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PARTICULAR TRIBOLOGY PROBLEMS OF THE ROLLING CONTACT SURFACE

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Abstract: *The serious damage of contact surfaces when being dynamically strained may only be resolved gradually, using an experimental analysis of samples taken from the contact-stressed areas. The paper deals with a new theoretical approach to the loading analysis of contact surfaces during rolling. Presented experimental part of the research is based on the laboratory testing, with use of the two new-type designed experimental devices. There was pointed out the necessity of experimental research, focused on the limit states of the material and presented consideration about thermal effects in the contact along the slip characteristics, which is described within the entire range on the basis of the probability theory.*
Key words: *contact; surfaces; materials; dynamics; adhesion;*

1. INTRODUCTION

The persistent problems of damage to contact surfaces when being dynamically strained may only be resolved gradually, using up-to-date metallographic methods, i.e. experimental analysis of samples taken from the contact-stressed areas. However, this generally known fact has its difficulties. In this paper we want to point out especially those facts, which result from possible problems related to the knowledge of loading modes.

In principle there are two basic approaches. One is the analysis of samples taken from the contact area of a real component, which has been subjected to a work load. This method is generally used in cases of evaluation of the state, which obviously shows the existing erosion of the contact surface.

However, preventing the occurrence of contact layer erosion requires such laboratory processes, which can be based on knowledge of the nature of loading the material samples and its history and, especially, on the information characterizing the dynamics of loading. This is crucial (and still widely ignored) in roll-away type contact pairs.

Special attention is paid to the wheel and rail contact pair, which especially with an wheel of adhesion driven, is a typical example of dynamic load. In spite of this, most of the analyses of forces are unfortunately based on the classical Hertz theory.

For example, the work (Baumann, et al.,1996) points out the fact that the contact spot is the area where the force effect is of an impact nature. From the view of the material it is necessary to consider the influence of the speed of deformation, which can affect all material constants, including the basic parameters of the fracture mechanics.

An additional phenomenon, which must be paid special attention, is the origination of contact temperatures, which, especially as a result of tangential forces, may reach values at which structural influence of the material may occur in local areas (Ermolaev, 2000).

2. PHENOMENON OF OCCURRENCE OF POSSIBLE WAVE EFFECTS IN CONTACT AREA

The real material volumes in the contact area constitute a continuum in which, under specific conditions of loading, the energy is transferred by means of wave effects. The impact nature of the load can be described by amplitude density with a band spectrum, which in reality can overlap the line spectrum of natural frequencies, which is typical of the continuous environment of contact areas. Before the analytical speculation, based on (Achenbach, 1993) it is necessary to point out that the assumption of a homogenous continuum in the given case is not absolutely correct due to the existence of a considerably influenced thin superficial layer. Its dimension is very small in comparison with the dimensions of the contacting bodies. Therefore the indicated speculation can be considered a useful guide towards the values of the occurring dynamic stresses. The compression wave propagates in the direction of the normal line of the contact *(x)* at dilation speed c_1 . Its magnitude depends on modules E and G, Poisson number η, Lamé constant λ_1 and density ρ. The relations are:

$$c_1 = \sqrt{\frac{\lambda_1 + 2G}{\rho}}\,;\ \lambda_1 = \frac{E \cdot \eta}{(1+\eta)(1-2\eta)} \qquad (1)$$

For $E = 2.1 \times 10^{11}$ Pa, $G = 0.8 \times 10^{11}$ Pa, $\rho = 0.795\ Ns^2m^{-4}$, $\eta = 0.3$, the value of the dilation speed is $c_1 = 5.97 \times 10^3\ ms^{-1}$**.** The corresponding dynamic stress in the direction of the normal line x is established by the following equation:

$$\sigma_x = E\frac{1-\eta}{(1+\eta)(1-2\eta)}\frac{v_0}{c_1} = 0{,}47 \cdot 10^8\, v_0 \qquad (2)$$

3. LABORATORY DEVICE FOR DYNAMIC LOADING OF MATERIAL SAMPLES

A new type of testing device for the dynamic loading of test samples from the railway wheel/rail was developed in the laboratories of the Jan Perner Transport Faculty of the University of Pardubice. In principle it is the study of the contact area of the material, stressed by the time-variable radial force *R = R(t)* and incurred tangential force $T_{(t)}$ as a result of the slip process. The principle of the device can be seen in the diagrams in ***Fig. 1.***

In the horizontal direction the rest 5 is bound by horizontal drawbars 6, connected to the springs 8 with masses 7. The pressure lever 10, revolving around axis B, is controlled by the wound spring 11. The roll-away pulley 9 is located on the lever 10. The position according to ***Fig. 1*** refers to the situation when the spring with the set strength S induces reaction N between the pulley 9 and disc 2 with cut-out. Clearance z_1 is set between the tested sample 1 and the working disc 3. During the controlled rotation of discs 2 and 3 at the circumferential speed, corresponding to the selected slip s, the pulley 9 fits into the disc 2, whose cut-out is adjusted so that clearance z_2 appears. At this moment the dynamic reaction $R_{(t)}$ occurs between the sample 1 and the surface of the disc 3. At the existence of the set slip s the dynamic tangential force $T_{(t)}$ is incurred. Its magnitude and progress are determined by the modal setting by the horizontal link of the rest 2, which is realized by tuning using the masses 7. Two modes of loading are distinguished by the simultaneous evaluation of the time progress of the dynamic forces $R_{(t)}$ and $T_{(t)}$. If the line spectrum of the force $T(t)$ is separated from the band spectrum of the force $R_{(t)}$, the loading mode is near the possible occurrence of transient performance of self-excited oscillations of the relaxation type. If both spectra overlap mutually, the process of dynamic load of the sample 1 is accompanied by wave processes.

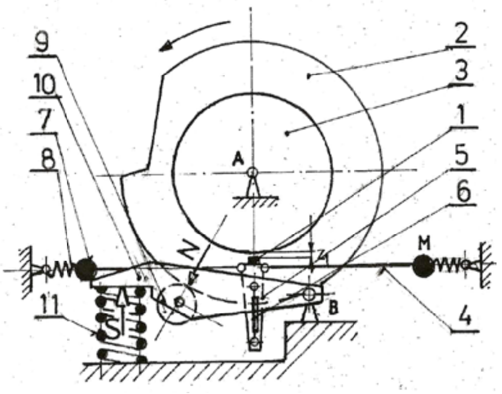

Fig. 1. Laboratory device type 1

The described test device thus provides the possibility of study of the influence of self-excited oscillations on the service life of the sample, and in the latter case the experimental study of the possible effects of wave processes is expected. The concept of the device enables simulating the real load of the contact spot with adjustable real slips. At the same time, as the sample is located on the stationary rest **5**, it provides the possibility of measuring the incurred contact temperatures.

4. LABORATORY DEVICE FOR THE STUDY OF ADHESION CHARACTERISTICS´

For the experimental study of the progresses of tangential forces at the set or variable slip **s** another type of laboratory device was developed, which is expected to verify or supplement the existing opinions, which are based on the established coefficient of adhesion μ, i.e. on the ratio between the radial loading force and the incurred tangential force. The principle of its activity is described by means of the diagram in ***Fig. 2***. The tested samples of material 2, 3 are disc-shaped and of the same diameter. Both discs are driven directly by the vector-controlled synchronous servomotors 4, 5. The upper system 3, 4 is located on the rest 6, which is pivoted in relation to the machine frame 1 around the indicated axis A. The servomotor 5 is located on the horizontally-sliding rest 7. The shaft of the upper disc 3 is fitted with the torsionally-flexible dynamograph 8. The radial loading of both discs can be adjusted by means of the vertical drawbars 9, which are linked to the girder dynamographs 10 in the bottom part. The dynamic component of this loading is incurred by the pair of rotational vibrators 11, whose motors are equipped with programmable control. The bearing of the vibrators on the spring-loaded rest 12 enables their self-synchronization. The horizontal oscillation of the rest 7 (indicated by arrows I, II), which bears the servomotor 5, is controlled by the program-controlled motor 13 by means of the crank mechanism 14.

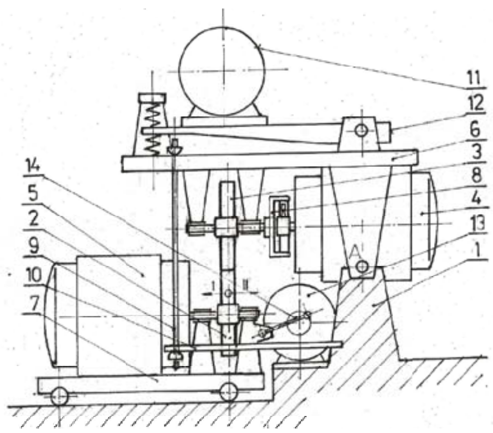

Fig. 2. Laboratory device type 2

The device is proposed for two test modes. In the first mode the speeds of both motors are set so that the selected tangential slip is incurred; it is also possible to set transverse oscillation of the rest 7. The flexible dynamograph 8 sends a signal about the value of the adhesively transferred torque including its changes in time. In this way it is possible to test the working modes within the entire range of the set tangential slips with the contribution of the transverse slips (Jakimovič et al, 2010). The modes are tested either as stable, or as transient. The second mode of tests has a similar nature, except that one of the servomotors is controlled as a generator. In this case the slip is incurred by adhesive processes in the contact of both discs. At these tests especially the dynamic manifests of the system around the maximum of the incurred tangential force are monitored, where unstable states are presumed on basis of the classical adhesion theory.

5. CONCLUSION

This paper gives basic information about two new types of testing devices for the study of the influence of the dynamic load of contact surfaces in the contact area of a rolling kinematical pair. The essential substantiation of building these facilities is presented in the introduction. The first two chapters deal with the possible occurrence of wave effects in the contact of the adhesion drive of a rail vehicle and points out the necessity of experimental research, focused on the limit states of the material. And, the next chapters present the crucial consideration about the thermal effects in the contact along the slip characteristics, which is described within the entire range on the basis of the probability theory (Likeš, Machek, 1981).

6. ACKNOWLEDGEMENTS

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