TWIN-DISC EXPERIMENTAL DEVICE FOR STUDY OF ADHESION IN WHEEL-RAIL CONTACT

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In order to understand friction processes in wheel-rail contact a new experimental device has been developed. Twin-disc approach has been used to determine adhesion curves in wheel-rail contact under various conditions. This paper describes some details about the design of the twin-disc experimental device. Finally, preliminary results are discussed.

Keywords: *wheel/rail contact, adhesion curve, twin-disc, traction*

1. Introduction

In railway transportation a wheel and rail contact is essential because it transfers all kinetic energy. An amount of the energy depends on adhesion in the contact; especially during acceleration and braking. During these processes a wheel slip may occur, which increases wear and damage of wheel and rail surfaces. Loss in adhesion may cause many serious problems such as extended braking distance and time delays [1, 2]. These problems are often related to railhead contamination.

Recently, many studies have been carried out to investigate mechanisms of adhesion loss between wheel and rail using experimental and theoretical approaches [3, 4]. The results indicate rapid decrease in the adhesion coefficient due to contact contamination. Extensive investigation of friction at wheel/rail interface was made in 1970s [5, 6]. It was found that a so-called third body layer consisting of oil, leaves, water and solid materials exists between wheel and rail. During a dry period a layer of natural dust, fragments from brakes and worn metal particles is formed. Humidity, fog or light rain are mixed together with the layer which creates a thin film with high level of viscosity. This film is resistant to removal from the contact and provides mixed lubrication conditions with a friction coefficient below 0.1. For example a heavy rain gives consistent adhesion level of 0.2–0.3.

Nowadays, many methods to determine the adhesion characteristics of a wheel/rail contact have been used. Experimental devices such as pin-on-disc, disc-on-flat and twin-disc have been introduced [7]. The twin-disc experimental approach has been found to be very useful for investigation of creep characteristics between wheel and rail.

This paper describes some details about the design of a twin-disc experimental device for the study of adhesion in wheel/rail contact under various conditions. Main parts of the device such as loading, drive and measurement systems are introduced. Finally, preliminary results are discussed.

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2. Twin-disc device

For the study of adhesion problems in wheel/rail contact a laboratory device has been developed and built at Faculty of Mechanical Engineering, Brno University of Technology. A scheme of the test rig is shown in Fig. 1.

The test rig is based on the principle of the twin-disc device. It consists of two discs which are independently driven at controlled rotational speed by electric motors with frequency converters and gearboxes, so the relative slip can be controlled accurately. When a slip is applied, one of the electric motors works as a generator and the generated electric energy is recovered in the system.

The upper disc is loaded with a loading arm against the lower disc which is mounted on flexible linkages. This allows transferring the traction force to a traction load cell. The test rig is equipped with a sealed chamber, which covers the discs and allows the application of sand and other contaminants into the contact.

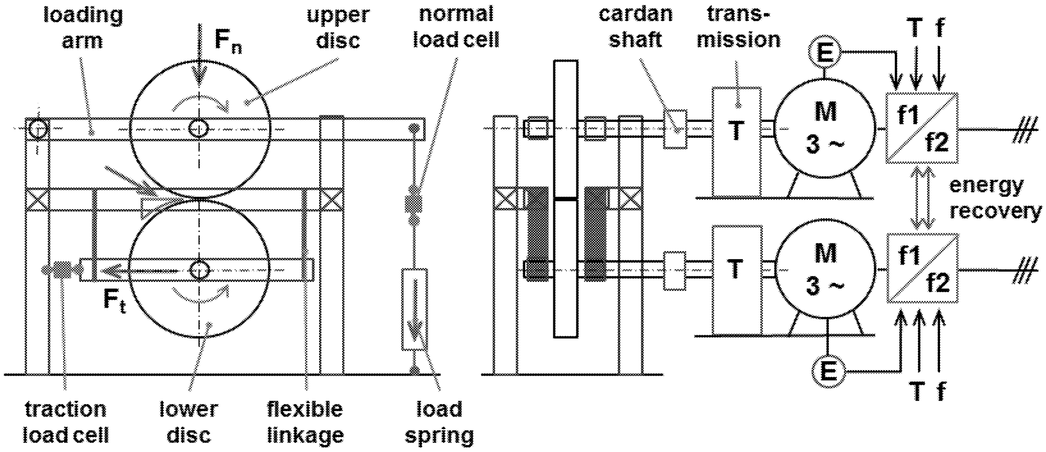

Fig.1: Scheme of the twin-disc device

3. Specimens

Fig. 2 shows the disc specimens and the contact geometry. The discs are scaled (1:3) with respect to the dimensions of real rail wheel and UIC 60 rail profile. Both discs are made of C45 steel which is an equivalent to wheel and rail steels UIC 900A and R7T respectively. The chemical composition and mechanical properties of discs are described in Tab. 1. The contact surfaces were hardened to a required hardness and were ground to a roughness of 0.4 μm.

	Chemical composition (wt. %)					Hardness
	C	Si	Mn	Ni	Cr	(HB)
Rail disc	0.46	0.25	0.65	0.30	0.25	290
Wheel disc	0.46	0.25	0.65	0.30	0.25	245
UIC 900A	0.70	0.35	1.10	–	–	280–300
R7T	0.52	0.40	0.80	0.30	0.30	245

Tab.1: Material chemical composition and hardness

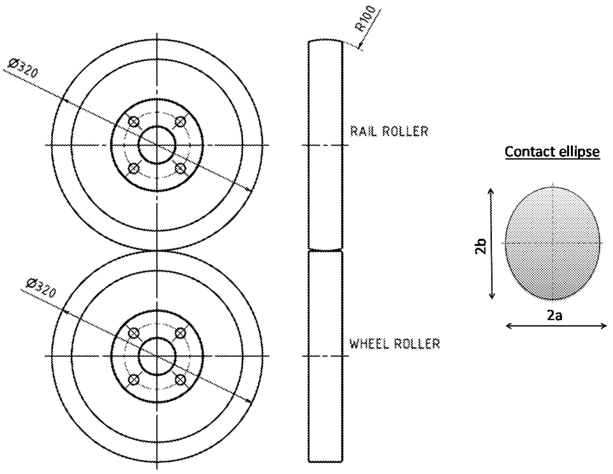

Fig.2: Geometry of discs and Hertzian contact

4. Loading system

A load is applied on the upper disc using a lever with spring-loaded mechanism. The load is controlled by a motion screw which pre-loads the spring on the end of the lever. The contact between the discs can be unloaded quickly using a motorized screw jack. The loading system is able to produce maximum normal load of 6 kN which corresponds to the maximum Hertzian pressure of 1.2 GPa. This pressure is typical for a contact between wheel and rail. The maximum Hertzian pressure $p_{\max}$ can be calculated by following equation [8]:

$$p_{\max} = \frac{3\,W}{2\,\pi\,a\,b} \tag{1}$$

where W is the normal force; a and b are lengths of semi-major and semi-minor axes of the contact ellipse. The lengths are defined by the following equations:

$$a = k_1 \left(\frac{3\,W\,R'}{E'}\right)^{\frac{1}{3}} , \qquad b = k_2 \left(\frac{3\,W\,R'}{E'}\right)^{\frac{1}{3}} \tag{2}$$

where k_1 and k_2 are the contact coefficients; R' is the reduced radius of curvature and E' is the reduced Young modulus. The lengths of the contact ellipse are 3.3 mm and 2.8 mm for normal load of 6 kN.

5. Drive system

The drive system is shown in Fig. 1. It consists of two 4-pole 15 kW AC motors controlled by Hitachi SJ700 series inverters. This enables to control the discs speed in the range of 0–1440 rpm. To maintain required torque two gear-box with ratio 4.57 were used. The maximum output torque of 435 Nm at 332 rpm can be achieved.

6. Measuring system

The measuring system includes two load cells for normal and traction force measurements and shaft encoders for monitoring the motors rotational speed. All data are acquired on a PC. A simple software was developed to set up input parameters – rolling speed and slip. The relative slip s is given by equation (3):

$$s = \frac{\omega_{\mathrm{wheel}}\, r_{\mathrm{wheel}} - \omega_{\mathrm{rail}}\, r_{\mathrm{rail}}}{\omega_{\mathrm{wheel}}\, r_{\mathrm{wheel}} + \omega_{\mathrm{rail}}\, r_{\mathrm{rail}}} \cdot 200\,\% \tag{3}$$

where ω_{wheel} and ω_{rail} are the rotational speeds of discs and r_{wheel} and r_{rail} are the radii of discs. The load is manually set up before the beginning of the test. Subsequently, the adhesion coefficient is calculated by equation (4):

$$\mu = \frac{W}{T} \tag{4}$$

where W is the normal force and T is the traction force.

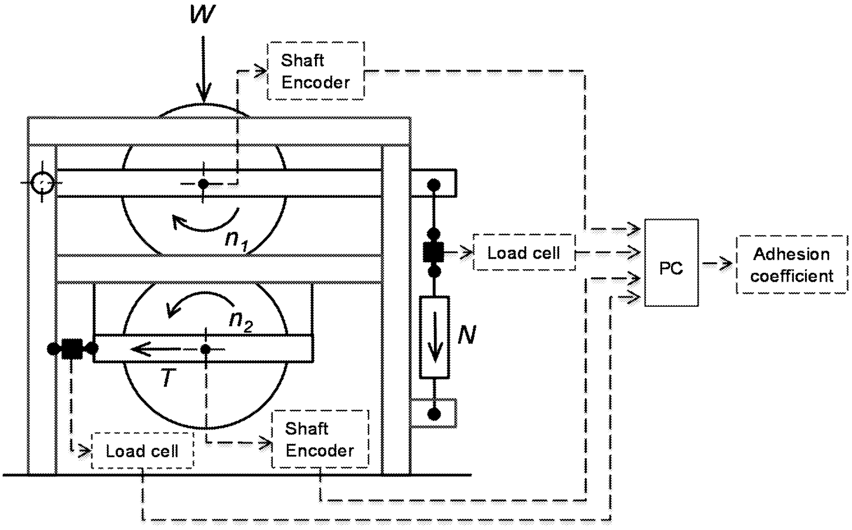

Fig.3: Measuring system

7. Test conditions

The twin-disc experimental device can be operated in two regimes, as shown in Tab. 2. The first one uses the gearboxes to achieve high torque and thus to allow high contact pressure. The second regime allows the system to achieve much higher rolling speed, however under lower contact pressure.

	Operating regimes	
	Regime 1	Regime 2
Hertzian pressure	1 GPa	0.6 GPa
rolling speed	0–20 km/h	20–90 km/h
adhesion coefficient	max 0.7	max 0.7

Tab.2: Regimes of operation of Twin-disc experimental device

During testing the contact can be contaminated with sand and water. Sand is supplied into the contact zone by a nozzle using compressed air. The water spraying system allows simulation of wet conditions. For increased temperature requirements a hot air generator can also be used.

8. Preliminary results and discussion

The preliminary tests were conducted under dry conditions. Fig. 4 shows rough data of the adhesion coefficient and the slip recorded during the test with variable slip of 0–10 % under pressure of 1 GPa and rolling speed of $1\,\mathrm{m\,s^{-1}}$. The data show good ability of the system to maintain constant slip. Fluctuations in normal load due to the passage of particles and roughness features through the contact are eliminated sufficiently by the spring based loading system.

The data were evaluated and adhesion curve was obtained (Fig. 5). The curve shows an initial increase in the adhesion coefficient with increasing slip and a point of saturation at approximately 5 % slip. The results correspond very well to the theoretical prediction.

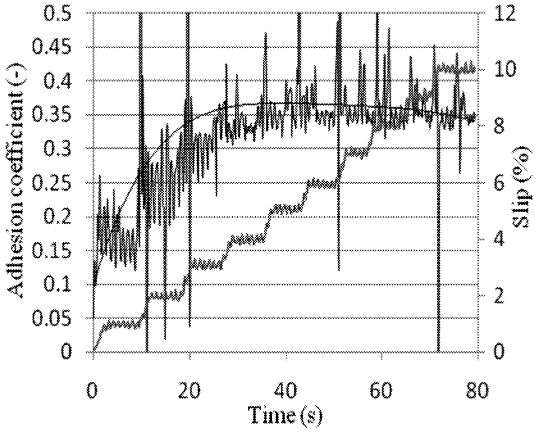

Fig.4: Dry test at slip variable from 0–10 %

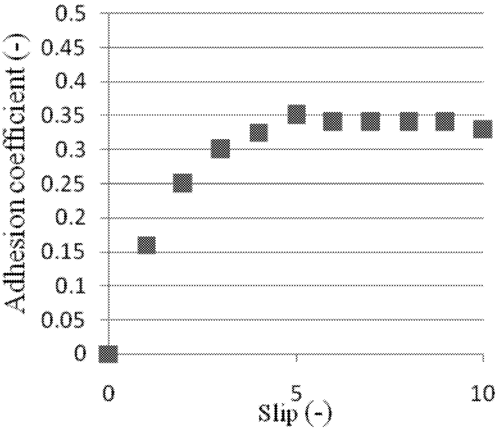

Fig.5: Dry test at slip variable from 0–10 %

9. Conclusion

A scaled twin-disc experimental device for the study of adhesion in the wheel/rail contact under various conditions and contaminations was developed. This device provides a rolling-sliding contact between the two disc specimens which simulates the contact of wheel and rail under closely controlled conditions. The preliminary results show sufficient stability of loading, motion and measurement systems. The results correspond very well to the theoretical prediction.

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