Journal of Achievements in Materials and Manufacturing Engineering

VOLUME 46
ISSUE 2
June
2011

Frictional couplings of wheel with a rail in a brake control system of rail vehicles

A. Baier [a], A. Niedworok [b,*]
[a] Institute of Engineering Processes, Automation and Integrated Manufacturing Systems, Silesian University of Technology,
ul. Konarskiego 18a, 44-100 Gliwice, Poland
[b] Laboratory of Applied Science, KOMAG Institute of Mining Technology,
ul. Pszczyńska 37, 44-101 Gliwice, Poland
* Corresponding author: E-mail address: aniedworok@komag.eu

Received 03.04.2011; published in revised form 01.06.2011

Manufacturing and processing

ABSTRACT

Purpose: Discussion on use of frictional coupling of wheel with a rail for detection of surface condition of track ways in coal mine undergrounds is the paper objective.
Design/methodology/approach: The method for detection of surface condition of track ways is based on using of dedicated converter installed on the locomotive chassis with active part in a form of "tracking wheel" that moves on the rail surface together with the locomotive. The converter is equipped with a system for torque load and a sensor measuring its rotational speed. Change of track surface is determined by momentary changes in rotational speed of "tracking wheel" due to its slippage.
Findings: The described method for detection of track ways surface condition enables to generate information signal which transferred to master braking control system of the locomotive eliminates excessive slippage during braking.
Research limitations/implications: The presented results confirm rightness of accepted method for detection of track ways surface condition indicating for necessity of modification of developed test rig to get repeatable information about current track surface.
Originality/value: The method for detection of track ways surface condition is the novelty approach to braking of rail locomotives used in the mining industry. It is also an alternative option to the present solutions based on known ABS (Anti-Lock Braking System) system used in automotive industry.
Keywords: Frictional coupling; Friction; Slippage; Braking; Rail locomotive

Reference to this paper should be given in the following way:
A. Baier, A. Niedworok, Frictional couplings of wheel with a rail in a brake control system of rail vehicles, Journal of Achievements in Materials and Manufacturing Engineering 46/2 (2011) 182-188.

1. Introduction

The problem of dangerous slippage during braking of rail vehicles including mine locomotives was a reason of undertaking R&D projects aiming at development of method for detection of track ways surface condition to ensure slipless braking at changeable condition of the track surface. The present brake systems of rail vehicles use ABS (Anti-Lock Braking System) system, known in the automotive industry, for slippage detection [1]. The principle of operation of such a system requires a minimum drive wheel slippage, what is not consistent with the standard requirements put to systems of this type of vehicle braking systems [2] (according to the standards rail vehicles should brake without slippage). Basing on the requirements of standards and striving for achievement of slipless braking, the method for assessment of current track surface condition, basing on use of frictional coupling of wheel with a rail, was suggested.

2. Requirements of the standard for braking systems of rail locomotives

Safety requirements for mine locomotives are included in PN-EN 1889-2+A1:2010 Standard: "*Machines for underground mining industry - Underground self-propelled machines -- Safety -- Part 2: Rail locomotives*" [2]. As regards the discussed problems the requirement of equipping the rail locomotive with main brake, emergency brake and parking brake is most important. Each of the systems should realize the braking process in such a way that: "*...Braking characteristics should be selected to stop the train without any slip and on possible shortest distance that reflects expected friction between wheels and rails at given load and inclination...*" [2]. Additionally the standard says that time between main brake or emergency brake initiation and achievement 90% of minimal braking force should not exceed 2 seconds [2].

Presented standard specifies features of the braking system of mine locomotive, which should be included in designing process and testing the machine. The tests are the basis for the certificate that permits use of the machine. Braking systems in the majority of manufactured mine locomotives meet the presented requirements. However, it should be noted that majority of the machines are the prototypes tested in a laboratory. During the tests manufacturers of machines are aware of the need to comply requirements of the PN-EN 1889-2+A1:2010 Standard, so they prepare dry and clean testing track. That is why during tests of braking systems proper friction coefficient between wheels and a rail is reported. Such testing conditions enable meeting of requirements of the standard that does not allow any slippage.

When comparing conditions that are during certificating tests with the real contortions (mine undergrounds) we have to include a possibility of significant deterioration of frictional conditions between wheels and a rail. Such deterioration is caused among others by contamination of rails with mixture of water and coal dust or what is worse with lubricants and oils. In such a situation reduction of friction coefficient can cause machine's slippage and can dangerously extend barking distance.

It should be noted that discussed systems for detection of slippage, based on known ABS (Anti-Lock Braking System) system used in automotive industry, do not meet requirements of the standard as shortening of braking distance is realized by cyclical brake activation and deactivation till the moment of minimal (safe) speed.

Thus, a possibility of applying the alternative method basing on constant analysis of track surface condition, should taken into consideration. Information signal about condition of the surface transferred to master brake system's controller of the machine would enable selecting the braking torque in such amount to not block the wheels. Such a solution would ensure effective shortening of brake distance with meeting requirement of the standard at the same time.

3. Method for detection of conduction of trackway surface

Method for detection of trackway surface condition is based on the developed converter installed on the locomotive chassis with active part in a form of "tracking wheel" that moves on the rail surface together with the locomotive. General concept of installation of the converter in chassis of rail locomotive was presented in Fig. 1.

Measurement converter was built of a small wheel, which rolls just on a rail ("tracking wheel"). PMDC motor and rotational incremental encoder were installed on one axle with the "tracking wheel". Entire device was installed on the locomotive chassis, on the cushioned arm, in rail axis [4]. The arm task is to ensure constant force of pressing of the "tracking wheel" to the rail (F_d) to reduce potential track unevenness [5].

The principle of operation of the system is as follows: during movement of rail vehicle the electric motor generates small braking torque (M_h) (of sense opposite to the direction of run). The torque value was selected in such way that "tracking wheel" was moving with a direction of machine travel. Detection of condition of trackway surface is realized by measurement and current analysis of rotational speed of the "tracking wheel" (n_p). Measurement of speed is realized through encoder. When the track is dry, rotational speed of "tracking wheel" is proportional to speed of rail vehicle movement. In the case of vehicle movement on a slippery section of the trackway (e.g. covered with oil) friction coefficient between converter wheel and rail suddenly decreases. Then the braking torque, which is generated by small electric motor, causes decrease of rotational speed (n_p). Microprocessor electronic system, which is an integral part of measurement converter, assesses condition of trackway surface on the basis of current analysis of momentary values of "tracking wheel" rotational speed. Obtained information is transformed into a signal, which is transferred to master braking control system of the rail locomotive. The system selects, if necessary, a value of braking torque in such way to eliminate dangerous slippage.

Place for installation of measuring system is selected depending on the design of chassis of a given type of locomotive [6]. Presented detection method can be used only in the case of rail locomotives equipped with braking system with a possibility of adjustment of its braking torque.

4. Stand for testing of frictional contact of wheel with rail

Verification of the method for detection of condition of trackway surface required carrying out tests of contact phenomena between rail and wheel. The "tracking wheel" of measurement converter was analyzed in a discussed case. A test stand, diagram of which is presented in Fig. 2, was designed for that purpose [7] [15]. It consists of steel disc, task of which is to simulate the trackway rail. Due to limited technical possibilities, a plane motion was changed into a rotational motion, which is easier in realization. External surface of disc is a path on which tested measurement converter ("tracking wheel") moves. The disc is driven by an electric motor *M* connected to the gear. Rotational torque of the motor and its rotational speed are adjusted through frequency converter. Encoder, task of which is measurement of rotational speed (n_b), was installed on disc axle, which simulates the rail.

A prototype of the converter, which was designed to determine condition of trackway surface, was installed on a path surface. According to the accepted concept, it consists of rolling wheel system, which is axially connected with DC motor and encoder. This system was installed above the path, on cushioned arm, which can adjust pressing force (applied by a screw, which presses a spring). A strain gauge force converter, which is placed between a spring and a component fixing the "tracking wheel", was used to determine precisely pressing force of the converter acting on path [8,9,11].

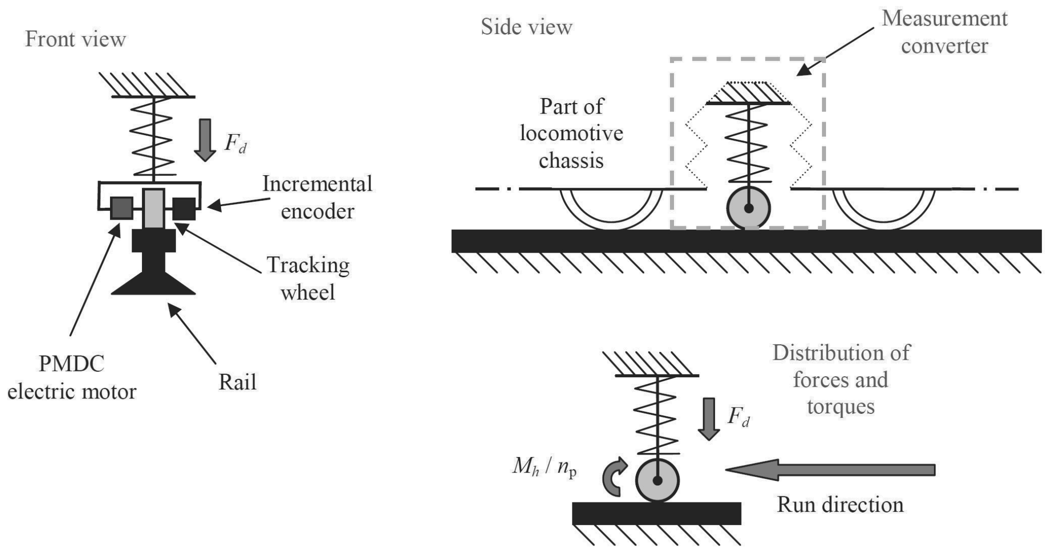

Fig. 1. Suggested method of converter installation in rail locomotive chassis [3]

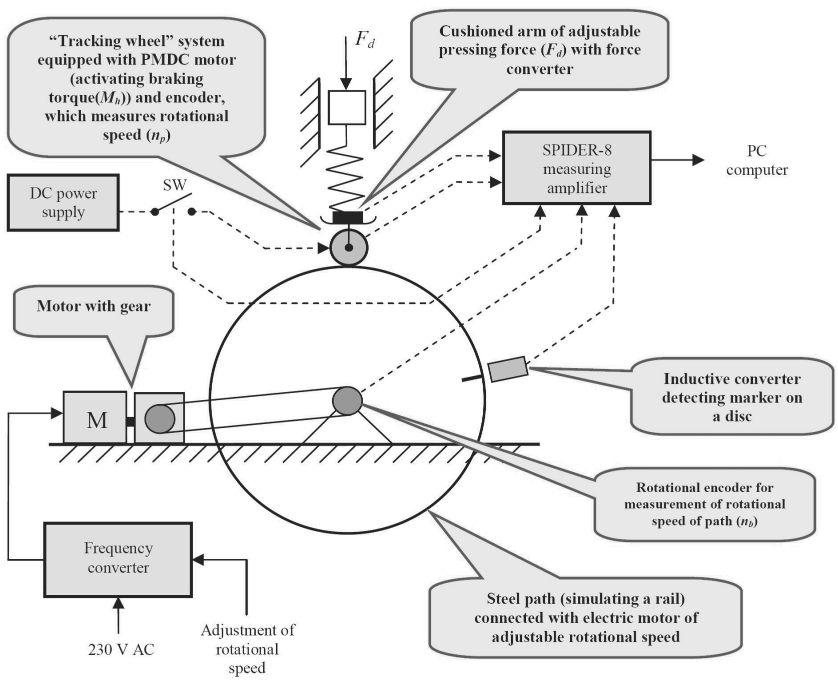

Fig. 2. Diagram of test stand [3]

The test stand was equipped with a system, which determines position of the contact point of "tracking wheel" with a path, to identify contamination of the path with substances decreasing or increasing friction coefficient.

This system consists of marker (placed on a side plane of a disc) and inductive converter, which detects the presence of the marker.

Incremental encoders were used as the converter for measurement of rotational speed of the "tracking wheel" and a path.

Electric motor, task of which is generation of braking torque (M_h), is supplied from DC power supply. Braking torque is adjusted by changing of adapter current limit. Voltage signal measured at contacts of SW switch was used for precise detection of time of applying of braking torque. Acquisition of measuring data was realized by 8-channel SPIDER-8 measuring amplifier manufactured by HBM. Measuring process is controlled by specialist CATMAN® software. The following is recorded during the measurements:

- rotational speed of the path n_b [rpm],
- rotational speed of the "tracking wheel" n_p [rpm],
- pressing force of the "tracking wheel" to path F_d [N],
- presence of marker on path disc - logic signal: 0 - present, 1 - absent,
- condition of contact of motor circuit generating braking torque [ON / OFF].

In Figs. 3 and 4 photos of test rig were given.

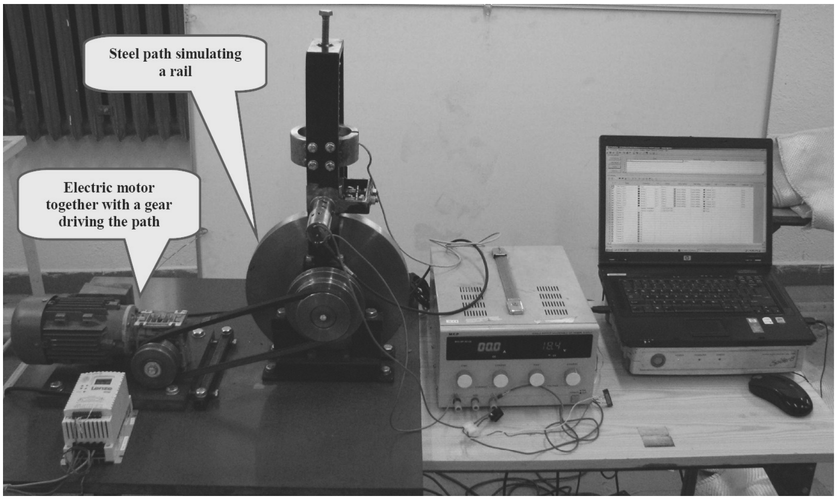

Fig. 3. View of the testing rig [4]

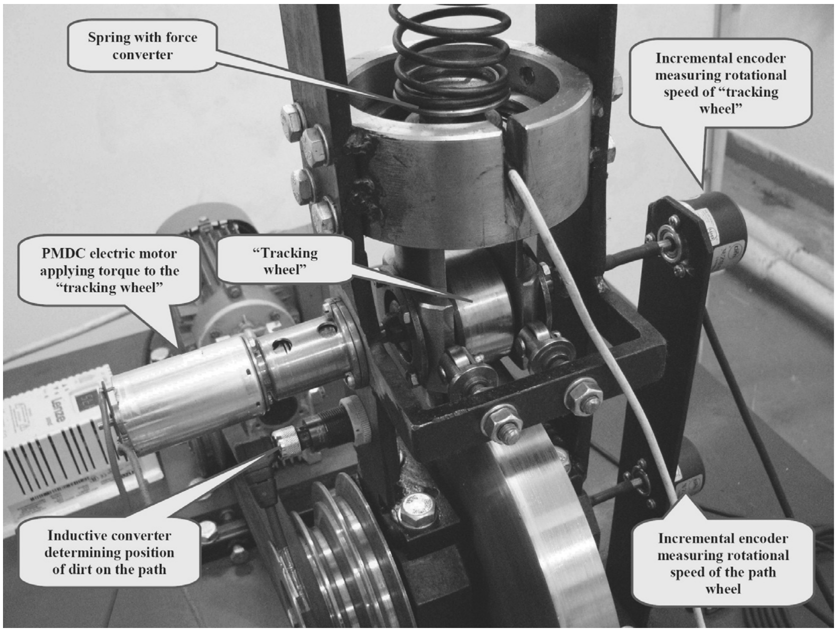

Fig. 4. View of the "tracking wheel" with a motor and incremental encoder [4]

5. Initial tests results

Initial tests were carried out to verify suggested method for detection of condition of trackway surface. Behaviour of the system in conditions of movement on a dry track (cleaned and degreased using isopropyl alcohol) and on a track evenly covered with oil film (Hipol Mineral oil) was presented in the paper. Time processes of rotational speed of “tracking wheel” (n_p) for four path speeds (n_b), separately for dry and for oiled track, were presented in Fig. 5 and Fig. 6. In both cases motor current (I_M) generating braking torque (M_h) was equal to 1.5 A and force pressing the converter to the path (F_d) was equal to 60 N.

Hatched areas mean time intervals and inform about applied braking torque (M_h).

Fig. 5. Diagram of rotational speed of the “tracking wheel” n_p for four path speeds n_b for dry track (F_d=60 N, I_M=1.5 A)

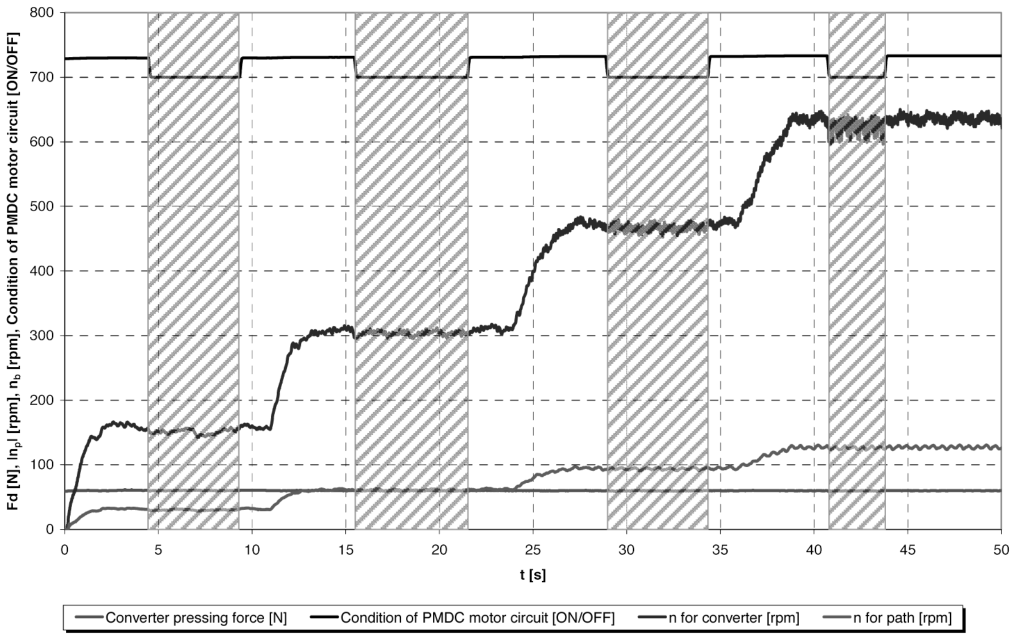

Fig. 6. Diagram of rotational speed of the “tracking wheel” n_p for four path speeds n_b for oiled track (F_d=60 N, I_M=1,5 A)

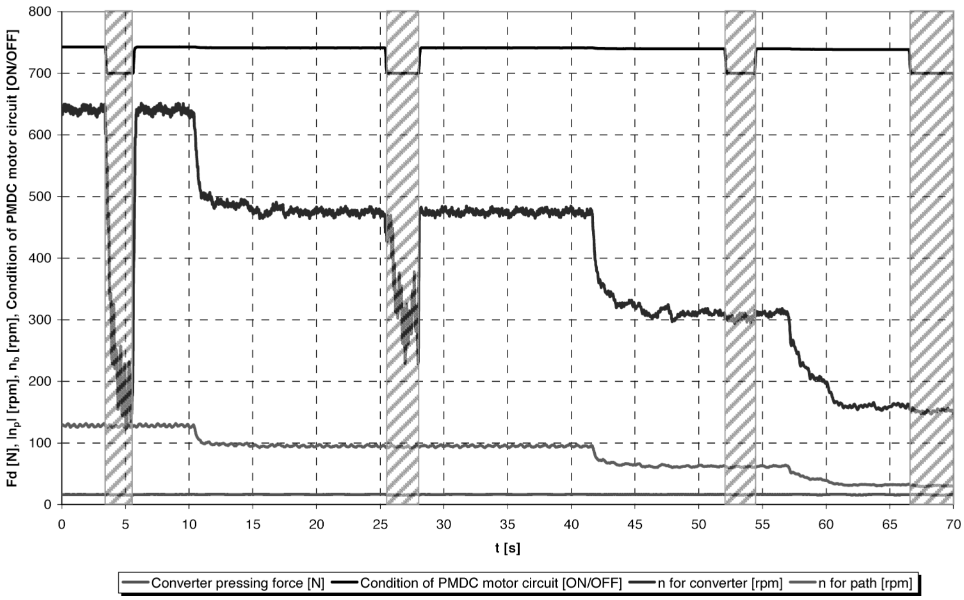

Fig. 7. Diagram of rotational speed of the "tracking wheel" n_p for four path speeds n_b for oiled track (F_d=16 N, I_M=1.5 A)

Initial analysis of obtained tests results proved that:

- in the case of dry track (cleaned and degreased) application of braking torque did not cause significant changes in speed of "tracking wheel" in the tasted range of changes of path rotational speed (150 - 650 rpm),
- in the case of oiled track (evenly covered with oil film) application of braking torque caused significant reduction of rotational speed resulting from slips of the "tracking wheel",
- in the case of oiled track, reduction of speed of "tracking wheel" was noticed only for high "travel speed" (high rotational speed of path)

Time process of rotational speed of "tracking wheel" (n_p) for four selected speeds of path (n_b) for oiled track are presented in Fig. 7. Current parameters of motor were the same as in Fig. 5 and Fig. 6 (I_M = 1.5 A). This time value of pressing force F_d, which was equal to 16 N, was reduced.

The following has been concluded on the basis of test results:

- strong dependence of the "tracking wheel" on pressing force F_d during application of braking torque,
- reduction of pressing force F_d increases range of "travel speed" (path rotational speed), for which detection is possible.

6. Conclusions

Presented in the paper method for detection of condition of trackway surface, which is based on using of coupling of wheel with a rail, is a novelty approach to increase of safety associated with braking of rail locomotives used in the mining industry. Continuous analysis of friction coefficient (traction), regardless of whether the machine accelerates, moves with uniform motion or it brakes, is the main advantage of the discussed method. It gives preceding information to master system controlling the brakes, which can select proper parameters of braking system operation in advance.

Developed test stand as well as the initial tests, which were carried out at this stand, confirm the rightness of the selected method. Comparative tests (for the same settings of braking torque (M_h) and path rotational speeds) showed significant reduction of rotational speed of "tracking wheel" in the case of movement on oiled track. Results of initial tests showed imperfections of the method, among others narrow range of path rotational speed, for which slippage can be detected.

Obtained tests results will be used for improvement of testing method and improvement of design of test stand to obtain repeatable information about present condition of the surface on which a converter, coupled with rail locomotive, moves.

References

[1] A. Niedworok, Literature analysis of the problems associated with electronic control of rail vehicles braking and tests assessing possibility of use of multi-disk brake as the actuating component in braking, Study developed within the task "Electronic system to control braking of mine underground locomotive", Initiatory grant - not published, KOMAG Institute of Mining Technology, 2009 (in Polish).

[2] PN-EN 1889-2+A1:2010, Machine for mining industry. Underground self-propelled machines. Safety. Part 2: Rail locomotives, Polish Committee for Standardization, Warsaw, 2010.

[3] A. Niedworok, Patent application P.394073 dated 01.03.2011, Organization: KOMAG Institute of Mining Technology (in Polish).
[4] A. Baier, M. Majzner, Journal of Achievements in Materials and Manufacturing Engineering 43/2 (2010) 577-585.
[5] A. Buchacz, Modelling, synthesis, modification, sensitivity and analysis of mechanic and mechatronic systems, Journal of Achievements in Materials and Manufacturing Engineering 24/1 (2007) 198-207.
[6] D. Guidaa, F. Nilvetti, C.M. Pappalardo, Parameter identification of a fullcar model for active suspension design, Journal of Achievements in Materials and Manufacturing Engineering 40/2 (2010) 138-148.
[7] A. Niedworok, Design assumptions for construction of the stand for testing frictional coupling of wheel with rail, Statutory project No. EG/E42-11764 - not published, KOMAG Institute of Mining Technology, 2010 (in Polish).
[8] D. Hadrys, M. Miros, Coefficient of restitution of model repaired car body parts, Journal of Achievements in Materials and Manufacturing Engineering 28/1 (2008) 51-54.
[9] S. Yanai, Y. Itoh, T. Nemoto, M. Kihira, H. Matsuura, Development of portable driving simulator system, Journal of Achievements in Materials and Manufacturing Engineering 29/2 (2008) 207-210.
[10] A. Baier, Method of integration of design and manufacturing processes, of functional groups of machines using a complex feature, Scientific Papers Silesian University of Technology, Gliwice, 2006.
[11] A. Baier, Aiding of design, virtual creation and investigation of machine elements and group of elements, Proceedings of the 3rd Scientific Conference "Materials, Mechanical and Manufacturing Engineering" MMME'2005, Gliwice-Wisła, 2005, 639-644.
[12] A. Baier, M. Majzner, Modelling and testing of composite fiber, Design and Construction Engineering 9/39 (2010) 22-28.
[13] M. Majzner, A. Baier, T. Koprowski, The position of the delamination of composite materials studies, Opencast Mining 4 (2010) 14-18.
[14] M. Majzner, A. Baier, Modeling of the selected composite elements, Opencast Mining 4 (2010) 218-221,
[15] A. Baier, J. Świder, M. Majzner, Research and analysis of the properties of composites for the construction of wagons, Design and Construction Engineering 11/38 (2010) 20-29.