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The results of brake tests of the DPKr-3 diesel train

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Abstract. JSC "Ukrzaliznytsia" purchased the first of three planned regional three-car (two main motor cars and one intermediate) diesel train DPKr-3 manufactured by PJSC "Kryukovsky railway car building works". To confirm the declared characteristics and safety indicators of the DPKr-3 diesel train, specialists department of Cars of Dnipro National University of Railway Transport named after Academician V. Lazaryan conducted complex certification tests, which confirmed the compliance of the stated parameters. One of the points of the Terms of Reference was to determine the brake pressure of the linings per 100 weight of the train in terms of cast iron brake pads. For this purpose, according to the methodology adopted in the territory of the former CIS, force sensors, which were installed in the tick mechanisms instead of the brake linings, measured the magnitudes of the forces of pressing the brake linings on the disks. However, during the tests it was found out that the current standards for calculating the provision of train brakes cannot be applied to modern rolling stock. It is recommended for rolling stock where the use of brake pads, and even more cast iron, is not provided by the design, to develop normative documents that would determine the standards for brakes by the results of calculations and tests.

Summary

The key role in the development of the economy of our country is played by Ukrainian railways. An extensive network of railroads connects hundreds of cities, allowing not only the connection of industrial centers but also the provision of passenger transportation in all directions. The rolling stock of Ukrainian railways in 2019 was updated with modern freight and passenger cars, Tryzub diesel locomotives manufactured by General Electric (USA), modernized the rail bus produced by the Polish company PESA, purchased the first of three planned regional three-car diesel DPKr-3 manufactured by PJSC "Kryukovsky railway car building works" (Ukraine). To confirm the declared characteristics and safety indicators of the DPKr-3 diesel train, specialists of Dnipro National University of Railway Transport named after Academician V. Lazarian conducted complex certification tests, which confirmed the compliance of the declared parameters. The brake system is the most important for providing safety, so determining the brake parameters of a diesel train was a mandatory test point.

Literature review

The question of efficiency and expediency of application certain brake systems on rolling stock, and especially on high-speed rolling stock remains relevant [1, 2]. In article [3] it is stated that a modern

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rolling stock should be equipped with several types of brakes that supplement the basic pneumatic brake. The modern rolling stock should be equipped with onboard brake control and diagnostics systems. It allows you to change the input parameters: brake weight percentage, braking modes, train length and track profile. The on-board unit registers the train deceleration and determines the optimum speed value [4]. Also, a lot of attention in international scientific editions has been paid to anti-use defense systems [5, 6]. The procedure for conducting and processing data of certification and acceptance brake tests of innovative rolling stock of railways is presented in the article [7] in which the results of the braking tests of a 2EV120 trunk freight locomotive with a design speed of 140 km/h are given. The tests were carried out in accordance with GOST R 55364. In article [8], it is noted that the braking distance calculation norms set by EN 14531 may not always give fairly accurate results and require revision. This conclusion was obtained when testing the EMU V250 passenger electric train with a maximum operational speed of 250 km/h designed for high-speed lines in Belgium and the Netherlands. Taking into account the values of the friction coefficients of friction brake linings, which depend on the speed and force of pressing, it became possible to obtain reliable results of the values of the brake path that coincide with the experimental data.

In article [9] is also noted the need to revise some regulatory documents for evaluating the performance of the rolling stock braking system. The differences between the requirements of the normative documents of Western Europe and the countries of the former Soviet Union are pointed out. The brakes of wagons made in Western Europe are calculated according to the requirements of TSI, where the output parameter is the braking weight, and for the 1520 mm track wagons, the force of pushing the brake pads in terms of cast iron pads. This problem is especially acute in countries that operate wagons built according to different standards, such as Lithuania.

Analysis of the literature in the field of research confirmed the relevance of the chosen topic. It should be noted that it is necessary to revise and introduce new national regulatory documents that would establish a methodology for conducting and analyzing the results of brake tests of modern rolling stock on Ukrainian railways.

The results of the brake tests of the DPKr-3 diesel train

After 4 years of successful operation of JSC "Ukrzaliznytsia" of the three-car diesel train DPKr-2, manufactured by PJSC "Kryukovsky railway car building works" [10]. On order of JSC "Ukrzaliznytsia" for regional passenger transportation, it was made with some changes to three wagon diesel train DPKr-3. The composition of the diesel train includes two main motor cars and one intermediate. The train diagram for stationary tests is shown in Figure 1. Figure 1 shows the wagon numbers and their weight in the loaded state, the designation of the trolleys and the total estimated pressure of the brake linings on the wheels of the trolley.

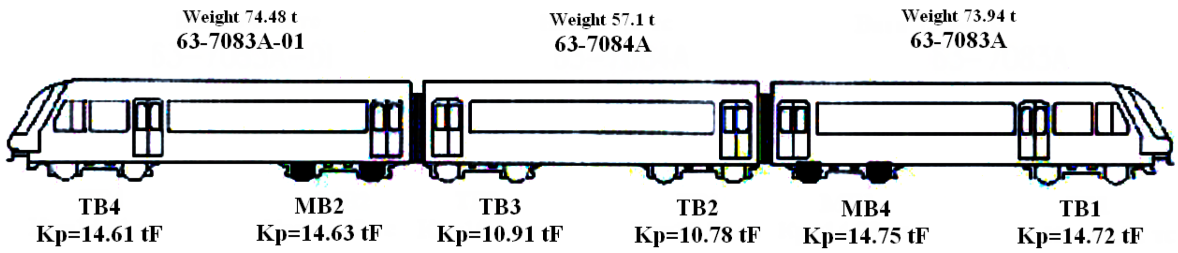

Figure 1. Scheme of DPKr-3 diesel train during stationary brake tests.

The diesel train is equipped with a system for regulating the pressure in the brake cylinders, depending on the load (population) of each individual cart. This makes it possible to realize the same specific braking force of each cart of a diesel train wagon, which provides smooth braking. One of the points of the Terms of Reference (TOR) [11] was to determine the brake pressure of the linings per

100 weight of the train in terms of cast iron brake pads. For this purpose, according to the methodology adopted in the territory of the former CIS, force sensors, which were installed in the tick mechanisms instead of the brake linings (Figure 2), measured the magnitudes of the forces of pressing the brake linings on the disks. Wheeled brakes are mounted on a diesel train. The pressing forces were measured in the empty and loaded states three times with pneumatic emergency, electro pneumatic and parking brake operation.

Figure 2. Installation of force sensors in determining the force of pressing the pad.

There were no "emissions" when determining the force of pressing the plates on the disks and the average values of the three measurements were taken into account. Table 1 shows the average values of the actual presses of the brake pads on discs in the empty and loaded states under different braking modes.

Knowing the magnitudes of the actual pressures, the calculated formulas [13] for the composite brake pads have been calculated using the known formula.

$$K_P = 1.22K\frac{0.1K+20}{0.4K+20}, \quad (1)$$

where K is the value of the actual pressing of the brake lining of the brake disc, kN.

To assess the braking performance of the rolling stock, use the force factor of the brake pad lining [13].

$$\delta_P = \frac{\sum K_P}{Q}\frac{r}{R}, \quad (2)$$

where $\sum K_P$ is the total estimated compression of the brake linings of the wagon, kN;

Q – weight of the wagon, kN;

r – is the average friction radius of the brake disc, 322 mm;

R – is the wheel radius of the rolling circle, 467.5 mm.

The results of the calculations of the calculated pressures and the coefficients of the pressing force in terms of the composite and cast iron brake pads of the individual wagons and the brake coefficient of the diesel train as a whole are shown in Table 2.

Table 1. The average values of the actual presses of the brake pads on discs in the empty and loaded states under different braking modes.

Kind of braking, others	State	Pressing, kgF (63-7083A)			Pressing, kgF (63-7084A)		
		Car Truck TB1	Car Truck MB1	Total	Car Truck TB2	Car Truck TB3	Total
Pneumatic	Loaded	15203	15244	30447	10468	10610	21078
	Empty	15318	14280	29598	10223	10225	20448
Electro pneumatic	Loaded	15763	15483	31246	11509	11598	23107
	Empty	15078	14662	29740	11175	11266	22441
Parking brake	Loaded	13104	11987	25091	8085	8139	16224
	Empty	12980	11983	24963	8046	8149	16195
Weight, kgF	Loaded	73940			57100		
	Empty	69193			52126		
Kind of braking, others	**State**	**Pressing, kgF (63-7083A-01)**			**Diesel-train**		
		Car Truck MB2	Car Truck TB4	Total			
Pneumatic	Loaded	15088	15069	30157	81682		
	Empty	14317	14389	28706	78752		
Electro pneumatic	Loaded	15337	15625	30962	85315		
	Empty	14443	15056	29499	81680		
Parking brake	Loaded	12200	13220	25420	66735		
	Empty	12191	13053	25244	66402		
Weight, kgF	Loaded	74480			205520		
	Empty	69706			191025		

Table 2. The results of the calculations of the calculated pressures and the coefficients of the pressing force in terms of the composite and cast iron brake pads of the individual wagons and the brake coefficient of the diesel train.

Wagon	Weight, kN	Compositional		Cast iron	
		$\sum K_P$, kN	δ_P	$\sum K_P$, kN	δ_P
63-7083A	725.35	289.06	0.27	342.92	0.33
63-7084A	560.15	212.81	0.26	270.56	0.33
63-7083A-01	730.65	286.82	0.27	340.86	0.32
Diesel train	2016.15	788.69	0.269	954.32	0.326

At a speed of 140 km/h. according to the chart given in the guide to traction calculations [12], the effectiveness of composite brake pads (pads) is increased by 1.22 times compared to cast iron. Pressing the composite pads on the axle 342.92/4=85.73 kN of the motor car 63-7083A will correspond in terms of cast iron pads to the pressure of 104.59 kN.

In this case, the force coefficient of pressing δ_P in terms of cast iron brake pads will be:

$$\delta_P = \frac{104.59 \times 4}{725.35} \frac{322}{467.5} = 0.397 . \quad (3)$$

According to the Terms of Reference the single minimum brake pressure, in terms of cast iron brake pads, must be at least 78 tons for every 100 tons of diesel train weight.

Taking into account the coefficient of efficiency at a speed of 140 km/h. brake pressure, in terms of cast iron brake pads, for every 100 tons of diesel train weight is 39.7 tons. The condition of the TOR according to the above calculations is not fulfilled.

According to the Standards for non-self-propelled rolling stock [13, Table 9.2] the minimum permissible value of the coefficient of pressure of the brake pads (composite) or lining of disc brakes of passenger cars at maximum speeds up to 160 km/h and pneumatic brakes is 0.3. There is no value for speeds up to 140 km/h.

According to the Standards for non-self-propelled rolling stock [14, Table 9.2] the minimum permissible value of the compression ratio of composite brake pads for wagons weighing 64-75 t (diesel wagon motor cars) and speeds of 140 km/h is 0.25, which is less than calculated and satisfies the condition. For wagons weighing 53-64 tones (towed diesel train car), the minimum permissible value is 0.27, which is more than calculated and does not satisfy the condition. These regulations do not apply to diesel trains, and the requirements of the existing braking regulations [15, 16, 17] cannot be applied to DPKr-3 diesel trains equipped with KNORR-BREMSE wheel-disc brakes.

The task of determining the single minimum brake pressure in terms of cast iron brake pads, for every 100 tons of diesel train weight, was decided to solve from the opposite, applying the nomogram of the brake path of the passenger train with cast iron brake pads during emergency braking.

During running tests for pneumatic emergency braking in the loaded state on a straight section with a value of ±2 ppm (thousandths), the average value of the braking distance according to the results of three brakes was: at a speed of 140 km/h – 868 m, at a speed of 120 km/h – 634 m at a speed of 100 km/h – 473 m, at a speed of 80 km/h – 290 m. If found the amount of braking pressure per 100 tons of train weight by nomogram (Figure 3) [18, Figure 317a] with such values of the braking distance, its value is more than 100 tons per 100 tons of train weight (Figure 3).

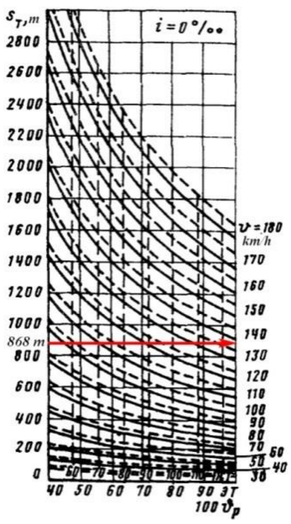

Figure 3. Nomogram of the brake path of the passenger train with cast iron brake pads.

Conclusions

For such diesel trains (DPKr-2, DPKr-3), where the use of brake pads, and even more cast iron, is not provided by design, it is necessary to develop normative documents that would determine the brake standards for this type of rolling stock based on the results of calculations and tests. Otherwise, the VU-45 brake certificate data does not reflect the actual values. Taking into account the coefficient of efficiency at a speed of 140 km/h. brake pressure, in terms of cast iron brake pads, for every 100 tons of diesel train weight is 39.7 tons. Found the amount of braking pressure of train by nomogram its value is more than 100 tons per 100 tons of train weight.

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