Errors of car wheels rotation rate measurement using roller follower on test benches

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Abstract. The article deals with rotation rate measurement errors, which depend on the motor vehicle rate, on the roller, test benches. Monitoring of the vehicle performance under operating conditions is performed on roller test benches. Roller test benches are not flawless. They have some drawbacks affecting the accuracy of vehicle performance monitoring. Increase in basic velocity of the vehicle requires increase in accuracy of wheel rotation rate monitoring. It determines the degree of accuracy of mode identification for a wheel of the tested vehicle. To ensure measurement accuracy for rotation velocity of rollers is not an issue. The problem arises when measuring rotation velocity of a car wheel. The higher the rotation velocity of the wheel is, the lower the accuracy of measurement is. At present, wheel rotation frequency monitoring on roller test benches is carried out by following-up systems. Their sensors are rollers following wheel rotation. The rollers of the system are not kinematically linked to supporting rollers of the test bench. The roller follower is forced against the wheels of the tested vehicle by means of a spring-lever mechanism. Experience of the test bench equipment operation has shown that measurement accuracy is satisfactory at small rates of vehicles diagnosed on roller test benches. With a rising diagnostics rate, rotation velocity measurement errors occur in both braking and pulling modes because a roller spins about a tire tread. The paper shows oscillograms of changes in wheel rotation velocity and rotation velocity measurement system’s signals when testing a vehicle on roller test benches at specified rates.

1. Introduction
One of the main drawbacks of car diagnosing on roller test benches is a wheel rotation rate measurement error.

Figure 1 shows the changes in rotation rate of wheel ωк and signal ωд of the rotation rate measurement system using a roller follower on a roller test bench [1].

The relation was determined by A.I. Fedotov, a Professor of the Motor Transport Department of Irkutsk National Research Technical University, using a mathematical simulation method [2].

2. Materials and methods
To check his results, the authors decided to analyze the processes and demonstrate the functional relations shown in the article [3].
For this purpose, an experimental method was developed. It is based on the comparison of rotation rate measurement results for roller followers and car wheels (Fig. 2) [4].

The experiment was carried out during emergency braking followed by releasing brakes [5].

The roller follower’s inductive sensor signal (Fig. 3a) and car wheel’s regular inductive sensor signal (Fig. 3b) were recorded.
Figure 3. Inductive sensors of the measurement system: a - roller follower’s inductive sensor signal; b - car wheel’s regular inductive sensor signal.

The sensor signals were transmitted through the ATS and processed with ZETLab programs (Fig. 4).

Figure 4. Measurement system.

3. Results and discussion
Based on the results processed, the oscillograms of rotation time-rate relations were developed (Fig. 5, 6, 7, 8).

Figure 5 shows that the roller follower does not decelerate at a low acceleration rate of 20 km/h and emergency braking.

When releasing brakes followed by the acceleration up to the rate of 5 km/h without depressing an acceleration pedal, one can observe a slight delay of $\Delta t_p=0.5$ sec. The difference of rotation rates measured by a regular sensor and a roller follower’s sensor is $\Delta \omega_p=0.01$ sec$^{-1}$. 
Figure 5. Car wheel’s rotation rate measured with a regular wheel’s and a roller follower’s sensors on the roller test bench at the initial braking rate of 19 km/h followed by releasing brakes and retardation without depressing an acceleration pedal up to the rate of 5 km/h (1 is a wheel rotation rate measured with a regular wheel sensor; 2 is a rotation rate measured with a roller follower).

As the rate increases, the delay time increases.

Figure 6 shows that the delay time for the roller at the acceleration is 27 km/h and emergency braking is $\Delta t = 0.02\text{sec}$. The difference of rotation rates measured with a regular sensor and a roller follower’s sensor is $\Delta \omega = 0.9\text{sec}^{-1}$.

When releasing brakes, delay time $\Delta t_r = 0.1\text{sec}$ decreases and delay time $\Delta \omega_r = 3\text{sec}^{-1}$ increases. Decrease $\Delta t_r$ is due to the increase in the initial braking rate while experimenting.
Figure 6. Car wheel’s rotation rate measured with regular wheel’s and roller follower’s sensors on the roller test bench at the initial braking rate of 27 km/h followed by releasing brakes and retardation without depressing an acceleration pedal to the rate of 18 km/h (1 is a wheel rotation rate measured with a regular wheel sensor; 2 is a rotation rate measured with a roller follower).

Figure 7 shows the following delay parameters: $\Delta t_r = 0.02$ sec and $\Delta \omega_r = 0.9$ sec$^{-1}$, $\Delta t_p = 0.1$ sec and $\Delta \omega_p = 3$ sec$^{-1}$.

Figure 7. Car wheel’s rotation rate measured with a regular wheel’s sensor and a roller follower’s sensor on the roller test bench at the initial braking rate of 40 km/h followed by releasing brakes and retardation without depressing an acceleration pedal to the rate of 28 km/h (1 is a wheel rotation rate...
measured with a regular wheel sensor; 2 is a rotation rate measured with a roller follower).

Figure 8 shows an increase in delay parameters: $\Delta t_r = 0.11$ sec and $\Delta \omega_r = 2$ sec$^{-1}$, $\Delta t_p = 0.08$ sec and $\Delta \omega_p = 16$ sec$^{-1}$.

![Figure 8](image)

**Figure 8.** Car wheel’s rotation rate measured with regular wheel’s and roller follower’s sensors on the roller test bench at the initial braking rate of 56 km/h followed by releasing brakes and retardation without depressing an acceleration pedal to the rate of 42 km/h (1 is a wheel rotation rate measured with a regular wheel sensor; 2 is a rotation rate measured with a roller follower).

Let us determine the relative rotation rate measurement error by formula [6]:

$$\Delta = \frac{\Delta \omega}{\omega_{max}} \cdot 100\%,$$

(1)

where $\Delta$ is the relative rotation rate measurement error; $\omega_{max}$ is the real wheel rate measured with a regular car’s sensor, sec$^{-1}$; $\Delta \omega$ is the difference of rotation rates measured with a regular sensor and a roller follower, sec$^{-1}$.

Figure 9 shows oscillograms of wheel rotation rate measurement errors on the roller test bench for emergency braking.
Figure 9. Changes of a measurement error of wheel rotation rate for a roller follower at the initial braking rate: an error as the relative difference of rotation rates $\omega_r$ measured with a regular sensor and a roller follower (a); an error expressed as a percentage.

Figure 10 shows the similar results obtained when releasing brakes.

Figure 10. Changes of a measurement error of wheel rotation rate for a roller follower when releasing brakes followed by retardation without depressing an acceleration pedal: a - an error as the relative difference of rotation rates $\omega_r$ measured with a regular sensor and a roller follower; b - an error expressed as a percentage.

The oscillograms of the changes in the delay time for roller $\Delta t$ at the initial and final wheel rates have been constructed as well (Figure 11).

Figure 11. Changes $\Delta t$ in the delay time for the roller at the initial and final wheel rates: a - when braking; b - when releasing brakes.

4. Conclusion
1. Measurement systems of the wheel rotation rate of existing motor vehicles on the roller test benches fulfill their functions only at low (up to 5 km/h) rates [1] which has been confirmed by the experiment.
2. Increase in the initial rate above 5 km/h results in significant measurement errors of the rotation rate, which can exceed 85%.

3. Use of contactless (including laser) measuring methods is one of the promising ways to increase the measurement accuracy of the rotation rate.

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