Calibration Methods of Force Control Diagnostic System of A Rolling Stock on the Run

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Abstract. In article the technique of calibration of system of dynamic control of a rolling stock is described. The scheme of carrying out and the device for calibration of dynamic control of a rolling stock is provided. Dependence of dynamic force on temporary parameters of blow is defined.

1. Introduction
The control systems of a wheel attack (hereinafter referred to the System) based on the elastic contraction of a rail measure the magnitude of force with a limited accuracy [1]. At the present moment there are no certified calibration methods for such systems in our country. This paper presents calibration methods of the control systems of the attack wheel to rail [2] in the field conditions (hereinafter referred to the Method). The Method determines a confidence error for force measurement as ±5% with a confident coefficient of \( P = 0.95 \).

The System calibration is performed by the direct comparison method. The System calibration can be primary and periodic with the same range of activities for both. While calibrating the following operations are conducted: a visual inspection, a testing, a metrological examination, a measurement of actual value of dynamic force measured [3,4].

While testing a rolling stock runs through the System control section and measurement data comes from all System channels [5]. Calibration is performed on each sleeper and in the intercrib work across the control section (figure 1а). The ranges of forces applied are 25–50 кN, 50–75 кN, 75–100 кN, 100–125 кN, 125–150 кN.

2. Experiment
To produce a dynamic force an impact device is used (figure 1b), it consists of a hammer and a centering tube. The hammer is a set of plates (figure 1b; position 6 and 7) and striker pins (figure 1b; position 5) put on a stud M10 and fixed with a screw (figure 1b; position 1).

Plates and striker pins are made of steel 45 or steel with a higher yield point and provide a hammer weight variation in the range of 5–15 kg at a pitch of 2 kg. The diameter of plates and striker pins is (98±1) mm. It is measured with a caliper ШЦ-150 or other measurement tools with the same accuracy; maximum permissible error is ±0.5.

The lower plate in the hammer is made of duralumin D15 or other alloy with similar density (±20%) to meet \( l > 2 \cdot d \); it should prevent hammer sticking while falling. A hammer weight is determined with a permissible error of ±1 % by weighing on the platform scales ВСП-15.2-4ТК or other measurement tools with the same accuracy; received data is stated in the record sheet. It is acceptable to weigh
components by themselves and then to determine a hammer weight by totaling provided that a combined error does not exceed a maximum permissible error.

A centering tube allows an ordered motion of a hammer. It is made of a polypropylene with a coefficient of sliding friction on steel not more than 0.15 or other material with a lower friction ratio.

![Image](71x719)

**Figure 1.** Scheme of a control section (a) and an impact device (b) to produce a dynamic force.

The tube ID is (100±1) mm, tube length is min 2 m. There are four guide lines in 90° at the end of the tube to position devices on the rail. The tube is fit on the rail upright (out-of-upright is max 20 mm/m); uptightness is controlled with a block level (its length is 300 mm, readability is 0.1 mm/m) as per GOST 9392–75 or other devices with similar accuracy. Three through-holes of (10±0.5) mm in diameter are made in the tube to fix the weight at the height of (500±2) mm, (1000±2) mm, (1500±2) mm. Through-hole height is controlled with a 2.5 m measuring reel as per GOST 7502–98 or other devices with similar accuracy with max 1% permissible error.

Before and during testing a maximum height of a hammer above a top of rail, fall time and time of hammer-and-rail contact are measured and stated in the reports. Fall time and time of hammer-and-rail contact are measured with a digital-storage oscilloscope and/or an acceleration indicator.

To time the blow with a circuitry an electrical circuit is made up, it consists of a) a digital-storage oscilloscope or other similar electrical signal measuring devices with time permissible error of ±0.01 sec or with similar accuracy; b) a hammer; c) a rail in the control section; d) a source of constant voltage with 1–5 V; e) fixed resistors with nominal electrical resistance $R_1 = R_2 = R_3 = (200±10)$ Ohm (figure 2a).

An electrical circuit on the 1st channel of the oscilloscope captures the fall time on the top of a rail and the hammer-and-rail contact time equal to the blow time. An electrical circuit on the 2nd channel records the time of a hammer start. An electrical circuit on the 3d channel registers the fall time on the $2\cdot\Delta L$ height. An electrical circuit on the 4th channel of the oscilloscope captures the fall time on the $\Delta L$ height.

When the hammer is falling, a digital-storage oscilloscope records signals shown in figure 3. The time of a hammer run to a blow $t_1, t_2, t_3, t_4$ and a blow time $\tau_1$ are determined / measured by received signals. Measurement data is stated in the due form reports.
Figure 2. Scheme of a calibration device (a), scheme of calibrating with measurement systems (b):

$R_1, R_2, R_3$ – resistance, $a_1, a_2, a_3, a_4$ – acceleration indicators, $l_b$ – distance between a striker pin and a center of hammer weights, $f_c$ – flexing electrical contact.

Figure 3. Signals recorded on Channels 1,2,3,4 at hammer falling.

A hammer weight center is calculated with CAD facilities in order to time the blow with an acceleration indicator. Maximum permissible error for finding a hammer weight center is ±10 mm. Four acceleration indicators (with range of -2000g – +2000g m/s², resolution limit max 10g) are fixed.
at the center-of-weight-level height on perimeter every (90±5)° to measure vertical acceleration (figure 4). Signals received from acceleration indicators are registered and averaged. Duration $t_2$ of a hammer blow on the rail is determined at the 5% level of peak acceleration. Measurement data is stated in the due form reports. Average time is calculated by formula:

$$\tau = \frac{t_1 - t_2}{2}$$

Uncertainty of blow time is evaluated and stated in the report. Average force of a blow is calculated by formula and then stated in the report:

$$F_m = \frac{m \cdot \sqrt{2 \cdot g \cdot L}}{\tau},$$

where $g = (9.81±0.01)$ m/s² - reference value.

![Figure 4. Vertical acceleration – impact time relation.](image)

3. Conclusion
The force determination error is calculated by difference between hammer acceleration and nominal magnitude of gravity depending on fall time then it is registered in the report. The range of permissible confidence error of force generation is calculated with confident coefficient of $P = 0.95$. An error of average dynamic blow force generation does not exceed 5%.

While dynamic force measuring, safety instructions are to be followed. At least two specialists conduct the operations. If measurements are performed in the field conditions, specialist wear orange reflective jackets and there must be a signalman on the railway track. Calibration of the control systems of the attack wheel to rail is performed at temperature from -25 to +35 °C, atmospheric pressure of 84–107 kPa (630–800 mmHg), relative humidity of 30–80%.

4. References
[1] Stepanova L N, Bekher S A and Kochetkov A S (2009) Measurement error analysis of moving wheel vertical forces to rail *Testing. Diagnostics* 12 54–60
[2] Otto L (2008) Monitoring railway wheel defects with rail installed measuring device *Publications of the Finnish Rail Administration* 12 90
[3] Sekula K, Kolakowski P (2013) Identification of Dynamic Loads Generated by Trains in motion using Piezoelectric Sensors *Proceedings of ISMA2010 including US2010* 1099–1118
[4] Sharpe P (2010) Measuring of the road-bed rigidity *Railway Gazette International* 9 190–194
[5] Stepanova L N, Kabanov S I, Bekher S A and Kolomeets A O (2013) Fast strain-gauge system for freight car wheel roll surfaces defects monitoring in movement *Sensors and Systems* 10 38–44