VIBROSTABILITY PECULIARITIES OF DISK BRAKE IN AUTOMOBILE ANTI-LOCK BRAKING SYSTEM

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ABSTRACT
On the basis of the automobile braking mathematical model describing brake pads oscillation process taking into account the influence of anti-lock braking system, disk brake vibrostability calculation method is worked out. As a result the algorithm of differential equations solving that describe the dynamics of automobile braking process is proposed. Considered model of braking dynamics establish interaction between braking and tire-road coupling moments. The calculations of disk brake vibrostability taking into consideration the impact of anti-lock braking system action are carried out.

Keywords: vibrostability, disk brake, ABS, friction oscillations

To ensure control and safety in the braking process automobiles are equipped with anti-lock braking systems (ABS). Although improving automobile braking characteristics, anti-lock braking system increases brake loading, which impacts the brake reliability [1,2]. One of the significant characteristics of automobile brake device is the vibrostability, which determines the motion smoothness and operation stability of brake. Friction fluctuations originated in the brake devices are caused by brake disk surface roughness and adversely impact the brake vibrostability and prevent the reliable functioning.

Not only the forces within the brake device have influence on oscillations aroused in the automobile brake device at braking process, but also the forces acting on the whole vehicle. For this reason to calculate the brake device vibrostability the calculation model of the whole vehicle is used which describes the movement of automobile on a plane surface during braking, taking into account the dynamic load transfer on wheels. For calculation of the automobile brake device vibrostability the oscillatory model of disc brakes [3] is used, which describes a rotating disk with inertia moment I, and pads with weight m considered as solids elastically contacting with the disk and interacting with the motionless frame of brake device by an elastic link simulated by a spring.

The oscillatory process of the automobile disc brake device is described by a differential equations system as follows:

$$\begin{align*}
\ddot{\theta}, & \dddot{x}, \dddot{\theta} \ 	ext{T}_f, \\
\dddot{\phi}, & \frac{\ddot{m}}{2} \dddot{\phi} \ c \dddot{x} \ F_f, \\
\end{align*}$$

(1)

where $T_f$ and $F_f$ -brake torque and friction force in coupling, $cx$ – elastic link force between pad and frame, $x$ – acceleration of the pad, $\theta$–angle acceleration of the brake disk.

Actual pressure on brake pad is assumed as a constant in the given system of the equations (1), i.e. the influence of anti-lock braking system is not taken into account, the basic purpose of which is to prevent the wheel blocking by means of changing the pressure. The considered model of brake dynamics establish interaction between braking and tire-road coupling moments:

$$\begin{align*}
\dddot{\theta}, & \dddot{\phi} \ c \dddot{x} \ F_f \\
\dddot{\phi}, & \frac{\ddot{m}}{2} \dddot{\phi} \ c \dddot{x} \ F_f, \\
\dddot{\phi}, & \frac{\ddot{m}}{2} \dddot{\phi} \ c \dddot{x} \ F_f. \\
\end{align*}$$

(2)

where the first equation describes the automobile gravity centre movement, the second equation–the movement of vehicle gravity centre along axis z, perpendicularly to the road surface, the third equation– the angle of different regard to horizontal axis y, which passes through the automobile centre of gravity.
The solution of the system of equations (2) is carried out by a numerical method with a software package MathCAD. The results are given graphically on Fig.1.

The calculation model is capable to research the brakes vibrostability with applying of anti-lock braking system and at exploitation of the automobile in different road conditions.

Figure 1. The spectrum of the brake pad fluctuations (a) and brake torque changing (b) depending on the time of braking

Appropriate test bench experimental investigations of the disc brake equipped with the simulator of anti-lock braking system are carried out. Investigations are carried out on asbestos-free friction materials such as Bastenit [4]. Calculation values of vibrodisplacements do not exceed the experimental results more than 25%. Thus curves almost repeat each other during a braking cycle (Fig.2).

Figure 2. Analytical (1) and experimental (2) curves of the pad displacements

The analysis of investigations results shows that the frictional fluctuations occurred in brake devices, equipped with anti-lock braking system, differ from conventional brake devices fluctuations, the amplitude of which up to 4 times exceeds the amplitudes of conventional brake devices fluctuations. Simultaneously the high frequency component of the fluctuations is less up to 3 times, thus the highest frequency appeared at the stopping moment of the brake disk. The calculated data of the brake pad vibrodisplacements magnitude with anti-lock braking system are 20% higher.

The mathematical model sufficiently represents the dynamics of the fluctuations during braking and the divergence of the calculation data with the experimental results does not exceed 25%. It enables the investigation of oscillatory spectrum dynamics during braking under different road conditions. The calculation method can be used for rating the vibrostability of existing brakes, as well as those being developed. As a result the existing brake devices design can be modified and new brake materials with appropriate tribological characteristics can be developed.

REFERENCES