
# STRENGTH PROBLEMS OF THE TRAVELLING MECHANISMS OF THE OPEN PIT MACHINES

**Srđan Bošnjak[1], Zoran Petković[2], Nebojša Gnjatović[3], Vaso Mihajlović[4] Goran Milojević[5]**

***Summary:*** *The extremely heavy duty conditions of the Surface Mining Machines (SMM) provide fertile ground for the occurrence of the various types of failures in their travelling mechanisms and belonging substructures. Although failures of the SMM travelling mechanisms occur infrequently, they may lead to very serious or even disastrous consequences. Even in cases when consequences are not catastrophic they cause direct costs, as well as indirect costs due to the downtime that substantially diminishes the effects of SMM exploitation. Furthermore, replacement of damaged parts is executed on site, often in hard working conditions that essentially prolong the downtime of the complete surface mining system. This paper discusses the causes of the failures in the vital parts of the crawler travel gear of the bucket wheel excavators and spreaders: chain links, track wheels, two-wheel bogies and undercarriage. Based on the results of the analytical–numerical–experimental analyses, it was concluded that: (a) chain links' failures are caused by 'manufacturing-in' defects; (b) track wheels' failures are caused by 'design-in' and ' manufacturing-in' defects; (c) failures of the two-wheel bogies and undercarriage are caused by 'design-in' defects. Besides that, the redesigned structures of the two-wheel bogies and undercarriage are presented. The validity of the presented reconstruction designs are unquestionably confirmed by their failure less exploitation after the reconstruction. Finally, the obtained results are important because the same problems could arise in the crawler travelling mechanisms of wide class of earthmoving and material handling machines.*
***Keywords****: surface mining machines, crawler travelling mechanisms, damage diagnostics, stress-analysis, experimental investigations, redesign.*

## 1. INTRODUCTION

The highly pronounced mobility of the surface mining machines (SMM) in harsh working conditions presents fertile ground for various types of failures in their travelling

[1] Professor Srđan Bošnjak, Belgrade, Faculty of Mechanical Engineering, sbosnjak@mas.bg.ac.rs
[2] Professor Zoran Petković, Belgrade, Faculty of Mechanical Engineering, zpetkovic@mas.bg.ac.rs
[3] Assistant Nebojša Gnjatović, Belgrade, Faculty of Mechanical Engineering, ngnjatovic@mas.bg.ac.rs
[4] Researcher Vaso Mihajlović, Belgrade, Faculty of Mechanical Engineering, vmihajlovic@mas.bg.ac.rs
[5] Researcher Goran Milojević, Belgrade, Faculty of Mechanical Engineering, gmilojevic@mas.bg.ac.rs

mechanisms. Although infrequently, failures of SMM travelling mechanisms may lead to very serious or even disastrous consequences, similar to those resulting from failures of vital superstructure parts. However, even in cases when consequences are not catastrophic, failures of the SMM travelling mechanisms cause high financial losses. Furthermore, the replacement of damaged parts is executed on site, often in hard working conditions, by that essentially prolonging the downtime of the complete surface mining system. Losses caused by machine downtime i.e. the system as a whole, may exceed direct material damage several times [1].

This paper discusses the causes of the failures in the vital parts of the crawler travel gear of the bucket wheel excavators and spreaders: chain links, track wheels, two-wheel bogies and undercarriage.

## 2. CRAWLER CHAIN LINKS' FAILURES

Stacker ARs 2000 presents the final link in the system for continuous overburden removal in the open pit mine “Kostolac” – Serbia. During the stacker’s travel from the erection site to the open pit mine, three crawler chain links fractured, presenting an indication of the problems that were to occur during exploitation. In fact, after only 1000 working hours (about three months), 30 chain links sustained fractures, Fig. 1(a) [1]. The similar fractures occurred during perennial exploitation of the bucket wheel excavator (BWE) SchRs 1760 (operating in open pit mine “Kolubara” – Serbia), Fig. 1(b).

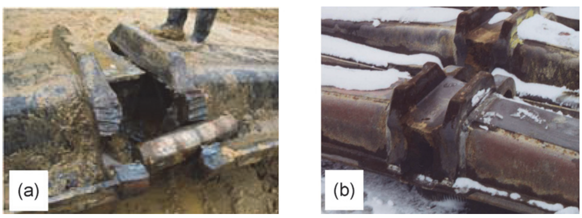


Fig. 1 *Typical chain link fracture: (a) ARs 2000 [1]; (b) SchRs 1760 [2]*

After calculation of the chain link stress state by applying the linear finite element method (FEM), it was concluded that the maximum level of stresses in the critical zones for both, ARs 2000 and SchRs 1760 chain links, does not compromise the integrity of the considered structures, Fig. 2.

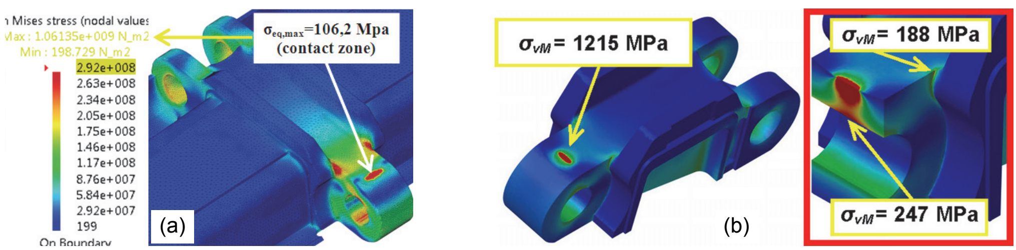


Fig. 2 *Distribution of von Misses stresses in critical zone:*
*(a) ARs 2000 [1]; (b) SchRs 1760*

Experimental investigations were conducted on specimens made of the chain links' broken parts, Fig. 3. Substantial deviation of the mechanical properties of the material with respect to those prescribed by the standard as well as the existence of macro and micro cracks in the material structure indicate that presented failures of both chain links belongs to the class of failures caused by the so-called 'manufacturing-in' defects.

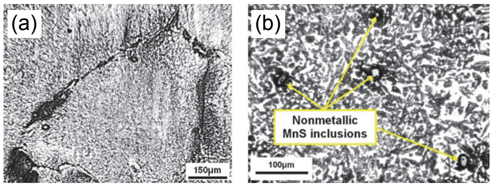


Fig. 3 *Microstructures of chain links samples: (a) ARs 2000 [1]; (b) SchRs 1760 [2]*

## 3. TRACK WHEELS' FAILURES

Serious track wheels threads damages, Fig. 4, occurred immediately after the beginning of the overburden system exploitation approximately at the same time as fractures of stacker ARs 2000 crawler chain links. Both analytical and numerical analysis pointed out that contact stress values are inadmissibly high. Inclination of chain link towards the track wheel causes changes in the geometry of contact and the contact surface load as well, which leads to considerable changes of the stress field and multiple increase of contact stresses, Fig 5. The results of the numerical and experimental analyses as well as the fact that damage to the track wheels threads occurred during the first 1000 working hours (fatigue crack propagation had not been able to develop yet), point out that static overstressing (i.e. design fault) joined with lower material properties than required (i.e. manufacture faults) is the main cause of wheel damages [3].

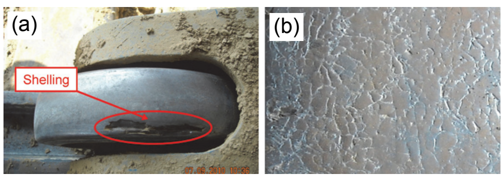


Fig. 4 *Track wheels damages: (a) shelled tread; (b) cracks on the tread [3]*

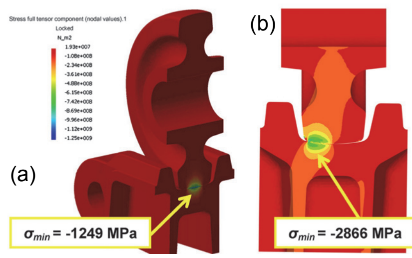


Fig. 5 *FEA results: (a) normal components of stress tensors in vertical direction; (b) components of stress tensors in the direction of contact surface perpendicular [3]*

## 4. FAILURES OF THE TWO-WHEEL BOGIES

The main reason for structural failure of bucket wheel excavator SchRs 1760 two wheel bogie (TWB), Fig. 6, was its insufficient strength under the lateral forces acting during curve travel [4].

Fig. 6 *Typical failure of the TWB structure*

Two variants of the TWB structure were analyzed: the originally designed and the redesigned, Fig 7. Three calculation models for stress state identification were used for each of the variants [5]. The first does not include the influence of the track wheel axle on the lateral loads distribution. The second model includes the mentioned influence while the third considers the track wheel axle as a structural part of the TWB. Models M1, M3 and M5 describe the original, while models M2, M4 and M6 describe redesigned structure behavior. In all of the studied cases, the stress state in the redesigned TWB structure is considerably lower than that in the original TWB structure, Fig 8. Experimental results obtained on a test board especially designed for this purpose [4], confirmed the validity of the TWB reconstruction design. Based on the fact that the results of the FE analyses indicate a considerable influence of track wheel axles on the TWB structure stress state [5], Fig. 9. Nevertheless, the conservative approach to calculating the TWB structure, using models which do not include track wheel axles, provides sufficient TWB carrying capacity even in the case of unforeseen loads.

Fig. 7 *Original and redesigned TWB structure*

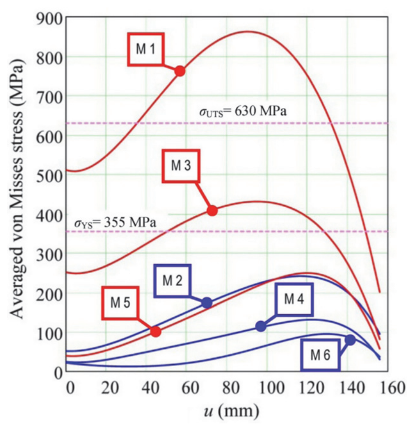


Fig. 8 *Comparative distribution of averaged von Misses stresses in the critical zones [5]*

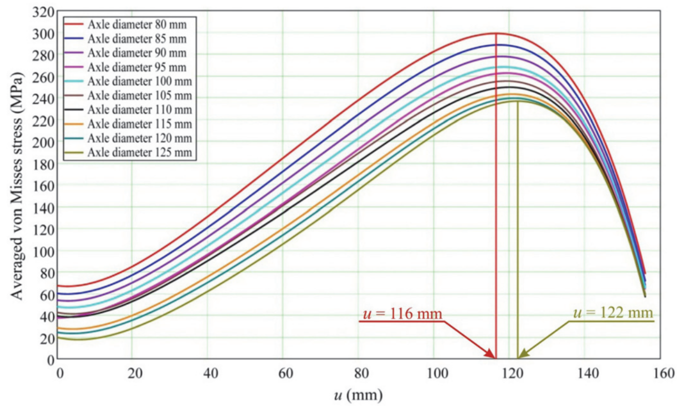


Fig. 9 *Dependence of von Misses stresses on the track wheel axle diameter (M 5) [5]*

## 5. FAILURES OF BWE C-700S UNDERCARRIAGE

Rigid connections between the undercarriage and crawler beams, Fig. 10 (a), offers a very high factor of safety against tipping but at the same time make unfavorable conditions for adapting to the form of the ground surface. In order to stop the cracks from appearing, the undercarriage structure was intuitively reinforced by building in vertical plates thus strengthen the connection girders, Fig 10 (b). In a very short period of time after the reconstruction, new cracks occurred on elements of the original undercarriage structure and even on added structural elements [6]. The analysis of the undercarriage stress–strain state is performed for three variants, Fig. 10, for 3-point and 4-point leaning and for five load cases described in [6], Fig. 11. Reasons for cracks appearance within both the original and the intuitive redesigned undercarriage structure are design faults.

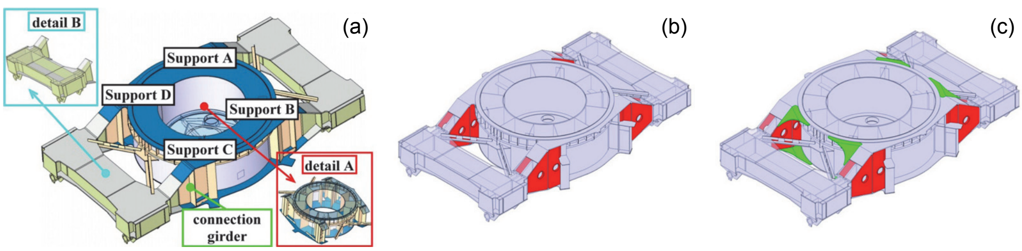


Fig. 10 *3D models of undercarriages: (a) The original undercarriage design (Variant I); (b) Intuitive redesigned undercarriage (built in structural parts are shown in red), (Variant II); (c) Undercarriage redesigned according to [7]*

## 6. CONCLUSION

Based on the results of the analytical–numerical–experimental analyses, it can be concluded that: (a) chain links' failures are caused by 'manufacturing-in' defects; (b) track wheels' failures are caused by 'design-in' and ' manufacturing-in' defects; (c) failures of the two-wheel bogies and undercarriage are caused by 'design-in' defects. The presented results have wider significance because the same or similar concept of travelling mechanisms and their vital subassemblies are frequently used in other types of excavators and earthmoving machines as well as mobile cranes.

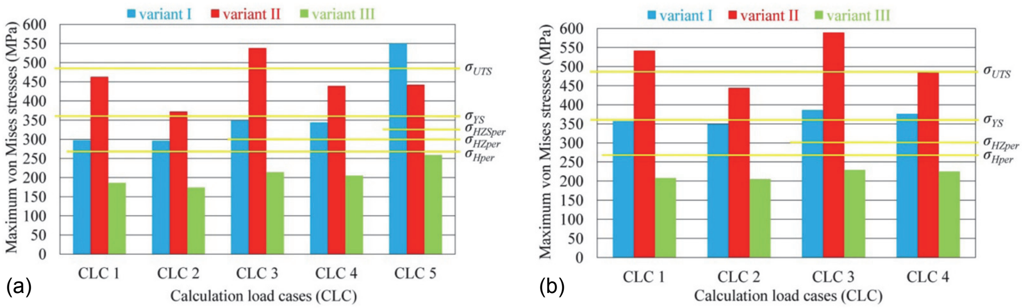


Fig. 11 *Stress states: (a) in cases of 4–points leaning; (b) in cases of 3–points leaning*

## ACKNOWLEDGEMENT

This work is a contribution to the Ministry of Education, Science and Technological Development of Republic of Serbia funded project TR 35006.

## REFERENCES

[1] Bošnjak, S., Arsić, M., Zrnić, N., Odanović, Z., Đorđević, M. (2011). Failure Analysis of the stacker crawler chain link, *Procedia Engineering. 10*, pp. 2244-2249.

[2] Bošnjak, S.,Momčilović, D., Petković, Z., Pantelić, M., Gnjatović, N. (2012). Failure Investigation of the Bucket Wheel Excavator Crawler Chain Link, *Proceedings of the Fifth International Conference on Engineering Failure Analysis, ICEFA V*, pp. 8.

[3] Arsić, M., Bošnjak, S., Odanović, Z., Dunjić, M., Simonović, A. (2012). Analysis of the Spreader Track Wheels Premature Damages, *Engineering Failure Analysis*, vol. 20, pp. 118-136.

[4] Bošnjak, S., Petković, Z., Zrnić, N., Pantelić, M., Obradović, A. (2010). Failure analysis and redesign of the bucket wheel excavator two-wheel bogie, *Engineering Failure Analysis*, vol. 17, no. 2, pp. 473-485.

[5] Bošnjak, S., Petković, Z., Gnjatović, N., Jerman, B., Milenović, I. (2012). Finite Element and Experimental Strength Analysis of the Bucket Wheel Excavator Two-wheel Bogie, *Proceedings of the XX International Conference MHCL'12*, pp. 141-148.

[6] Bošnjak, S., Petković, Z., Simonović, A., Zrnić, N., Gnjatović, N. (2013). 'Designing – in' Failures and Redesign of Bucket Wheel Excavator Undercarriage, *Engineering Failure Analysis*, Article in press.

[7] Bošnjak, S., Petković, Z., Simonović, A., Cvjetinović, I. (2006). Redesign of the bucket wheel excavator's C – 700 S undercarriage. *University of Belgrade – Faculty of Mechanical Engineering*, Report No. 261/06, Belgrade. [in Serbian]