COMPUTER MODELLING FOR BETTER BUR PERFORMANCE[1]

Daniel Hajduk [2]
Gilson Teixeira Cornelio [3]
Felipe Gustavo Bernardes [3]

Abstract

The objective of the paper is to show the ways how to increase the backup rolls (BUR) performance by means of computer simulation of chamfer form, grinding of the BuRs and estimation of other relevant stresses causing contact fatigue spalling. A simplified spring-beam model was developed as a basic tool to obtain a contact load distribution between rolls. From the load distribution Hertzian stresses and other stress components are calculated for the roll campaign. Equivalent stress is evaluated and fatigue analysis performed. The edge relief (chamfer) is designed using 3-D finite element analysis. Knowing all important stresses it is possible to predict the danger of spalling on the backup barrel length and to predict the proper length of BuR campaign, considering all relevant loads on line.

Key words: Backup rolls; Spalling; Chamfer of BuRs; Roll grinding.

MODELAMENTO COMPUTACIONAL PARA MELHOR RENDIMENTO DE CILINDROS DE APOIO

Resumo

O objetivo do artigo é mostrar alguns meios de se incrementar o desempenho de cilindros de apoio (BuR – Back-up Roll) por meio da simulação computacional da forma do caimento e retificação dos cilindros e da avaliação de outros esforços relevantes que possam causar o lascamento por fatiga do contato. Um modelo simplificado de feixe de molas foi desenvolvido como uma ferramenta básica para obter uma distribuição de carga do contato entre rolos. Dos esforços da distribuição de carga, com base nos estudos de Hertz, e outros componentes de carga são calculados para a campanha do cilindro. Os esforços equivalentes são avaliados e a análise da fatiga executada. O caimento da borda é projetado usando a análise de elementos finitos com um modelamento em 3-D. Sabendo os esforços principais, é possível prever o risco de lascamento ao longo da mesa e prever a vida do cilindro em uso, de forma otimizada.

Palavras-chave: Cilindros de apoio; Lascamento; Caimento de borda; Retificação.

[1] *Contribuição técnica ao 46° Seminário de Laminação – Processos e Produtos Laminados e Revestidos, 27 a 30 de outubro de 2009, Santos, SP.*
[2] *ITA Ltd., Martinská 6, 709 00 Ostrava, Czech Republic, mail@ita-tech.cz*
[3] *Aços Villares S.A., Pindamonhangaba, São Paulo, Brasil*

1 INTRODUCTION

Backup rolls are very loaded machine parts. Most frequent damages are spalling of the surface and cracking especially in edge region of the barrel and transverse cracks of the neck. Spalling (Figure 1) is caused mainly by contact stress between WR and BuR but other loading may play important rolls as well. Cracking of the roll surface in edge region is caused by the same mechanisms. Transverse cracks of the neck are comparatively rare and there will be not discussed in this paper.
Most important loading phenomena in BuRs are as follows:

- Hertzian contact load between BuR and WR,
- Residual stress in roll (thermal treatment),
- Bending stress.

Computer modelling can detect the stress level of the most important loads, can help to redistribute the loads and help to estimate the length of roll campaign.

Figure 1: Extensive Spalling of BuRs.

2 CONTACT (HERTZIAN) STRESS

According to Hertz theory maximum HMH stress can be found under the surface. The depth of stress maximum depends on diameters of rolls, specific contact force and mechanical properties of roll materials. In common BuR for HSMs 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.

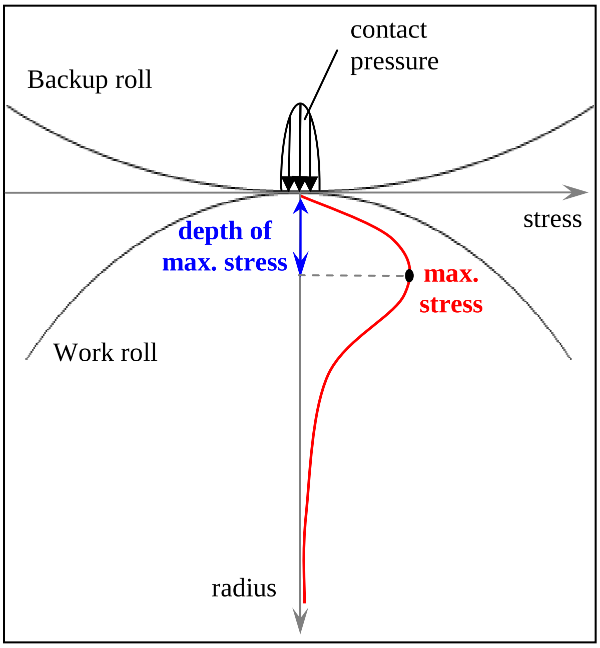

Figure 2: HMH stress in rolls.

There are several possibilities how to reduce the highest stresses leading to cracks:

- redistribute the specific force in the roll length:
  - use sound chamfer
  - use positive grinding of BuRs,
- reduce the specific force:
  - by less positive bending,
  - by correct drafting.

2.1 Models for Computer Simulation

To determinate contact specific load either full 3D model based on FEM or simplified (special) models can be used. Full 3D FEM solution is general, can be used for investigation of various phenomena but is rather complicated, it needs trained stuff and is very time consuming.

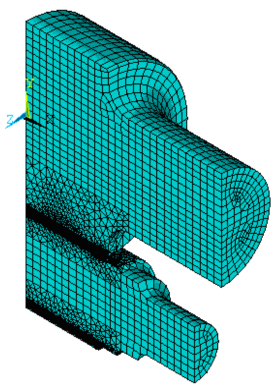

Figure 3: 3D FEM model of 2h roll stack (due to symmetry only ¼ geometry).

Simplified models are always restricted as to the precision but they can be very fast and user friendly. The models are mainly so called spring-beam models, where both rolls are considered as beams and contact deformation between WR – BuR and WR – strip is modelled by nonlinear springs connecting the beams.

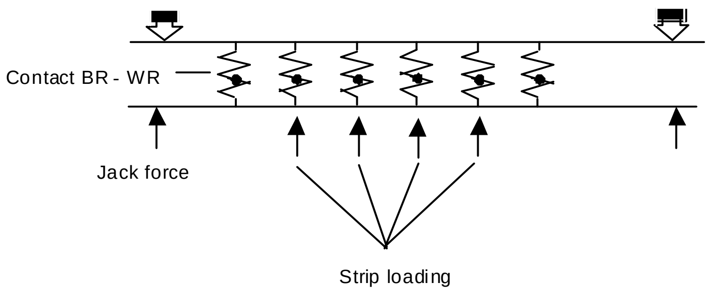

Figure 4: Simplified spring – beam model.

Stiffness of nonlinear springs can be determined from classical Hertz theory or from theory of elastic halfspace. The second one is more complex, considering the interactions between neighbouring springs. Despite of the necessarily of iterative algorithms due to the contact nonlinearities, the solution can be very fast (500 – 1000 ms on common PC).

2.2 Chamfer of BuR

Sound chamfer can reduce the peaks of specific force at the end of barrel significantly.(1,2) For big BuRs three basic forms of chamfer were investigated (Figure 5).

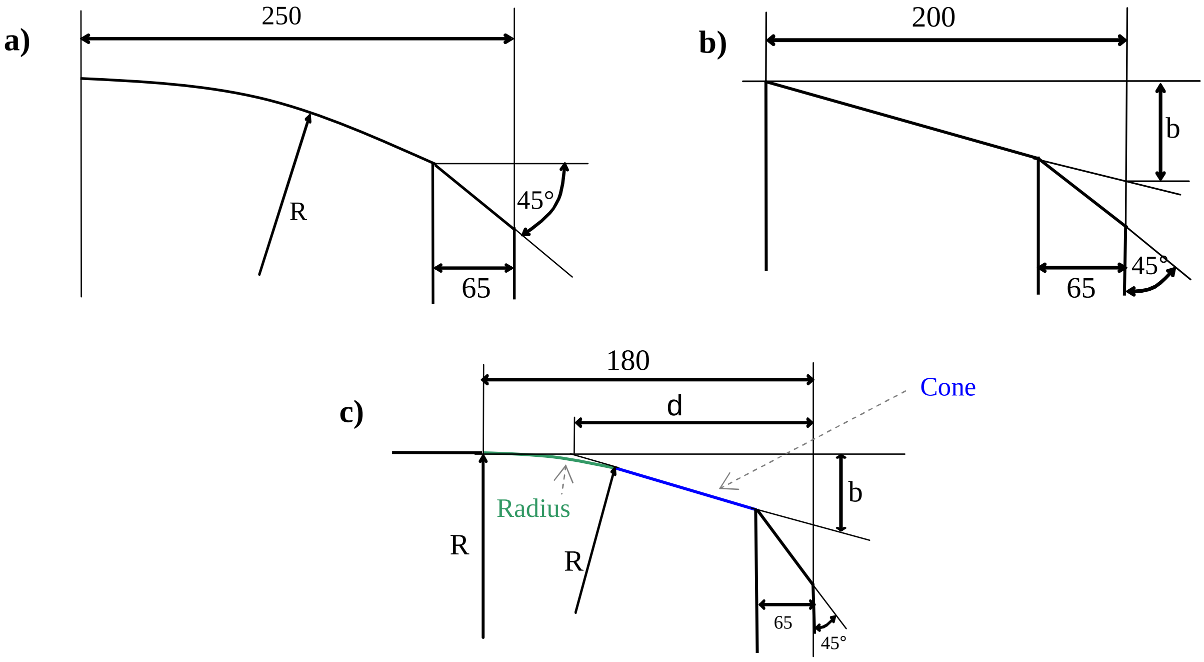

Figure 5: Investigated form of chamfers.

The length and depth of chamfer depends on dimensions of BuR. Very deep chamfers cause sharp concentration of specific force. Very long chamfer can shorten the contact line between WR and BuR which can cause instability of rolling of narrow strips. As to the form the best one chamfer found is combination of radius and conical part (form c)). Figure 6 demonstrates the influence of three chamfers on specific force distribution.

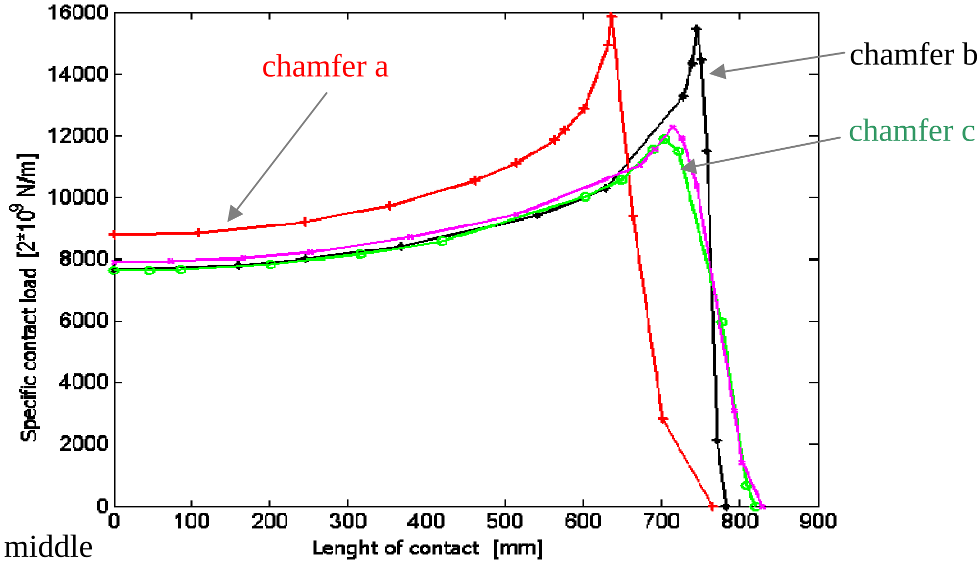

Figure 6: Specific force between WR and BuR (one half of length).

2.3 Grinding of Rolls

Another effective tool for redistribution of specific force offers grinding of rolls, especially positive grinding of BuRs.[1,3] Suitable grinding can disburden outer parts of the barrel. Fig. 7 shows the distribution of specific force for cylindrical BuR (ø 1730 mm, barrel length 1780 mm) and for the BuR with positive grinding +100 µm. In wider strips it equalizes the specific force, in narrower strip the maximum specific force is transferred into the central part of the barrel.

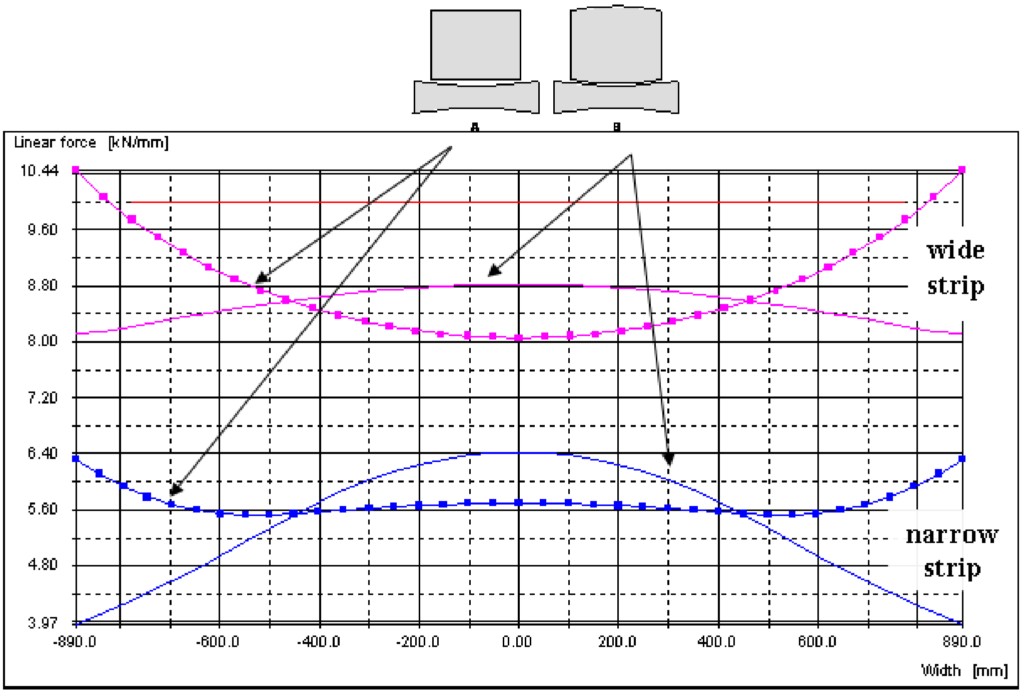

Figure 7: Distribution of specific force between WR and BuR.

2.4 Influence of bending

Positive bending can increase the contact pressure at the ends of BuR barrel considerably. Influence of bending forces on HSM finishing stand 2000 mm can be seen in Figure 8. Regarding BuR spalling it is better to use positive bending only at the beginning of the WR campaign (low thermal chamber on WRs) to get the target crown. Most strips can be rolled using negative or very low positive bending. This can prolong the length of campaign and reduce the danger of spalls.

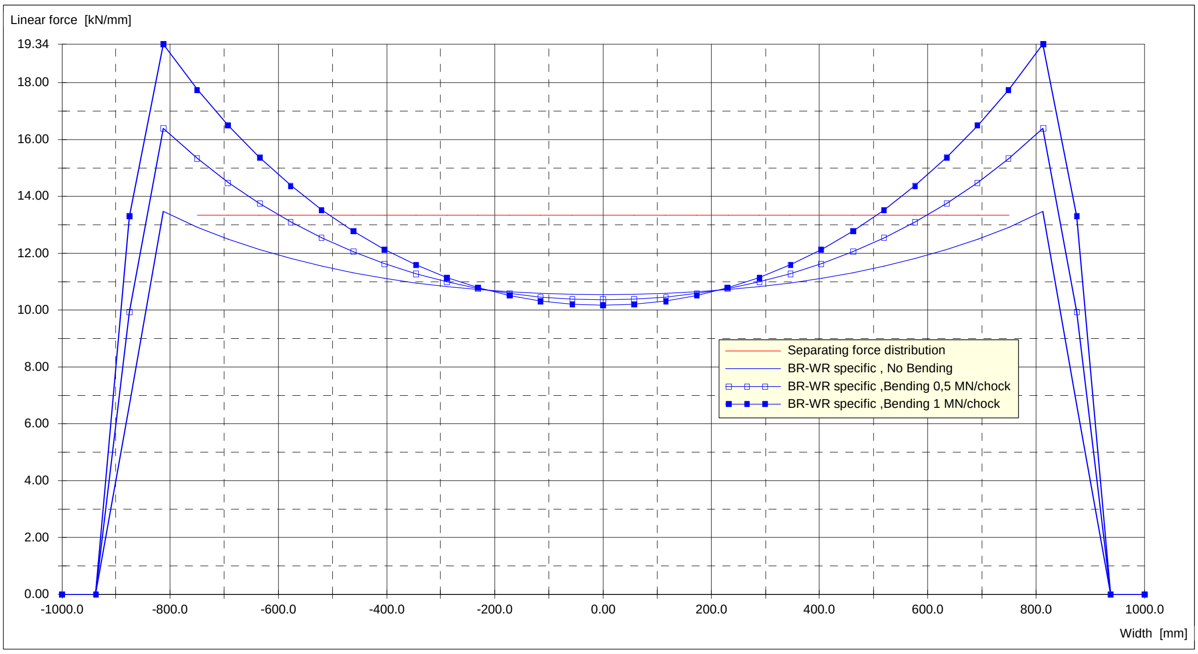

Figure 8: Influence of positive bending force.

3 ESTIMATION OF THE CAMPAIGN LENGTH

Max. length of BuR campaign or number of loading cycles must not exceed the critical number of loading cycles that lead to crack initiation.
The length of BuR campaign is closely related to the depth of grinded layer. Every loading cycle (revolution of BuR) with stresses, that cause plastic deformation damages the roll material. The roll can stand only limited numbers of loading cycles before first microcracks are initiated. If the material is damaged or even contains first microcracks, it should be removed. In other words, the longer campaign with loading under treshold, the thicker surface layer should be removed. Estimation of the treshold load is rather complicated. It depends not only on separating force and bending applied but on the permanent residual stresses due to thermal treatment and other manufacturing reasons and mechanical properties of the layer.
Both mechanical properties (hardness) and residual stresses changes with the roll radius and that makes the prediction even more complicated.

3.1 Estimation of Residual Stresses

Under certain simplistic assumptions it is possible to calculate residual stresses due to thermal treatment of rolls. Those stresses can be measured in thin layer under the surface by drilling method as well. Residual stresses measured on sleeved BuRs are demonstrated in Figure 9.

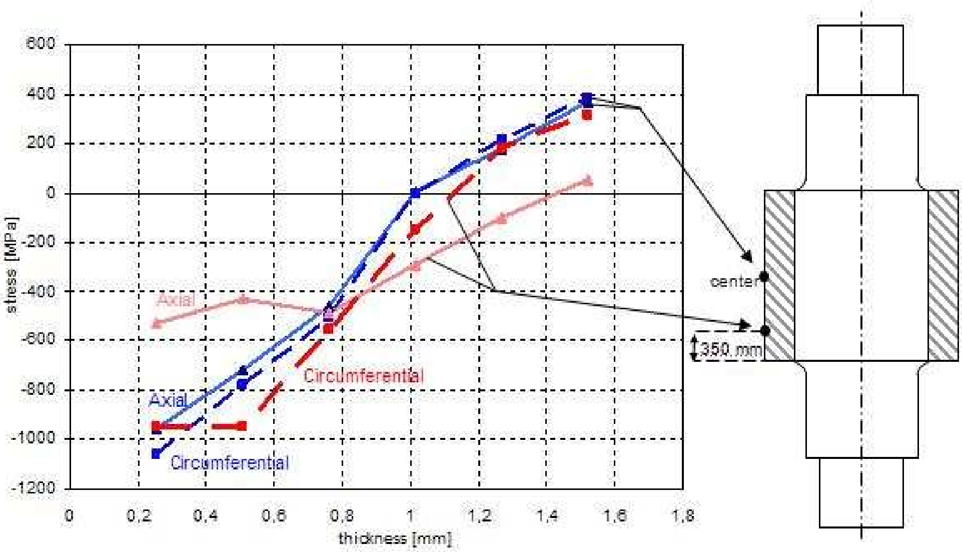

Figure 9: Measured residual stresses (in 2 points) under the surface of the sleeved BuR.

The level of circumferential and axial stresses is comparatively high. A computer simulation considered only stresses generated due to temperature fields in the sleeve during thermal treatment. No volumetric changes caused by austenite decomposition were considered. The analysis showed regions under the roll surface with high negative stresses. The level of computed circumferential and axial stresses is slightly lower (25%) than measured ones. This might be caused by lower yield stress (1100Mpa) in computer simulation than in reality (1300MPa).

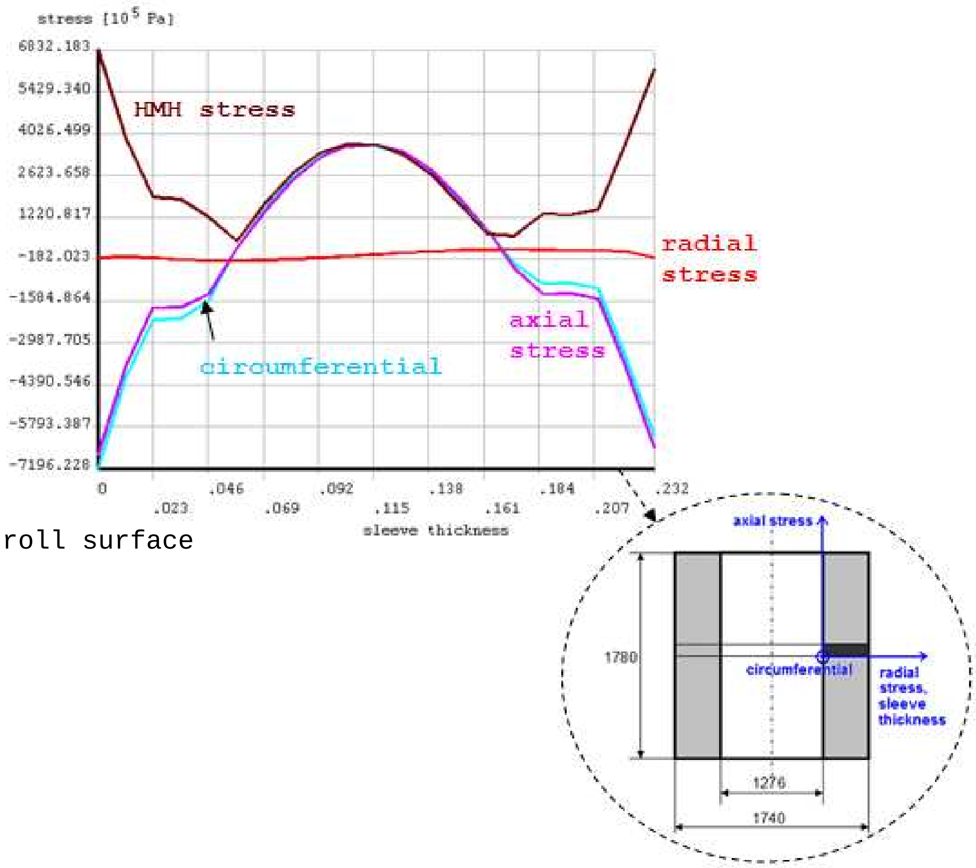

Figure 10: Computed distribution of residual stresses in the sleeved roll.

3.2 Monitoring of BuR Loading

First attempt to on-line prediction of BuR campaign length has been made. The software gets rolling speed, separating force, bending force and other parameters on-line. The roll barrel length is divided into 40 points. For each point specific force between rolls is calculated. Maximum and minimum HMH stress for every point and every roll revolution is calculated. Loading cycle is compared with the limit of Smith's diagram. If the load exceeds the critical values, the number of planned revolutions is reduced it means the length of campaign is shortened.

4 CONCLUSION

The paper explained main reasons of BuR spalling/cracking and presents some possibilities how to reduce the danger of spalling. Computer modelling helps to learn the importance of relevant phenomena. FEM and simplified model enable optimization of BuRs chamfers, BuR and WR grinding and other parameters. A new monitoring on-line system for BuR has been briefly described. This system is being developed together with Villares RMS and will be available in near future.

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