



ANALYSIS OF FRICTION COEFFICIENTS OF CERTIFIED COMPOSITE BRAKE BLOCKS IN FREIGHT RAILWAY WAGONS

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Abstract – Due to the increasing public demand for reducing railway noise emissions, the implementation of composite brake blocks for freight wagons has intensified over the past twenty years. Consequently, composite brake blocks have become mandatory for newly manufactured freight wagons operating in international railway traffic. However, only a relatively small number of manufacturers have successfully certified this type of brake block in accordance with the applicable European standards. These standards specify a set of performance requirements that must be verified through type testing performed on certified brake test benches and in exploitation. Despite the extensive laboratory testing procedures, it is also essential to evaluate the braking performance on the specific freight wagon equipped with the tested composite brake blocks. These tests reveal the operational characteristics of individual brake block types under realistic service conditions. This paper presents and analyses selected results obtained from braking performance tests carried out on a freight wagon equipped with three different types of certified composite brake blocks.

Keywords – composite brake block, slip brake test, friction coefficient, deceleration.

1. INTRODUCTION

In 2003, the former International Union of Railways (UIC) officially approved the use of K-type composite brake blocks in international railway transport [1]. Since then, conventional grey cast-iron brake blocks installed on existing freight wagons have gradually been replaced by LL-type composite brake blocks, while L-type brake blocks have been introduced to a lesser extent.

The requirements governing the design, dimensions, performance, and testing of composite brake blocks are specified in UIC and EN standards [2, 3]. These standards define the functional requirements for brake blocks acting on the wheel tread within tread braking systems, as well as the interface requirements between the brake block and the railway vehicle.

Furthermore, the standards establish testing procedures for verifying compliance with safety and interoperability requirements, material quality control procedures to ensure product reliability and conformity, and requirements related to environmental protection.

The introduction of composite brake blocks has significantly contributed to reducing railway noise

while maintaining the required braking performance. Nevertheless, the braking characteristics of composite materials differ considerably from those of conventional cast-iron brake blocks. Their friction coefficient depends on several operating parameters, including braking force, vehicle speed, contact pressure, wheel temperature, and environmental conditions. Consequently, each type of composite brake block exhibits distinct braking characteristics that must be evaluated through laboratory and vehicle tests before being approved for service.

The objective of this paper is to analyse the braking performance of a freight wagon equipped with three different types of composite brake blocks by comparing stopping distance, mean deceleration, and the variation of the friction coefficient during braking.

2. ADVANTAGES AND DISADVANTAGES OF COMPOSITE BRAKE BLOCKS

The application of composite brake blocks in tread brake systems, as well as composite inserts in disc brake systems, provides significantly lower variation in braking force throughout the braking process. As a result, the braking force remains more uniform over the

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entire speed range separated from the available wheel–rail adhesion, representing one of the principal advantages of composite friction materials.

Owing to their more stable friction characteristics, composite brake blocks with a higher nominal friction coefficient can be employed without increasing the risk of wheel locking at low speeds, which is a common drawback of conventional grey cast-iron brake blocks. This constitutes another important advantage of composite materials, as the required braking force can be achieved with a lower brake block contact force due to the higher friction coefficient.

The reduced contact force enables the use of lighter brake rigging components while maintaining the same braking performance. Furthermore, the required brake cylinder force is lower, allowing the installation of smaller brake cylinders. Consequently, the overall mass of the mechanical braking system can be reduced, contributing to lower vehicle weight and improved operational efficiency.

An additional benefit of composite brake blocks is the substantial reduction in rolling and braking noise. According to published studies, the replacement of cast-iron brake blocks with composite materials can reduce rolling noise by more than 8 dB, which represents a significant improvement in terms of environmental protection and passenger comfort.

Despite these advantages, several operational challenges remain. One of the primary concerns is the increased wheel tread wear associated with certain composite materials, which requires more frequent wheel reprofiling and consequently increases maintenance costs.



Fig.1. Composite brake block

3. TYPE TESTS

To verify the performance characteristics described above, each type of composite brake block shall successfully complete a comprehensive type testing procedure before being approved for operational use.

Type testing includes the assessment of the following characteristics:

- brake block design and geometry;
- instantaneous and mean friction coefficient;
- static friction coefficient;
- performance under wet friction conditions;
- tendency to collect metallic particles and the formation of surface deposits ("stickers");
- behaviour under wheel-slide or wheel-locking

conditions;

- wear characteristics of both the brake block and the wheel under different axle loads and braking conditions;
- friction performance under winter operating conditions;
- influence on railway signalling systems (electromagnetic interference and related effects);
- material properties and quality characteristics of the brake block.

Certification requires a multi-stage approval pathway [4] comprising laboratory dynamometer bench testing, full-scale slip brake vehicle testing under dry and winter conditions, and a 12-month operational monitoring phase in revenue service.

Because the certification procedure is extensive, technically demanding, and time-consuming, only a limited number of manufacturers have obtained approval for composite brake blocks intended for international railway traffic. The list of approved brake blocks is maintained by the European Union Agency for Railways (ERA) and UIC.

4. SLIP BRAKE TEST

Following the installation of an approved type of composite brake block on a freight wagon, the braking performance of the complete braking system must be verified. If the measured braking characteristics satisfy the requirements specified by the applicable standards [6, 7], the corresponding brake block type is approved for use on that vehicle, and its designation is marked on the wagon.

Whenever the brake block manufacturer or brake block type is changed, the wagon must undergo a new series of brake performance tests.

This paper analyses the results obtained from brake performance tests carried out on an Sgnss 60' container flat wagon equipped with three different types of composite brake blocks in a 2×Bg brake configuration. The tested brake blocks are designated as Type A, Type B, and Type C.

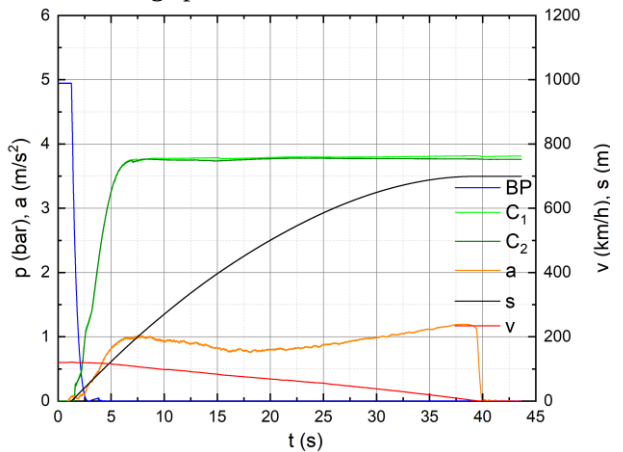
All tests were conducted in full accordance with the methodology specified in [6] without any irregularities [8]. Before testing, all brake blocks were properly bedded-in until a contact pattern exceeding 85% was achieved, thereby ensuring stable friction conditions during the measurements.

4.1. Test results

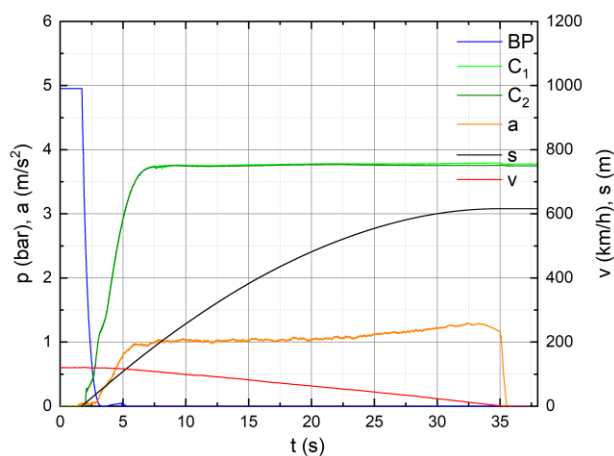
Figure 1 presents representative results obtained during the brake performance tests. The following symbols are used: BP – brake pipe pressure, C - brake cylinder pressure, v – speed, s – stopping distance, a – deceleration.

The results presented in Figure 1 correspond to tests performed with a wagon axle load of 18 t/axle and an

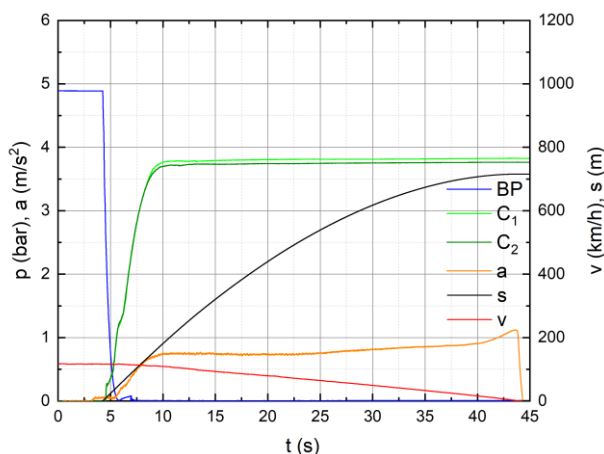
initial braking speed of 120 km/h.



a) Brake blok type A



b) Brake blok type B



c) Brake blok type C

Fig.1. Braking diagrams

Table 1 summarizes the corrected test results for the loaded wagon, including the stopping distance (s), brake mass percentage (λ), mean deceleration (a_m), and mean friction coefficient (μ) for all three tested brake block types. [9, 10, 11].

Tab. 1. Measured corrected test results-loaded wagon

Brake block	m	V	p _{nom}	λ	S	a _m	μ
	[t]	[km/h]	[bar]	[%]	[m]	[m/s ²]	[-]
A	72 t	100	3.80	105	460	0.95	0.263
		120		110	648	0.96	0.264
B		100		100	480	0.91	0.251
		120		101	697	0.88	0.243
C		100		86	553	0.78	0.214
		120		91	760	0.80	0.221

The results clearly indicate that the stopping distances differ among the tested brake block types. Consequently, the corresponding brake mass percentages are not identical and, for some brake block types, deviate from the acceptance range prescribed by the applicable standard ($\lambda=100-105\%$) [2, 7]. These differences indicate that the effective friction coefficients of the tested brake blocks are not equivalent under identical operating conditions.

Tab. 2. Measured corrected test results- empty wagon

Brake block	m	V	p _{nom}	λ	s	a _m	μ
	[t]	[km/h]	[bar]	[%]	[m]	[m/s ²]	[-]
A	19.2 t	100	1.30	109	444	0.99	0.259
		120		114	629	0.99	0.269
B		100		112	433	1.02	0.277
		120		118	610	1.02	0.279
C		100		92	516	0.84	0.242
		120		97	721	0.85	0.245

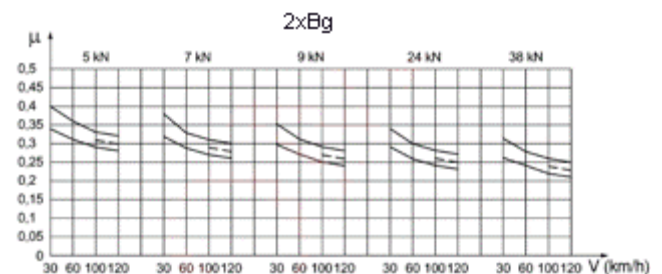


Fig.2. Permissible values of the friction coefficient of for K brake block [2]

In these tests, where the brake block force acting on the wheel is approximately 18 kN, the prescribed mean friction coefficient specified in UIC Leaflet 541-4 should be within the following limits:

- 0.245–0.285 at 100 km/h;
- 0.235–0.275 at 120 km/h

Furthermore, the deceleration curves shown in Figure 1 demonstrate that the braking behaviour varies throughout the braking process. Since the braking force is directly related to the friction coefficient, the observed variation in deceleration indicates continuous changes in the friction characteristics during braking.

This behaviour is mainly caused by the reduction in vehicle speed and the increase in brake block temperature resulting from frictional heating.

For Brake Block Type A, the deceleration initially increases to a maximum value, then decreases before increasing again as the wagon approaches a stopping. This behaviour indicates a more pronounced variation in the friction coefficient during braking.

In contrast, Brake Block Types B and C exhibit considerably more stable deceleration value, indicating more consistent friction characteristics throughout the braking process.

Table 2 presents the corrected test results obtained for the empty wagon.

Comparison of the results obtained for the loaded and empty wagon shown that the friction behaviour of the tested brake block types is influenced by the wagon load. For the empty wagon, Brake Block Type A exhibits a lower mean friction coefficient than Brake Block Type B, whereas the opposite trend is observed for the loaded wagon.

These differences can be attributed to the different chemical compositions and mechanical properties of the composite friction materials used by the manufacturers. As a result, each brake block type exhibits distinct friction characteristics, which directly influence the braking performance of the freight wagon.

5. CONCLUSION

The analysis of the brake performance test results demonstrates that different types of composite brake blocks exhibit significantly different braking characteristics, even when tested under identical operating conditions.

The measured stopping distances, mean deceleration values, and friction coefficients varied among the tested brake block types, confirming that the friction behaviour of composite materials depends on their composition and operating conditions.

These differences make it difficult or even impossible to replace one approved brake block type with another on the same freight wagon while maintaining compliance with the braking performance requirements specified in the applicable standards. Consequently, wagon owners and operators cannot simply substitute brake blocks with more readily available or less expensive alternatives without additional tests.

Whenever a different brake block type is introduced, brake performance tests must be performed. Depending on the test results, modifications to the braking system may be required to ensure compliance with the prescribed braking performance.

The brake blocks shown in this paper are based on organic composite materials. In addition to these

materials, sintered metallic composite blocks offer superior thermal endurance compared to organic matrix blocks. However, sintered blocks require significantly longer bedding-in distances to reach 85% contact area and exhibit higher aggressiveness toward wheel steel.

Experience from railway operation and published UIC technical reports indicates that, despite their environmental advantages and substantial noise reduction, composite brake blocks continue to present several operational challenges, and further research is required to optimize their characteristics.

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