings of conference. 46 Rolling seminar. ABM. Santos, Brazil; 27-30 October 2009.

3 ITA Ltd.: *Software RollFlex*. Online [http://www.ita-tech.cz/en/products-services/rolling/profile-and-flatness/rollflex-software].

4 Ohkomori Y, Kitagawa I, Shinozuka K, Miyamoto R, Yazaki S, Inoue M. Cause and Prevention of Spalling of Backup Rolls for Hot Strip Mill.

5 ITA Ltd.: Projekt FR-TI3/053: Zlepšení magnetických a užitných vlastností pásů z orientovaných tranformátorových ocelí. Technická zpráva spolupříjemce za rok 2013. (in Czech). Ostrava: ITA Ltd. December 2013. 17 p.

6 Ferfecki P, Fojtík F, Halama R, Hajduk D. Numerické zkoumání vlivu tvaru okrajové části opěrného válce na napjatost a porušování. (in Czech). Hutnické listy. 2010, Nr. 2, LXIII. pp. 72 77. ISSN 0018-8069.