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FRICTION AT RUBBER-METAL SPRINGS

Dušan Stamenković[1], Miloš Milošević[2]
[1]Univesity of Niš, Faculty of Mechanical Engineering, Serbia, dusans@masfak.ni.ac.yu
[2]Univesity of Niš, Faculty of Mechanical Engineering, Serbia, mmilos@masfak.ni.ac.yu

Abstract: *Rubber possesses large elasticity, as well as a characteristic that, during loading, absorbs a certain quantity of energy on the basis of the presence of a large internal friction. Therefore, the rubber is frequently used for suspension drives of vehicles and stable facilities. Rubber-metal springs present assemblies which comprise from rubber blocks and metal plates which are joined in series. Connections between metal plates and rubber blocks are realized by processes of vulcanization or gluing rubber blocks on metal plates. However, it is possible to realize free contacts as well. In that case, connections between rubber blocks and metal plates are realized by applying pressure and resulting static friction. Rubber springs are mostly loaded with pressure loads, in a smaller amount with shear loads or at the same time with pressure and shear loads. Rubber-metal springs are at the same time shock absorbers as well, because they own elastic and damping characteristics simultaneously and because of that they can work in a combination with steel springs or independently (without shock absorbers). This paper researches the friction between rubber and metal which can significantly influences damping characteristics of rubber-metal springs. In the framework of the experimental research that has being conducted at the Faculty of Mechanical Engineering in Niš the coefficient of the static friction between the rubber and metal has been established in different contact conditions. Moreover, compressions of rubber-metal springs are also performed and force-distance diagrams are recorded. In this way, the mutual influence of the static friction between the rubber and the metal pad and the accumulated/absorbed energy within a rubber-metal spring is analyzed.*

Keywords: *rubber-metal springs, elasticity, coefficient of static friction, hysteresis*

1. INTRODUCTION

Rubber is a very adaptive material with many favorable characteristics. It has been successfully applied in many fields of technique more than hundred years. Because of its excellent physical characteristics, the production of rubber springs is one of the most important usages of rubber. Comparing to metals, rubber has significantly larger elasticity, it possesses certain damping which is especially convenient when resonant vibrations have appeared, and it can accumulate the energy in greater amount than steels. At rubber-metal springs the rubber has been joined to the metal plates which serve for providing more convenient fastenings and positioning. Assembling and maintenance of rubber springs are quite simple.Parts made of rubber, especially rubber springs have found wide application at transport facilities, road and railway vehicles.

The use of rubber for the bearing springs of road and rail vehicles started a few years after the discovery of vulcanization. When a vehicle's spring medium is steel, rubber is still often necessary for modifying the characteristics of steel springs, to reduce the weight of steel necessary by absorbing occasional overload impacts, or to introduce some damping. Rubber suspensions are now used on many types of vehicles.

2. RUBBER-METAL SPRINGS

Rubber-metal springs are usually loaded to compress or shear, but very often to a combination of the both states. At stable facilities these springs are used for elastic supporting of aggregates (Fig. 1).

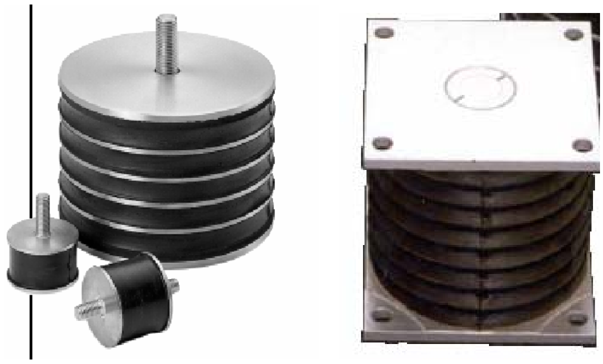


Figure 1. Rubber-metal springs – elastic supports

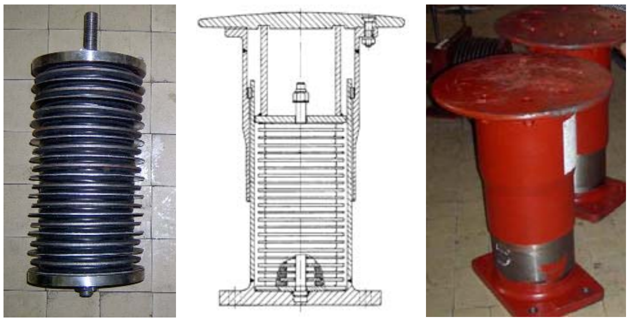
Rubber-metal springs at railway vehicles are used for primary and secondary suspensions and elastic supports of aggregates. Moreover, a specific application of rubber-metal springs is for maintaining wagons connection in a train. That equipment is known as the buffing and draw gear. The railway vehicles suspension represents an elastic connection between vehicles parts and it has the function to provide the stability and comfort during the ride, as well as to suppress vibrations and noise. The suspension can be done with plain steel springs, coil steel springs, rubber-metal elements and air pillows. Additional elements of suspensions are shock absorbers which can be done as frictional or hydraulic ones. They have a task to suppress vibrations of vehicles parts which occur during the ride [1].

Their basic advantages of rubber springs in respect to metal ring springs are: smaller price, simpler building in, smaller mass, do not corrode, do not break and there is no need for lubricating.

The lack of rubber springs is, unlike those of metals, the sensibility to changing of load regimes at low temperatures, and under the influence of an aggressive environment. So, the rubber keeps successfully its elastic characteristics up to -30°C, but at low temperatures it rapidly loses the elasticity, in other words it becomes stiff and fragile.

2.1 Buffing and draw gear of railway vehicles

The buffer gear has a very important function of maintaining mutual distances between railway vehicles in a train. Their properties are of the crucial influence on transferring and reducing impact loads by which stability and safeness of railroading and manoeuvre are affected. Rubber-metal springs that fill buffers, as the substitution of spring systems made mostly of metal ring springs, have been introduced in the practice at the seventies of the passed century. The assembly of a rubber-metal spring consists of metal carriers in the shape of circular plates or rings that are connected to the natural or synthetic rubber by procedures of vulcanization or pressing or free contact. In this way the advantages of both component elements are involved within themselves: high abilities of deflection and amortizations of the rubber and large surface loads which are sustained by metal parts (Fig. 2) [2].

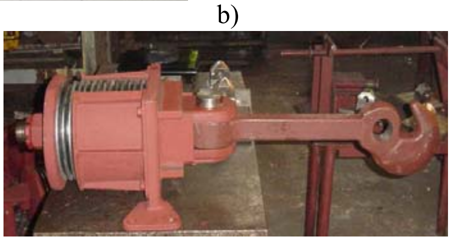


a) b) c)

Figure 2. A buffer filled with a rubber-metal spring
a) A rubber-metal spring; b) A cross section of a buffer; c) Buffers

The draw gear of railway vehicles has the task to transfer the traction force from a locomotive to wagons in a train. Since this kind of equipment carries very changeable and large axial forces, the elasticity of the draw gear, as well as its ability of absorbing the shock energy are very significant characteristics. Because of these requirements, next to bandage and ring springs, the draw gear is most often built with rubber-metal springs (Fig. 3) [2].

a) b)



c)

Figure 3. Draw gear with rubber-metal springs
a) A rubber-metal spring; b) A draw gear;
c) A draw gear with a draw-bar

2.2 Buffing characteristics of rubber-metal springs

An important consequence of the unique stress-strain properties of rubber is its ability to store large amounts of energy and to release most of this energy on retraction. However, the return stress/strain curve never coincides with the outward curve, hence there is a loss of energy (hysteresis) which appears as heat and can lead to a damaging rise of temperature in unfavorable circumstances.

Changing of intensity and frequency of the load changes the load dependency and elasticity of rubber elements. Therefore the elasticity and shear modules are quite different at a static loading in contrast to a dynamic loading. Because of the processes of rubber breaking that is of the large complexity and insufficiently known, the computation of deformations is performed taking into account static loads, while the lifetime is estimated experimentally.

The testing of elastic characteristics of rubber-metal spring assemblies, as well as assembled buffers is performed at a hydraulic press by compressing up to the maximal deflection of 105 mm or to the maximal force of 1000 kN, following with decompressing. During the both cycles the characteristic "force –deflection" is recorded (Fig. 4). This testing enables elastic and absorption characteristics of rubber springs to be determined on the basis of the accumulated work (the work of compression) and absorbed work (energy) that presents the difference between the work of compression and work of decompression. The testing of elastic characteristics of spring assemblies of draw gear is performed on an identical way, by compression up to the maximal deflection of 55 mm or to the maximal force of 850 kN [3, 4].

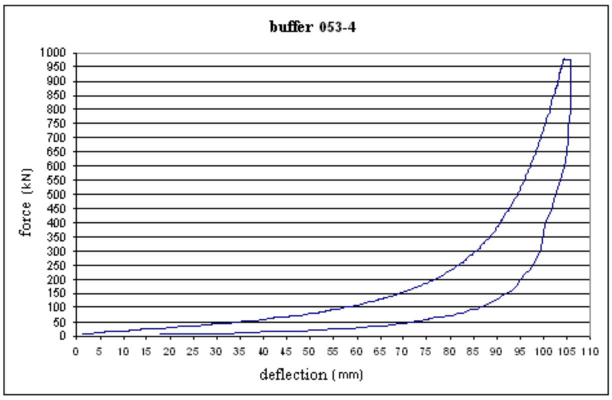


Figure 4. The statical characteristic of a buffer rubber-metal spring

2.3 Frictional characteristics of rubber

Rubber has a very high coefficient of friction, and hence unique gripping properties. Use is made of this in many engineering applications; for example, rubber is not always bonded in bushes, since its frictional grip is almost equal to a bond.

Fig. 5 shows the effect of lubricating the ends of the rubber under compression. Provided that the steel ends are clean the grip is almost equal to that of a bonded sample. This diagram shows the importance of bonding even when the rubber is under compression since the accidental entry of oil into a non-bonded interface would completely alter the spring characteristics of the unit [5].

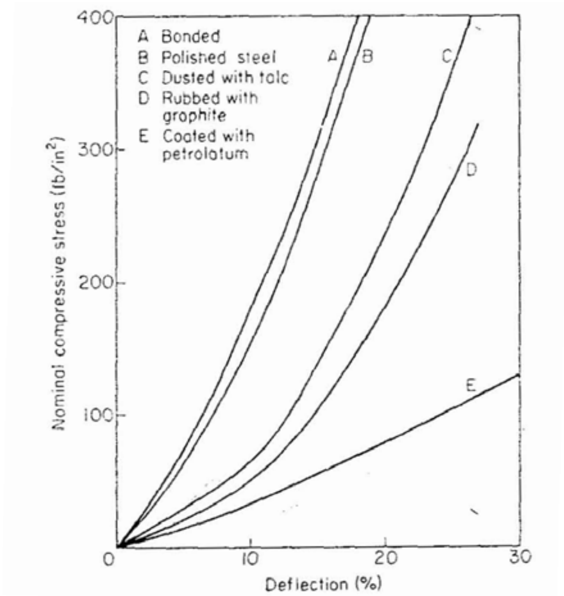
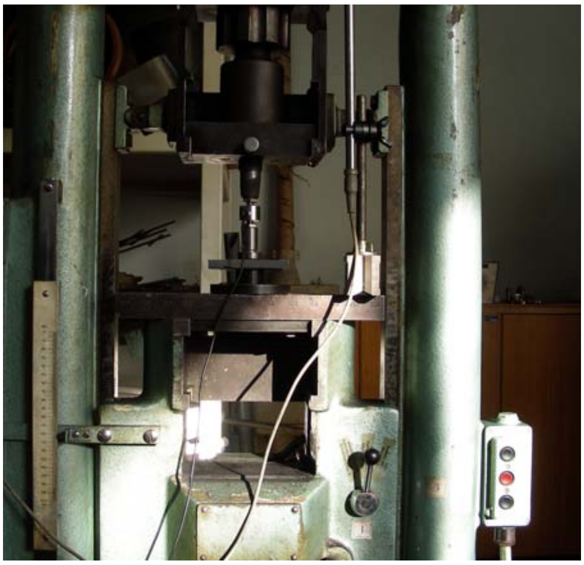


Figure 5. Effects of surface conditions on the stress/deflection curve for rubber under compression [5]

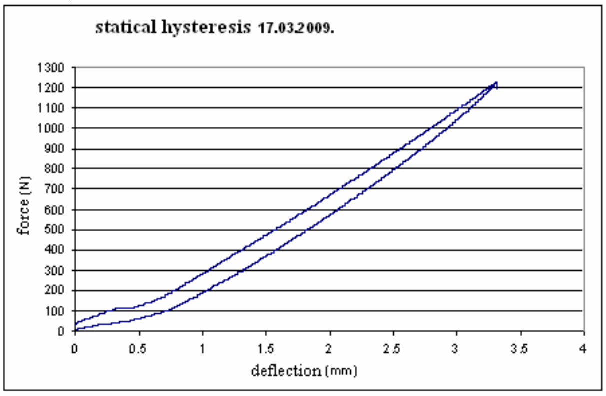
Another important characteristic of rubber friction is that when the rubber is wetted by water, friction is greatly reduced. Water is an almost ideal lubricant for rubber.

3. EXPERIMENTAL RESEARCH

During the realization of the project "Development of rubber-metal elements for railway vehicles" in the framework of the program of research in the area of the Technological development of the Ministry of Science (2005-2006) of Republic of Serbia, it has been noticed that the amount of the accumulated/absorbed energies of rubber-metal springs loaded to compress depends on the contact between the rubber and the metal. If this contact is fastened, in other words if it has been done by the vulcanization or gluing, then the elastic/buffering characteristics of those springs correspond to designer defined demands. However, if the contact between the rubber and metal element is free (has not been fastened) then the elastic characteristics of the rubber-metal springs are influenced by the states of the contact surfaces, that is the respective coefficient of static friction. For the purpose of the research of this phenomenon an experiment has been carried out at the Faculty of Mechanical Engineering in Niš, Serbia.



a)



b)

Figure 6. The testing of the static hysteresis by compresion of rubber test tubes in the Laboratory of the Faculty of Mechanical Engineering in Niš, Serbia
a) The measuring place;
b) A record of the static hysteresis test

A measuring place for the testing of the static hysteresis of rubber test tubes (dimensions ∅35.7x17.8mm) loaded to compress is shown on Fig. 6 a). The procedure for this testing has been established on the Faculty of Mechanical Engineering in Niš, Serbia. Fig. 6 b) shows a recorded diagram of the static hysteresis of a rubber test tube for the case of the testing with sand papers in contacts between the rubber test tube and metal plates from the both sides.

Table 1 presents the results of the testing of the static hysteresis of the rubber test tubes with different conditions of the contacts between the rubber test tubes and metal plates. For the first testing, between the rubber and metal plates the sand papers were placed, for making a very fixed contact. Then, the pure contact between the rubber and metal surfaces was used. Afterwards, the contact between the rubber and metal was moistened with water. Finally, the contact between the rubber and metal was coated with some oil.

Fig. 7 shows the comparative elastic characteristics of the same sample of the rubber test tube obtained during the compression phases of the testing of static hysteresis for different states of the contact surfaces.

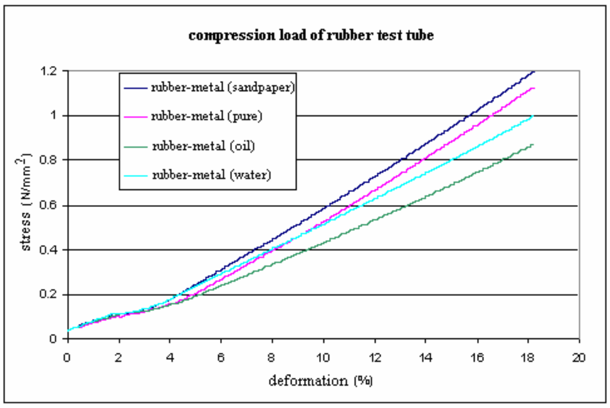


Figure 7. The function of the elastical characteristic of the states of the contact surfaces

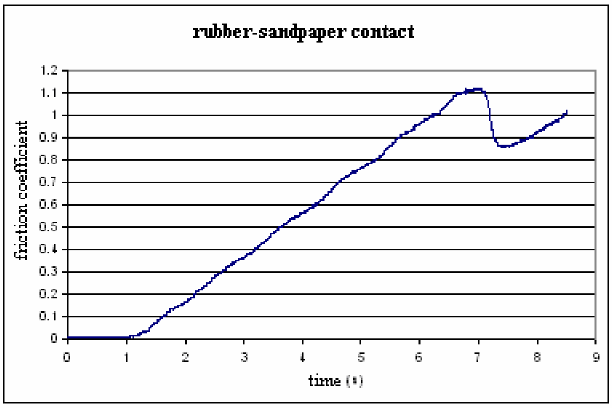
For the purpose of establishing tribological characteristics of rubber-metal contact surfaces for different contact conditions, the testing of the static frictional forces on a sample of a rubber test tube loaded with a weight has been done at the Faculty of Mechanical Engineering in Niš, Serbia. The loaded rubber test tube was forced to slide along a sandpaper, pure metal surface, moistened metal surface and metal surface coated with a thin layer of oil. On Fig. 8 a) the measuring place used for testing static frictional forces is presented, and on Fig. 8 b) the characteristic diagram of the friction coefficient in the function of time. During the performing of experimental probes, the measuring

Table 1. The results of the static hysteresis testing for different states of contact surfaces

No	Condition of contact surfaces	Max force	Deflection (at the force of 1200 N)	Accumulated work	Absorbed work	Statical hysteresis
		(N)	(mm)	(Nmm)	(Nmm)	(%)
1.	Rubber-metal (sandpaper)	1200	3.25	1766	241	13.6
2.	Rubber-metal (pure)	1200	3.41	1814	291	16.1
3.	Rubber-metal (water)	1200	3.80	2141	677	31.6
4.	Rubber-metal (oil)	1200	4.17	2291	459	20.0

values of static friction forces have differed even for the same contact conditions and especially for the cases with water and oil. This can be explained by changeable adhesion forces caused by fluids in the surface layer. The value of the friction coefficient has been largest in the case of the contact of the rubber and sandpaper (μ=0.8-1.1). In the case of the contact of the rubber and clean metal the value of the friction coefficient was from 0.66 to 0.71, while in the case of moistening the contact between the rubber and metal the value of the friction coefficient was from 0.64 to 0.86. The smallest value of the static friction coefficient was in the case of the contact of the rubber and metal greased with oil (0.5-0.7).

a)



b)

Figure 8. The measuring of static friction forces
a) The measuring place; b) The recorded diagram of the friction coefficient in the function of time

4. CONCLUSION

Elastic/buffing characteristics of rubber-metal springs correspond to demands set by a designer only for the case when the contact between the rubber and metal parts in a spring is done by the process of vulcanization or gluing. However, if the contact is free then these characteristics can vary in the function of the state of the contact.

The performed experimental research indicates that the rubber-metal springs loaded to compress, the contact condition between the rubber and metal parts can significantly affect elastic and buffing characteristics of springs. The obtained results show that if there is some water or oil in the contact of the rubber and a metal part it will give larger elasticity, in other words, the accumulated and absorbed energy of a rubber-metal spring will be grater.

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