ISSN 1330-3651 (Print), ISSN 1848-6339 (Online)
UDC/UDK 620.178.4:622.232.8-231.3]:519.6

STRAIN GAUGES MEASUREMENTS AND FEM ANALYSIS OF ELEMENTS OF CHASSIS OF OPEN CAST MINING MACHINES

Paweł Maślak, Tadeusz Smolnicki, Damian Pietrusiak

Original scientific paper

In the paper are shown selective elements of chassis of open cast mining machines: control steering track and caterpillar tracks of open cast mining machines. Loads on each element are defined in accordance with current standard requirements norms. After setting boundary conditions, stress analysis was done. Results of analysis are shown in the table. Indication of the most endangered places was based on the results of analysis. Strain gauges measurements were also performed in 9 measuring points: 6 points on track's supports, 2 on caterpillar's support and one on steering control. The measurements were taken by multichannel recorder during the driving of the conveyor. The measurements were taken for many settings of the body and the chassis with different angles of steering set. After examination of the measurement results some figures were obtained that show turning of caterpillar sets, increasing and decreasing steering force and track force on caterpillar during driving and turning.

Keywords: *open cast mining machines, track chassis, strain gauges measurements*

Mjerenja tenzometarskim trakama i MKE analiza elemenata šasije rudarskih strojeva za površinski kop

Izvorni znanstveni članak

U članku su prikazani odabrani elementi šasije rudarskih strojeva za površinski kop: upravljački trakt i gusjenice rudarskih strojeva za površinski kop. Opterećenja na svakom elementu su određena u skladu s postojećim normama. Nakon postavljanja graničnih uvjeta, provedena je analiza naprezanja. Rezultati analize su prikazani u tablici. Indikacija najugroženijih mjesta je bazirana na rezultatima analize. Mjerenja tenzometarskom trakom su također provedena na 9 mjernih točaka: 6 točaka na nosačima staze, 2 na potpornjima gusjenice i jedna na uređaju za upravljanje. Mjerenja su obavljena multikanalnim registratorom tijekom pokretanja konvejera. Mjerenja su provedena u različitim položajima karoserije i šasije pod različitim uglovima sklopa za upravljanje. Nakon pregleda rezultata mjerenja dobiveni su podaci koji pokazuju skretanje gusjeničnih sklopova, povećanje i smanjenje snage upravljanja i vučne snage na gusjenici tijekom vožnje i okretanja.

Ključne riječi: *rudarski strojevi za površinski kop, šasija staze, mjerenja tenzometarskim trakama*

1 Introduction

The aim of the research was to identify the loads on multicaterpillar track chassis and calculate the strength of elements of chassis. The measurements were taken on open cast mine machine: mobile transfer conveyor, shown in Fig. 1. The biggest problem in such kind of machines is to properly diagnose the state of machine and remove from usage before any dangerous, for people and machine, accident takes place [1, 2].

The aim of the research, the mobile transfer conveyor A2RsB 12500 was designed in early 70' last century, on the basis of TGL Standards [8]. There were many indefinite problems, which are still unknown. Nowadays we cannot answer the question how long the machine will work without any failure, therefore the assessment of actual technical condition needs to be done.

Figure 1 Open cast mine machine

2 Multicaterpillar track chassis

The chassis of open cast machines like mobile transfer conveyor consists of up to 12 caterpillar tracks connected into sets of 2 or 4, of which some are steered. The scheme of chassis that is the aim of the research is shown in Fig. 2 [3, 4].

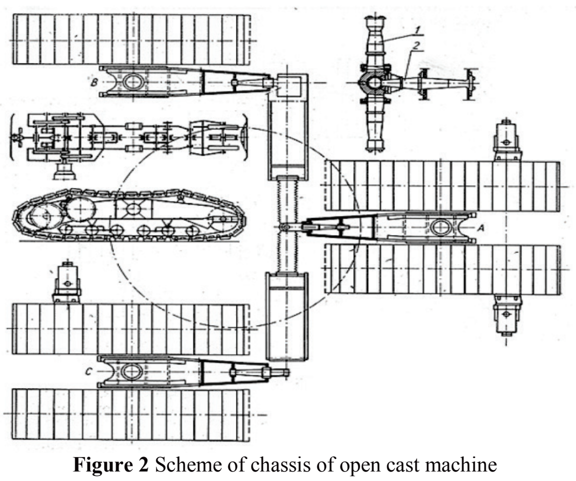

Figure 2 Scheme of chassis of open cast machine

Multicaterpillar track chassis consists of 6 caterpillar tracks which are connected by axis and the steering drawbar. The scheme of the chassis is shown in Fig. 3. Two caterpillar tracks are connected into one set, where there are 3 sets. Two of the sets are fixed and do not have the possibility to turn, one set is steered by driveshaft and has a possibility to change the relational angle between the portal of the machine and the main axis of the set. Tracks are powered by electric motor, one caterpillar track by one motor.

3 Boundary conditions

Nowadays standards state that the friction is held at the value of 0,6. It is the maximum value that is taken from the update standards [7]. Several cases of loads and boundary conditions are used for strain calculations. According to the standards, loads cases do not include all of the possibilities of real loads [3, 5]. In the presented paper the most popular cases of used boundary conditions are shown. In Fig. 3 the boundary conditions used for calculations of caterpillar track are shown [6, 7, 8]. The caterpillar track is loaded on each arm or on drive-wheel and tension-wheel. The caterpillar track is fixed on its axis bushing. The forces F_1 and F_2 are generated by the reaction with the ground, the force Q is the result of the interaction with the ground during the turning, force F_b comes from the reaction of electric motor.

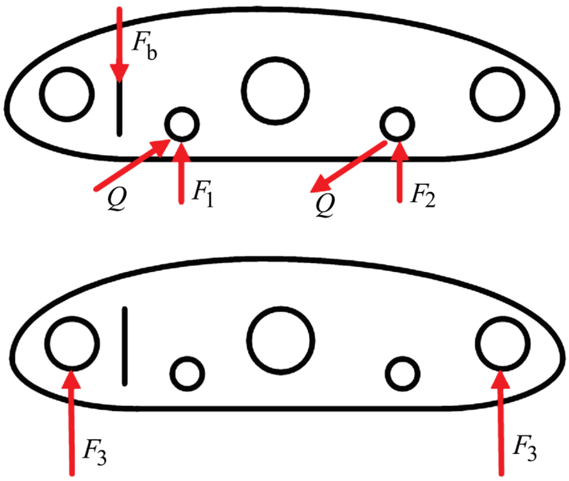

Figure 3 Scheme of load on caterpillar track

The most appropriate for the calculations of steering drawbar case of boundary conditions is to fix one end of the steering drawbar and apply force at the other end in the horizontal direction, that is perpendicular to the main axis of the drawbar and the vertical force applied to the place, where the ball joint is situated.

4 Numerical measurements

Numerical analysis was done using the Finite Element Methods. Calculations were done for 5 different schemes of loads on caterpillar track and for 2 different schemes of load on driveshaft according to the standards. Some of the results of calculations of caterpillar track are shown in Figs. 4 to 7 and the calculations of driveshaft are shown in Figs. 8 to 10. In Figs. 11 and 12 are shown the results of nonlinear calculations. The maximum value of stress calculations is lower than in the linear calculations and the field of maximum value is smaller.

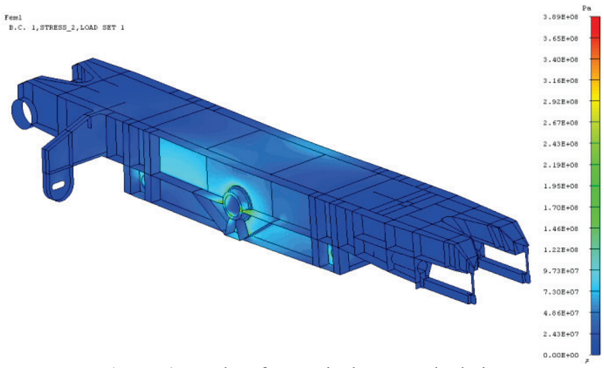
Figure 4 Results of numerical stress calculation of caterpillar track (Pa), load set 1

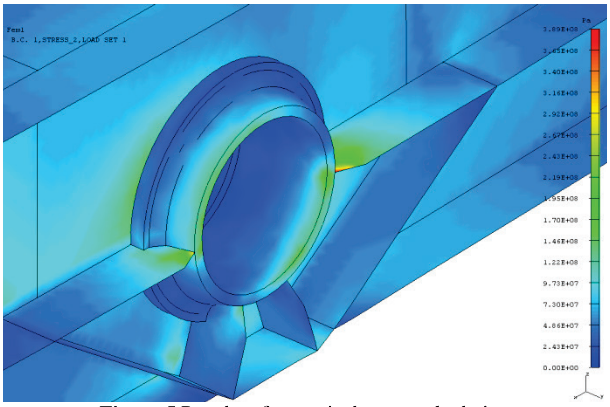
Figure 5 Results of numerical stress calculation of caterpillar track (Pa), load set 1

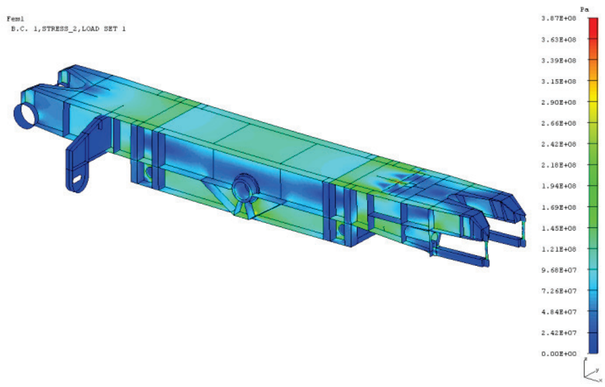
Figure 6 Results of numerical stress calculation of caterpillar track (Pa), load set 2

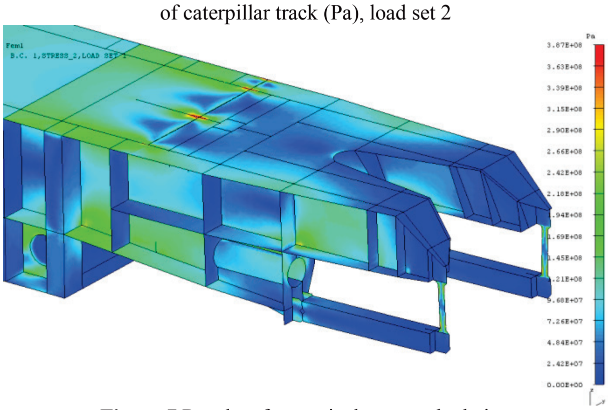
Figure 7 Results of numerical stress calculation of caterpillar track (Pa), load set 2

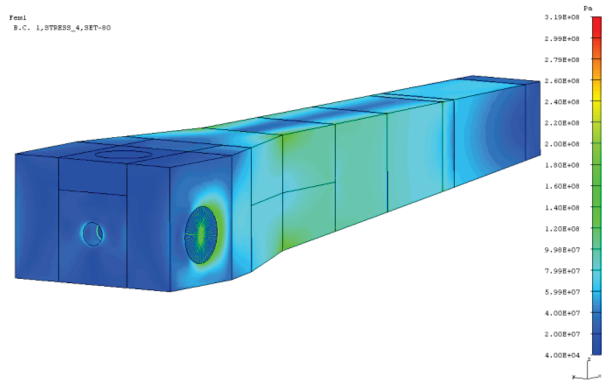

Figure 8 Results of numerical stress calculation of driveshaft (Pa), load set 1

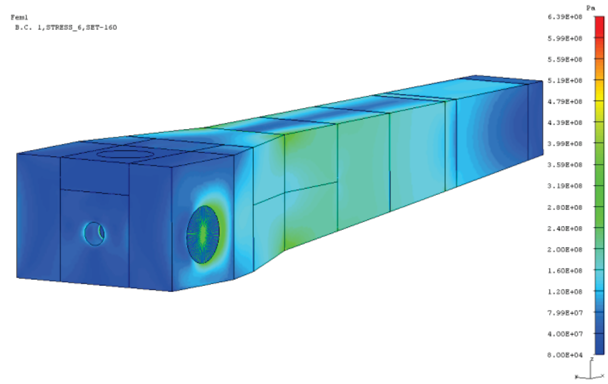

Figure 9 Results of numerical stress calculation of driveshaft (Pa), load set 2

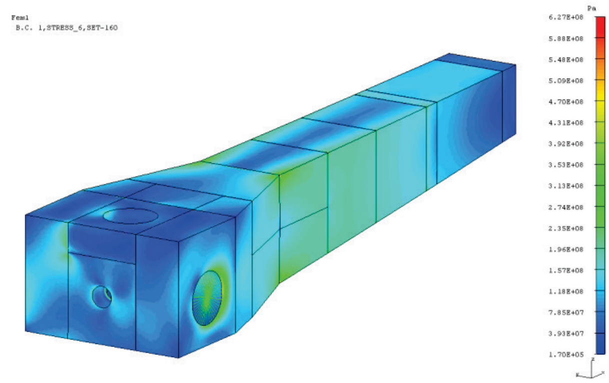

Figure 10 Results of numerical stress calculation of driveshaft (Pa), load set 3

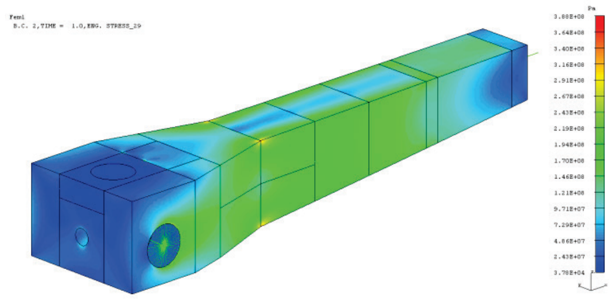

Figure 11 Results of numerical stress calculation of driveshaft (Pa), nonlinear type of material

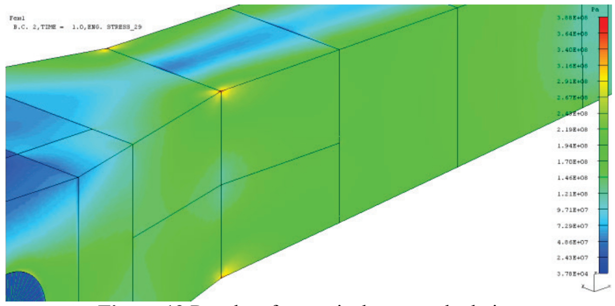

Figure 12 Results of numerical stress calculation of driveshaft (Pa), nonlinear type of material

5 Strain gauges measurements

Strain gauges measurements were performed in 9 measuring points. There are 6 points on caterpillar tracks where the traction forces were measured. Strain gauges were located on the supports of caterpillar's track, where the motion is fitted. The other 2 strain gauges were located on each truss and the last one was located on the drawbar. The measurements were taken during the drive in different directions: forward and backward, with different positions of the center of gravity, with different positions of the load carrying structure and the chassis. The measurements were taken during machine turning to the right and to the left, driving forward and backward with and without the overburden. During the measurements over 30 sets were recorded.

The data acquisition was conducted by multichannel recorder. All of the signals were recorded parallel with each strain gauge.

6 Results of strain gauges measurements

Results of the measurements show that the real traction force is not linear, but very stochastic. Traction force was gained during driving forward and backward. Traction force for forward drive is shown in Fig. 13. The average value is at the level of minus 50 kN with amplitude at the level of 70 kN.

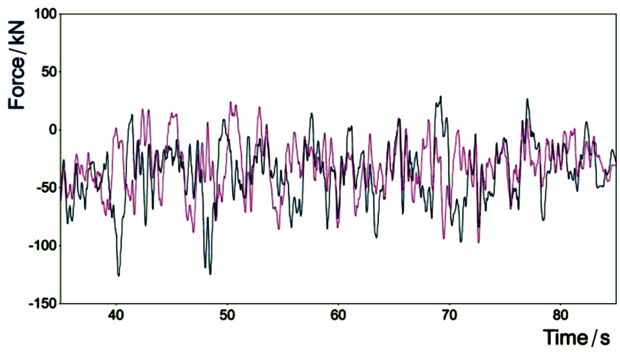

Figure 13 Traction force of steering caterpillar track set –right and left caterpillar - forward drive

The results of measuring the steering force are shown in Fig. 14. The most important thing in this measurement is to show how the force changes its value during turning the steering caterpillar track set. Steering force changes from 0 kN to over 600 kN during turning.

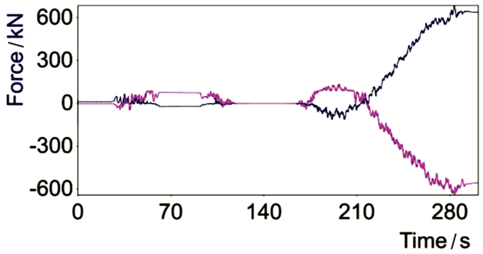

Figure 14 Steering force in trusses – forward drive, turning right from 0º to 13º

Measured steering force is over 3 times higher than the force calculated by using analytical method. The calculated steering force is at the level of 170 kN. The calculated force depends on static variables and is not related to the change of the angle of the steering set. Measurements show that the force changes its value during the steering and driving the entire machine.

7 Conclusion

There are many indefinite problems with the loads on the chassis of open cast mining machines. Existing equations do not take into consideration any stochastic loads. The measurements show that the traction force changes very rapidly and has a very high value of amplitude. Currently there is lack of guidelines to receive the appropriate boundary conditions and operational loads. It is necessary to conduct more research on open cast mining machines to define more properly the loads acting on multicaterpillar track chassis. The measurements should be taken in different conditions: during the winter and the summer, when the ground is frozen, wet and muddy or dry and sandy. Research should be done in different positions of the entire machine and with or without transporting the overburden.

8 References

[1] Bosnjak, S.; Arsić, M.; Zrnić, N.; Rakin, M.; Pantelić, M. Bucket wheel excavator: integrity assessment of the bucklet wheel boom tie-rod welded joint. // Engineering Failure Analysis. 18, (2011), pp. 212-222.

[2] Rusiński, E.; Harnatkiewicz, P.; Kowalczyk, M.; Moczko, P. Examination of the cause of a bucket wheel fracture in a bucket wheel excavator. // Engineering Failure Analysis. 17, (2010), pp. 1300-1312.

[3] Smolnicki, T.; Maślak, P. Experimental identification of loads in multi-caterpillar mechanism of the ride of dumping conveyor, 6th International Conference Mechatronic Systems and Materials, MSM 2010.

[4] Bosnjak, S.; Zrnić, N.; Gnjatović, N. Geometry of the substructure as a cause of bucket wheel excavator failure, Machine Design, edited by S. Kuzmanović, pp. 135-140, University of Novi Sad, 2009.

[5] Bosnjak, S.; Zrnić, N.; Simonović, A. Computer Aided Design and Calculation of Bucket Wheel Excavators, Machine Design, monograph edited by S. Kuzmanović, pp. 135-142, University of Novi Sad, 2007.

[6] Kovacevic, D.; Budak, I.; Antic, A.; Kosec, B. Special finite elements: teoretical background and application. // Tehnicki vjesnik-Technical Gazette. 18, 4(2011) pp. 649-655.

[7] Standard PN-G-47000-2:2005 Górnictwo odkrywkowe - Koparki wielonaczyniowe i zwałowarki - Część 2: Podstawy obliczeniowe, (In Polish).

[8] DIN 22261-2 – Bagger Absetzer und Zusatzgeräte in Braunkohlentagebauen.

Author's addresses

Paweł Maślak, Ph.D. candidate, M.Sc. Eng.
Wrocław University of Technology
Faculty of Mechanical Engineering
Wybrzeże Wyspiańskiego 27, 50-370 Wrocław, Poland
E-mail: pawel.maslak@pwr.wroc.pl

Tadeusz Smolnicki, Professor, Ph.D., D.Sc.
Wrocław University of Technology
Faculty of Mechanical Engineering
Wybrzeże Wyspiańskiego 27, 50-370 Wrocław, Poland
E-mail: tadeusz.smolnicki@pwr.wroc.pl

Damian Pietrusiak, Ph.D. candidate, M.Sc. Eng.
Wrocław University of Technology
Faculty of Mechanical Engineering
Wybrzeże Wyspiańskiego 27, 50-370 Wrocław, Poland
E-mail: damian.pietrusiak@pwr.wroc.pl