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PROBLEM OF INCREASING THE ACCURACY OF RAILWAY CARRIAGES WEIGHING IN MOTION

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Abstract - In this work we represent our experience in building railroad scales for weighing carriages in motion. A moving train weighing process consists of load cells signal filtration, axle weight calculation and carriage and locomotive identification. We created several filtration algorithms for clearing a load cell signal from bad oscillations that take place in a system. Also we built a carriage identification algorithm that determines how many carriages are being weighed at the moment. The difficulty in this field is that there are a lot of different types of carriages and locomotives on the railways of The Russian Federation, all of them have different lengths, axle arrangements and bases. Also we are working on a scales for weighing tanks with liquids in motion.

Keywords: railroad scales for weighing in motion.

1. INTRODUCTION

Railway carriages and tanks weighing in motion system consists of one or several weighing platforms, built-into railway lines, a set of load cells, an analog-digital converter (junction box) and an information processing system (PC based software). A weighing platform, a part of railway lines defined length, is set on four load cells. A quantity of carriage axles, situated on the scales at the moment of weighing, depends on the platform length. Depending on the platform length there are several possible ways to configure the system: one axle weighing (the platform is about 1m length, Fig. 1, a.), two axles (one bogie) weighing (approximately 3m length, Fig. 1, b), for a whole carriage one time weighing it is possible to use two one-bogie platforms (Fig. 1, c) or one full-length platform.

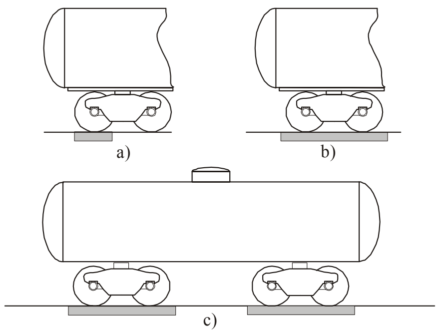

Fig. 1. Different types of dynamic railroad scales

In a described one-axle weighing system, which is shown on Fig. 2, four TENSO-M BR type load cells used connected to a two-channel TENSO-M PD-01 analog to digital converter. PD-01 sends two-channel signal (from the both rails) to a PC through the RS-485 protocol, where all the data is processed by a special software.

Fig. 2. TENSO-M RD-D one-axle dynamic railroad scales

When weighing a moving train we perform the following tasks:
- load cell signal filtration (noise oscillation excluding);
- axle weight calculation (finding a part of a signal that represents an axle weight);
- carriage identification (finding which axle belongs to which carriage or a locomotive).

2. SIGNAL FILTRATION AND AXLE WEIGHT CALCULATION

To find an axle weight useful signal right, we need to understand what kind of oscillations there are in a train when it moves. On Fig. 3 the elements of the oscillation system are shown, each of them has its own natural frequency: ground, concrete basement, weighing platforms on load cell bearings, a moving carriage on its spring supported chassis. Here we may also add the oscillations of a moving train, caused by gaps in carriage couplings, irregular motion, unstable locomotive tractive force and irregularity of the leading railway lines. To decrease the influence of these oscillations we set up a claim about the leading railway lines linearity and create a filtration algorithm that gives maximum effectiveness in suppressing the described oscillations.

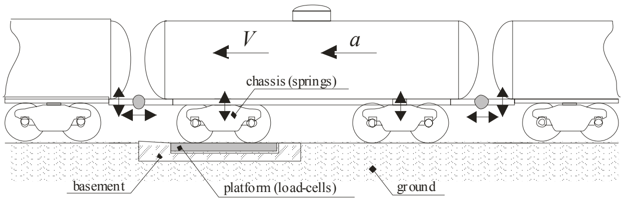

Fig. 3. A moving train: an oscillation system

the source signal but still has some noise. In the case of a higher order filter with a less cutoff frequency we have a more smoothed curve, but with a bigger phase displacement. Advantages and disadvantages of the both cases are obvious – on the one hand we have to exclude unnecessary noise signal, on the other – we have to repeat the source signal with a minimum phase displacement to calculate a distance between following axles (see the text below).

After filtration we have to find a part of the signal representing an axle on the platform excluding the parts when an axle drives into a platform and drives off (p. 3-4, see Fig. 4). To do this we analyze a slope of curve in each point. When we got a horizontal region initial and end points

Table 1. RD-D scales weighing in motion results

Carriage No	Static weight, kg	Dynamic weight, kg											
		1	Δ	δ, %	2	Δ	δ, %	3	Δ	δ, %	4	Δ	δ, %
1	94450	94350	100	0,11	94450	0	0,00	94300	150	0,16	94350	100	0,11
2	91467	91250	217	0,24	91300	167	0,18	91350	117	0,13	91250	217	0,24
3	26867	26800	67	0,25	26850	17	0,06	26900	-33	-0,12	26800	67	0,25

A sample signal, recorded when one axle passes the RD-D platform, is shown on Fig. 4 (with PD-01 ADC converter, conversion frequency 300Hz). We can describe different parts of the signal trapezoid shaped:

- p.1 - 2 – a platform is empty, there is no load applied;
- p.2 - 3 – an axle drives into a platform;
- p.3 - 4 – an axle drives over the platform;
- p.4 - 5 – an axle drives off the platform;
- p.5 - 6 – platform is empty.

A useful part of the signal is a height of a trapezoid – we need to process data between points 3 and 4. As a spectrum analysis of the signal indicates, all the oscillation processes frequencies that take place in a system are over the range up to 10-12Hz.

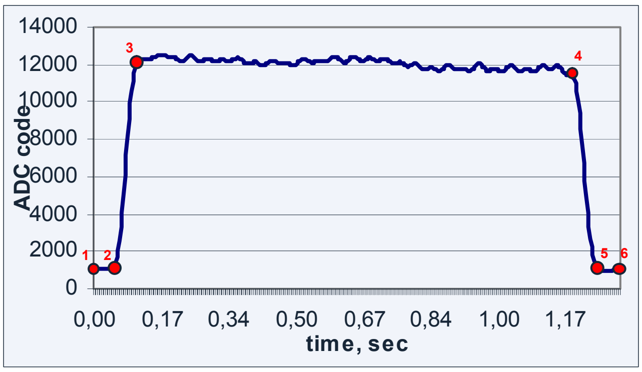

Fig. 4. One axle scales passage sample signal

As a filtration algorithm we chose Bessel filter, because it has no overcorrection at stepwise signal reaction and, at the same time, it has rather steep dip of phase frequency response curve.

Sample results of different created filters are shown on Fig. 5. There are two filters with different orders and cutoff frequencies. Less order filter repeats the trapezoid form of

and ADC code of an empty platform, we simply integrate the points range to calculate an axle weight.

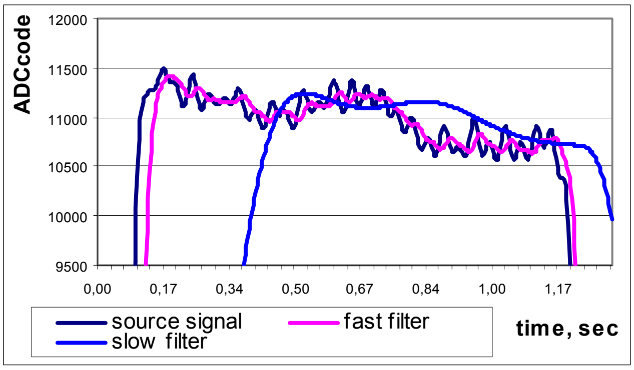

Fig. 5. A sample result of fast and slow filters work

When using worked out algorithms on one-axle railroad scales we get 0,25% accuracy with a train speed up to 15Km/h (see Table 1). Here a platform length and ADC conversion rate are important: the bigger they are the better accuracy we can get and the faster a train can go when weighing. On Table 1 there are several realizations of weighing in motion results given. There was a train composed of two full carriages and one empty. Each of them was weighed statically on the RD-D scales (trains stopped with every axle on the platform one by one) three times. Then weighing in motion results were compared to static weights.

3. CARRIAGES IDENTIFICATION

Carriage identification task is not of less importance. When a train goes through the scales platform we get a series of axles. Having processed each of them, we know its weight, time when it went over the platform, its moving speed, and distances between neighbor axles. After that we have to find out which axle belongs to which carriage or a locomotive.

In fact, carriage and locomotive fleet of the railways of The Russian Federation (track width 1520mm) consists of more than 300 carriages and more than 30 locomotives. All of them have different axle arrangements (there are 4-, 6- and 8-axle carriages and locomotives available), different lengths and different carriage- and bogie-bases. This fact makes the identification more complicated.

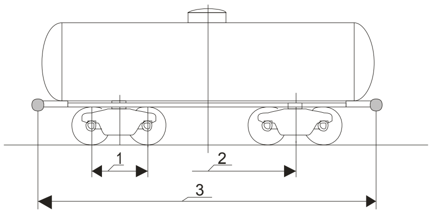

Fig. 6. Basic dimensions of a tank

Basic dimensions of a tank are shown on Fig. 6:

1. Boogie base: a distance between two axles in a boogie, it is equal to1850mm for all the freight carriages and tanks;
2. Carriage base length: a distance between the boogie centers;
3. Carriage length – a distance between the couplings.

The distances between the first(last) axle and a couplings are equal in most cases. When creating an identification algorithm we focused on a standard boogie-base dimension, a distance between two axles, – 1850mm. To calculate the distance between two axles we need to know time points when each axle was driving into the platform (p.3 at Fig. 4). Here we can see a connection between the filtration task described above. In this case we need minimum phase displacement of a filtered signal.

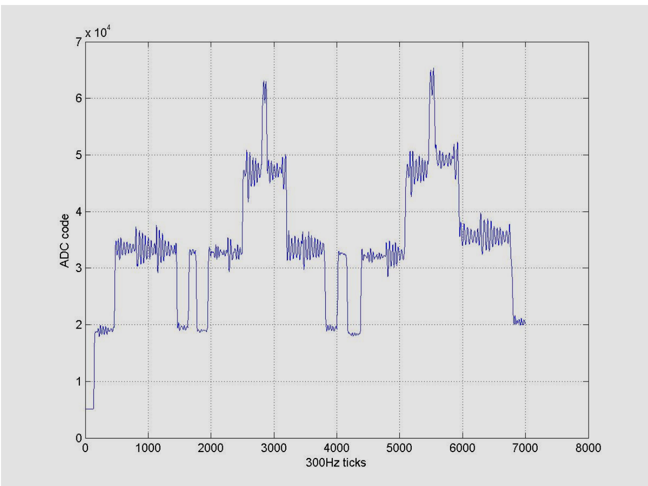

Fig. 7. A part of a load cell signal recorded in a 3.7m-length platform

Having created the identification algorithm, we came to a conclusion that the platform length plays a big part: the shorter it is, the easier it is to identify the locomotive and the carriages. Like it shown on Fig. 7, if the length is big, 3 or 4 axles can be on the platform at the same time. That makes the identification process more difficult. In such cases we may use an additional information from a patch-control transducers, installed near the platform.

4. INCREASING THE ACCURACY

To make a conclusion at this moment we can say that having a short platform (one- or two-axles at the same time) it is easy to identify carriages in a train. The easiest way is one-axle weighing in motion. On the other hand, the less platform length we have, the less useful signal time we get. To increase the weighing accuracy and provide a sufficient train speed when weighing, we should increase an ADC frequency and make the platform length bigger. In the case of a long platform, to make the identification process easier, we may use additional sensors that record time points when axle moves over it.

Also it is important to mention that in this task the following question is valid: what form should have an ideal axle passage? I was talking about creating a filter, integrating the signal to find a weight and that was with regard to the signal that looks like a trapezium with a horizontal upper base. Perhaps, because of an impact blow, that take place when an axle drives in the platform, or something else, the trapezoid base is not linear, maybe it depends on some other reasons. For example we know that there is a lot much more noise in the signal of an empty carriage, and a full carriage plays a buffer's role in an oscillating train. Also the passage signals differs from axle to axle depending where in the train a carriage situated: a carriage in the end of a train oscillates much more than carriages situated in the middle, and the accuracy of weight measurement of the first carriage right after the locomotive is often quite worse than others because of an additional force acting through a link from a heavy locomotive.

5. TANKS WITH LIQUIDS WEIGHING IN MOTION

Until now we were talking only about weighing different types of carriages with a hard loads. A new field of weighing for now is weighing liquids in motion. The point is that there is a tank's center of gravity shifting when the train moves. To weigh such a tank it is necessary to have all the tank axles placed on the platform when weighing.

On the assumption of a big variety of tank types there is a new task appears – to configure a weighing system for a set of specific tanks and carriages models. We have to decide how many platforms and what platform lengths we need for this set. Here we talk about full carriage-length platforms that are quite expensive. We have produced a special software that gets the model list and generates an optimized configuration of the system.

Measuring a distance between axles is easier if using path-control transducers. Knowing time intervals between transducer events we calculate a speed and between-axle distance, then we get the load cell signal parts to be processed for each axle weight calculation. So additional information from the path-control transducers increases the reliability of the whole system, because we don't need to process the load cell signal to find the time points when each axle drives in the platform and when it drives off (like it shown on Fig. 7).

The second task we are working on is an investigation of oscillatory processes that take place in liquids that fills the tank when it moves. The aim of such investigation is to increase a whole system accuracy by finding more additional ways to process the signal for measuring a tank weight.

In fact if we weigh a tank in motion, the time when all the axles are on the platform is not so big. A time of useful signal is not much bigger comparing to one-axle scales for example. As en example to show this, we can take 7.8m based 4-axle tank (a full length is 12m), to make it placed on the scales when weighing alone, the platform length should be also 12m, so all the four axles can go together only 2,35m. If a train speed is 2m/s, we get a little more than one second of useful signal.

I.e. having a longer platform we don't have more useful signal to process and there is also a big increase of price of the system because of the big metal-construction, more load cell quantity and a lot more of concrete works. Our aim is to get a possibility to weigh the liquid tanks using a shorter platforms, one-boogie scales for example. In this case we don't have a load that falls on all the axles at the same time, but we get more opportunities to measure the load of each axle. And the question is if it is possible to get the better accuracy or no.

6. CONCLUSION

At this time with our systems and software algorithms we get a good accuracy level in hard weights weighing in motion. In this paper, I mentioned the general ways and features that are advisable to know when building the scales for weighing in motion. We need to think of a moving train as an oscillation system including the railways and a concrete basement, we have to know what types of carriages and tanks we need to weigh to build an identification algorithm.

To measure liquid loads it is necessary to have all the tank's axles on the platform at the same time and there should be no any other tank's axles. Here we attend to configure the system for a specific customer interest (finding an optimized quantity and lengths of the platforms). Also we investigate the oscillations of liquids in a moving tank, the results of such investigations will be published in our future paper works.

A separate task is to find out if it is possible to measure a liquid's weight using a short platform and if the accuracy will stay acceptable in such case. These days we are working on a scale model of a weight measuring systems and a liquid filled tank to answer this question.

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