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CASE STUDY OF THE CHAIN EXCAVATOR

STUDIJA OŠTEĆENJA LANČANOG BAGERA

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Ključne reči
- lančani bager
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- naponi
- lom i zamor
- trošenje
- FEM, CAD

Abstract

The chain excavator is the main technological part of a cleaning machine which is used for technological operation of railway maintenance. The purposes of the sub-assembly are to excavate the crushed stone (ballast) from the railway, under the sleeper and to transport it to the screen, where it is cleaned, sorted and reused. The chain excavator is loaded in bending, abrasive wear, shock, tension and other stresses. Due to these stresses, the chain excavator has defects as fractures, fatigue, wear and other. These defects can lead to a dangerous malfunction, defects, or immobilizations of the cleaning machine with risks for safety work and important losses of productivity and value. In this paper we establish and present the stress system, wear zones and some defects and fractures of elements of the chain excavator. Another important novelty is the FEM analysis using CAD for some extreme stress cases and the comparison of this analysis with experimental conclusions in situ. Effects of some types of usual defects are also analysed.

Izvod

Lančani bager je glavni tehnološki deo železničke mašine za čišćenje, koja se upotrebljava za tehnološku operaciju u održavanju železničkih šina. Svrha podsklopa jeste u izvlačenju kamena tucanika, oko šina, ispod pragova i njihov transport do čistača, gde se obavlja čišćenje, sortiranje i priprema za ponovnu upotrebu. Lančani bager je opterećen na savijanje, abrazivno trošenje, udar, zatezanje i druga naprezanja. Usled ovih napona, kod lančanog bagera se javljaju defekti, kao što su prelomi, zamor, trošenje i drugi. Ovi defekti mogu dovesti do opasnog kvara, grešaka i imobilizacije mašine za čišćenje, sa rizikom za siguran rad i značajne gubitke produktivnosti i cene. U ovom radu smo utvrdili i predstavili sistem naprezanja, zone trošenja i pojedine defekte i lomove elemenata lančanog bagera. Drugu bitnu novinu čini FEM analiza korišćenjem CAD za neke ekstremne slučajeve napona i poređenje ove analize sa eksperimentalnim zaključcima in situ. Uticaji nekih tipova uobičajenih defekata su takođe analizirani.

INTRODUCTION

Technical conditions for exploiting the railway in utmost safety and comfort, require a certain constructive prism structure of the ballast (crushed stone), that must posses elasticity and permeability qualities (Fig. 1, pos. 1, 2, 3). Also, the rail- sleeper system must have a certain geometry (dimensions, shapes, positions) not only in the transversal section, but also in the longitudinal one.

The crushed stone starts to degrade because of physical and natural phenomena, leading to the clogging and contamination of the crushed stone prism. Some of these phenomena are: the friction between the surface and the edges of crushed stones, under effects of loadings and displacements, which leads to the appearance of wear particles; the variation in temperature between the natural cycles of freezing and thawing, which leads to cracking and breaking (shredding) of stone; the depositing of solid particles which are in suspension in the air, or the leaking of materials from the wagons; the humidity and precipitations under the form of rain and snow that lead to washing, displacement, depositing and concentration of small and fine particles in the clogging phenomenon and similar processes. The contamination or clogging of the crushed stone prism over a certain clogging degree (> 30%) produces unfavourable/unwanted effects over the railway properties.

Through mechanical operations of the screening of crushed stone and the removal of waste from the crushed stone prism, the elasticity and permeability qualities are re-established, obtaining important technical and economical advantages, /1/.

The technological operation by cleaning of the ballast' prism is made by the ballast cleaning machine. The chain excavator takes the ballast bed material from the track. A cleaning railway machine is presented in Fig. 2. This type of excavation chain uses five exchangeable scraper fingers. The chain links are made of high-alloyed steel (Fig. 3).

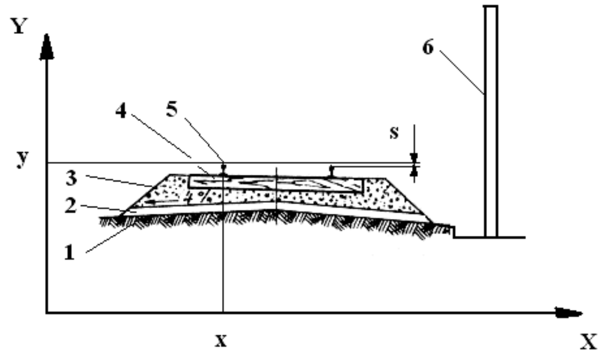

Figure 1. Cross section of railway: 1–soil; 2–under layers of sand and gravel; 3–ballast (crushed stone); 4–sleeper; 5–rail (main wire); 6–protection panel with multiple roles (phonic, safety); s–super elevation.
Slika 1. Poprečni presek železničkog koloseka: 1–tlo; 2–podslojevi peska i šljunka; 3–kamen tucanik; 4–prag; 5–šina (žica za glavno napajanje); 6–zaštitni panel sa višestrukom ulogom (zvuk, bezbednost); s–nadvišenje

Figure 2. Ballast cleaning machine.
Slika 2. Mašina za čišćenje podloge (tucanika)

Figure 3. Chain excavator.
Slika 3. Lančani bager

The high-alloyed steel is of 120Mn12 or TMn13. The chemical composition (% wt.) and mechanical properties are given below in Table 1.

Table 1. Chemical and mechanical properties of steel 120Mn12.
Tabela 1. Hemijske i mehaničke karakteristike čelika 120Mn12

C	Mn	S	Cr	Ni	P	S
1.25–1.40	12.5–14.5	0.50–1.10	≤ 1	≤ 0.50	≤ 0.11	≤ 0.05

σ_c (N/mm^2)	σ_r (N/mm^2)	A_5 (%)	Z (%)	KCU 30/2	HB
250–400	800–1000	40–55	35–40	20–30	180–220

ANALYSIS OF BEHAVIOUR OF CHAIN ELEMENTS

To perform the analysis we used data gathered from maintenance activities for 5 years, where 6 ballast cleaning machines were used and had reconditioned 1000 km of railway.

In general, in normal conditions the ballast contains no foreign objects and waste deposits. In these conditions, the stress produced in the chain elements is not harmful to the chain integrity.

The performed analysis, characterising the deterioration of the chain elements, resulted in the following:

a. In the contact zone, between the surfaces of chain elements with the ballast prism, the stones forming the "wall" behind the chain excavator have a wear-like action on the metallic elements of the chain that are in motion. If the contact between the metallic elements and the stone is made through a corner or a sharp edge, in favourable stress conditions, a cutting type phenomenon occurs that leads to the removal of a portion of the metal. This removal of metallic material will produce a scratch, whose dimensions will depend on several factors (Fig. 4). The scratch may act as a tension accumulator, with corresponding consequences on the maximal tension state of the analysed area, or it may contain a crack/ microcrack. In the interior of the scratch, it is possible that microcracks may exist, which in favourable conditions can evolve over time. The wear phenomenon has been previously studied /2-5/.

Figure 4. Wear of the chain elements by micro cutting.
Slika 4. Trošenje elemenata lanca mikro rezanjem

b. If the contact takes place on larger surfaces and is smaller in intensity, then a normal wear phenomenon occurs (Fig. 5), which over time reduces the dimensions of metallic elements that form the chain (Fig. 10).
c. Wear can also appear at the contact between metallic elements that form the chain. In this type of joint, the dust (dry or wet), in the beginning having dimensions of a very small particle, enters in between the moving elements (Figs. 5, 6, 7). During the movement time, the wear phenomenon increases the space between moving elements, so larger rock particles may enter. In this way, the wear phenomenon continues to accelerate.

Figure 5. Normal wear of chain elements on contact surfaces (sliding).
Slika 5. Normalno trošenje elemenata lanca, na dodirnim površinama (klizanjem)

Figure 6. The chain excavator where there are deposits of particles that favour wear.
Slika 6. Lančani bager na mestu naslaga čestica koje izazivaju trošenje

Figure 7. The chain excavator where there are deposits of particles that favour wear.
Slika 7. Lančani bager na mestu naslaga čestica koje izazivaju trošenje

d. Wear at the corner of scrapers. The scrapers have a conic shape with a corner at the end. The contact between the scrapers and crushed stone produces wear, which leads to the increasing of the corner's radius (Fig. 8).

Figure 8. Wear of the scrapers.
Slika 8. Trošenje strugača

e. Fracture of metallic elements of the chain. This phenomenon has been observed in the connecting chain links and scraper shovels, also. (Figs. 9, 10).

Figure 9. Fracture of chain elements (connecting chain links).
Slika 9. Lom elemenata lanca (vezne karike)

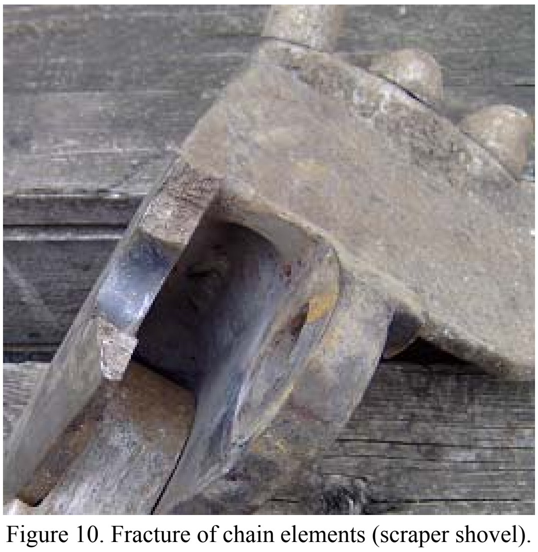

Figure 10. Fracture of chain elements (scraper shovel).
Slika 10. Lom elemenata lanca (kašika strugača)

In general, the majority of fractures occur in the bolt assembling area. From analysing the fractures, we observe:
– fractures occur in the case of overloads determined by foreign elements in the ballast or by stones from the ballast which are joined (“glued together” or clogged) by dust mixed with water, oil and similar processes;
– fractures appeared only in areas of high wear in the presence of concentrators leading to the decrease of dimensions in the assembling bolt areas (Figs. 4, 5 and 10);
– when fracture did not occur in an area with high wear, the structure of the material was analysed, and structural defects in the material were noticed (Fig. 9);
– fracture does not occur in normal functioning conditions;
– the wear is at an acceptable level in normal functioning conditions.

FME ANALYSES

Two situations are analysed: the *normal functioning situation*; the *overload functioning situation*, in the case where the overload acts at the least favourable location.

The chain is modelled using the AutoDesk Inventor programme. Two connecting chain links are modelled, one scraper shovel, two bolts and five scrapers. In the model we neglected the constructive details and the series of design elements that did not contribute neither to the increase nor the decrease of equivalent tensions which do not influence the stress state, these being considered to have only a technological role. We also neglected the connecting radius from the model /6, 7/. Because the maximal equivalent tensions are not in these areas, this approximation does not lead to errors in the simulation. The design is approached in this way because any additional surface in the model leads to a larger number of finite elements. A large number of finite elements requires an unjustified consumption of resources during the simulation. The model used in the simulation is described in Figs. 11 and 12.

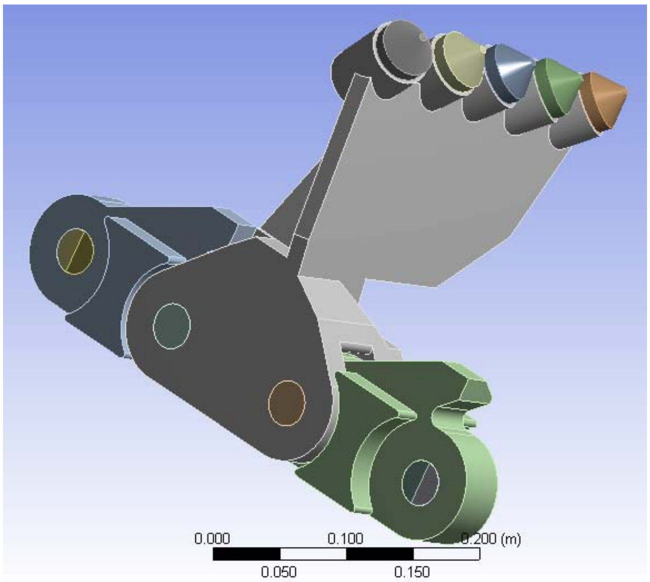

Figure 11. Modelling the chain excavator elements.
Slika 11. Modeliranje elemenata lančanog bagera

The simulation of stress states using the finite element method (FEM) is realised through Ansys Workbench 12, Academic version. A fine mesh (Fig. 12) is used with the refining of the areas of interest. Over 1 million finite elements are used.

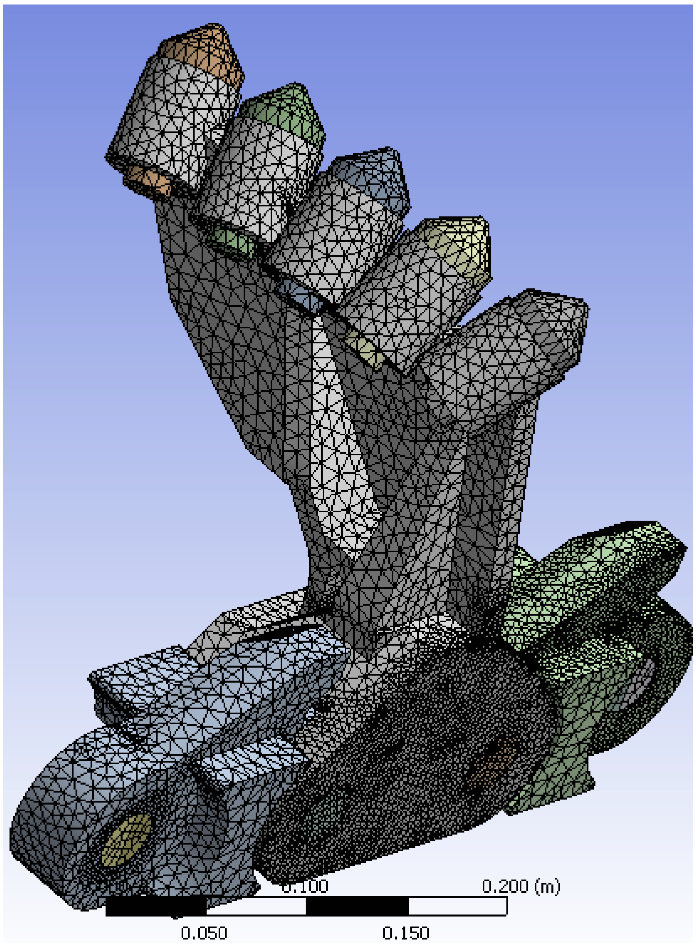

Figure 12. Meshing of the chain excavator elements.
Slika 12. Mreža elemenata lančanog bagera

NORMAL FUNCTIONING SITUATION

In the normal functioning situation, the stress is considered a pulsating stress. In this simulation we determined the maximal equivalent tensions and estimated the functioning life span, expressed in the number of cycles. The obtained results for equivalent tensions are described in Figs. 13 and 14. In Figs. 15 and 16, the life spans are described, expressed in numbers of cycles.

OVERLOAD FUNCTIONING SITUATION

Overloading could be produced by foreign bodies which may be found in the ballast prism. In simulations presented here the equivalent tension stresses are determined. In this situation it is considered that the scraper shovel has stopped its movement. This constrain is applied to the farthest scraper. In Figs. 17 and 18, the maximal equivalent tension stresses are described not only in the entire chain, but also in its components (scraper shovels and connecting chain links).

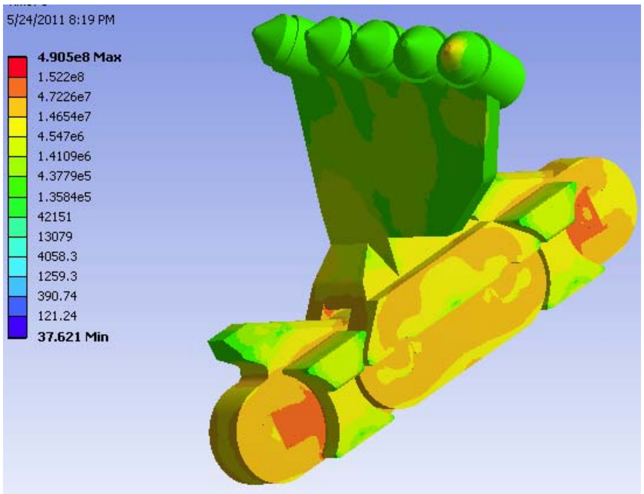

Figure 13. Equivalent stress state (von Mises) in chain elements.
Slika 13. Stanje ekvivalentnih napona (fon Mizes) u elementima lanca

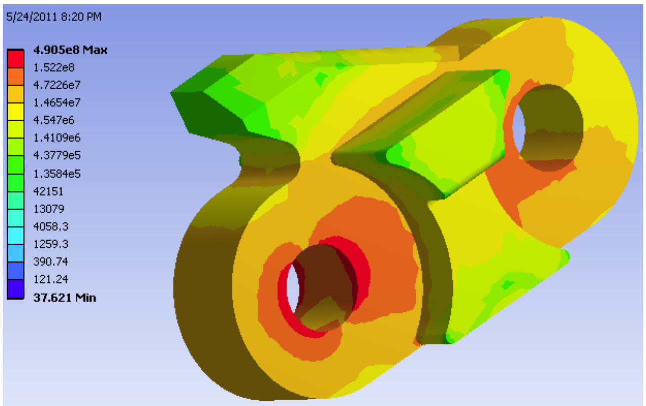

Figure 14. Equivalent stress state (von Mises) in connecting chain link.
Slika 14. Stanje ekvivalentnih napona (fon Mizes) u veznim karikama lanca

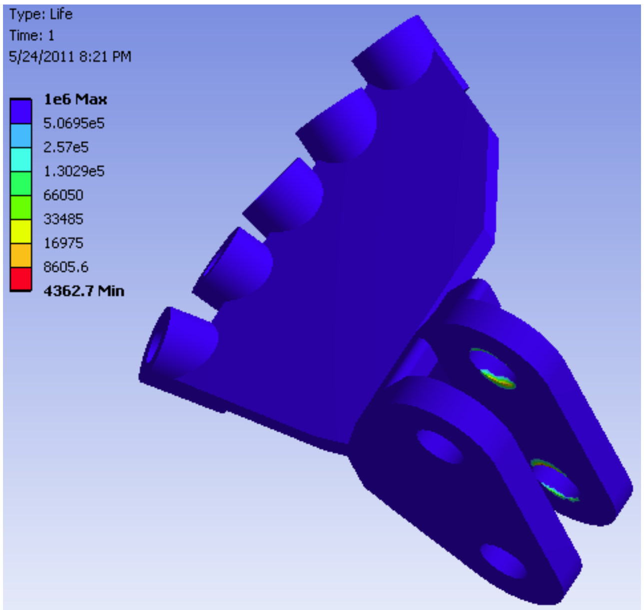

Figure 15. Life spans of the scraper shovel.
Slika 15. Procena veka kašike strugača

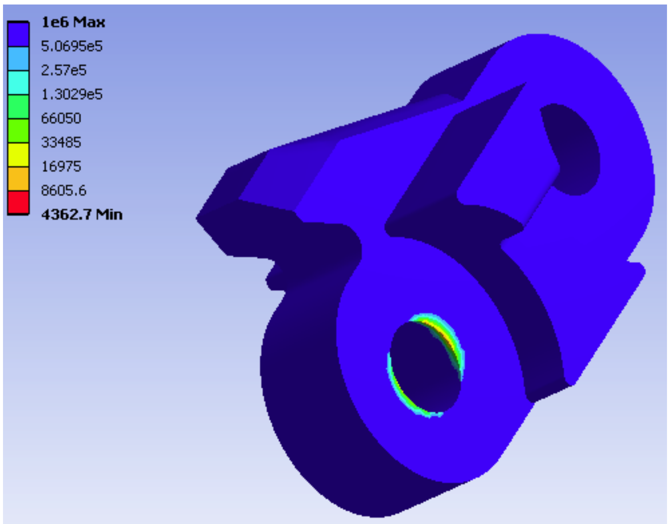

Figure 16. Life spans of the connecting chain link.
Slika 16. Procena veka vezne karike lanca

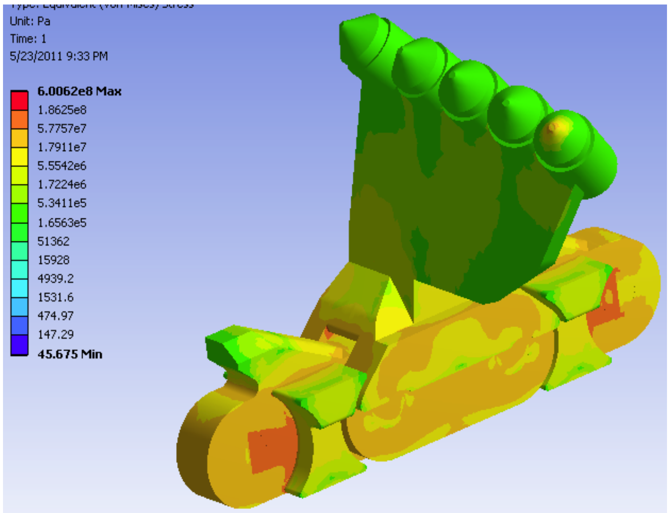

Figure 17. Equivalent stress state (von Mises) in chain elements.
Slika 17. Stanje ekvivalentnih napona (fon Mizes) u elementima lanca

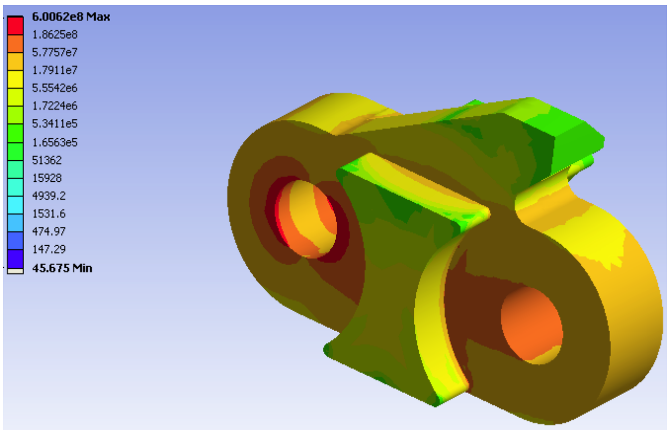

Figure 18. Equivalent stress state (von Mises) in connecting chain link.
Slika 18. Stanje ekvivalentnih napona (fon Mizes) u veznim karikama lanca

CONCLUSIONS

After analysing the ways of deterioration and simulations that have been realised, it can be concluded:

The main deterioration is caused by wear. During normal functioning, the stress state is not dangerous. It can become dangerous if the wear reaches a critical value and if the material (structural) defects are present in the critical area. The life span, expressed in the number of cycles, is very large, with the exception of a very small area from the assembly zone, between the connecting chain link and bolt.

At overload, the stress state may become critical in the case of repeated high stresses and the presence of wear and structural defects of the material. It must be mentioned that the maximal stresses can be repeated for different values. More stresses repeated by smaller values of the maximal overload, can lead to fracture by accumulated deterioration.

The plating of the areas that are exposed to strong wear phenomena with materials that have a high resistance to wear can be a solution, especially for the scraper shovel.

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