Blata J, Šeděnka D, Kašiar Ľ, Volna P. Examining the condition of the ball and the ball track on the heavy machine ZP6600. Diagnostyka, 2017;18(3):85-91

DIAGNOSTYKA, 2017, Vol. 18, No. 3

ISSN 1641-6414
e-ISSN 2449-5220

EXAMINING THE CONDITION OF THE BALL AND THE BALL TRACK ON THE HEAVY MACHINE ZP6600

Jan BLATA[1], David ŠEDĚNKA[1], Ľubomír KAŠIAR[2], Peter VOLNA[2]

[1]VŠB – TU Ostrava, 17.listopadu 15, 708 33 Ostrava – Poruba, davidsedenka@seznam.cz
[2]Department of transport and handling machines, Faculty of Mechanical engineering, University of Žilina, Univerzitná Street, 8215/1, 01026 Žilina, Slovakia
lubomir.kasiar@fstroj.uniza.sk

Abstract

The article deals with the examination of the state of the ball track at the heavy machine ZP 6600/Z79. This kind of machines are located in Doly Bílina. Article presents results of material exams which were taken on given samples and it describes the progress and results of the numeric calculations for the state of tenseness. The material tests were realized in an external cooperation. The numeric simulation of the tenseness was made in the VÚHU a. s. on the 3D model of the contact by a method of the ultimate elements. The used method works with the ending parts at the bottom of part of the ball track when it touches the ball. To determine the internal and contact forces in the ball and the bottom part of the ball track we used the software called COSMOS/DesignStar ver. 6.0. The result was an evidence for the decision about the depth of the turned layer of the material in order to create a new groove of the bottom part of the ball track.

Keywords: ball track, material exam, state of tenseness, contact tension

1. INTRODUCTION

An original idea replacement of a ball track at the heavy machine ZP 5500.5 with a ball track from the heavy machine ZP6600/Z79 came from the SD a. s. - Doly Bílina. This track was also already worn, but the radius of a groove within the bottom parts of the track and the radius of balls were almost identical. The friction was increasing and pieces of the track material were torn out. The decision about the renovation of the track depended on the determination of the groove size degradation at the ball track. The measuring was made by the employees of the SD a. s. - Doly Bílina in cooperation with workers from VÚHU a. s. Most. The material tests were undertaken on the given samples of the bottom part of the ball track at the heavy machine and a numeric simulation of the tensions state in the contact area of the ball and the bottom part of the track. The result was an evidence for the decision about the depth of the turned layer of the material in order to create a new groove of the bottom part of the ball track [1, 2, 3, 4].

The material tests were realized in an external cooperation with the company UNIPETROL RPA s.r.o., a testing laboratory number 1050 accredited by ČIA. The numeric simulation of the tenseness was made in the VÚHU a.s. on the 3D model of the contact by a FEM method (Finite Element Method).
The given parameters:

- the bottom part is made from the steel 16 540.8, ΦD = 110 mm,
  maximum wear value = 5 mm
- the balls are made from the steel GCr15SiMn (G20Mn5; AISI 5210; DIN 100Cr6), ΦD = 100 mm,
- The total weight of the rotating top of the heavy machine is 1580 tons.

The wear of the bottom part is determined by measuring the distance between the bottom and the upper track at designated locations once per month. Balls are checked by visual inspection around the perimeter and the points used to exchange them.

The following Figure 1 shows the surface state of the groove at the bottom part of the track.

Fig. 1. A groove of the track part

2. MATERIAL TESTS

After the consultation with the material laboratory, the collection of samples was made from the maximally loaded bottom part of the ball track (marked as Stv A). Three couples of samples were taken, marked as 2s, 4s and 7s. Each couple consisted of one sample (a shorter one) from the lowest point of the ball track and of one sample from unused area of the bottom part next to the track itself. The collection was made by drilling with a crown drill during a slow motion and proper cooling. Figure 2 shows the collected samples [5, 6].

Fig. 2. The collected samples

The list of tests was as follows:

- chemical structure of the material,
- hardness measurements in the connection with the depth of the track,
- metallographic analysis.

The results of the tests are described in the protocol 399/13.

The chemical analysis proves the declared steel 15 341. Only the content of the carbon is higher – 0,48 %. In accordance with ČSN, the maximal content of the carbon is 0,43 ± 0,02 %.

The results are summarized in the tables 1 and 2.

Table 1. Hardness values

	Hardness in the ball track /HV10/			Hardness off the ball track /HV10/
Depth /mm/	Sample 2s-2A	Sample 4s-4A	Sample 7s-7A	Sample 2s-2B
2	280	265	267	270
4		276		
6	289	269	259	290
8		263		
10	279	264	260	272
12		246		
14	299	249	267	277
16		259		
18		248		279
20	286	257	260	274

It is obvious that the strength of the material is not influenced so much by the operation of the track.

Table 2. Strength values

	Strength in the track /MPa/			Strength off the track /MPa/
Depth /mm/	Sample 2s-2A	Sample 4s-4A	Sample 7s-7A	Sample 2s-2B
2	900	850	856	865
4		884		
6	927	862	832	930
8		844		
10	896	847	835	871
12		788		
14	962	797	856	888
16		832		
18		794		896
20	918	826	835	877

3. METALLOGRAPHYC TESTS

Detailed results of the made metallographic tests are declared in the laboratory protocol 399/13. Here is a summary of results from the protocol.

There were microscopic cracks and structure deformations found on the samples A from the bottom point of the ball track (contact of the ball with the groove). These cracks are maximally 0,6 mm deep. On the samples B (unused area of the bottom part), there were some structure deformations found. The maximal depth is 0,16 mm [7, 8, 9].

In accordance with the results, the structure of the groove is influenced by the operation life of the ball track to the maximal depth of 0,6 mm. The material of the track is not so homogenous.

The selected pictures from the protocol are displayed on the following Figures 3, 4 and 5.

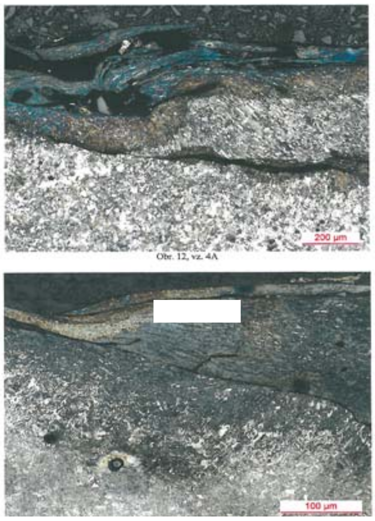

Fig. 3. View depth of cracks

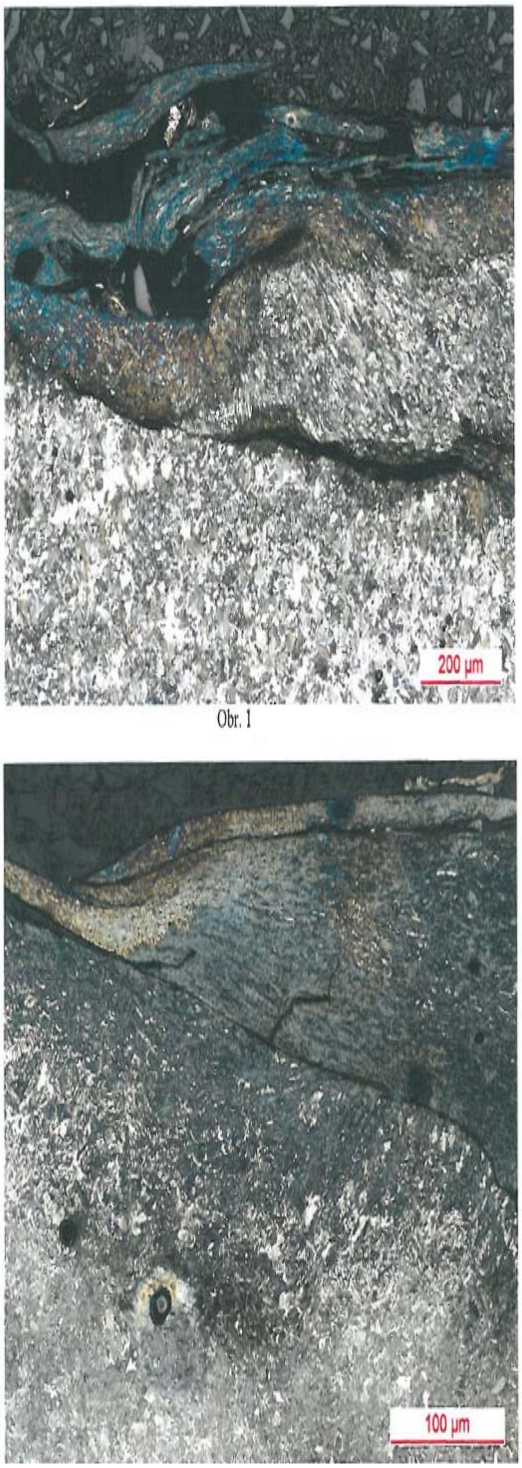

Fig. 4. The cracks in samples of the material collected from the bottom part of the track groove. In the upper part is the sample 4A, in the lower part is the sample 7A

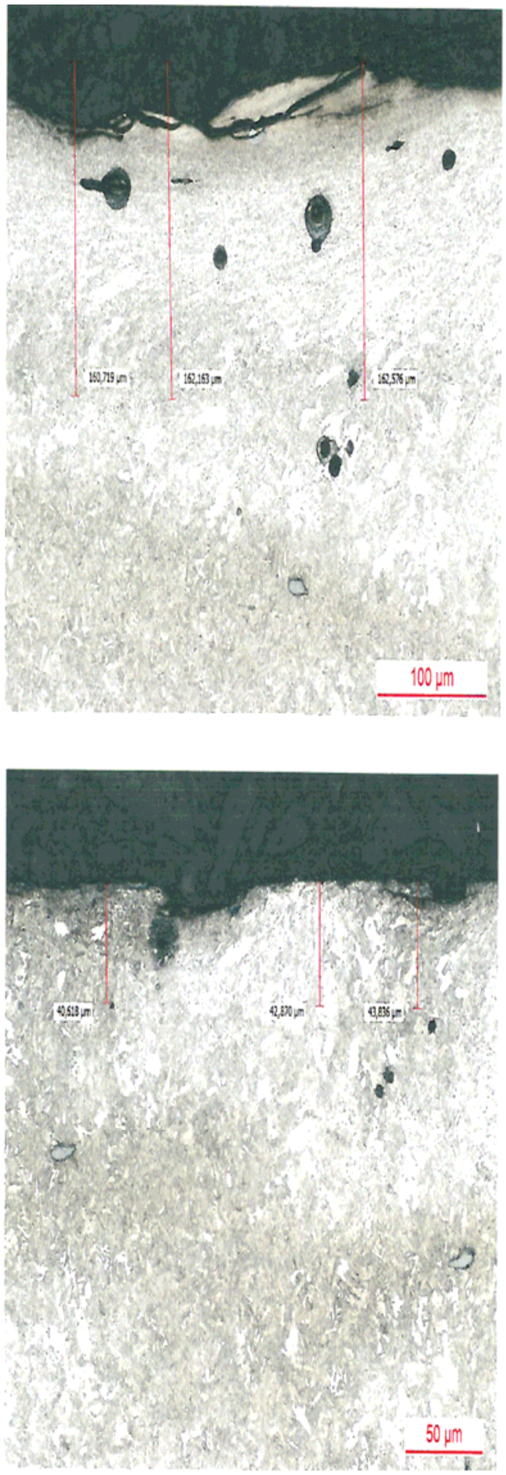

Fig. 5. The deformation of material of the sample 7B collected outside the groove of the track

4. THE SIMULATION OF THE TENSENESS STATE IN THE CONTACT OF THE BALL WITH THE GROOVE

To determine the internal and contact forces in the ball and the bottom part of the ball track we used the software called COSMOS/DesignStar ver. 6.0 developed by the company Structural Research and Analysis Corporation. This software uses a method of the limit element elements.

Characteristic values of the material:
Bottom part → ΦD = 110 mm, steel-15 341.9

- fu = Rm = 880 ÷ 1050 MPa
- fy = RK = min 475 MPa
- sum of contraction ν = 0,3
- tensibility 14 %
- measured weight 7800 $kg.m^{-3}$

Ball steel → ΦD = 100 mm, GCr15SiMn

- fu = Rm = min 900 MPa
- fy = RK = min 500 MPa
- tensibility 5 %
- measured weight 7500 $kg.m^{-3}$

4.1. Geometry

The sizes and the shape of the calculated 3D model were taken from the drawing V004693 (Source SD a. s. - Doly Bílina) „Obnova kulové dráhy zakladače ZP6600.10“. A model consisting of a ball and a bottom part of the track was made. The sizes of both subjects were modified in accordance with the distance between the balls. The model is shown in the Picture 6.

4.2. Supporting – boundary conditions

The bottom part of the track is situated with its lowest area on a fixed support. The vertical areas of the bottom part, which are common with the missing symmetrical part, have so called symmetric placement. It means the placement which simulates internal forces in the common area of the model and the missing part. A similar symmetric placement was applied on the given areas at ¼ of the ball model. See Pictures 6, 7 and 8.

4.3. Model data

There was a mesh of finite elements of the type TETRA 10 created on the model. Their nominal size was 6,095 mm with a local mesh setting in the contact areas of the sphere with the lower part to a size of 0.2 mm of the element.

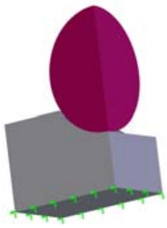

Fig. 6. The model of the contact between the ball and the groove

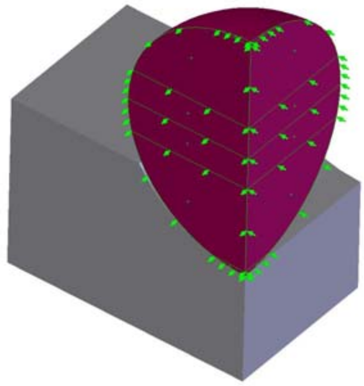

Fig. 7. Symmetrical placement of the ball

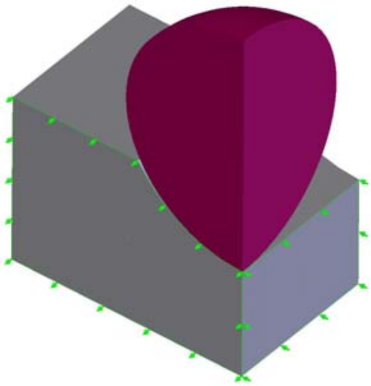

Fig. 8. Symmetrical placement of the part

4.4. Loading

The following loading affects the ball track of the heavy machine:

– permanent loading – the own weight of the ball and the own weight of the rotating top of the heavy machine;
– random loading:
  - caused by friction when rolling the balls,
  - caused by wind at the heavy machine,
  - caused by the lean of the heavy machine,
  - caused by the own substance of the material on the belt conveyors [10, 11].

4.5. Own weight of the ball track

The loading with its own weight of the model is generated by a program automatically for the weight acceleration g=10 $m.s^2$ [12, 13].

4.6. Own weight of the rotating top

The weight of the rotating top 1580 tons influences the ball track with the weight force Q = 15800 kN. It is divided into N = 301 ball with the same distance s = 125 mm. There is the maximal possible eccentric loading e = 3000 mm where the value of the maximal weight force F, influencing one ball, F_{max} = 2Q/N = 31600/301 = 105 kN. This means a double value with the same distribution of loading (e = 0 mm). The value of the ball loading is F_{jm} = 52,5 kN [14].

Loading with friction within the rolling ball

The resistance at friction is approximately 1% of the vertical loading of the ball. This loading is irrelevant.

Loading with wind at the heavy machine

It is included in the estimation of the own weight of the rotating top.

Loading of the lean of the heavy machine

It is included in the estimation of the own weight of the rotating top.

Loading of its own weight of the material on the conveyer belts

The probable weight of the material on the conveyor belts is 20 t, ie. 1,27 % from the total weight of the rotating top. This loading is irrelevant. Its influence on the eccentricity of the total weight of the rotating top is already included in the estimation of the won weight of the rotating top [15].

The loading of the model – see Figure 9.

4.7. Effective tenseness

The calculation was made with a linear statics for two loading states. One for the loading of a ball with the force F_{jm} = 52,5 kN and for the loading of the ball with the maximal force F_{max} = 105 kN. The contact of the two objects was secured by a condition „no penetration“.

The following Figures 10 and 11 show graphical results for the effective tenseness in accordance with the Mises Theory in the main planes of the given ellipsoid.

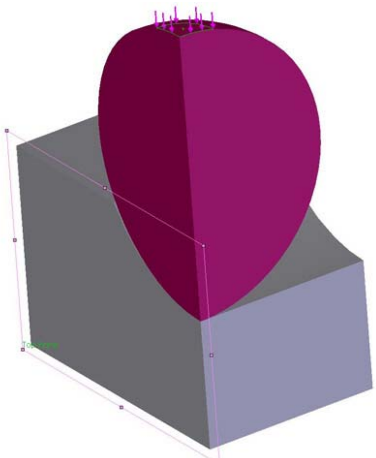

Fig. 9. Loading of the model

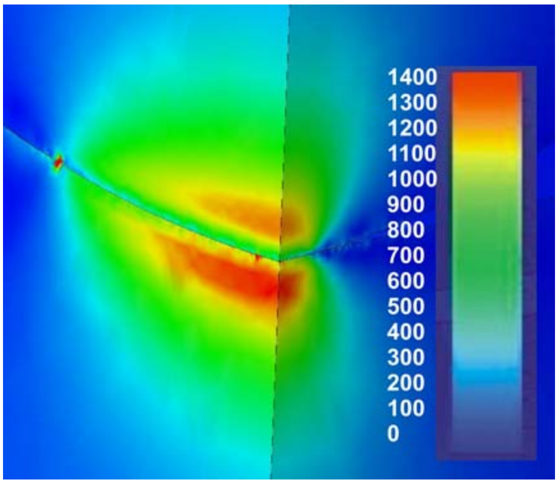

Fig. 10. Effective Strength at 105 kN according to von Mises

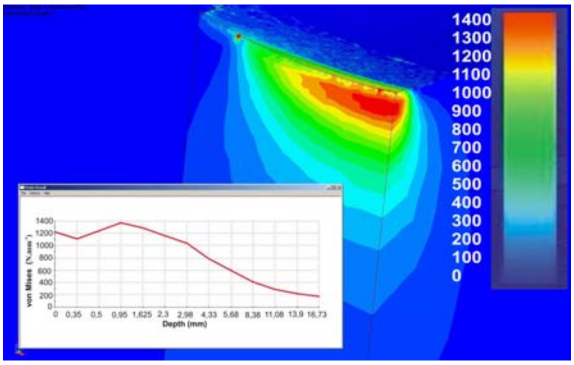

Fig. 11. Groove – effective tenseness for the loading 105 kN in the connection with the distance from the center of the contact

4.8. Contact pressures

The figures from 12 to 14 show in the graphical form of results for the contact pressures in the main planes of the given ellipsoid. The longer axis of the ellipsoid is located in the plane of the track groove cut, the shorter axis is in the direction of the tangent to the ball track [16].

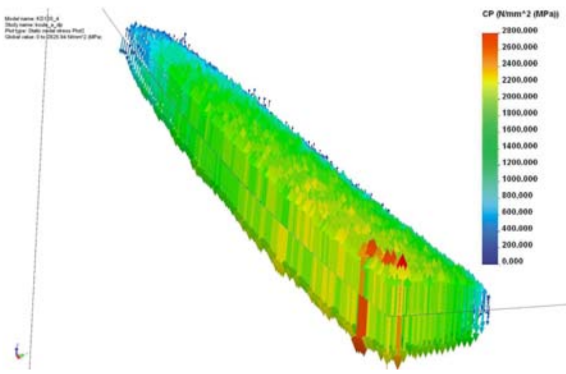

Fig. 12. ¼ of the ellipsoid for the contact pressures

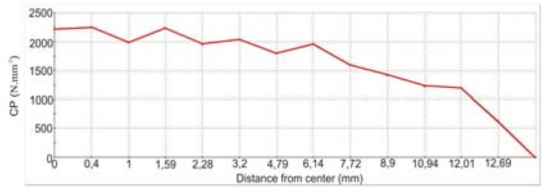

Fig. 13. The contact pressures in the contact of the ball with the bottom part for the loading 105 kN, longer axis of the ellipsoid; in connection with the distance from the centre of the contact

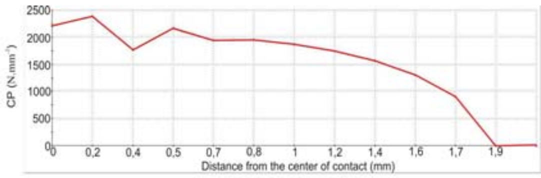

Fig. 14. The contact pressures in the contact of the ball with the bottom part for the loading 105 kN, shorter axis of the ellipsoid; in connection with the distance from the centre of the contact

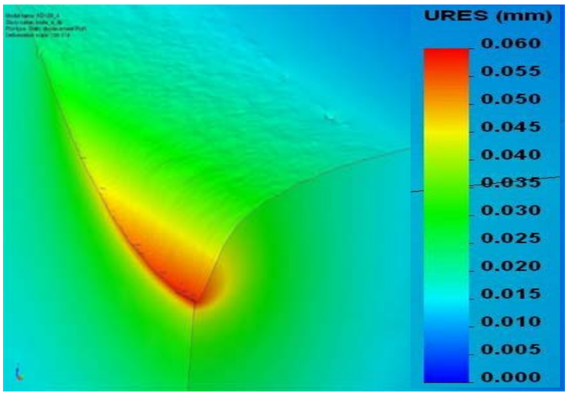

Fig. 15. Deformation of the groove of the track in the contact for loading 105 kN

5. SUMMARY

The results obtained can be summarized as follows:

1. Chemical structure proves the declared steel. The content of the carbon overreaches the limit a bit - 0,48% instead of max. 0,45%.
2. The hardness of the material increases from the surface to the depth 4÷6 mm, then it decreases. The values of the hardness are 246÷299 HV10. The firmness on the samples from the groove is lower 7 % in comparison with the samples taken out of the groove. The individual samples and their hardness do not overreach 10 %.
3. Metallographic analysis showed a change in the structure of samples from the groove crack – the depth was 0,6 mm. The change of the structure mainly depends on the dishomogeneity of the material and on the existence of the holes. The samples out of the groove showed no cracks and less dishomogeneity.
4. The contact pressures were calculated for nominal and maximal loading of the ball. The maximal loading is 105 kN and represents a double nominal loading and it will be never reached at the machine. The calculated progresses of the contact pressures have a shape of an ellipsoid with the centre in the contact point of both objects, the main axis is horizontal and it is located in the plane of the groove cut, the side axis is horizontal and lies in the plane of the tangent of the ball track. The progresses of the contact pressures in these axis are for the maximal loading and they are shown on the Figures 13 and 14. The contact pressures reach the maximal value of 2250 MPa in the centre of the objects contact. In accordance with the law of the ellipsoid they decrease to zero. In the main axis the distance is about 12 mm. In the side axis the distance is about 1,9 mm. For the nominal loading of the ball (52,5 kN), the contact pressures reach the maximal value 1600 MPa in the center of the objects contact.
5. Maximal deformation of both objects in the contact point is 0,06 mm. See Figure 15.
6. Maximal effective tenseness is in the centre of the contact of both objects. It increases from the surface to the depth at about 1 mm (1400 MPa) and then it decreases. At a depth of 3.6 mm, it is already below the material strength of 880 MPa. The progress of the effective tenseness corresponds the laboratory results well in the sense of the plasticization of the material in the places of dishomogeneity into the depth of 0,6 ÷1 mm.
7. The progress of the contact pressures CP can be shown by the following graph, where we can specify the equation of the ellipsoid.
8. The above mentioned proves that the material of the bottom part of the ball track is influenced with the operation of the ball track into to depth of about 3,6 mm (cracks, change of the structure, packing).
9. Before the future use of the parts of the ball track it is recommended to remove the upper layer of the material in the groove to the depth of 3,6 mm.
10. The plan for the future is to change the material of the lower part of the track.
11. We plan to subject design to further simulations for better distribution of contact pressures.

SOURCE OF FUNDING

The problem was solved and the article was written in cooperation with the companies SD a. s. – Doly Bílina and UNIPETROL RPA s.r.o. The author thanks for his cooperation to all who are involved in the solution.

This paper is the result of the project implementation: VEGA 1/0766/15 "Research of noise emissions sources in the railway transport and methods of their effective reduction.

REFERENCES

1. Hojdar J, Helebrant F, Gondek H. Povrchové dobývací stroje I, Ostrava 1991.
2. Klouda., P. Měření stavu kulové dráhy ZP6600/Z79 na DB, VÚHU a.s., č.TPD-002/14.
3. SKF, Mechanismus poškození, Evolution 4/2012
4. Šimůnek J. Části strojů pro povrchovou těžbu – kolesová rýpadla, Ostrava 1985.
5. Stuchlý V, Poprocký R. Údržba strojov a zariadení; vedecký redaktor: Peter Palček. - 1. vyd. – Žilina, Žilinská univerzita, 2013
6. Blatnický M, Dižo J. Structural design and strength analysis of parts of the hydraulic arm intended to be mounted on light truck chassis. Diagnostyka, 2016; 174: 39-48.
7. Zvolensky P, Stuchlý V, Grenčík J, Poprocký R. Evolution of maintenance systems of passenger and freight wagons from the ECM certification point of view. Communications: scientific letters of the University of Žilina, 2014; 16(3A): 40-47.
8. Grenčík J. Manažérstvo údržby: synergia teórie a praxe / - 1. vyd. - Košice: Beki Design, 2013.
9. Blatnický M, Dižo J. Use of multibody system dynamics as a tool for rail vehicle behaviour diagnostics. Diagnostyka, 2016; 17(2): 9-16.
10. Pačaiová H, Grenčík J, Legát V. Maintenance effectiveness and its performance measurement methods. Maintworld: maintenance and asset management, 2011; 4: 10-15.
11. Grenčík J. Proactive operation.In: Maintworld: maintenance and asset management,2013; 5(3): 26-27.
12. Wieczorek AN. Designing machinery and equipment in accordance with the principle of sustainable development. Managament Systems in Production Engineering, 2015; 1(17): 10-13. DOI 10.12914/ MSPE-05-01-2015
13. Grenčík J. Harmonisation of maintenance performance indicators. Diagnostyka, 2009; 2(50): 3-6.
14. Stuchlý V, Poprocký R, Kaczmarek M. Reliability evaluation as a means of increasing the efficiency of equipment maintenance. Advances in science and technology. Research Journal, 2016; 10(32): 40-46.
15. Grenčík J, Legát V. Maintenance audit and benchmarking - search for evaluation criteria on global scale. Eksploatacja i Niezawodność - Maintenance and Reliability, 2007; 3:34-39.
16. Galliková J, Poprocký R. Computer-aided analysis and the consequences of failures of the selected vehicle subsystem. TRANSCOM; 2015: 58-63.

Received 2017-06-20
Accepted 2017-08-18
Available online 2017-08-21

Jan BLATA an assistant professor at VŠB - Technical University of Ostrava, Faculty of Mechanical Engineering, a head of the approved training center at ATD ČR in the field of thermodiagnostics and tribodiagnostics.

Ľubomír KAŠIAR received his B.Sc. degree in 2013 and M.Sc. in 2015 in mechanical engineering from the University of Žilina. He is currently the Ph.D student in the field Maintenance of transport means at the University of Žilina and he is working on the oriented on technical diagnostics.

David ŠEDĚNKA finished his bachelor's study in 2012 and his post-graduate master's degree at VŠB-TU Ostrava in 2014. He is currently studying in the doctoral study program at VŠB-TU Ostrava in a program focused on technical diagnostics of machines.

Peter VOLNA received the Master degree, in Mechanical Engineering at the University of Žilina. He is a PhD student in Mechanical Engineering at the University of Žilina and his thesis is oriented on reliability, availability, maintainability and safety of technical systems.