Determining the geometrical parameters of spring suspension of locomotives

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Abstract. The paper considers the issues of measuring the geometric parameters of the springs using a laser-optical sensor. The features of an automated rig for measuring the parameters of the springs are presented. The work also investigates the operation of the laser-optical sensor. The results obtained allow using the laser-optical sensor for measuring the geometric parameters of the springs of a rolling stock. The measurements obtained with the laser-optical sensor to determine the parameters of the locomotive suspension springs are presented.

1. Introduction
In accordance with the innovative development program of the Russian Railways Company, the quality of the parts and products used in the railway transport should be high, since the safety of the transport of passengers and goods depends on each mechanical assembly and individual parts.

In this regard, during overhauls of locomotives, all components and all parts included in their composition are inspected, as well as individual components and components are replaced or repaired in accordance with standards and tolerances, tested and adjusted to restore their operational characteristics and guarantee their performance [1-4].

Testing of spring suspension of locomotives includes testing under the action of a test load to determine the value of permanent deformation and under the action of a static load to determine the magnitude of the chamber of the spring.

Residual deformation is defined as the difference between the heights of the spring in the free state before and after compression under a test load. The test is performed as follows: the spring is pressed twice with the test load and after removing the load, the spring height is measured in the free state. Then, the spring is again loaded with the test load, completely unloaded, and its height is measured. In this case, the height of the spring in the free state measured first, must remain unchanged.

The springs that have passed the tests for the absence of permanent deformation are tested to determine the actual chamber of the spring under the working static load, which is defined as the difference between the height of the spring in the free state and the height of the spring under the working static load. At the same time, the measured actual chamber of the spring given in the tables should not deviate from the calculated value by more than +12 and -8%.

To date, on the market there are automated spring calibration stands to measure the geometrical parameters of the springs, which are based on two basic non-contact measurement techniques: shadow
method and triangulation method [5-10].

2. Triangulation measurement method using automated bench

To determine the geometric dimensions of the calibrated spring, a non-contact method is used. For this, an optoNCDT 1700 laser sensor shown in Figure 1 was selected.

This sensor works using the principle of optical triangulation and has high accuracy and resolution. The measurement results from the digital output of the sensor are sent to an industrial computer. The main advantage of the sensor is the laser system, which allows taking into account the reflective properties of the surface (mirror metal, black rubber or shiny varnish).

![Figure 1. OptoNCDT 1700 laser optical sensor](image)

To improve the accuracy of movement of the measuring laser system, profile rail guides are used. The principal design of the rolling guide rails is shown in Figure 2.

![Figure 2. Rail design](image)
A rail on both sides has longitudinal parallel support tracks for rolling elements (balls or rollers). The shape and number of tracks are determined by the type of rolling elements and the operational characteristics of the system. On a rail, a movable carriage is mounted having internal longitudinal support surfaces (their number and shape correspond to the support tracks of the rail) and longitudinal return channels of the rolling bodies. At the ends of the carriage, end plates (caps) are fixed that provide closed movement of the rolling elements from the support tracks of the carriage to the return channels and back. In the carriage, limiters are also mounted that protect the rolling elements from falling out during an emergency displacement of the carriage from the rail.

The profile rail guides have numerous benefits, including low friction, no jamming and slippage, and smooth linear movement, even under heavy loads. Due to their ability to maintain high efficiency and operating parameters over a long period of time, they meet a wide range of tasks solved on general industrial and precision equipment.

The profile rail guides and movable carriage are components of the linear displacement module, driven by an asynchronous motor with a frequency converter.

The linear displacement module is shown in Figure 3.

The laser sensor is installed on the movable carriage, which measures the distance from the measuring surface of the sensor to the measured spring.

3. **Experimental studies of rig measurement system**

The geometric dimensions of the spring, as shown in Figure 4, are determined as follows.

The scanning distance obtained between the measurements corresponding to the values $L_1$ and $L_3$, $L_1'$ and $L_3'$ determines the diameter of the spring rod $d_1$. The distance between the measurements corresponding to the values $L_1$ and $L_2$, $L_2$ and $L_3$, $L_1'$ and $L_2'$, $L_2'$ and $L_3'$ determines the radii of the spring bar. In this case, the values of $L_1$, $L_3$, $L_1'$, $L_3'$ are selected according to the maximum value of the measured distance, while $L_2$ and $L_2'$ are selected according to the minimum value of the measured distance to the neighboring spring rods.

The minimum scanned distance to the spring bar closest to the sensor, corresponding to the values of $L_2$ and $L_2'$, and the minimum distance to the spring bar, remote with respect to the sensor, determine the outer diameter of the spring $D$.

The value of the inner diameter of the spring $d$ is determined by the value of the outer diameter $D$ minus the doubled value of the diameter of the bar $d_1$. 

![Figure 3. Linear displacement module](image-url)
The spring pitch is defined as the average scanned distance between the measurements corresponding to the values of L2 and L2'.

![Spring bar diameter measurement](image)

**Figure 4.** Spring bar diameter measurement

The results of scanning the suspension springs with the optoNCDT 1700 laser-optical sensor are shown in Figures 5 and 6.

In Figure 5, the spring is located on the test rig in a way that its end face is pressed to the right side of the bench.

In Figure 6, the spring is located on the test rig in a free state and is not pressed against the side wall of the bench.

To process the results for the suspension springs scanned by the optoNCDT 1700 laser-optical sensor, a computer program was developed that implements the above-described algorithm for determining geometric dimensions.

The results of processed data obtained during the scanning of the suspension spring by the optoNCDT 1700 laser-optical sensor are shown in Figure 7.
Figure 5. Scanning of spring pressed against the end

Figure 6. Scanning of spring not pressed against the end
4. Conclusion

By using the optoNCDT 1700 laser-optical sensor, it is possible to measure the geometrical parameters of the spring suspension of locomotives. This ensures high measurement speed, which allows increasing the productivity of spring calibration. The use of a laser-optical sensor also provides high measurement accuracy.

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