The Track and Rolling Stock Interaction under the Heavy Haul Conditions

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Abstract. In order to study and assess the traffic safety there has been simulated a train movement along the track, having a plan and a profile, corresponding to the actual current track outline on which the diesel locomotives Vityaz 2ТЭ25А are operated. The Kuznetsovskiy pass of the Far East Railroad has been chosen as the most difficult section. As a result of the calculations, values of main dynamic parameters of all sections of diesel locomotives have been determined when simulating a train moving along tangent track sections and curves of radius 200–600 m on descents and ascents with a slope of 25 ‰ in the traction and slowing-down mode, as well as longitudinal forces in automatic couplings of cars along the whole length of the train.

1. Introduction
The main problems of the heavy-train traffic are related to the longitudinal dynamics and the resulting longitudinal forces in the train at braking. To study the effect of these forces on the dynamic parameters and on the impact on the track parameters of each undercarriage in the train, the computer simulation was carried out using the software package Universal Mechanism [1]. An estimation of the magnitude of the longitudinal forces that arise when driving a heavy train along a track with a complex plan and a profile is presented below, the main dynamic parameters, as well as the parameters of the impact on the track are determined.

Figures 1 and 2 show a train model consisting of 70 cars with five sections of a TЭ25A diesel locomotive: three – in the head end and two – in the rear end of the train.
There has been simulated a train movement along the track, having a plan and a profile, corresponding to the actual current track outline on which the diesel locomotives Vityaz 2ТЭ25А are operated. The Kuznetsovskiy pass, which is located on the 202–206 km of the Pivan – Sovetskaya Gavan section of the Far East Railroad, has been chosen as the most difficult section. The diagram of the plan and the profile of this section is shown in Figure 3.

On the selected section of 5 km long there is an ascent of 1.5 km long with slopes of 21–25 ‰, an almost horizontal platform of 330 m long (slope of 1.2‰) and then a long descent with slopes of up to 25‰. At the same time, on this section there are many curves with a radius of 190–485 m and a length of 213–655 m, which have different directions (right and left curves). The allowable speed of trains on this section is 35–45 km/h.

The estimated oscillograms of frame and lateral forces, the bogie yaw angles on the first section, which is the head section, are shown in Figure 4, and on the fourth section, located in the rear end of the train, in Figure 5. The deviation of the bogie yaw angle from the zero level shows the passage of a section of the track, which has a curve, by this section of the diesel locomotive.

The initial speed when simulating the movement of a train in the traction mode along the Kuznetsovskiy pass was 50 km/h. During uphill operation the train speed decreased to 16 km/h and on further descent it increased to 50–55 km/h.

The maximum value of the frame force was 52 kN, the lateral force – 80 kN during the fourth section passing a curve with a radius of 200 m at a speed of 45 km/h, which is lower than the standard values [2].

The estimated minimum value of the safety factor against wheel derailment, when the train moved along the Kuznetsovskiy pass, was 2.65 for all sections of the diesel locomotives, which is significantly higher than the minimum standard value of 1.4 [3].
Oscillograms of longitudinal forces in the automatic couplings of all five sections of diesel locomotives and some freight cars, obtained by simulation of the movement of the train, consisting of 70 freight cars, through the Kuznetsovskiy pass, are shown in Figure 6. From the oscillograms one can see that the largest longitudinal force is obtained on the rear automatic coupling of the third head section.

Figure 3. Schematic representation of the plan and the profile of the Kuznetsovskiy Pass (198–210 km of the Pivan-Sovetskaya Gavan line of the Far East Railroad).
Figure 4. Estimated oscillograms of dynamic parameters of the first section of a diesel locomotive when simulating the movement of a train through the Kuznetsovskiy pass in the traction mode, consisting of three head and two pushing sections of diesel locomotives and 70 freight cars.

During the 145–180th s the longitudinal force was 981–1030 kN (100–105 tf), i.e. no exceedance of the standard value of 1177 kN (120 tf) was observed [4]. At the rear automatic couplings of the
Regarding the freight cars, the greatest longitudinal forces were obtained from the cars in the head of the train. The maximum values of the forces on the first ten cars were 932–883 kN (95–90 tf). It was revealed that the closer the car is to the rear end of the train, the lower the maximum values of the longitudinal forces arising during the train movement (Figure 6, b).

Since for a long time a longitudinal force was obtained, reaching the value of 981 kN (100 tf) and even exceeding it, which is close to the limit value of 1,177 kN (120 tf), the simulation of the train movement along the Kuznetsovskiy pass with the same number of diesel locomotive sections, but fewer cars, was carried out.

The analysis of the oscillograms of the calculated longitudinal forces in the automatic couplings of the train, consisting of 45 freight cars, shows that there is a slight decrease of the longitudinal forces on the automatic couplings of the diesel locomotives and the freight cars. The maximum values of the longitudinal force on the automatic coupling of the section #3 were no more than the limit force of 981 kN (100 tf), in addition, the time of its action was significantly reduced. The time, when the force values are in the range of 932–981 kN (95–100 tf), is no more than 5 s.

Comparison of the distribution of the maximum values of the longitudinal forces along the length of the entire train set for trains consisting of 45 and 70 freight cars shows that the longitudinal compression forces on trains of various lengths are practically at the same level. We can note only a slight increase of the longitudinal compression forces on the last 5 freight cars of the shorter train. In this case, all the maximum values of the longitudinal forces do not exceed 62 tf.

![Figure 6. Estimated oscillograms of the longitudinal forces in automatic couplings when simulating the train movement through Kuznetsovskiy pass in the traction mode.](image)

At the same time, the calculated longitudinal tensile forces are greater than the recorded compression forces. And if on diesel locomotives automatic couplings with a different number of freight cars, the difference between maximum longitudinal forces is insignificant, as noted above: for the train of 70 cars – 1,030 kN (105 tf), for the train of 45 cars – 981 kN (100 tf), then on the freight cars the maximum longitudinal tensile forces for the train of 70 cars are in the range of 294–932 kN (30–95 tf), and for the train of 45 cars, much lower, – within 216–549 kN (22–56 tf).
2. Conclusions
The simulation of the movement of a heavy 61,782 kN (6300 tf) train along the real track of a complex plan and a longitudinal profile (Kuznetsovskiy pass of the Far East Railroad) shows that the dynamic parameters of the diesel locomotives are within the standard values, however, in the automatic couplings of the train, longitudinal forces may occur, reaching the maximum value of 1177 kN (120 tf). The reduction of the number of cars to 45 leads to a decrease of the maximum values of the longitudinal forces (compression – no more than 608 kN (62 tf); tension – no more than 981 kN (100 tf)).

3. References
[1] User Guide of the Universal Mechanism Software Package 8 2016
[2] GOST R 55050-2012. Railway Rolling Stock. Standards of Permissible Impacts on the Track and Test Methods 2013 29
[3] GOST R 55513-2013. Locomotives. Requirements for Strength and Dynamic Qualities 2014 45
[4] Railway Transport Infrastructure on the Sections of the Movement of Freight Trains of Increased Weight and Length. Technical Requirements: JSC “RZD” Order No 678 dated 18.04.2016