Pakistan Journal of Life and Social Sciences
www.pjlss.edu.pk

https://doi.org/10.57239/PJLSS-2026-24.1.0067

RESEARCH ARTICLE

Analysis of the Braking System Performance of the RSM-181 Combine Harvester on a Hard Surface

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ARTICLE INFO

Received: MAY 25, 2026

Accepted: JUNE 20, 2026

Keywords

Operational Safety

Agricultural Machinery

Braking Distance

Functional Testing

Combine Harvester

Hard Surface

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ABSTRACT

This paper presents the results of functional testing of the braking system of the RSM-181 Torum 785 combine harvester on a hard surface. The tests were conducted in accordance with GOST 12.2.002.3-91 on a concrete test area at an initial speed of 27 km/h and with a force applied to the service brake pedal not exceeding 600 N. The average braking distance of the combine harvester equipped with a transport trailer and header was 10.004 m, which is below the maximum permissible value of 12.96 m. However, in two of the five test runs, the deviation from straight-line travel during braking exceeded the allowable limit (0.71 m and 0.98 m compared with the permissible value of 0.5 m), while the variation in braking distance reached a factor of 1.42. The obtained results indicate the need for further investigation of the causes of instability in braking performance and for the development of recommendations aimed at improving the braking system of the RSM-181 Torum 785 combine harvester to ensure safe operation.

INTRODUCTION

The current stage of agricultural development is characterized by the widespread adoption of high-performance harvesting machinery capable of operating within strict time constraints and under diverse soil and climatic conditions. One of the most advanced Russian combine harvesters is the RSM-181 Torum 785 combine harvester, with a productivity of up to 45 t/h. The machine is designed for harvesting all major grain crops, including cereals, legumes, oilseeds, groat crops, and row crops. In addition to high operational productivity, next-generation combine harvesters are capable of travelling at transport speeds of up to 25–30 km/h, allowing rapid movement between fields and reducing logistical costs. They also provide high field operating speeds exceeding 6 km/h. Under optimal conditions, including grain moisture content of 14–18% and crop yields of 25–35 centners/ha, harvesting speeds may reach 7–8 km/h. According to data published by the Federal State Statistics Service (Rosstat) [Nosikov et al., 2020], the average grain yield in Russia in 2025 was 33.7 c/ha, which satisfies the agronomic requirements for combine harvester operating speeds during harvesting. However, increasing travel speeds inevitably impose higher demands on braking systems in terms of reliability, effectiveness, and the ability to maintain vehicle stability under various braking conditions.

Combine harvesters operate not only in agricultural fields but also on public roads. Consequently, manufacturers are required to ensure compliance of braking systems with the Technical Regulation of the Customs Union “On the Safety of Wheeled Vehicles” (TR CU 018/2011) [Rybak et al., 2024, Beskopylny et al., 2024] and relevant interstate standards, including GOST 12.2.019-2015 [Brusenkov et al., 2017] and GOST 12.2.002.3-91 [Rybak et al., 2025]. These regulatory documents establish requirements for maximum braking distance, permissible control force, and vehicle stability and directional control during braking.

Despite the existence of a comprehensive regulatory framework, practical experience indicates that the actual braking performance of combine harvesters on hard surfaces may vary considerably depending on the technical condition of individual components, adjustment settings, component wear, the mass of towed equipment such as transport trailers and adapters, and the loading condition of the machine.

Therefore, the relevance of the present study is determined by the need to obtain reliable data on the performance of the braking system of the RSM-181 combine harvester on a hard surface under conditions closely corresponding to real operating practice and to assess its compliance with current regulatory requirements.

The aim of this study was to evaluate the performance of the braking system of the RSM-181 Torum 785 combine harvester on a hard surface based on functional test data, including an assessment of braking distance, directional stability during braking, and factors affecting braking non-uniformity and dynamic loading. The results will make it possible to assess the compliance of the existing braking system with safety requirements and to develop recommendations for improving braking systems in next-generation combine harvesters.

MATERIALS AND METHODS

For the functional tests, an RSM-181 combine harvester with a total operating time of 100 engine hours was used. The object of the study was the harvester braking system, including the master brake cylinder (Figure 1), brake calipers (Figures 2 and 3), and brake disc (Figure 4).

Figure 1: Master brake cylinder

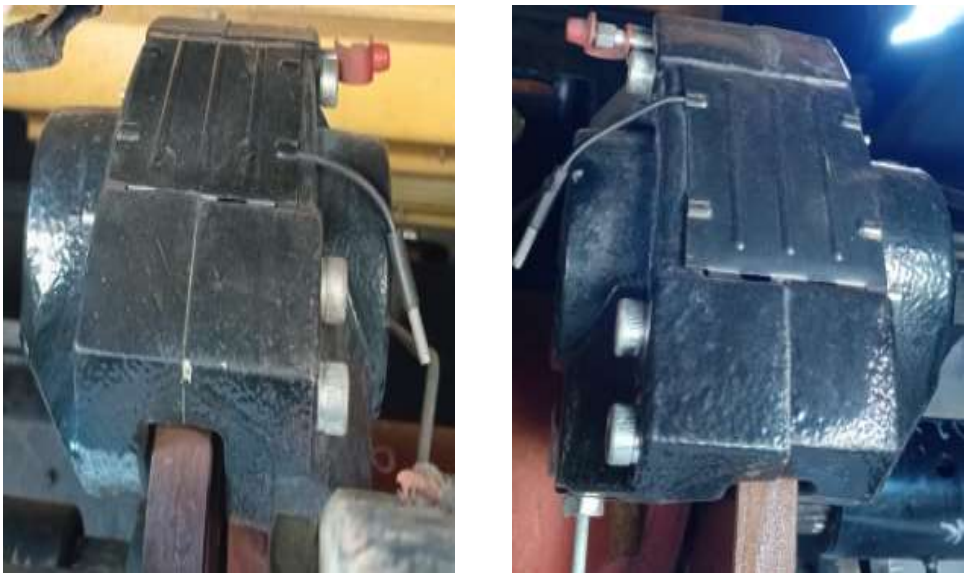

Figure 2: (A) Right brake caliper; (B) Left brake caliper

The primary function of the braking system is to provide controlled and regulated reduction of the machine's speed, complete stopping, and stationary holding of the machine, including on slopes, for the required period of time. These functions are achieved through the generation of braking force between the wheels and the supporting surface.

The braking system is operated by the driver using the brake pedals. The force applied to the pedals is transmitted to the master brake cylinder, which converts the mechanical input into hydraulic pressure in the brake fluid. The fluid is then delivered to the wheel brake calipers, causing the friction pads to be pressed against the brake discs. The parking brake is generally equipped with a mechanical actuation system (control cables) and is intended to keep the machine stationary during prolonged parking, particularly on inclined surfaces.

Table 1: Test Conditions

Parameter	Value	
	According to GOST requirements*	Test Data
Ambient temperature, °C	−10 to +35	16–31
Wind speed, m/s	Less than 10	5–6
Longitudinal slope, %	Not more than 1	Not more than 1
Transverse slope, %	Not more than 3	Not more than 2
Test surface	Concrete or asphalt	Concrete

* GOST 12.2.002.3-91 "Occupational Safety Standards System. Agricultural and Forestry Vehicles. Determination of Braking Performance."

This standard is part of the Occupational Safety Standards System (SSBT) and establishes unified methods for determining the braking performance of vehicles, including the measurement of braking distance, steady-state deceleration, and braking stability. It also specifies the maximum permissible values of these parameters and the allowable force applied to the control devices.

In the present study, this standard was used as the regulatory basis for testing the braking system of the RSM-181 Torum 785 combine harvester. The relationship between the standard and the study lies in the fact that GOST 12.2.002.3-91 defines the test conditions, including the type of surface, initial speed, maximum pedal force, and brake disc temperature conditions, as well as the criteria for evaluating braking performance. Comparison of the measured parameters with the prescribed limits makes it possible to determine whether the braking system of the investigated combine harvester complies with the applicable safety requirements.

Table 2: Combine Harvester Characteristics Considered During Functional Testing

Parameter	Value		
	According to the Manufacturer's Specifications	Test Data	
Machine model	RSM-181 Torum 785	RSM-181 Torum 785	
Front drive wheel tire size	900/60 R32 BELSHINA	900/60 R32 BELSHINA	
Front drive wheel tire pressure, bar	2.1 ± 0.1	2.1 ± 0.1	
Rear steering wheel tire size	500/85 R24	500/85 R24	
Rear steering wheel tire pressure, bar	1.7 (2.4) ± 0.1	2.1 ± 0.1 for parking brake testing; 2.4 ± 0.1 for braking distance measurements	
Operating weight of the combine harvester without interchangeable attachments, kg	20,293	20,293 according to the nameplate	
Permissible towing mass, kg	5,500	Transport trailer weight	2,950
		Header weight	4,400
Maximum travel speed, km/h	—	27	

RESULTS AND DISCUSSION

Tests were conducted to evaluate the ability of the braking system of the RSM-181 Torum 785 combine harvester to hold the machine stationary on a 12° slope with an additional load of 7,350 kg simulating the weight of a header and transport trailer.

During the test, the combine harvester was positioned on a 12° downhill slope. The parking brake was engaged, the transmission was set to neutral, and the service braking system was not activated. No wheel slip or parking brake slippage was observed. The temperature of the parking brake disc increased from 35°C to 39°C.

The combine harvester was then positioned on a 12° uphill slope. The parking brake was engaged, the transmission was set to neutral, and the service braking system was not activated. No wheel slip or parking brake slippage was observed. The temperature of the parking brake disc increased from 32°C to 35°C.

The combine harvester was positioned on a 12° slope to evaluate the service braking system by applying a force of 600 N to the brake pedal located in the operator's cab. The applied force was measured using a Sensorika-M brake pedal force sensor. The parking brake was disengaged, and the transmission was set to neutral. The machine was positioned on a downhill slope, and no wheel slip was observed.

The combine harvester was also positioned on a 12° uphill slope to evaluate the service braking system by applying a force of 600 N to the brake pedal. The applied force was measured using a Sensorika-M [Rybak et al., 2025]. brake pedal force sensor. The parking brake was disengaged, and the transmission was set to neutral. No wheel slip was observed.

The service braking system tests of the RSM-181 Torum 785 combine harvester were carried out on a concrete test track in accordance with GOST 12.2.002.3-91 (Type 0 test: cold condition, with brake disc temperatures not exceeding 100°C), using a transport trailer with a mounted header. Braking was performed in accordance with the operator's manual, with the travel control lever set to the neutral position and the coupled service brake pedals depressed. The test results are presented in Table 3.

According to the requirements of GOST 12.2.019-2015 and GOST 12.2.002.3-91, the braking distance of a fully equipped machine operating at maximum transport load must not exceed 12.96 m at a travel speed of 27 km/h and a brake pedal force not exceeding 600 N. Analysis of the data presented in Table 3 showed that the average braking distance of the tested RSM-181 Torum 785 combine harvester equipped with a transport trailer and header, without wheel lock-up and at a brake pedal force as close as possible to, but not exceeding, 600 N, was approximately 10.004 m. This value was lower than the maximum permissible braking distance specified by the standards.

Table 3: Results of Braking System Tests.

Parameter	Test Results				
	Test No. 1	Test No. 2	Test No. 3	Test No. 4	Test No. 5
Maximum pedal force, N	595	480	595	571	541
Initial braking speed, km/h (m/s)	27 (7.5)	27 (7.5)	27 (7.5)	27 (7.5)	27 (7.5)
Braking distance, m	9.6	12.25	9.3	8.6	10.25
Permissible braking distance, m	12.96	12.96	12.96	12.96	12.96
Braking time, s	2.46	2.7	2.1	2.4	2.3
Deviation from straight-line travel during braking, m	0.08	0.71	0.35	0.06	0.98
Permissible deviation from straight-line travel during braking, m	≤ 0.5				

CONCLUSION

As a result of the functional tests, it was established that the braking system of the RSM-181 Torum 785 combine harvester complies with the requirements of GOST 12.2.019-2015 and GOST 12.2.002.3-91 regarding its ability to hold the machine stationary on a 12° slope. The average braking distance of the combine harvester equipped with a transport trailer and header, at a

service brake pedal force not exceeding 600 N, was 10.004 m, which is below the maximum permissible value of 12.96 m. However, under test conditions with pedal forces approaching the specified limit (not exceeding 600 N with an allowable deviation of 10%), the braking distance ranged from 8.6 to 12.25 m. The maximum braking distance exceeded the minimum value by a factor of 1.42, indicating considerable variability in braking performance. In two of the five test runs, the permissible deviation from straight-line travel during braking was exceeded: the regulatory limit of 0.5 m was exceeded, with measured deviations of 0.71 m and 0.98 m, respectively. The obtained results indicate the need for further investigation of the factors responsible for braking distance variability and directional instability during braking of the RSM-181 Torum 785 combine harvester, as well as for the development of recommendations aimed at improving the design and adjustment of the braking system to ensure consistent and safe operation.

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