A METHOD FOR TRAIN WEIGHT ESTIMATION

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ABSTRACT

There are difficulties and deficiencies in procedures of weighing of railway cars and trains, as well as there is a persisting need to know cargo loads on the rail track. The article offers a simple way to estimate weight of a train as it moves along a control track section. It is based on measurement of intensity of magnetic field generated by locomotive DC traction motors. The role of weighing devices is performed by ferroprobes having as recording devices milliammeters with a calibrated scale for measuring train weight. The results achieved by the authors confirm method's effectiveness.

Keywords: train weight, locomotive, DC traction motors, constant magnetic field, magnetic field intensity, ferroprobes, train weighing method.

Background. *Weighing of trains today is complex, energy-intensive, expensive procedure, which often does not provide sufficient accuracy.*

Calculation methods for estimating mass of rolling stock are well known and are described in detail in the literature [1, 2], but they are very time-consuming and require gathering of large amounts of information.

Objective. *The objective of the authors is to highlight problems arising during train mass measuring and to offer a simple method of train weighing on the move using ferroprobes.*

Methods. *The authors use general scientific and engineering methods, experimental studies, evaluation approach, evaluation method.*

Results.

On the move or in stand-by mode

There are various methods for measuring train weight on the move via pressure sensors located under the rail. Their main disadvantage is poor accuracy. Practices have shown that at the time of passage through the sensor area, fluctuations of the wheels of the car have a significant impact on measurement accuracy, while presence of defects on wheel thread leads to impacts of high intensity on the measuring section. When weighing tanks on the move there are additional problems – weighing accuracy is very dependent on oscillations of the liquid at the time of passage of the sensor area.

Therefore, a «mitigating area» should be located at a distance of 70–100 m from measurement area (weights). It is necessary to ensure within this «mitigating» area:

– straightness of rails within the limits of ± 2 mm vertically and horizontally;

– difference in height of rails within the limits of ± 1 mm;

– possible high track rigidity, for which concrete sleepers are laid with steps between them of 460–500 mm, followed by a thorough two-week surfacing.

In front of «mitigating area» it is necessary to limit and reduce speed in order to have time for damping of vibrations of the car before it passes through the zone of weights. From the exit of the weights area the same low-speed section is required, but a bit shorter (of 20–30 m).

To reduce dynamic error train passage through weights should be carried out at a constant speed without jumps and abrupt braking.

The magnitude of dynamic errors of weights is affected by the state of rolling stock and, in particular, by the state of the coupler and wheel sets of cars.

Similar problems arise during in-motion weighing on the scales with strain gauge rail RTV-D. Another existing method of determining train weight on the basis of its speed (Russian patent № 1059445) excludes construction of loading platform with force measuring sensors. However, it has disadvantages:

1. The method is quite expensive because of the need to install inductor on the train and to place the loop line along the track.

2. A method is laborious, since it requires specification of coefficient values included in the calculation formula to ensure sufficient accuracy of mass determination.

3. Accuracy of train weight calculation depends on the mathematical model relating speed and mass of the vehicle and including a significant amount of the required parameters.

Measurement of weight on weighbridge as a compact platform allows to weigh only standing cars. The method is complex and is time-consuming.

Ferroprobe as weights

The authors propose a new method of estimating train weight, simplifying measurement which does not require embedding of sensors in railway track elements, as well as electrical circuits and design elements of locomotive or car, but at the same time provides necessary measurement accuracy. It promises to improve process efficiency, to significantly reduce power, time and financial costs, as it goes without complex and expensive equipment and without additional staff.

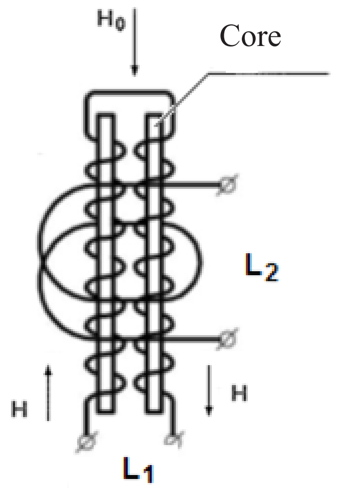
The proposed solution is as follows.

The value of magnetic field intensity generated by locomotive DC traction motors is measured. As it is known, the amount of current consumed by traction motors is determined by the magnitude of the load on its shaft, which, in turn, depends on the mass of cargo transported and traffic conditions – speed, features of track section (hump, slope, quality of railway tracks, etc.).

The motor current induces a constant, slowly varying magnetic field, and its intensity can be measured. The proposed solution uses the relationship between intensity of magnetic field generated by DC motor, and load on the motor shaft, which determines train weight.

To measure the magnetic field intensity various sensors can be used, in particular ferroprobes representing transducers of magnetic field intensity into the current value. Ferroprobe measurement method is quite simple, well studied and allows to achieve the required accuracy [3–6].

Ferroprobe has high sensitivity and in measurement of strong magnetic fields does not require installation in the immediate vicinity of the motor or its power supply circuits. An ammeter (milliammeter), scale of which is calibrated in necessary units, is used as an indication device.



Pic. 1. Ferroprobe device: H – excitation field, H_0 – measured magnetic field.

When a locomotive without a train is moving on the control section of the track with a certain constant, pre-picked up speed, readings of milliammeter are recorded, which are taken as zero weight load. When the locomotive is driving with a hitched train on the same section (or similar to control section) with the same constant speed, milliammeter reading corresponds to the weight of cargo transported, excluding total weight of cars' dead weight, which is known.

Thus, for mass measurement it is necessary to:

• provide for the control section of the track, or section, similar to the control section by its parameters, on which measurements are made and to which corresponds the scale of measuring device milliammeter;

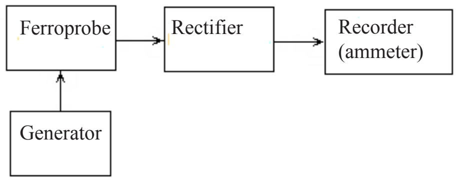
• provide for movement for at least one minute on this section at the same constant speed, at which calibration of measuring instrument scale was performed;

• take measurements in a non-contact mode with a device, which is a ferroprobe inverter of magnetic field intensity of the traction motor into the value of current, take readings from the measuring device, the scale of which must be pre-calibrated in units of mass.

Content and operation

Pic.1 shows a differential ferroprobe with two permalloy cores with excitation winding L_1, consisting of two halves.

The first half of excitation winding L'_1 is on the one core, the second L''_1 (wound counter-currently to the first) is on the other core. The diameter of the wire of excitation winding is 0,3 mm, the number of coils of each half is 200. Winding is single-layer, made coil to coil. It is connected to the pulse generator. Over two cores with windings L'_1 and L''_1 measuring winding L_2 is located with the number of coils 2000 and 0,1 mm wire diameter. It is multi-layered, made coil to coil. The measuring winding is connected via a rectifier to recorder, which is ammeter (milliammeter). The measuring winding can be connected to an oscilloscope, which allows to observe the distortion of rectangular voltage pulses when exposed to an external magnetic field.



Pic. 2. Block diagram of measuring device.

To protect ferroprobe against external influences protective cover is used, which is a tube made of brass [7].

To compensate for the effect of extraneous sources additional third winding L_3 is provided, located on top of the main windings (not shown in Pic.1). Wire diameter of additional winding is 0,1 mm, the number of coils is 500.

The block diagram of the measuring device, through which the method is realized, is shown in Pic. 2.

The block diagram includes:

– A pulse generator that generates rectangular pulses supplied to the excitation winding L_1 of the ferroprobe;

– Ferroprobe comprising three windings;

– Rectifier;

– Recorder – milliammeter.

Diagram of ferroprobe's winding connection is shown in Pic. 3.

Compensation of external fields is carried out with switched off locomotive motor with variable resistor R_2 via setting the zero value of the current measured by milliammeter. The value of resistors R_1 and R_3 is selected depending on the device used and voltage magnitude.

Generator of rectangular pulses can be performed using three NAND elements, powered by a 9 volt source. It is desirable to provide the possibility of regulation of frequency, for example, using the scheme described in [8]. The intensity of magnetic field generated by the traction motor, and hence the value of train weight are determined by indicators of milliammeter.

Scale calibration and measurement

The result is achieved through two consecutive steps:

1. Calibration of scale of a measuring device (milliammeter).

2. Actual measurement of train weight.

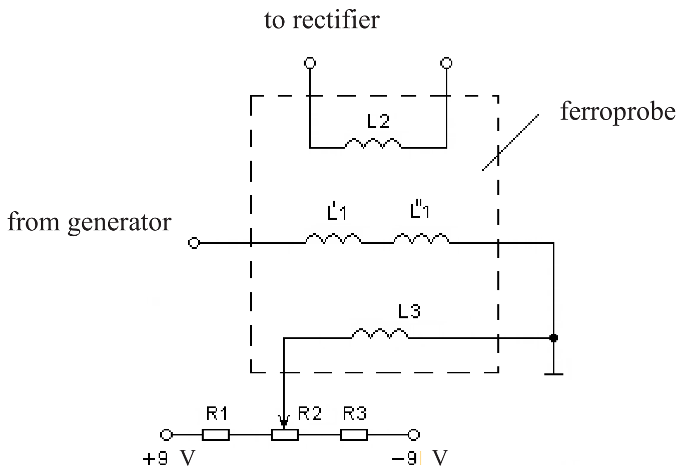
Scale calibration is performed in the following order.

1. Track section is selected with certain parameters, which is declared as a control one. For example, a horizontal straight (without slopes) section with a length exceeding the length of the train, which weight is planned to be measured. It is desirable for it to have such parameters, which are most characteristic of the proposed train route.

2. Locomotive movement without a train is performed on the control track section in a certain mode (a constant speed is assumed). The travel time should be sufficient to record the milliammeter reading, which is taken as the zero weight of cargo.

3. The same motion on the same section (or similar) is carried out with a hitched train, which weight of cargo is known. Indications of milliammeter will match the total cargo weight minus total weight of cars' dead weight, which is also known.

4. Actions taken in step 3 can be repeated with other cargo weight for a more accurate calibration of



Pic. 3. The scheme of connection of ferroprobe windings.

the scale and error elimination. At the same time scale of calibrated milliammeter is almost linear.

When using the method for one brand locomotives there is no need for calibrating the measuring device scale for each locomotive. It is enough to provide only the same installation location of a sensitive element (ferroprobe).

Measurements of cargo weight of a train should be made through driving on the control (or similar) section of the track in the same mode as when calibrating the measuring device.

Technical result and conclusions

The proposed method eliminates the need for sensors embedded in the railway track elements, circuits and elements of locomotive design, does not require complex technological equipment, reduces the cost of measurement, while ensuring sufficient accuracy.

The measuring device (milliammeter) can be installed almost anywhere in the locomotive that provides the convenience of recording measurement results by assistant driver without additional staff.

Device implementing the method is characterized by low power consumption, it is compact (its dimensions may match the size of the mobile phone) and does not contain expensive elements either require special maintenance. Pre-starting procedure is calibration of measuring device scale (milliammeter) in units of mass.

Application of the method confirmed that the measuring devices' readings are not dependent on fluctuations of car wheels, the state of the coupling, the presence of defects on wheel thread, fluid oscillations in tanks at the time of train passage on the measuring track section. No «mitigating area» is required, it is enough to ensure a constant engine speed and, therefore, a certain speed without jumps and abrupt braking. Possible fluctuations in readings of the measuring device do not create problems, since the average value is detected within a few seconds from the start of observation.

It should be noted that the effect is achieved by using a DC locomotive with pulse speed control. This is a limiting factor for this method of measuring train weight. Nevertheless, the vast majority of freight locomotives of JSC Russian Railways is represented by just such locomotives, therefore, the applicability of the method is not in doubt.

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Article received 07.12.2015, accepted 18.02.2016.