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LABORATORY WEAR ASSESSMENT OF SELECTED ELEMENTS OF RAILWAY TRANSPORT MEANS

Summary. Wheel – rail friction is a basic phenomenon that enables railway transport running. That friction is accompanied by a wear, that determines wheels durability and reliability. Wear influences strongly the railway transport safety.
Wear of railway wheels depends on their working conditions and also on their material. In this paper results of laboratory tests that simulated tribological pair wheel flange – rail side have been presented. The results enabled to determine the influence of selected working conditions i.e. load, sliding distance and velocity, and also material parameters such as chemical composition and hardness on the wear of simulated pair.

LABORATORYJNA OCENA ZUŻYCIA WYBRANYCH ELEMENTÓW ŚRODKÓW TRANSPORTU SZYNOWEGO

Streszczenie. Tarcie pomiędzy kołem kolejowym a szyną jest podstawowym zjawiskiem umożliwiającym funkcjonowanie transportu kolejowego. Towarzyszy mu zużycie trybologiczne, decydujące między innymi o trwałości i niezawodności kół kolejowych. Wywiera ono również znaczący wpływ na bezpieczeństwo transportu kolejowego.
Zużycie kół kolejowych zależy od warunków ich pracy, a także od materiału, z którego są wykonane. W pracy przedstawiono wyniki badań laboratoryjnych, w których modelowano skojarzenie obrzeża koła kolejowego – bok główki szyny. Wyniki te pozwoliły na określenie wpływu wybranych warunków współpracy, tj. obciążenia, drogi tarcia i prędkości oraz parametrów materiałowych, obejmujących skład chemiczny i twardość, na zużycie modelowanego skojarzenia.

1. INTRODUCTION

A friction is for ages a basic phenomenon utilized in transport. It lets also running a railway one. Despite the existence of a magnetic railway, which trains reach a speed of 500 km/h [1], a continuous development of conventional railways takes place. Opening in 1st July 2006 a 4064 km long, conventional railway line from Peking to Lhasa in Tibet confirms this. The highest point of this line is situated 5072 meters above sea level what is a world record.

Conventional trains can also compete with magnetic ones in achieving high speeds. A French TGV train achieved in 3rd April 2007 a speed of 574.8 km/h. These examples of conventional railways development prove that, the railway transport based on a friction phenomenon is and will be of great importance.

A friction causes a tribological wear. The elements of rail vehicles with one of the highest wear rates are wheels. The wear determines their durability, reliability and thus the safety of railway transport. The most significant is the wear of flanges when they slide over the outer rail in curved track in the dry friction conditions [2, 3]. So sliding wear testing machines are used to simulate the tribological pair: wheel flange – rail side and to investigate the wear of the elements of that pair [2, 4].

The wear depends on working conditions, such as: load, sliding distance and speed [5, 6]. Wheel material parameters such as: chemical composition and hardness also significantly influence the wear [2, 4, 5].

In this work the influence of above mentioned factors on wear of specimens made of steels grades 45 and 55 (according to Polish Standard PN-93/H-84019). These steels can be used to simulate materials used for railway wheels manufacturing [7].

2. EXPERIMENTAL

The purpose of this work was to study the influence of load, sliding distance and speed on wear behaviour of specimens made of steels corresponding to these ones used in railway transport for wheels. To achieve this goal some laboratory wear tests have been carried out. The tested materials were two medium – carbon steels grades 45 and 55. Their chemical composition and hardness are presented in table 1.

Table 1

Chemical composition and hardness of the tested steels

Steel	Chemical composition											HB
	C	Mn	Si	P	S	Cr	Ni	Cu	Al	Mo	Sn	
45	0,47	0,69	0,23	0,007	0,019	0,14	0,18	0,22	0,021	0,06	-	250
55	0,58	0,61	0,2	0,014	0,014	0,09	0,05	0,14	0,004	0,001	0,001	206

Laboratory wear tests were conducted on a modified Timken wear testing machine. The two counterbodies were cylinders with perpendicular axes (Fig. 1). Specimens made of the tested materials were cylinders with a diameter of 10 mm. Counter - specimens were bearings type 30204A outer rings with a diameter of 47 mm, These rings were made of steel grade ŁH15, with a hardness of 62 HRC. During the tests a counter – specimen rotated while a specimen was motionless. The result of rubbing in each test was a wear scar on the surface of a specimen (Fig. 2). Dimensions of these scars have been utilized to calculate a wear volume with the aid of an optical method described elsewhere [8].

Test parameters were as follows:

- load P,
- sliding speed (linear velocity of the outer surface of a counter - specimen) v,
- sliding distance L.

Because of an increase of a wear scar surface during the test a pressure decrease in counterbodies contact took place. From this reason it was unable to characterize the load by pressure. So a normal force between the specimen and counter – specimen has been used as a load.

139 tests have been carried out. Thee different normal loads (63.1, 108.2 and 153.3 N) were applied. Sliding speeds were as follows: 0.12, 0.25, 0.36 and 0.49 $m \cdot s^{-1}$ Tests were performed for the following sliding distances: 7.38, 14.76 and 22.15 m.

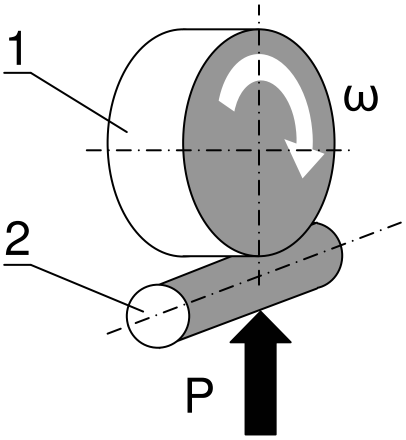

Fig. 1. A scheme of the research system: 1 – counter-specimen; 2 – specimen, P – load, ω – angular speed of the counter-specimen

Rys. 1. Schemat systemu badawczego: 1 – przeciwpróbka; 2 – próbka, P – obciążenie, ω – prędkość kątowa przeciwpróbki

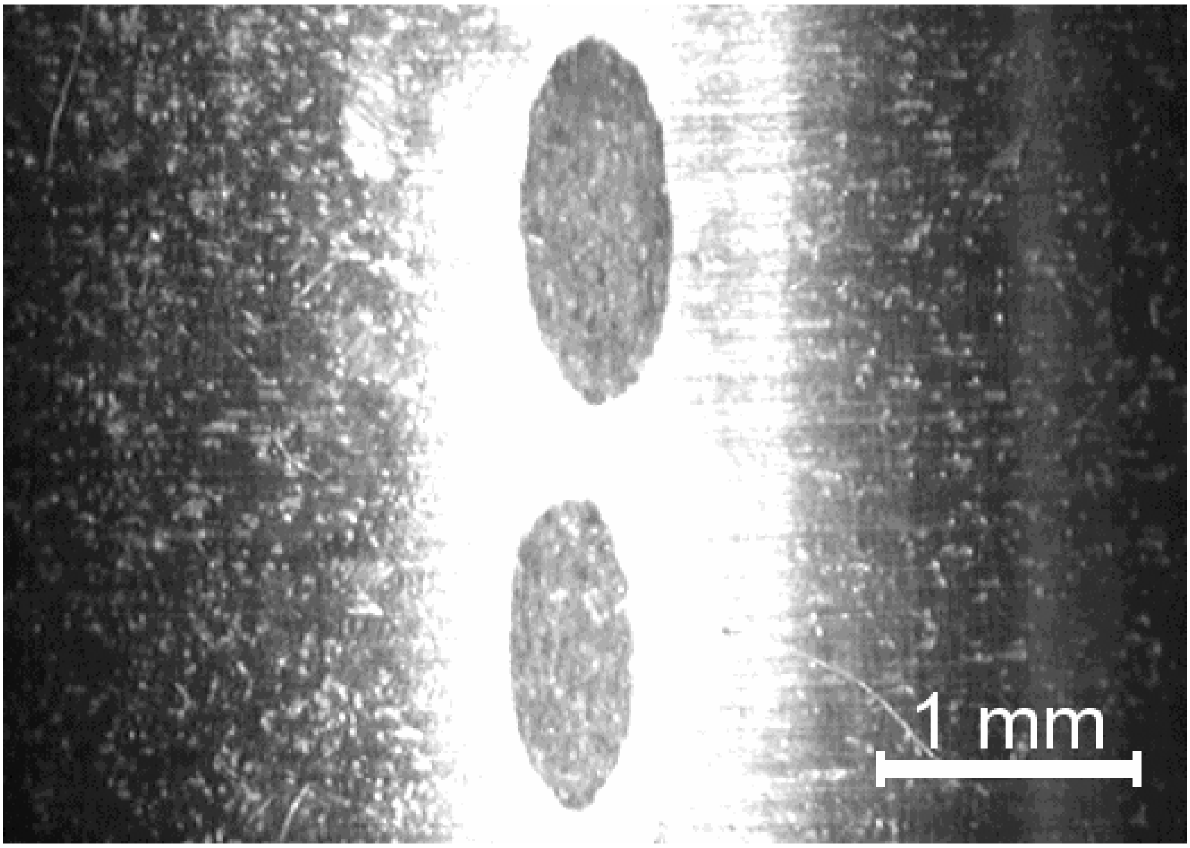

Fig. 2. Examples of wear scars obtained on specimens made of steel grade 45

Rys. 2. Przykładowe ślady zużycia otrzymane na próbce ze stali 45

3. RESULTS AND DISCUSSION

In Fig. 3 the influence of sliding distance and load on the wear volume of the steel grade 55 has been presented. This figure shows that an increase of these parameters causes an increase of the wear volume. Such influence of the load on the wear may be caused by an abrasive wear intensification.

Because of significant greater hardness of counter-specimens than the specimens, an intense microcutting of the latter may happen when the load increases. A longer rubbing in dry conditions corresponding to greater values of sliding distance results in greater wear volume of specimens. Wear volumes presented in Figs 3 – 6 are averages from three tests.

Figs. 4 - 6 show the dependence between sliding distance, speed and wear of the steel grade 45 for different loads. For the lowest and medium tested loads an increase of sliding speed decreases the wear, except the test with the lowest tested sliding distance (Fig. 4 and 5). The reason of this decrease may be the presence of the oxide films on the rubbing surfaces caused by frictional heating intensification [9]. These oxides prevent metal – to – metal contacts and adhesion which lowers the wear [9]. The shortest, tested sliding distance is probably too small to form an oxide film thick enough to protect effectively the rubbing surfaces and almost no speed effect on wear behaviour of tested steel have been observed (Fig. 4). The higher loads in connection with a high speed can produce a frictional heating enough to decrease the wear with the increase of sliding speed from 0.25 to 0.36 $m \cdot s^{-1}$, even if the sliding distance is small (Figs. 5 and 6).

For the highest tested load and greater sliding distances a beneficial influence of speed increase on wear can be observed only for speed increase from 0.12 to 0.25 $m \cdot s^{-1}$. If speed increases from 0.25 to 0.36 $m \cdot s^{-1}$, a wear increase has been observed (Fig. 6). The probable reason of this increase may be an oxide film growth and removal intensification in higher temperature. Nevertheless the wear volume for the sliding speed of 0.36 $m \cdot s^{-1}$ and sliding distance of 14.77 and 22.15 m still remains smaller than for the 0.12 $m \cdot s^{-1}$ (Fig. 6). This shows the beneficial effect of oxides on wear of the tested steel.

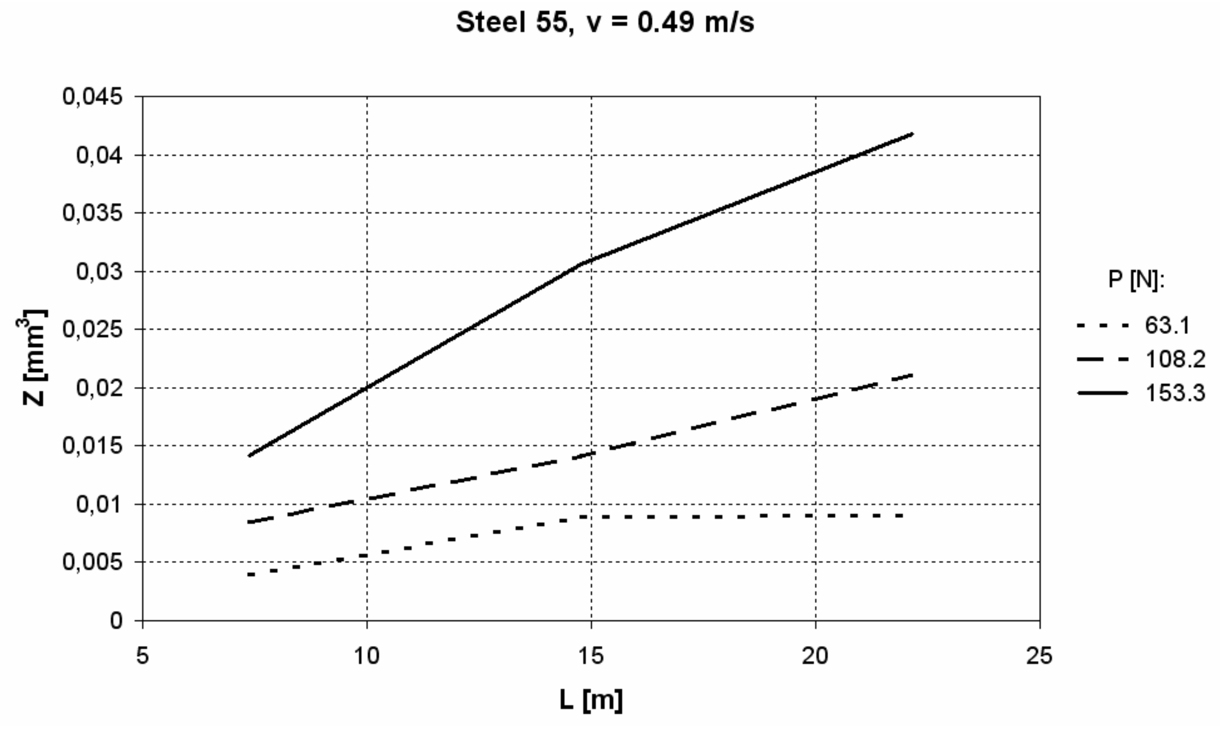

Fig. 3. The influence of sliding distance and load on wear volume of steel grade 45, for a sliding speed of 0.49 $m \cdot s^{-1}$

Rys. 3. Wpływ drogi tarcia I obciążenia na zużycie objętościowe stali 45 dla prędkości poślizgu 0.49 $m \cdot s^{-1}$

The wear of both the tested steels has been presented in Fig. 7. This figure shows quadratic surfaces fitted to the test results with the aid of the Levenberg – Marquardt method. As can be seen in Fig. 7 the wear of the tested steel grade 45 is lower than the 55 one, despite the higher carbon content of the latter (table 1). The reason of this may be significant higher hardness of the steel grade 45 which increases its wear resistance [4].

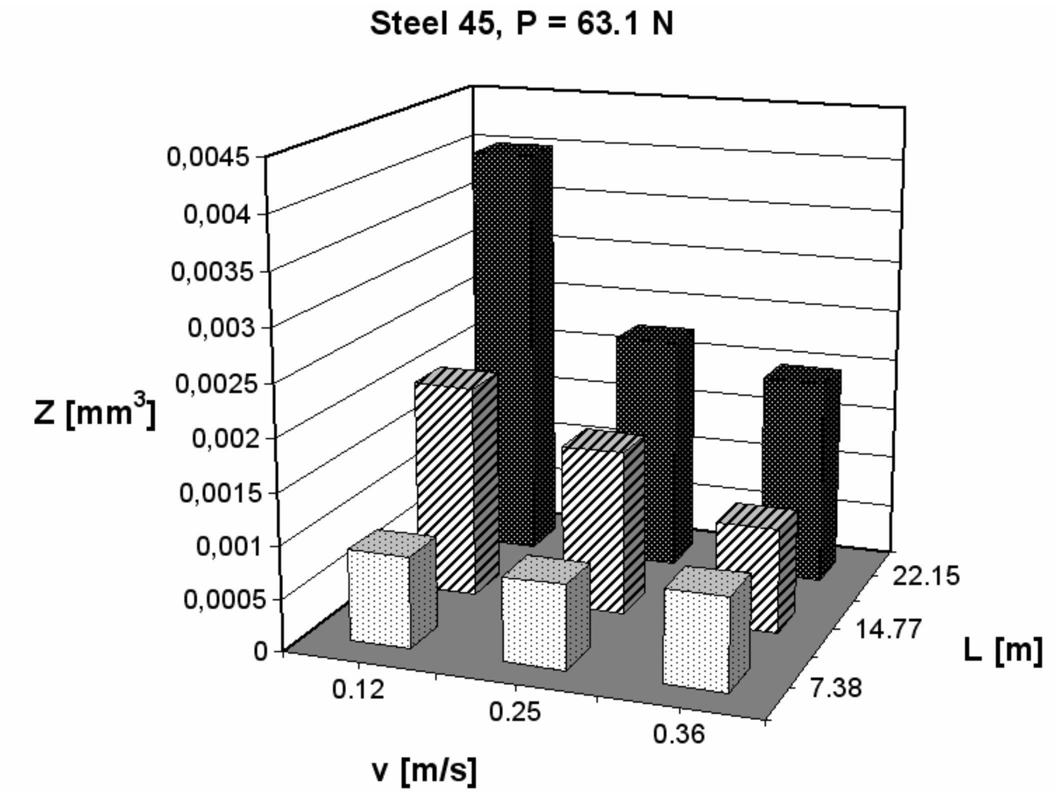

Fig. 4. The influence of sliding speed and sliding distance on wear volume of steel grade 45, for a load of 63.1 N
Rys. 4. Wpływ prędkości poślizgu i drogi tarcia na zużycie objętościowe stali 45 dla obciążenia 63.1 N

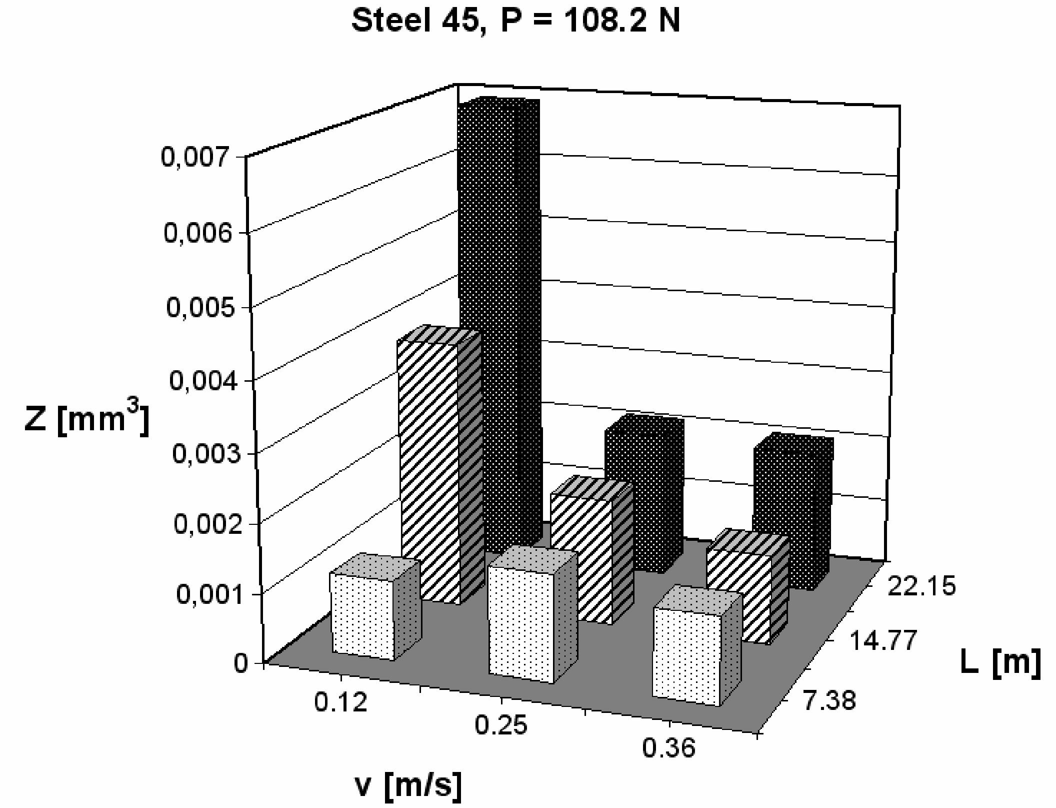

Fig. 5. The influence of sliding speed and sliding distance on wear volume of steel grade 45, for a load of 108.2 N
Rys. 5. Wpływ prędkości poślizgu i drogi tarcia na zużycie objętościowe stali 45 dla obciążenia 108.2 N

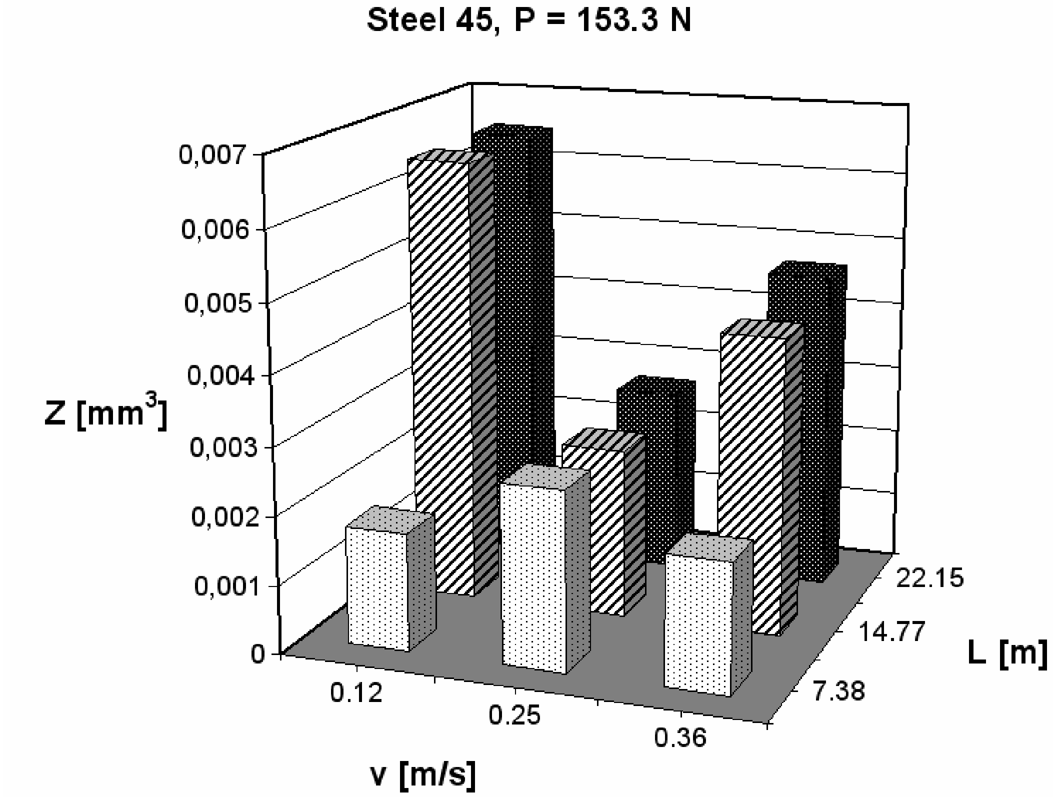

Fig. 6. The influence of sliding speed and sliding distance on wear volume of steel grade 45, for a load of 153.3 N
Rys. 6. Wpływ prędkości poślizgu i drogi tarcia na zużycie objętościowe stali 45 dla obciążenia 153.3 N

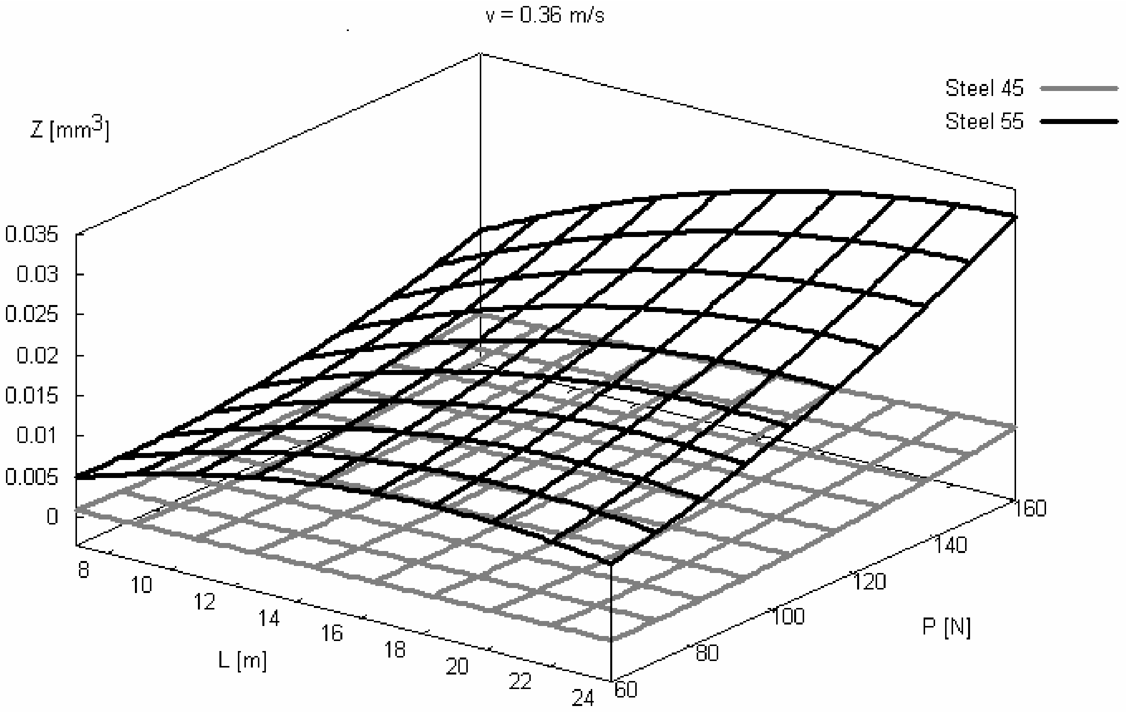

Fig. 7. The influence of load and sliding distance on wear volume of steel grade 45 with hardness of 250 HB and steel grade 55 with hardness of 206 HB, for a sliding speed of 0.36 m · s^{-1}
Rys. 7. Wpływ obciążenia I drogi tarcia na zużycie objętościowe stali 45 o twardości 250 HB oraz stali 55 o twardości 206 HB dla prędkości poślizgu 0.36 m · s^{-1}

4. CONCLUSIONS

Wheel – rail friction is necessary for railway running transport. It results in wheel and rails wear. The wear depends on such parameters as load, sliding distance and speed. These ones are a result of railway transport operation. An increase of load and sliding distance increases the wear. An influence of sliding speed on wear is also significant. For the most of the tested conditions a speed increase decreases the wear, because of the appearing of the oxide films on the rubbing surfaces. Such films prevent metal – to – metal contacts and adhesion. For some of the tested conditions i.e. high load and medium and high sliding distance and speed an increase of the wear volume with speed increase took place. It may be caused by oxidation and removal of oxide films intensification.

Significant role for railway wheels wear plays also material parameters such as chemical composition and hardness. In this work the influence of these parameters on wear has been studied. In the tested range the hardness effect prevailed on the effect of carbon content. The harder the steel the smaller its wear, even if its carbon content is smaller than the softer one.

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