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EFFECT OF WHEEL SLIPS ON THE DURABILITY OF SURFACE LAYER IN THE WHEEL-RAIL SYSTEM

Summary. Relationship between a force on the drive wheel and a slip of the wheel on rail is one of the major factors dealing with the wheel/rail system. From theoretical considerations and investigation carried out it is clear that a slip at the circumference of drive wheels always appears during the rail vehicle running. Under operation conditions a phenomenon of macro slip and side-slipping is especially undesirable and harmful, since it causes an excessive wear of rolling wheel surfaces owing to generation of such defects as spallings, shellings, flat places etc. Thermal aspects of the martensite formation have been taken into consideration too.

WPŁYW POŚLIZGÓW KOŁA NA TRWAŁOŚĆ WARSTWY WIERZCHNIEJ W SYSTEMIE KOŁO-SZYNA

Streszczenie. Jednym z ważniejszych czynników, które dotyczą problemu sprzężenia kół z szynami, jest zależność między siłą na kole napędowym a poślizgiem tego koła po szynie. Z przeprowadzonych badań laboratoryjnych i eksploatacyjnych oraz rozważań teoretycznych wynika, że poślizg na obwodzie kół napędowych występuje zawsze w czasie ruchu pojazdu szynowego. W warunkach eksploatacyjnych szczególnie niepożądane i szkodliwe jest zjawisko makropoślizgu i zarzucania, które powoduje nadmierne zużycie powierzchni tocznych kół kolejowych poprzez m.in. powstawanie defektów takich jak wykruszenia, wyłuszczenia, płaskie miejsca. W pracy omówiono termiczne aspekty tworzenia się martenzytu.

1. INTRODUCTION

Development of the railway transport involves a reduction in running times and there by an increase in running speeds. In the consequence cooperation conditions of the wheel/rail couple change for the worse. Basing on the previous laboratory and operation tests performed one can state that costs, resulting from railway set repairs due to forming of flat places and spalling of rolling wheel surfaces, will have been growing up considerably and actually they amount to several hundred million dollars for the international railway industry annually [3].

The problem of surface layer durability of the system has remained still insolvable. Research works, devoted to questions of accelerated wear of the rolling wheel surfaces have been developed [1, 2, 3]. It is already known that a direct cause of occurring that type of surface defects during the operation period is the following:

- Badly adjusted, frozen or damaged brakes,
- Malfunctioning anti-slip devices,
- Relatively high braking forces as compared with adhesion forces of wheel-rail contact,
- Heavy proneness of steels, used for rolling wheels, to forming martensite structures.

Under real conditions of the wheel set operation on a track there appear wheel slips in relation to a rail at contact points [5]. In conjunction with that there are distinguished three kinds of slips: a slip in longitudinal direction (lengthwise the track axle), a crosswise slip (perpendicular to the track axle) and a drilling slip (connected with the wheelset turn in relation to the axle orthogonal to a track plane as well as with wheel elastic strain).

The performed laboratory and operation tests have revealed that slips during starting and braking display the greatest values. By way of example the slip values are presented in the fig. 1 and 2.

In Japan in high-speed trains of Shinkansen "STAR 21" type there had been applied a new method of slip control due to which advantageous results were obtained, especially under bad conditions of the wheel/rail couple cooperation.[4] Usage of the proposed method of control (monitoring and adjustment) of wheel slips has contributed to a considerable improvement of the wheel/rail system operation and, thus, to a significant prolongation of applied running times of wheels between succeeding rollings.

2. THERMAL ASPECTS OF MARTENSITE FORMING

Available reference and experimental data convinces that just slips in the wheel-rail system cause to achieve temperatures, initiating structural changes in the wheel material. When a wheel is locked and is skidding along a track there a flat place is often formed on the rolling surface of the wheel. At the same time there are generated high temperatures adequate for pearlitic austenitizing the wheel steel, i.e., to reach a critical temperature A1. Many authors have succeded to prove the above-mentined experimentally and theoretically (Jaeger, Archard, Tanvir)[3]. In their works there are accepted the following assumptions:

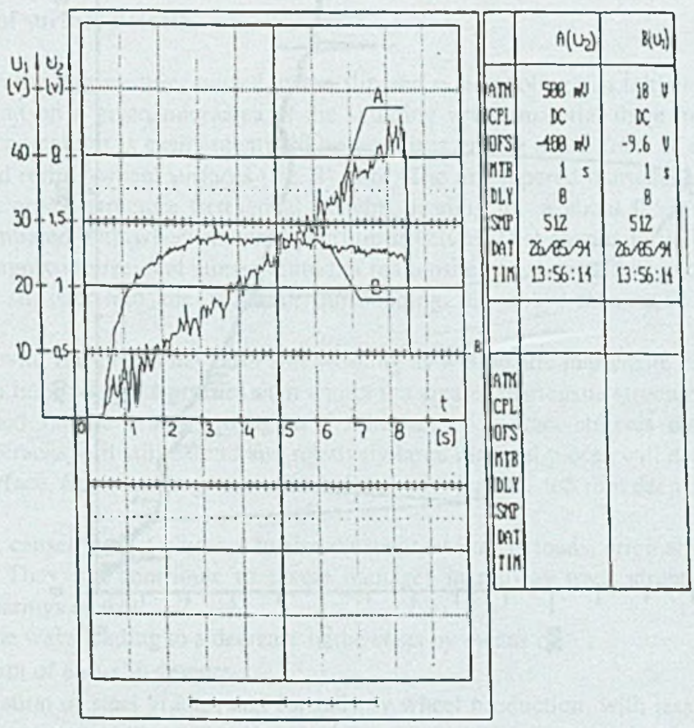
- There-dimensional problem, simplified to a two-dimensional area,
- Effects of the plastic strain are neglected so that a slip velocity for all contact points is equal with a relative slip velocity (Vs)

- Total friction energy, transformed into thermal one,
- α- a fraction of the heat, absorbed by the body, 1-α - a fraction of the heat remained in the counterbody.

On the basis of the above assumptions there was formulated the following dependence between the velocity V, the friction coefficient μ, the thermal properties α and K, the temperature Θ and the slip R for a wheel being braked on a rail (R<1 and V>Vw):

$$\Theta_w = \Theta_R = \frac{2.26 P\mu}{K}\sqrt{\frac{a\alpha V}{\pi}} \times \left(1-\sqrt{1-R}\right)$$

Examples of the temperatures generated in the contact wheel/rail for skidding wheels are presented in the Table 1. The presented results were calculated according to the Archard's equation[3].



A(U₂): B(U₁) - przebiegi prędkości obwodowych kół w funkcji czasu t

Fig. 1. The graph of Ff(t)
Rys. 1. Wykres F=f(t)

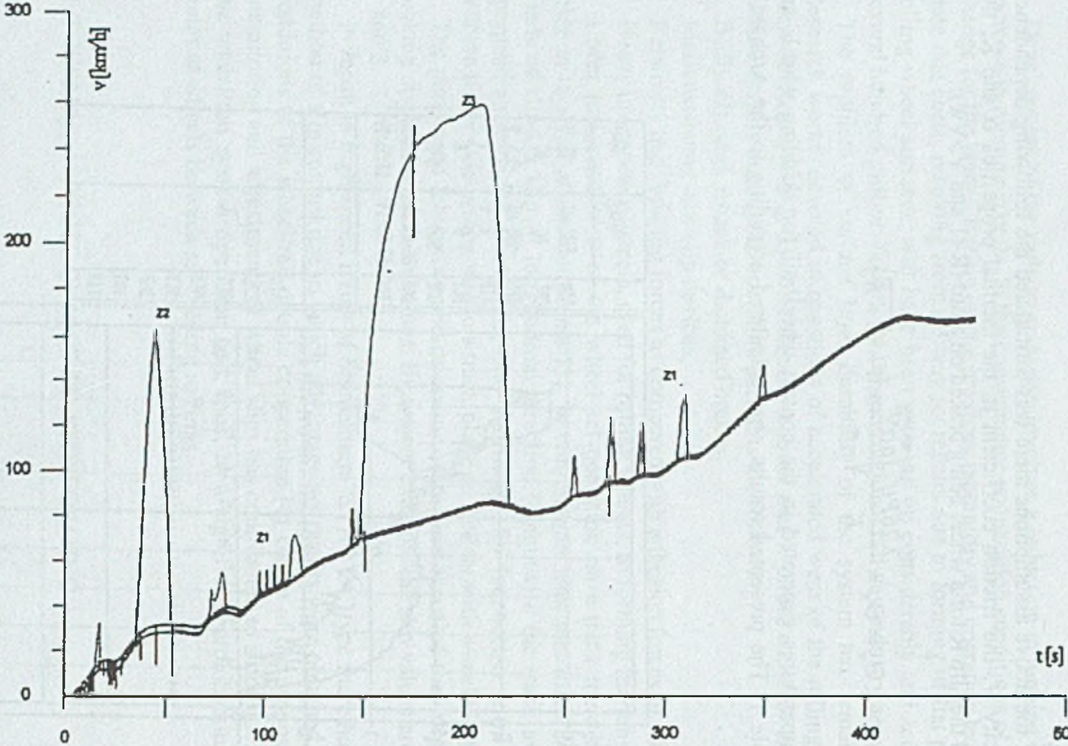


Fig.2. The V=f(t) curve
Rys.2. Krzywa V=f(t)

Table 1

Temperatures, generated at the wheel/rail contact during wheel skidding for the different running times V and the friction coefficient μ[3]

	P. = 3200 kg		P. = 10 000 kg	
	a = 5.45 mm		a = 8 mm	
V (m/s)	μ = 0.1	μ = 0.3	μ = 0.1	μ = 0.3
0.5	122	367	218	653
1	177	531	314	941
1.5	219	657	388	1163
2	254	763	450	1350
3	314	941	554	1663
10	581	1744	1025	3075

2.1. Formation of surface defects

An increase in the temperature, caused by the slip and rapid cooling can initiate martensite transformation and on a given micraarea of the skidding wheel material there martensite is formed. Macroscopically it is easily identified because it is visible in the form of clear, shiny spots on operated rolling-wheel surfaces (fig. 3) [3,6]. The untempered martensite is a brittle phase and has a cristal structure (tetragonal system), leading to an about 0.5% volumetric expansion as compared with wheel-material pearlitic structure. That change in volume results in very high compressive residual stresses into the martensite structure and respectively high tensile residual stresses into the material, surrounding the above-mentioned martensite structure.

If a wheelset with flat places has been still working as well as the martensite has not been removed through improving the profiles then within the area of martensite structure there will have been formed fatigue cracks owing to the impact of contact stresses during wheel skidding. Those cracks will still extend and relatively large material pieces will detach off the rolling wheel surface. Such spallings are used to leave cavities of 1 to5 mm deep, surrounded by cracks.

The spallings, caused by flat places, can also create great impact loads, originating from the skidding wheel. They can contribute to severe damages in railway track structure, vehicle mounting and bearings as well.

There are some ways leading to a decrease in the costs by means of:

- improvement of anti-slip devices,
- implementation of steel grades, and for railway wheel production, with less pronemess to generate martensite structures.

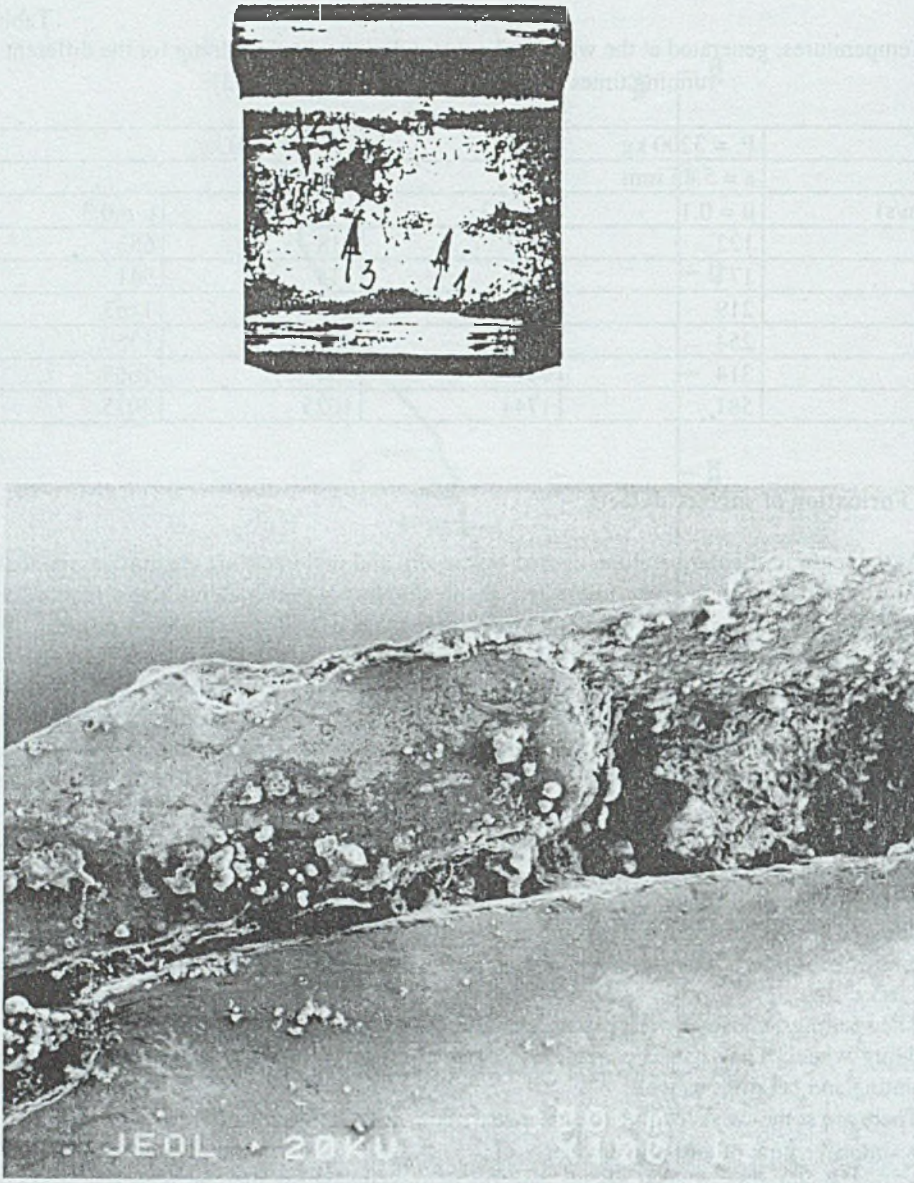


Fig.3. A fragment of rolling wheel surface with distinctly visible places, evidencing the initiation of martensite transformation (clear, shiny areas) and spallings (dark areas). Below one can see an image (from the scanning microscope) of the surface defect of that type

Rys.3. Fragment powierzchni tocznej koła z wyraźnie widocznymi miejscami, świadczącymi o zapoczątkowaniu przemiany martenzytycznej (jasne, błyszczące pola) i wykruszeniami (ciemne pola). Ponizej obraz z mikroskopu skaningowego tego typu defektu powierzchniowego

2.2. Slip controlling in the system wheel-rail

To solve the problem of wheel slipping of electric railway vehicles, first of all, one should study closely this phenomenon during starting /braking. An axle velocity should be determined precisely to this end. In this case one should be careful at choosing and installing of sensors. At the first place eccentricity between the axle, where the sensor is installed, and the axle of steel sensing element must be very low (small), because it causes fluctuations in an instantaneous velocity. A conventional method for determining the wheel slip is based on calculation of impulses of the steel sensing element, fixed at one end of the wheel axle (of the wheelset) or at the tractive motor shaft. It is very difficult to choose a sensor (a sensing element) with so many impulses per rotation as an encoder has in industrial use. Therefore in the work [4] there was applied a method for calculation of the mean impulse width. Usage of this method is essential to detect small slips and adhesion loss. A practical method, controlling slips for vehicles with electric three-phase motors, is based on the use of the least velocity of all the motor axles as a value of the reference frequency of an inverter controlling device and feeding asynchronous traction engines. It is proposed to this end to detect small pseudo-slips too. There is also a possibility to predict adhesion "on line" so that to cope with slip-readhesion reiteration under bad conditions of the wheel/rail system operation, for example, icy rail, steep gradient, etc. Test results have evidenced the effectiveness of the proposed control of adhesion loss[4].

3. CONCLUSIONS

Considering a world-wide interest in the problem of martensite forming around flat places on the rolling surfaces of railway wheels, caused by slips it seems to be advisable:

- to carry on investigation, leading to a better understanding of the conditions, promoting the formation of structures of that kind,
- to improve anti-slip devices by means of implementation of the method of controlling slips and readhesion prediction.

4. ACKNOWLEDGEMENTS

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Streszczenie

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