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17–19 May 2018, Zadar, Croatia

Road and Rail Infrastructure V

Stjepan Lakušić – EDITOR

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CHANGE OF SPRING CONSTANT FOR SPRINGS WITH CORROSION

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Technical University of Sofia, Bulgaria

Abstract

The purpose of this article is to investigate the change of the spring constant with springs subjected to corrosion. We have used in our investigation 12 tension coil springs. We have determined the spring constant using the measurement of natural frequency of spring-mass system and high accuracy measurement of the spring mass with electronic analytical balance. We have done processing of the springs in corrosion environment using an accelerated method for electro-chemical corrosion setting the springs under maximally identical conditions. After their processing in this corrosion environment, we have determined again the spring constant of the springs. We have presented to you the results in a form of a scheme. We have analysed the obtained results and have made conclusions about the change of the spring constant of the springs.

Keywords: coil spring, corrosion, spring constant, spring with corrosion

1 Introduction

The springs are a very important element in numerous parts of machines, elements, parts and transportation vehicles. Sometimes, they are subjected to climatic influence and this causes their corrosion. There have been made many studies on the subject of the springs, but most of then have been focused on the fatigue and failure analysis of the spring and its influence [2-7]. In fact, almost all the springs have been made of stainless steel (corrosion resistance) and there are even patents for this type of production [8-11]. In real conditions however, sooner or later, springs corrode (although to a minimal degree) and that is caused by different factors (climatic influence) [12]. A typical example of such influence is a spring subjected to atmospheric influence.

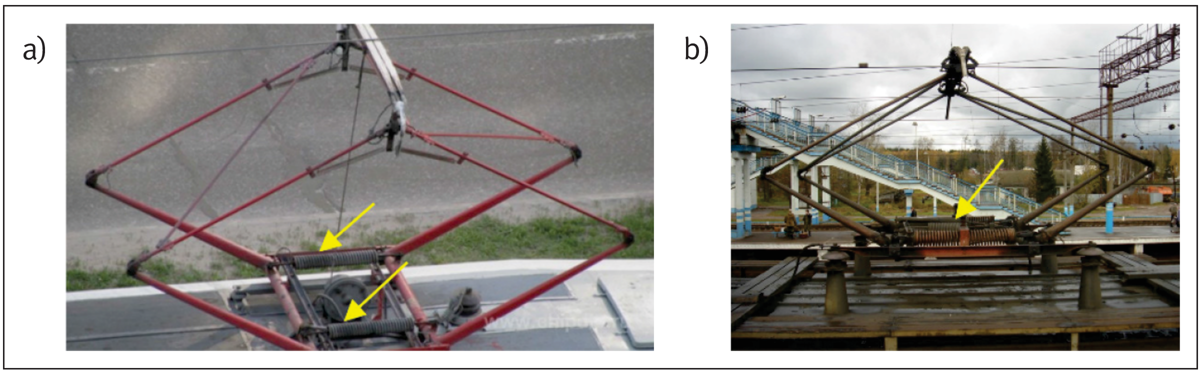

Figure 1 Springs used in pantographs of electric rail vehicles: a) antograph of a tramway, b) pantograph of a locomotive

We have shown on Fig. 1 and Fig. 2 examples of springs subjected to atmospheric influence – these are the springs in the pantographs of the tramways and the electrical locomotives, as well as the springs under the poles of the trolleybuses. Some of the springs in the vehicles take part in certain elements concerning their safety – a spring used in drum brakes (Fig. 3), as well as in some other mechanical parts (Fig. 4).
The purpose of this article is to establish the influence of the spring degree of corrosion over its spring constant, since the spring constant is the basic component for the calculation of the spring and its change will doubtlessly have an effect over the function of the spring.

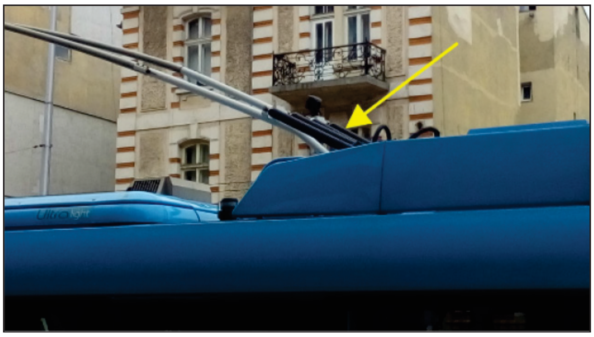

Figure 2 Springs used in trolleybus poles

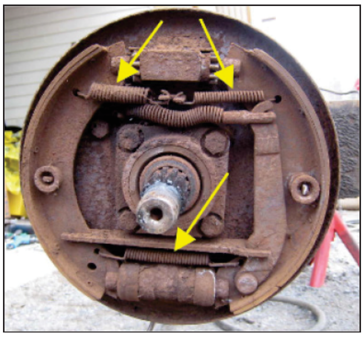

Figure 3 Springs used in drum brakes

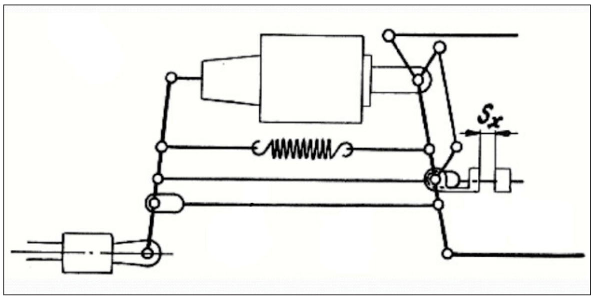

Figure 4 A mechanism used to handle loads of a freight car

2 Our choice of experimental samples

We will focus our investigation on 12 springs. We have chosen tension coil springs with the following parameters:
- length – 80 mm;
- spring wire diameter – 1 mm;
- material – stainless spring wire (standard EN 10270-3) X10CrNi18-8 (name according EN 10027 – part 1 and part 2)

3 Determination of the spring constant

There are two methods for the determination of the spring constant – static and dynamic. With the static method, the spring constant is determined on the base of the elongation of the spring when it is subjected to tension with constant force. With the dynamic method, free vibrations of a spring-mass system are caused and the natural frequency is measured [1]. When we use the static method, the mechanical system must be in a state of equilibrium, since even a slight vibration of the spring will reduce the accuracy. This might prolong the time necessary for measurement, because there might arise a need to wait for the mechanical system to reach again a state of equilibrium. Besides that, technically speaking, it would be much more difficult to measure with high accuracy the static elongation of the spring, while the frequency of spring oscillations would be easily measured with high accuracy. Eg. 1 presents the dependence between the natural frequency of the spring-mass system and the spring constant [13], [15].

$$f = \frac{1}{2\pi}\sqrt{\frac{c}{m}} \tag{1}$$

where f is the natural frequency of the spring-mass system, c is the spring constant, m is the mass of the spring. From Eq. 1 we can determine the spring constant (Eq. 2).

$$c = 4\pi^2 f^2 m \tag{2}$$

From Eq. 2 we can see that in order to determine the spring constant we have to calculate the frequency of its own vibrations and the mass of the spring. The set-up that we have used in order to determine the natural frequency of the spring-mass system has been shown on Fig. 5.

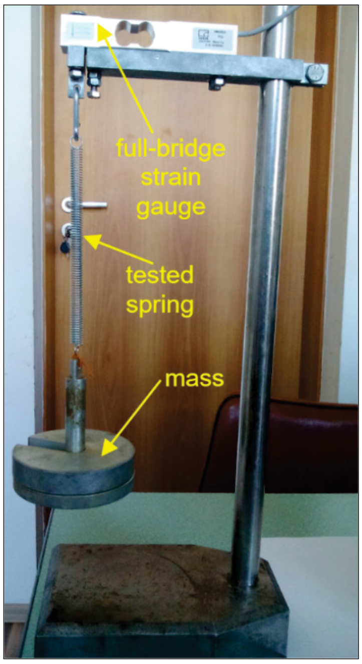

Figure 5 The set-up that we have used in order to determine the natural frequency of the spring-mass system

It consists of the following parts – force meter with four strain gauges installed, connected in a full-bridge circuit. The spring is placed at the force meter. On the other end of the spring a mass is placed. In this way, free vibrations of the spring-mass system are caused and the force with which it influences the force meter is transformed into an electrical signal via the full-bridge strain gauge circuit. We have shown a block-scheme of the system for measurement and processing of the signal from full-bridge strain gauge circuit on Fig. 6.

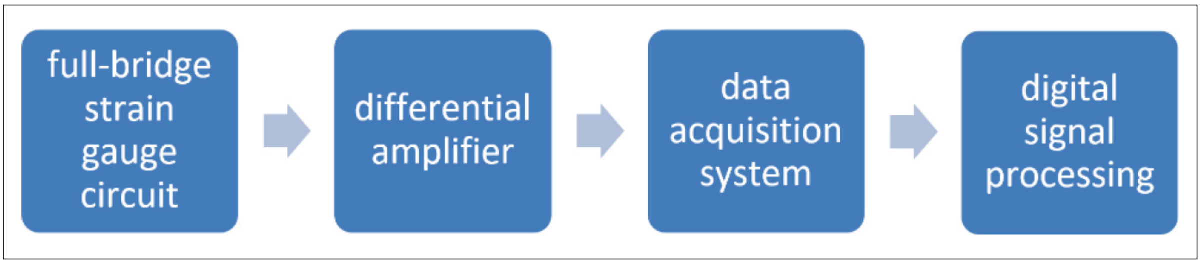

Figure 6 Block diagram of the system for measurement and processing of the signal from full-bridge strain gauge circuit

This system consists of the following parts – differential amplifier, which amplifies the voltage difference between the two diagonals of the strain gauge full-bridge. The digital signal, obtained at the end of the data acquisition system is saved in the computer memory. After this, we have done a software determination of the natural frequency of the spring-mass system. This software determination includes filtering of the signal from noises, measurement of the frequency for numerous periods and statistical processing in order to eliminate mistakes having arisen during the calculation of the data. After this, we establish the average values for the numerous periods we have investigated.
We have used electronic analytical balance in order to determine the mass of the springs.
The spring constant is determinate by the dependence described in Eq. 2 on the basis of the measured natural frequency of the spring-mass system and the measured mass of the spring.

4 Treatment of the springs in corrosive environment

In order to establish the change of the spring constant, all the springs have been subjected to the influence of corrosive environment. The idea is to achieve a very similar degree of corrosion of all of them. We have used an electro-chemical method to enhance the corrosion. All of them have been placed in one and a same pot [14]. The corrosion environment is a solution of 5 % NaCl. The electrical current through all of the springs is constant – 37 mA ± 2 %. All the springs are investigated under maximally identical conditions:

- same electrical current;
- same duration of the treatment in corrosive environment;
- same electrolyte for all the springs – with the idea that any change of the temperature and the PH of the electrolyte, during the treatment, would influence to an identical change in corrosion rate for all the springs.

The experimental set-up we have used is shown on Fig. 7.

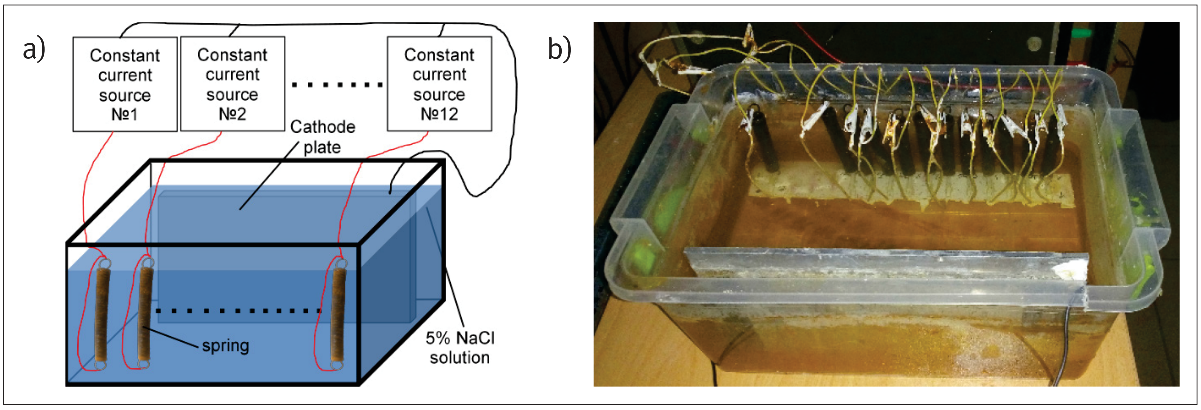

Figure 7 The used experimental set-up: a) block scheme, b) photo of the used experimental set-up

5 Experimental

The block diagram of the experimental procedure has been presented on Fig. 8. Before the treatment in corrosive environment, we have measured the spring constant of all the springs, using the method, described in Section 2, as well as their mass. After that we have subjected them to electro-chemical corrosion, according to the method described in Section 4. After subjecting them to corrosion treatment, we have measured again the mass of the springs, as well as their spring constant according to the method, described in Section 2.

Figure 8 A block scheme of the experimental procedure

In Table 1, we have shown the mass of the springs before and after the corrosion treatment and the percentage of the loss of the mass of the springs. It can be easily noticed that the degree of the corrosion of all the springs is very similar.
In Table 1, we have also shown the spring constant of the springs before and after the corrosion treatment and the percentage of the change of their spring constant. It can be noticed that when the springs have very similar degree of corrosion, the differences in their spring constant are also quite minimal. Besides that however, the change of the spring constant becomes considerable under rather low level of corrosion. We have shown on Fig. 9 a photo of a spring before and after its treatment in corrosion environment.

Table 1 Measuring results

№	Mass before corrosion [g]	Mass after corrosion [g]	Mass loss [%]	Spring constant before corrosion [kg/s^2]	Spring constant after corrosion [kg/s^2]	Spring constant change [%]
1	14.3800	12.3467	14.14	1.4528	0.93290	35.79
2	14.3654	12.2530	14.70	1.4536	0.91008	37.39
3	14.3997	12.3832	14.00	1.4575	0.92394	36.61
4	14.3855	12.3722	14.00	1.4599	0.94239	35.45
5	14.3857	12.3590	14.09	1.4530	0.92421	36.39
6	14.3851	12.3210	14.35	1.4572	0.93492	35.84
7	14.4185	12.4202	13.86	1.4401	0.92716	35.62
8	14.4030	12.3424	14.31	1.4556	0.92583	36.40
9	14.4068	12.3410	14.34	1.4659	0.93303	36.35
10	14.4234	12.3583	14.32	1.4539	0.92290	36.52
11	14.3722	12.3122	14.33	1.4598	0.92479	36.65
12	14.3801	12.3199	14.33	1.4600	0.95344	34.70

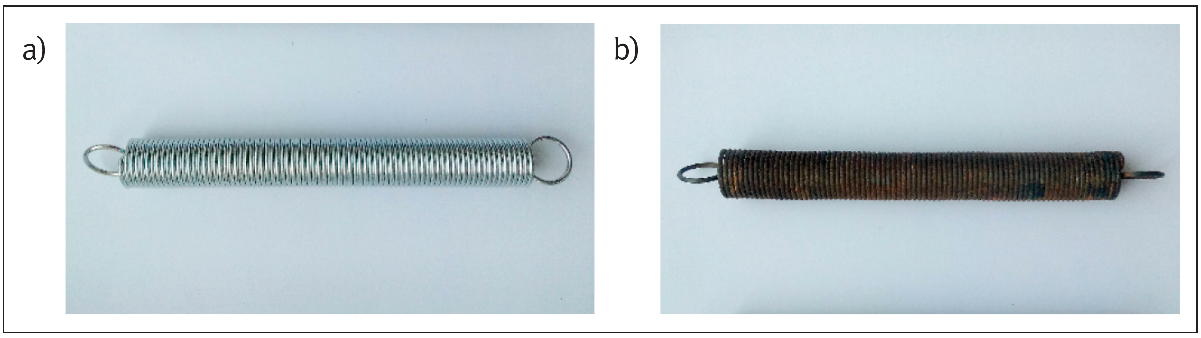

Figure 9 A photo of a spring: a) before corrosion, b) after corrosion

6 Conclusions

The results of our study show beyond any doubt the corrosion influences the spring constant. The absence of research until now is due to the circumstance that all the springs should be made according to a standard, requiring their production from stainless steel. There is a need to make a theoretical-calculating model for the determining of the influence of the corrosion on the springs, as well as to its effect on the function of every element. The presumption that the spring would not corrode during the expected term of function is not reasonable. In real conditions, many of the machines, the elements and the parts, as well as the vehicles, often continue to be used even after the presumed term of exploitation and this requires the problem with the corrosion to be studied thoroughly. This might lead to additional usage of the springs with the idea of their optimising.

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