Improving measuring line parameters of the UIC test bench

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Abstract. This article deals with the description of the management of variable braking force at the request of multi-level braking on certification test bench UIC. The device is used to analyze the frictional properties of rolling stock brake accessory components. The introduction of the article describes and approaches the function of the measurement and control process. Based on the UIC standard, the requirement for variable braking force for multi-level braking is described. The conclusion of the article is devoted to evaluating the accuracy of measured data and analyzing undesirable phenomena.

1. Introduction
The University of Žilina has one of the few specialized brake test benches UIC in Europe in the heavy laboratory of the Department of Transport and Handling Technology. The brake linings of disc and shoe brakes of rail vehicles around the world are tested on it. In the mentioned state, certified components can be used for vehicles that move up to a speed of 350 kilometers per hour, which represents a category D category. [3, 4]

In this state, constant innovation is needed, which takes place by increasing the simulated speeds, braking masses, increasing the accuracy of measurement and evaluation, and the like. The reason is the ever-increasing demands on the braking systems of rail vehicles. [5, 6]

In order for our department to be able to issue certificates of conformity to manufacturers, it must also undergo regular certification by a superior body. Whether in the event of any change in concept for the purpose of innovation or only after the expiration of the license. The testing body is a group of experts known as ERRI B 126.3 set up by the UIC. During regular testing, each certification body submits the appropriate technical documents to its test bench. On the basis of these documents, each certified workplace will receive standard brake linings and blocks on which they will perform precisely determined measuring procedures. The accuracy of the condition is assessed on the basis of the deviation of the measured values from the average value measured by other test benches in the world. If the deviation is within the tolerance band, the condition is satisfactory; if it is out of tolerance, repairs to the measuring system and subsequent corrective tests must be performed. If the erroneous result is repeated, the certification license will be revoked by the center. [7].
2. Description of mechanical components brake test bench UIC

The mechanical line is driven by a 265 kilowatt DC motor (1). Power is transmitted by a axial pin coupling (7) to the gearbox (2) with a gear ratio corresponding to the given simulated travel speeds. The gearbox used is single-stage due to its simple design. If a different gear ratio is required, it can be exchanged for other gearboxes relatively quickly. [3] From the gearbox, the power then passes through the pin coupling (7) to the flywheels (3,4). Together they have a moment of inertia $I = 980 \text{ kg.m}^2$. From the flywheels, the power is further transmitted via a flexible coupling (7) to the shaft, on which, according to the current measuring program, either a disc is mounted or one wheel from the train wheelset is pressed. The shaft is mounted at the ends of the main bearing housings (5). From the inside of the main cabinets are smaller bearing cabinets, frame. These smaller housings ensure the exact axial position of the measuring frame relative to the rotating axis. The frame is freely rotatable relative to the axis of the cradle principle. The frame is supported by a connection to the base grate via a tangential force sensor (9). The sensor captures the reaction force and thus provides one of the main information about the derived braking torque. The brake mechanism is mounted on the frame. Two types of frames are used. Disc brake test frame and brake shoe test frame. In place of the lever mechanism of both types of frames, there is another force sensor for measuring the braking force of the levers of the mechanism. The transmission of the actual temperature of the brake disc or wheel is ensured by means of a 12-channel ring head located at the end of the main shaft (8). For accurate wheel speed measurement, an IRC305 optical speed sensor is mounted in the ring head holder, which generates 1250 pulses per revolution. [1, 2]

![Figure 1. Current connection concept of the UIC brake bench test](image-url)
3. Description of measuring and control block

The control and measurement line consists of a measurement program which, based on a request for a measurement procedure with the help of a developed macro, sends control commands via a communication interface with the support of drivers to the hardware. The hardware converts commands into electrical signals to control actuators.

At the same time, the hardware processes the electrical signals from the individual sensors and forwards them to the control program, which cooperates with the associated evaluation program. The evaluation program statistically analyzes the measured data and writes it into tables and graphs. Based on the measured results, test reports are then issued. Some of the signals are also used as feedback to control the whole process. [8]

Figure 2. Block diagram of the control chain
4. Multi-level braking process

Figure 4 shows a breakdown of the brake pad manufacturer's requirements for a given test program, including multi-level braking and variable simulated weight. [10]

| Brake No. | Speed (km/h) | Brake mass (kg) | Brake force Q0 (kN) | Initial temperature (°C) | Braking parameter requirements |
|-----------|--------------|----------------|---------------------|--------------------------|-------------------------------|
| Bedding in | 1-6          | 250-170          | 170-80              | 90                        | Pad bedding in with squeeze 95% of their surface according to EN 144-4; <80 mm/s. |
|            | 6-10         | 250-170          | 170-80              | 90                        |                               |
| Pre-Test   | 11-16        | 250-170          | 170-80              | 90                        |                               |
|            | 14-18        | 250-170          | 170-80              | 90                        |                               |

Figure 3. Demonstration of the brake component manufacturer’s requirement for variable braked mass

The braking process is prescribed by UIC 548. The standard precisely defines the level of braking force based on speed. When using multilevel braking, the initial speed $v_0$ at point 0 begins to brake by increasing the braking force $F_b$ at point 1 to the level $F_b(1)$ at the speed point $v(1)$, increasing the braking force to the level $F_b(2)$. Such an increase in braking force is repeated until you stop. In the case of one increase in force during the entire braking process, we speak of two-level braking. [11]

Figure 4. Multilevel braking (UIC 548 3. edition 2018)
5. Evaluation of control accuracy

The following figures show a two-level braking curve for a simulated braked mass of 4000 kg at a speed of 350 km/h with a braking force of 19 kN and at a speed below 215 km/h with a braking force of 25 kN. All graphs in this section are independent axle braking distance.

Figure 5 shows the required braking force (FB) in green, the braking force (FB) measured in black and the tangential force (FT) measured in red. By statistical analysis, we found that the course of the measured braking force is in the tolerance field of the required braking force in the prescribed braking program. From the course of the tangential force, we concluded that after reaching the value of the braking distance of approximately 3300 meters, there is an undesirable oscillation of the system. After reaching a distance of 3,500 meters, it stabilized again. Small fluctuations also occur at a distance of 4000 meters in a narrow spectrum. We analyzed which other measured quantities are affected by the oscillation. [15]

Figure 5. The course of braking and tangential force

Figure 6 shows the speed in black and the average temperature of the six thermocouples placed on the brake disc in green. We can see that the oscillation of the tangential force is not shown in the velocity graph. After reading the values of speed and distance traveled, we can conclude that the oscillation occurs at speeds of approximately 150 and 100 kilometers per hour. [14]

Figure 6. Course of speed and mean temperature of the brake disc
Figure 7 shows the course of the coefficient of friction. As we can see in the figure, the oscillation of the sensed tangential force has a direct impact on the evaluated quantities. The picture also shows that at the same time, or at the same distance traveled, the coefficient of friction also oscillates.

![Figure 7. The course of the coefficient of friction](image)

Figure 8 shows the oscillation profile of the simulated braked mass. As shown in the figure, the value of the braked mass oscillates regularly regardless of the oscillation of the tangential force. It follows that the oscillation of the tangential force does not have a significant effect on the regulation of the simulated weight.

![Figure 8. The course of the simulated weight](image)

The accuracy of the electronic simulation of inertial masses is assessed by analyzing the test results of the ERRI B 126 / RP 18 prescription program. Here, the calculation of the actual instantaneous simulated mass $m_{\text{sima}}$ and the mean simulated mass $m_{\text{simm}}$ integrated along the braking distance achieved by the control of the braking drive is performed.

The value of the instantaneous simulated mass is expressed by the formula:

$$m_{\text{sima}} = \frac{2rF_i s}{Rv^2}. \quad (1)$$

It results from the equality of the braking work performed by the friction force $F_i$ and the wasted kinetic energy of the weight of the wagon corresponding to the brake, where $r$ is the friction radius, $s$ is the braking distance and $R$ is the wheel radius. [14]

The following applies to the mean simulated value:

$$m_{\text{simm}} = \frac{2r}{Rv^2} \int_0^s F_i ds. \quad (2)$$
6. Analysis of measured courses of quantities
During the measurements, it was found that at certain points of the braking distance covered, which belong to certain simulated speeds, undesired oscillations occur. These oscillations have an effect on the evaluated coefficient of friction. We tried to identify the source. We tried to verify the suspicion of the natural frequency of the entire flywheel chain. We placed a torsional vibration sensor on its free end. It is attached to the BKN coupling in place of the ring head.

Figure 9 shows graphs of individual measured quantities. First graph, simulated speed. The second graph shows the course of the tangential force. The third graph shows the course of torsional oscillation of the free end of the shaft. The third graph shows that several natural oscillation shapes appear during start-up. This causes an initial definition of the clearance of the couplings and the like. We are interested in oscillations in the speed range of approximately 90-100 kilometers per hour, which have stabilized and oscillate again in the speed range of 140-150 kilometers per hour. Another study found that the two resonant frequencies of the whole system are located in the range of these two velocities. [12,13]

![Figure 9. Comparison of the course of torsional vibration and tangential force based on the achieved speed](image)

Conclusion
In this article, I approached the function and principle of managing some UIC test bench processes located at the University of Žilina. I focused on the evaluation of the measured data and the description of individual disturbances and their possible causes. I found that during braking, the torsional vibration sensor at the expected speeds did not detect torsional vibrations as it did during the start-up of the entire system. The interference manifested itself on the tangential force sensor as a mirror-inverted oscillation of the free end of the shaft during start-up.

From this, we can conclude that during braking, the brake frame absorbs torsional vibrations, transmits them to the tangential force sensor and causes distortion of the data on the mean coefficient of friction.

In the following period, we will try to eliminate torsional vibrations by applying a torsional vibration eliminator based on the principle of a rotating pendulum and repeat the measurement again. We will try to eliminate the calculated mean value of the natural frequencies of 4.6 and 7 Hz.
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