# Requirements of UIC standards for brake triangles of railway vehicles

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*The brake triangles are among the most important parts in the braking system of railway vehicles. Given that their quality and reliability directly affect the safety of rail traffic, the requirements for their suppliers are very rigorous. In this sense, the production of brake triangles can only be entrusted to those suppliers who are able to provide appropriate proofs of the quality. The aim of this paper is to analyse the requirements of the International Union of Railways (UIC) for the brake triangles of railway vehicles. Special attention is paid to the requirements for inspection of brake triangles, which includes specific static and dynamic tests. The results of conducted research are basis for analysing the possibility of conquest of production of brake triangles for international market.*

**Keywords: Railway vehicles, Braking, Brake triangle, Testing, UIC 833**

## 1. INTRODUCTION

The role of braking is to ensure safely stopping and regulation the speed of the train during the running on the track. The quality and reliability of braking directly affects the safety and security of the railway transportation. Accordingly, all elements of the braking system must be designed and manufactured to successfully withstand all loads and conditions during operation, without failures.

The basic way for realization of the braking is by friction between the braking elements and the rotating elements of the railway vehicles. In case of the most freight wagons, the brake elements are brake shoes that act on the running surface of the wheel [1, 2]. The brake shoes are usually made of gray iron, and more recently of composite materials. The activation of the train braking causes the brake shoes to press against the running surfaces of the wheels where the friction occurs, which reduces the kinetic energy and slows the train down (Figure 1) [3, 4].

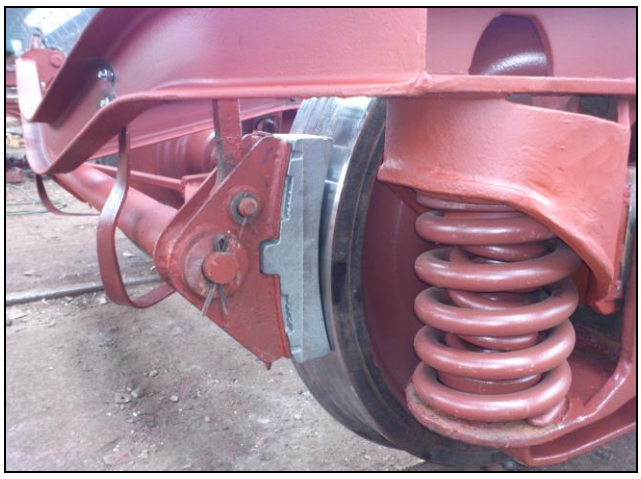

*Figure 1: Brake triangle, brake shoe and wheel*

The elements that provide transmission of braking force, i.e., friction between the brake shoes and running surfaces of the wheels are brake triangles (Figure 2). Given this role, brake triangles directly affect the quality of braking and therefore safety and security on the railway [5, 6]. That is why the requirements regarding their characteristics are very rigorous and they are defined in standards of International Union of Railways (UIC). These requirements must be met by every manufacturer of brake triangles for the international market.

*Figure 2: Brake triangles*

In accordance with the presented introductory notes, the aim of this paper is to analyze the requirements of the standard UIC 833 for the brake triangles of railway vehicles.

## 2. CHARACTERISTICS OF BRAKE TRIANGLES

According to the standard UIC 833, brake triangles are classified into two groups – brake triangles for nominal load $F_n$=60 kN and brake triangles for nominal load $F_n$=120 kN.

Brake triangles should be manufactured of carbon steels whose physical, geometric, chemical and mechanical characteristics must meet all the necessary requirements of ISO standards or European norms. The required Brinell hardness in relation to the tensile strength of the steel of which brake triangles are made is given in the Table 1.

The roughness of machined surfaces of brake triangles, measured as the arithmetical average variation Ra shall be within the limits as given in the Table 2.

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*Table 1: Required Brinell hardness of steel for brake triangles [7]*

| Tensile strength [N/mm$^2$] | Brinell hardness [HB] |
|---|---|
| 360÷440 | 100÷130 |
| 410÷490 | 115÷140 |
| 490÷590 | 140÷165 |
| 510÷610 | 145÷175 |

Brake triangles shall be correct throughout, including any welded areas, which must not contain any lack of fusion or reveal any defect such as lack of penetration, blowholes or inclusions. The welding operations must not have altered the characteristics of the base metal.

*Table 2: Required roughness of machined surfaces of brake triangles [7]*

| Nature of the parts | Average variation Ra |
|---|---|
| Trunnions | 3,2 μm |
| Parts fitted with a bush (bores or trunnions) | 0,8 μm |
| Bores without bushes | 3,2 μm |

The relative positions of the functional parts of brake triangles such as trunnions, traction head and holes for the traction pin, must meet requirements given in the Fig. 3 and Table 3.

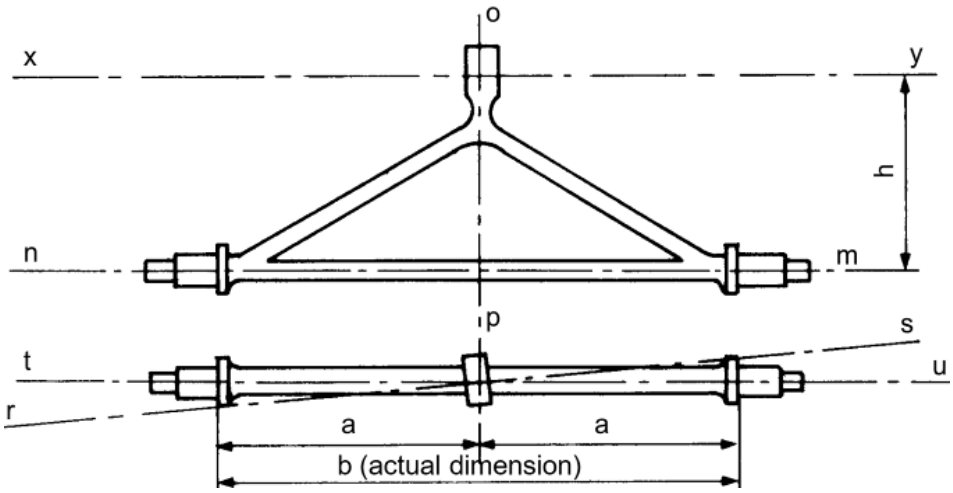


*Figure 3: Relative positions of functional parts of brake triangles [7]*

*Table 3: Requirements for relative positions of functional parts of brake triangles [7]*

| Relative positions of functional parts | Variation |
|---|---|
| Parallelism of the actual centre lines of the trunnions and of the bore of the traction head (xy and mn) | ≤ 5 ‰ |
| Parallelism of the actual centre line of the hole in the traction head and of the median plane containing the actual centre line of the trunnions (tu and rs) | ≤ 10 ‰ |
| Perpendicularity of the longitudinal centre line of the traction head in relation to the actual centre line of the bore (op and xy) | ≤ 3 ‰ |
| Symmetry of the surfaces of the shoulders of the trunnions in relation to the plane containing the longitudinal centre line of the traction head, measurements *a* | $b/2–a \leq 2$ mm |

The values of loads for brake triangles testing are given in Table 4. During the action of the nominal load $F_n$ applied in accordance with the diagram shown in Fig. 4, the height *h* of the brake triangle must not have an elastic deflection greater than 2 mm.

*Table 4: Values of loads for brake triangles testing*

| Type | "Zero" load | Nominal load $F_n$ | Test load $F_{ep}$ | Load variations during fatigue test |
|---|---|---|---|---|
| Triangle 60 kN | 5 kN | 60 kN | 90 kN | 10 kN to 60 kN |
| Triangle 120 kN | 10 kN | 120 kN | 180 kN | 20 kN to 120 kN |

After termination of force action, the height h must not have a permanent deflection greater than 0.1 mm. Also, there must not be any other permanent deformations that can affect the other parts of the brake triangle.

During the action of test load $F_{ep}$ (equal to 9/6 of the nominal load $F_n$), applied in accordance with the diagram shown in Fig. 4, the height *h* of the brake triangle must not have an elastic deflection greater than 3 mm. After termination of force action, the same height must not have a permanent deflection greater than 0.5 mm. After testing, no defects must be present.

Furthermore, the brake triangles must withstand $10^6$ cycles of tensile loads applied at a frequency between 2 Hz and 16 Hz, without any apparent defects. These loads must vary cyclically within the limits specified in Table 4.

The trunnions must have a surface hardness in the treated areas of at least 55 HRc and for a depth of at least 1 mm. The surface hardness, obtained at any point of the

bushes or the bores, must be between 58 and 62 HRc. The depth of the hardened part must be constant and between 1 mm and 1,5 mm.

Each brake triangle should have embossed marks such as: manufacturer’s mark, the last two figures of the year of manufacture, the mark of ownership of the purchasing Railway, etc.

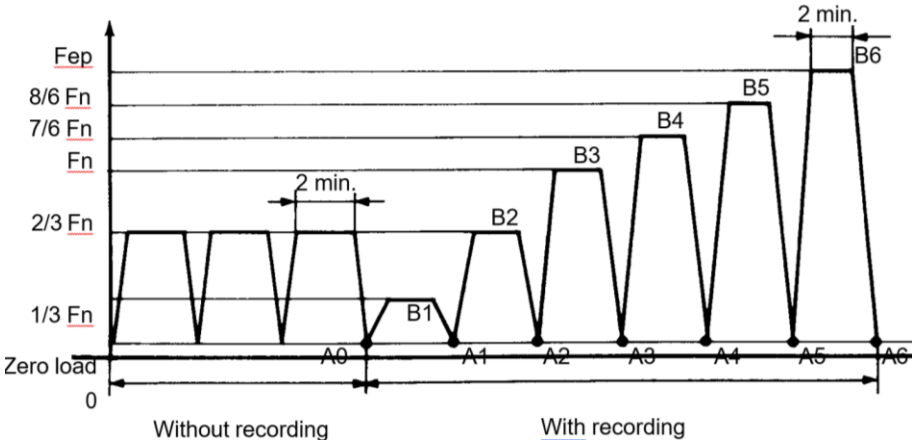


*Figure 4: Load-time diagram for brake triangles testing*

## 3. MANUFACTURE OF BRAKE TRIANGLES

The manufacture of brake triangles can only be entrusted to suppliers who have the appropriate approvals of the purchasing Railways. Each brake triangle prototype and conditions of its manufacture, must be approved by the purchasing Railway. In case of any changes in the design and characteristics of the brake triangles, as well as in their production process, the aforementioned approval procedure must be repeated.

*Table 5: Checks and tests of brake triangles [7]*

| **Nature of the tests and checks** | **Type of inspection** | **Proportion of the checks and tests** | | | | | |
|---|---|---|---|---|---|---|---|
| | | **≤ 50** | **51/150** | **151/500** | **501/1200** | **1201/3200** | **> 3200** |
| Appearance and dimensions of the component parts and finished items | Approval and Acceptance | As decided by the representative of the Railway | | | | | |
| Hardness tests on forged parts[a] and on finished parts[b] | Approval and Acceptance | 2 | 4 | 6 | 8 | 10 | 12 |
| Deflection tests on forged parts | Acceptance | As decided by the representative of the Railway, with a maximum of 2 per batch of 10 t | | | | | |
| Inspection of welds | Approval and Acceptance | As decided by the representative of the Railway. However, the approval must be renewed at least every twelve (12) months | | | | | |
| Static deflection test[c] | Approval | 8 parts | | | | | |
| | Acceptance | 1 | 2 | 3 | 4 | 5 | 6 |
| Endurance test under pulsating tensile loads[c] | Approval | 2 parts | | | | | |

a. Before submission for acceptance, the supplier shall have checked, under his own responsibility, the Brinell hardness on at least 10% of the forged parts.
b. Before submission for acceptance, the supplier shall have checked, under his own responsibility, the Rockwell hardness on at least 5% of the trunnions.
c. The parts intended for these tests shall not have been submitted to a tensile force greater than 2/3 of the nominal load $F_n$.

The forging operations in manufacturing of brake triangles shall be carried out at temperatures which ensure that no change in the characteristics can result.

The welding process in the production of brake triangles is left to the choice of the manufacturer. However, automatic welding processes must be approved by the purchasing Railway and cannot be changed without its approval. Manual welding procedures can only be performed by welders whose ability has been previously confirmed. In both cases, the issued authorizations are valid for a maximum of 12 months.

The heat treatment operations should be performed in such a way as to guarantee uniformity of treatment at all points on the same part and for all parts of the same furnace load. The furnace or quench bath temperatures should be checked with properly calibrated recording pyrometers.

Retouching and repair are strictly prohibited without the prior consent of the purchasing Railway. Removal of surface defects by grinding, chiselling, filing or any other approved process may be permitted, provided dimensional tolerances are met.

## 4. INSPECTION OF BRAKE TRIANGLES

The authorized representative of the purchasing Railway performs an appropriate inspection of the manufacture of brake triangles. He can carry out any checks he deems necessary to prove that all production conditions have been met. Additionally, he can be present at welding operations and at the individual tensile tests carried out by the manufacturer, and be provided with the charts of the recording pyrometers. Also, he must be informed of any change in the manufacturing process of brake triangles.

As for the acceptance inspection of authorized representative of purchasing Railway, a batch of parts intended for the acceptance procedure must be formed. It consists of at least 10 brake triangles (type to be accepted), manufactured by the normal production methods. These brake triangles intended for the acceptance procedure must not be exposed to a load greater than 2/3 of the nominal load $F_n$ (Table 4, Fig. 4).

The brake triangles must be subjected to checks and tests as given in the Table 5. They are performed either at the time of acceptance during submission or during manufacture.

The brake triangles intended for the endurance test under pulsating tension load must not be selected from those already subjected to the static deformation test. The tests prescribed by the acceptance program must be carried out by a laboratory approved by the purchasing Railway.

The brake triangles must be submitted for acceptance in the delivery condition, before any protective treatment. Previously, they must be subjected to static deflection tests in accordance to the details specified in Chapter 2. These tests are carried out on the number of samples which is defined in the Table 5.

### 4.1. Static tests of brake triangles under tension load

Static testing of brake triangles is performed on the test stand with horizontal or vertical movement, which must provide maintaining a constant load for at least 2 minutes and measuring this load with error less than 1%. The deflections must be measured by dial gauges with graduation of 0.01 mm. They must be rigidly fixed and their probes must make contact at right angles with smooth surfaces on the triangle to be tested.

The brake triangles can be tested individually or in pairs of two. The connections between the elements to be tested and the test stand must be in accordance with one of the arrangements shown in Figs. 5-8.

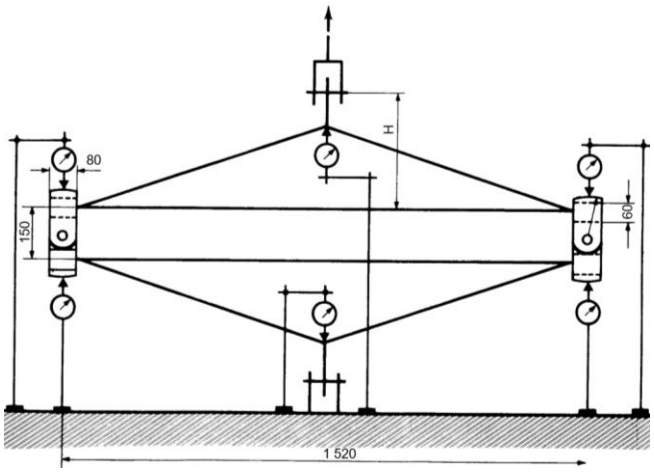


*Figure 5: Connections between brake triangles to be tested and test stand for static tests – variant 1 [7]*

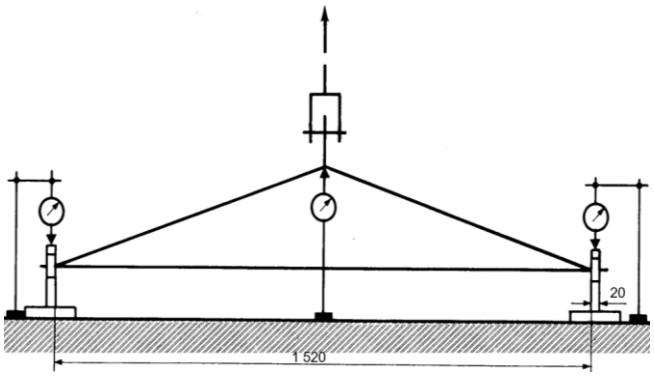


*Figure 6: Connections between brake triangles to be tested and test stand for static tests – variant 2 [7]*

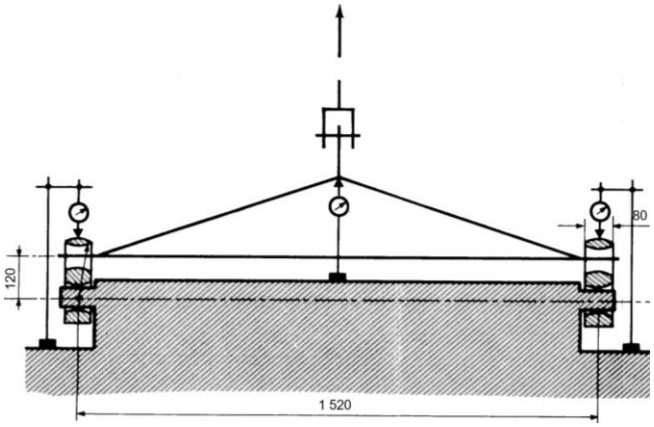


*Figure 7: Connections between brake triangles to be tested and test stand for static tests – variant 3 [7]*

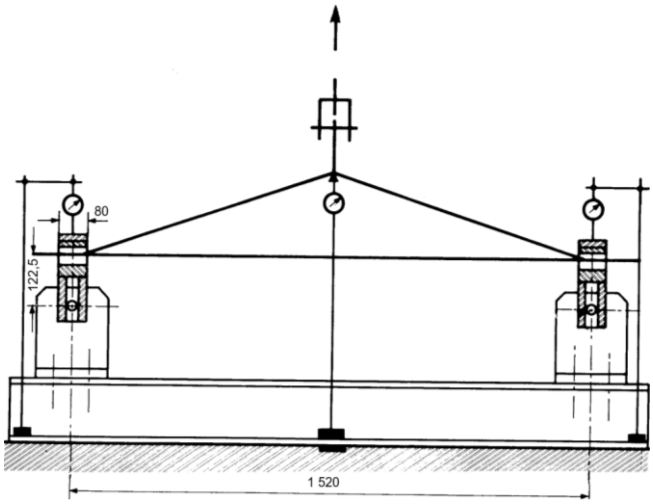


*Figure 8: Connections between brake triangles to be tested and test stand for static tests – variant 4 [7]*

Before conducting the static tests, three consecutive preliminary loads of 2 min duration and equivalent to 2/3 of the normal load $F_n$ specified in Table 4 must be applied. After that, the force returns to the “zero” load which is also listed in Table 4. These procedures are performed without recording deflection values.

After that, loads equal to 1/3 $F_n$, 2/3 $F_n$, $F_n$, 7/6 $F_n$, 8/6 $F_n$ and 9/6 $F_n$ are then applied, in turn, for two minutes each. The application of each new load is preceded by a return to the load that must not be less than the mentioned "zero" load specified in Table 4. The deflection values reading from dial gauges is performed for each of the "zero" loads and under each of the above mentioned loads, i.e. in the points A0, B1, A1, B2, A2, B3, A3, B4, A4, B5, A5, B6 and A6 (Fig. 4).

During the described test, the following deflections should be measured:

- Elastic deflection under the nominal load $F_n$ (equal to the difference in measurement results in points B3 and A3);
- Permanent deflection under the nominal load $F_n$ (equal to the difference in measurement results in points A3 and A0);
- Elastic deflection under the test load $F_{ep}$ (equal to the difference in measurement results in points B6 and A6);
- Permanent deflection under the test load $F_{ep}$ (equal to the difference in measurement results in points A6 and A0);
- Any permanent deflection, other than that obtained in the direction in which tension was applied (determined by comparing the measurements performed to the nearest 0.1 mm by reference to a surface-plate, before and after the tensile test).

4.2. Fatigue tests under pulsating tension load

The fatigue test under pulsating tension must be carried out on a tensile test stand with vertical movement, capable of applying loads varying within the limits specified in Table 4, at a frequency in range of 2 and 16 Hz. The test stand must be equipped with devices able of counting the number of cycles and registering the values of the loads applied.

The brake triangles to be tested must be mounted in the test stand by one of the assemblies shown in Figs. 7 and 8.

4.3. Approval inspection of brake triangles

Approval is refused if any of the results of static and fatigue tests are not in accordance with the prescribed conditions.

4.4. Acceptance inspection of brake triangles

Any defect in appearance or any difference in dimensions affecting their satisfactory use will cause the brake triangles to be rejected. In addition, any result inconsistent with one of the other tests will result in the rejection of the corresponding batch of brake triangles.

## 5. DELIVERY AND WARRANTY FOR BRAKE TRIANGLES

5.1. Delivery of brake triangles

After the acceptance inspection, the brake triangles must be protected against corrosion in accordance with the prescribed procedure agreed with purchasing Railway. After degreasing and brushing, the rough surfaces of the brake triangles must be protected with a layer of primer paint, the composition of which has been approved by the purchasing Railway. In addition, machined surfaces must be coated with an anti-rust agent.

5.2. Warranty for brake triangles

The warranty for the brake triangles is two years regard to any defect that can be imputable to manufacture. This period starts from the end of the year which last two figures of which are shown on the triangles.

If the brake triangles are intended for installation on a new railway vehicle, the date of delivery of the vehicle on which they are installed will be considered as the beginning of the warranty.

Brake triangles that during the warranty period reveal defects that make them unfit for use or are likely to reduce their service life will be rejected. Before being finally rejected, defective brake triangles may, however, be subjected to a verification test by the ordering Railway and the supplier. When the verification test confirms that the defects are definitely attributable to manufacturing or inadequate corrosion protection, the defective brake triangles are finally rejected.

When more than 5% of brake triangles from the same delivery show defects leading to rejection, the purchasing Railway may reject the entire delivery.

## 6. CONCLUSION

The braking system has a very important function in railway traffic. Its efficiency and reliability directly affect the safety and security on the railway. One of the most important parts of the braking system of railway vehicles are brake triangles. Their role is ensuring the transfer of braking force to the brake shoes that act on the surface of the wheel and brake the vehicle.

Given that their quality and reliability directly affect the safety of rail traffic, the requirements for suppliers of brake triangles are very rigorous. That is why the production of brake triangles can only be entrusted to suppliers who are able to provide appropriate proofs of the quality.

In this paper, the requirements of the International Union of Railways (UIC) regarding the brake triangles of railway vehicles are analysed. The standard UIC 833 named "Technical specification for the supply of brake triangles" has been studied in detail. The requirements for characteristics, manufacturing, inspection, delivery and warranty of brake triangles are analysed. A special attention is devoted to the requirements for inspection of brake triangles, which includes specific static and dynamic tests.

The results of the paper can be convenient basis for further research directed toward designing a test stand and equipment for testing static and dynamic characteristics of brake triangles. Consequently, they can be suitable for analysing the possibility of conquest of production of brake triangles for international market.

The idea for further research is oriented towards the development of methods for optimizing of structural design of brake triangles [9, 10].

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## REFERENCES

[1] D.Petrović, V.Aleksandrov, Železnička vozila – Osnove, Fakultet za mašinstvo i građevinarstvo u Kraljevu Univerziteta u Kragujevcu, Kraljevo, (2013), (in Serbian)

[2] G. Simić, Vagoni – Konstrukcija i proračun, Mašinski fakulteta Univerziteta u Beogradu, Beograd, (2013), (in Serbian)

[3] D. Petrović, M. Bižić, Doprinos Dobrivoja S. Božića razvoju kočnica železničkih vozila, Tematski zbornik nacionalnog značaja "Dobrivoje S. Božić – izumitelj savremenog sistema kočenja voza", Fakultet za mašinstvo i građevinarstvo u Kraljevu, Kraljevo, str. 19-42, (2016), (in Serbian)

[4] M. Bižić, D. Petrović, Problemi kretanja železničkih vozila sa osvrtom na kočenje i značaj Dobrivoja Božića, Tematski zbornik nacionalnog značaja "Dobrivoje S. Božić – izumitelj savremenog sistema kočenja voza", Fakultet za mašinstvo i građevinarstvo u Kraljevu, Kraljevo, str. 159-186, (2016), (in Serbian)

[5] M. Günay, M. Erdi Korkmaz, R. Özmen, An investigation on braking systems used in railway vehicles, Engineering Science and Technology, an International Journal, Volume 23, Issue 2, pp. 421–431, (2020)

[6] V. Ravlyuk1, M. Ravliuk, V. Hrebeniuk, V. Bondarenko, Research of the calculation scheme for the brake lever transmission and construction of the load model for the brake pads of freight cars, IOP Conference Series: Materials Science and Engineering, 708, 012026, (2019)

[7] UIC 833, Technical specification for the supply of brake triangles, International Union of Railways, (2004)

[8] EN ISO 4287, Geometrical product specifications (GPS) - Surface texture: Profile method - Terms, definitions and surface texture parameters, (2014)

[9] Goran Miodragović, Marina Bošković, Radovan Bulatović, The application of metaheuristic algorithms in multi-objective optimization of engineering problems, Engineering Today, Vol. 1, No. 3, pp. 7-15, (2022)

[10] Goran Pavlović, Boris Jerman, Mile Savković, Nebojša Zdravković, Goran Marković, Metaheuristic Applications in Mechanical and Structural Design, Engineering Today, Vol. 1, No. 1, pp. 7-15, (2022)