Test Determination of Mechanical Characteristics for Rubber Plates used at K Railway Fastening System

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The rubber is widely used at railway infrastructure and rolling stock. Rubber plates are used at rail – sleeper fastening systems, rubber elements are used for primary suspension at electrical locomotives (in Romania and abroad) and metro (subway trains) as elastic elements in buffers, or as insertion plates at streetcar wheels etc. From those examples we can see that rubber elements are used as elements which are directly involved in circulation safety.

Keywords: rubber plate, rail pad, K fastening, test, railway polyethylene

Before putting in service the railway parts are tested to be certified. The tests are made on parts from railway infrastructure or rolling stock. The materials used at rolling stock construction are: steel, aluminum alloys, plastic, rubber, composite materials, wood etc. For railway track the necessary materials are: steel, rubber, plastic, concrete, wood, coarse stone, sand, gravel materials etc.

The construction of track must ensure through its strength and component elements stability, the guiding safety and ride quality of the vehicles at established speed and weights. The main elements of the railway track are infrastructure (the subgrade) and superstructure (ballast and rails-sleepers elements). Two steel rails (fig. 1) are mounted on sleepers made from wood (for turnouts) or concrete (in stations or between them) either steel (on bridges) through the fastening system. The quality of a track is appreciated from its geometrical characteristics, from the supported weights of the railway vehicles and the allowed speed [1].

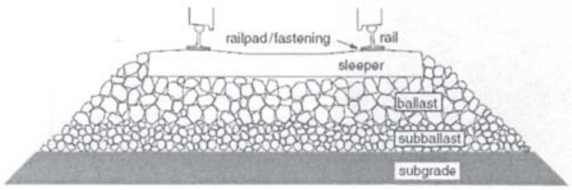

Fig. 1. Track section [3]

The railway superstructure is the main element regarding the vehicle – track interaction aspects. When a vehicle run on rails, static and dynamic loads occur and track imperfections affect ride quality of the vehicle and guiding safety [1].

K fastening system

During the time the railway fastening systems were changed to ensure the technical specifications of railways administrations. For example in 1962 a indirect fastening system was used for the first time in the purpose to mount the rails on sleepers; it was the K fastening system. That system became the most used fastening system on many decades, because it was the answer at two problems: supported speed was 120 km/h and the axle load was 220 kN. That speed and that axle load are today also the main line parameter for many conventional railways. In figure 2 is presented the K fastening system. In figure 3 is presented another fastening system – an elastically fastening used in our days as replacing system for K fastening system. But, the replacing of K fastening system on main lines will be made in decades and it is possible that this system to be used on secondary line or in station's marshalling yards.

This paper presents the tests performed at rubber rail pads used for K fastening system. Usually the rubber rail pads are manufactured for UIC 49 rails and UIC 60 rails (UIC = International Union Of Railways); the index 49 or 60 after UIC acronym indicate the rail mass per meter (UIC 49 have 49 kg/m). The UIC 60 rails are used on main railways lines while UIC 49 are used on secondary lines. The difference between two masses of UIC 49 and UIC 60 rails occur because the transverse is different; because of that, two types of rubber plates (rail pads) are necessary.

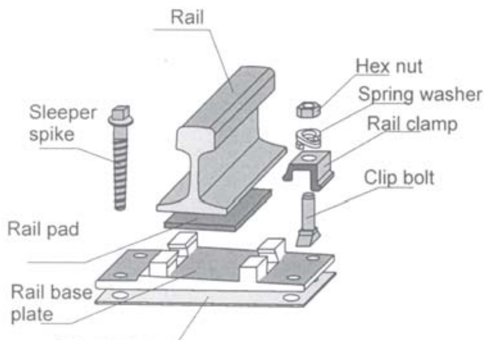

Fig. 2. K fastening system

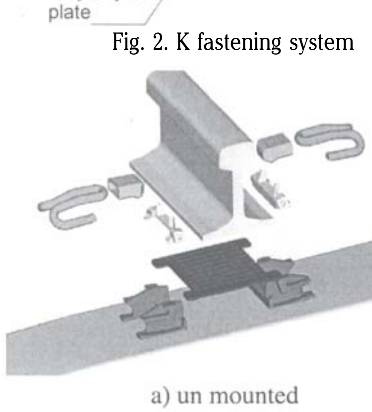

Fig. 3 Elastically fastening system (a)

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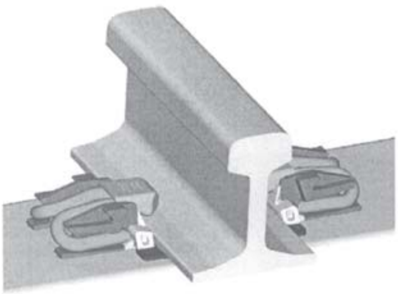


b) mounted

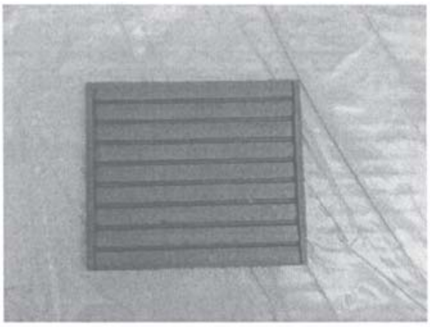
Fig. 3. Elastically fastening system (b)

Tests

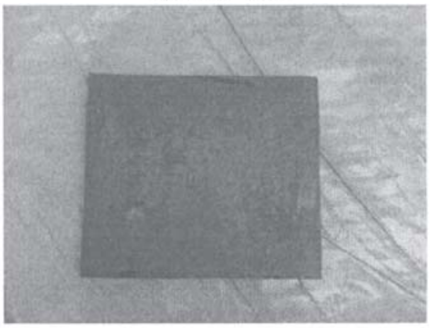
The tests performed at rubber rail pads are material tests and rail pad tests.

The material tests performed at rubber rail pads used for fastening systems are:

- Shore A hardness test on the rail pad as it is or after 7 days (168 h) maintaining at -40°C. This test is performed on three pads using a Shore hardness tester. The hardness is measured between grooves (fig. 4a) and at one centimeter or less from pad edge, in five different points. During tests the rail pad must rest on another pad from same category which rest on plane surface. For the testing report is used the smaller Shore hardness measured value. In figure 4b is presented back view of rail pad;



a) front view



b) back view

Fig. 4. Rubber rail pad

- fracture strength test for the plates in presentation form. For this test, it is necessary to use five rubber rail pads. From each pad, tensile probes are made so that the groove to be in the axis of the probe. One probe is used for fracture force determination and elongation. The other probe will suffer an artificial increasing age in a oven with frequently refreshed atmosphere by forced ventilation; the time is four days at 100°C+2°C or seven days at 70°C+2°C, depending if the rubber is natural or synthetic; on that probe, the fracture force and elongation are measured after the probe is released at ambient temperature for a period of 24 to 48 h. The tests are made similarly for the probes made from other four rubber rail pads. For the testing report are used the medium values before and after artificial ageing from five measuring tests. With those values, are calculated. A ratio (fracture force) and B ratio (elongation):

$$A = \frac{Fracture\ \ force\ \ after\ \ ageing}{Fracture\ \ force\ \ before\ \ ageing} \cdot 100 \qquad (1)$$

$$B = \frac{Elongation\ \ after\ \ ageing}{Elongation\ \ before\ \ ageing} \cdot 100 \qquad (2)$$

- elasticity modulus for 100% elongation measuring, in presentation form. The elasticity modulus is defined as tensile stress (in daN/cm^2) necessary to modify the 50 mm initial distance (between the marks) until the distance from marks is 100 mm. Three rubber rail pads are used; from each pad, two tensile probes are made. Before the test, one of the probes is artificially ageing four days at 100°C+2°C or seven days at 70°C+2°C, depending if the rubber is natural or synthetic; on that probe, the fracture force and elongation are measured after the probe is released at ambient temperature for a period of 24 to 48 h. The probe is subject to tensile force until the distance between probe marks (initial distance L_0 = 50 mm) become 100 mm; the speed of mobile head of the testing machine must be around 450-550 mm/min, then the tensile force is removed with decreasing speed of mobile head identical with increasing speed. The elasticity modulus is measured after the second tensile test (on the same probe) in similar condition like the first test. The tests are similarly made for the probes made from other two rubber rail pads. For the testing report are used the medium value before and after artificial ageing from three measuring tests;

- fracture elongation test in presentation form;

- mechanical characteristics determination (fracture strength, elasticity modulus for 100 % elongation, fracture elongations) after accelerated ageing for 96 h at 100°C;

- residual deformation measuring, after 50% compressive force and maintaining 24 h at 100°C. For this test, three rubber rail pads are used. From each pad, a 37 mm diameter circular probe is made. The center of the probe is in the axe of a groove. Each of the three cylindrical probes is put in a special device which allows a compression of the sample. The initial thickness e_0 is reduced with 50 %. In such condition, the device with the samples in it, is put in a oven for at 100°C+2°C temperature. After 24 h the device is removed from the oven and left at ambient temperature as long it is necessary so that all the parts of the probe to have laboratory's temperature. The probes are removed from the compression device. After one or two days at constant temperature, after removing from the oven, residual deformation e_r is measured. The measurement is made with a measuring device – micro gauge indicator – for example which press on 25 mm diameter circular surface and who push on the sample with a 10 N load. Residual stress is calculated with the expression:

$$C = \frac{e_0 - e_r}{e_0} \cdot 100 \qquad (3)$$

- residual deformation measuring for 50 % elongation and keeping the probe for 24 h at 100°C temperature. For this test, tensile probes are made; each probe is elongated with 50 % after 24 h maintaining at 100°C in an oven. From three rubber rail pads, three tensile probes are made. All the probes are put in a tensile device, where a 50 % elongation is applied. The probes and the tensile device are placed in an oven for 24 h at 100°C+2°C. After that period, the probes are removed from the oven, and left for at least 30 min to get ambient temperature in all parts. Then, the probes are removed from tensile device and left to relax one or two days. The distance L_r in mm, from the marks is measured. The initial distance between the marks is 50 mm. The medium value of all measuring will be kept for the testing report. The residual stress is calculated with the expression:

$$D = \frac{L_r - 50}{50} \cdot 100 \qquad (4)$$

- keeping of the characteristics (fracture strength, fracture elongation) after accelerated ageing during 96 hours at 100°C;

The tests performed on the products (K fastening rail pad) where:

- force versus deformation curve determination. The test is performed at 21°C+3°C on two rail pads. Each rail pad is mounted in two metal plates 140 x 210 mm. Between the metal plate and the rail pad, a piece of sand paper is added (132 x 200 mm). The thickness variation is measured with two 1/100 mm micro gauge indicators. To obtain a proper contact between the two metal plates, a load of 200 kN is applied twice. After that, the micro gauge indicators are calibrated at zero; the force is increased at 50, 100, 150 and 200 kN. At 200 kN the compression force is kept for one min. The loading speed is 150 kN/min. To draw the curve force versus deformation, the medium value of the micro gauge indicators is used. That curve is compared with limit curves defined in UIC leaflet 964-5;
- physical characteristics verification;
- geometrical characteristics verification.

Results and discussions

The tests were performed at Romanian Railway Authority, Romanian Railway Notified Body, Rolling Stock Laboratory (http://www.afer.ro).

Shore A hardness

The results are presented in the next tables (all in °ShA).

- Presentation form:
- After seven days at -40°C:

Table 1

Limit	Measured	Smallest	Largest
Minimum 65	68	67	69
	67		
	68		
	69		
	69		

Fracture strength

Table 2

Limit	Medium	Allowed variation	Measured variation
73	73	±10	+4
73			
74			
73			
74			

The results are presented in the next table (in N/mm^2):
Fracture elongation, presentation form

Table 3

Limit	Measured value	Medium value
Minimum 12,0	12,46	12,46
	12,51	
	12,18	
	12,51	
	11,53	

The results are presented in the next table (in %):

Table 4

Limit	Measured value	Medium value
Minimum 250	260	320
	320	
	320	
	300	
	320	

Elasticity modulus for 100 % elongation, presentation form

The results are presented in the next table (in N/mm^2):

Table 5

Limit	Measured value	Medium value
Minimum 3,0 Maximum 5,0	4,75	3,78
	3,78	
	4,48	
	3,78	
	3,72	

Residual deformation for 50 % elongation, after 24 h at 100°C

The results are presented in the next table (in %):

Table 6

Limit	Measured value	Medium value
Maximum 25	20	20
	20	
	20	

Mechanical characteristics after accelerated ageing after 96 h at 100°C (fracture strength, fracture elongation and elasticity modulus for 100 % elongation)

The results are presented in the next tables.

- Fracture strength (in N/mm^2):

Table 7

Limit	Measured value	Medium value
Minimum 10,0	10,71	10,71
	10,25	
	10,84	
	10,51	
	11,09	

- Fracture elongation (in %):

Table 8

Limit	Measured value	Medium value
Minimum 180	200	220
	220	
	250	
	234	
	210	

- Elasticity modulus at 100 % elongation:

Table 9

Medium initial value	After ageing	Medium value	Variation %	Limit
3,78	5,12	5,12	+35,44	±40 regarding to first column
	4,94			
	5,15			
	5,12			
	4,95			

Force versus deformation curve for rubber rail pads K49B type

In figure 5 is presented the force versus deformation curve for the second probe. On the graphic, bolded lines are the limits according to the standards.

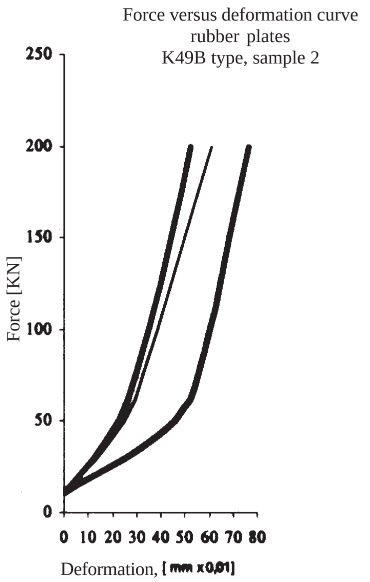


Fig. 5. Force versus deformation curve

Force versus deformation curve for rubber rail pads K60B type

In figure 6 is presented the force versus deformation curve for the first probe. On the graphic, bolded lines are the limits according to the standards.

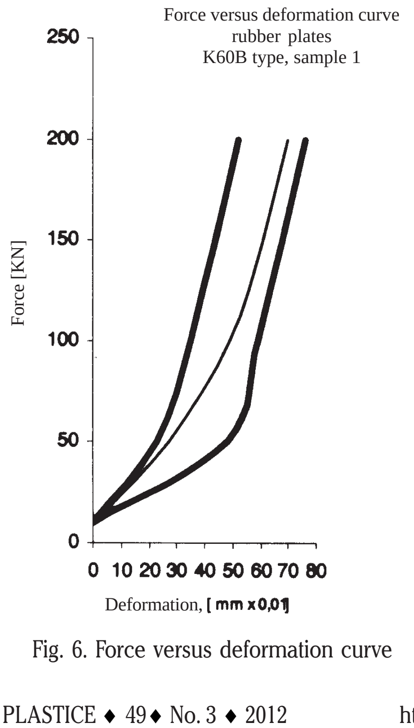


Fig. 6. Force versus deformation curve

The characteristics after accelerated ageing for 96 h at 100°C (fracture strength, fracture elongation)

The results are presented in the next tables (medium values).

- Fracture strength:

Table 10

Medium initial value N/mm^2	After ageing N/mm^2	Fracture strength %	
		Limit	Measured
12,46	10,71	Minimum 70	85,96

- Fracture elongation (in %)

Table 11

Medium initial value N/mm^2	After ageing N/mm^2	Fracture elongation %	
		Limit	Measured
320	220	Minimum 60	68,75

Conclusions

The rubber is widely used at in railways. Because of its use for circulation safety components, the tests performed on rubber parts are very important for all system. After performing test, if the product characteristics are according with standard, the product can be homologated or certificated and it is allowed to be put in service.

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