

# THE CORRELATION BETWEEN THE ACCELERATION AND CONTACT RESISTANCE TO A RELAY IN VIBRATORION MOVING

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**ABSTRACT:** This paper aims to analyze the effect of vibrations from the industrial environment on the contact resistance of electrical equipment, such as relays and contactors. The vibratory movements of such equipment have been simulated in the laboratory, following their influence on contact resistance. The results were processed, obtaining a series of diagrams .

**KEYWORDS:** contact resistance, vibration system, diagram of electrical contact resistance.

## 1. INTRODUCTION

Electrical equipment is usually used in industrial environments, where operation is carried out under particular conditions, generally characterized by disturbing actions. This disturbing actions influence the material of the electric contacts [2,5,6]. A disturbing element, commonly encountered in the industrial environment, is mechanical vibration, which influences the contact elements in particular, resulting the variations in the contact resistance. The present paper aims at carrying out such a study, regarding the contact resistance of a relay subjected to vibrational movements perpendicular to the contacts.

## 2. THEORETICAL PROBLEM

In the contacts of apparatuses used in electrical installations, such as relays, the two elements of the contact, the fixed contact and the movable contact, whose the defining structure is shown in Fig. 1, real come in contact with a small part, called the real contact area.

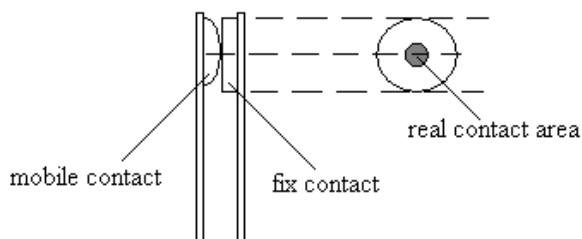


Fig.1 The principle structure of a punctiform contact

This real contact area is defined by the general relationship:

$$A_r = \frac{F}{\zeta H}$$

depends on the pushing force F on the contacts, the hardness of the material H and the Prandtl coefficient.

For a punctiform contact, of the form represented in Fig. 1, the Prandtl coefficient has the value "1", so the actual contact area can be defined by the relation:

$$A_r = \frac{F}{H} = \pi r^2$$

Mathematically, the relationship between the "r" radius of punctiform contact and the "F" force is deduced from the previous relationship.

$$r = \sqrt{\frac{F}{H\pi}}$$

The electrical contact resistance is defined as a sum of two resistances, according to the relationship:

$$R_C = R_S + R_P$$

where  $R_S$  is the striction resistance of the power lines, and  $R_P$  is the resistance of the disturbing films (generally oxide layers) on the surface of the contact.

Damage to the contact resistance may cause contact material deformation, welding point problems of the contact pads on the supports [6,7].

At the same time an increase in contact resistance leads to the appearance of thermal phenomena, which can cause the destruction of the contact system [1,4].

Fig.2 The distribution of the forces on the contact

In the previous figure  $\mathbf{F}_1$  is the attraction force generated by the electromagnet in the relay construction, and  $\mathbf{F}_2$  is the antagonistic force created by the mechanical spring in the relay construction.

When the relay operating without be subjected to vibrational motion, the result of these forces:

$$\mathbf{F} = \mathbf{F}_1 - \mathbf{F}_2$$

is constant for a normally open contact of the relay supply with the nominal voltage at the coil terminals.

According to the previous relationship between the contact resistance  $R_C$  and the pushing force on the contact,  $\mathbf{F}$ , the contact resistance will be constant in time.

At the occurrence of a vibrational movement, perpendicular to the axis of the contact surfaces, appear an inertial force, given by the relation:

$$\mathbf{F}_i = m_c \cdot \mathbf{a}_s$$

where  $m_c$  is the mass of the mobile contact and  $\mathbf{a}_s$  is the acceleration of the system. Due to this fact, over the constant force  $\mathbf{F}$  applied to the relay contacts, appear a variable additional force, which depends by the oscillation of the contact system, implicitly of the entire equipment. In other words, the force of push on the contact is a result of a continuous component  $\mathbf{F}$  and an oscillation component  $\mathbf{F}_i$ , according to the relation:

$$\mathbf{F}_C = \mathbf{F} + \mathbf{F}_i = \mathbf{F} + m_c \cdot \mathbf{a}_s$$

Taking this into account, it results that the contact resistance  $R_C$  is not a constant she will depend by the acceleration applied to the contact system according to a relation of the form:

$$R_C = \rho \sqrt{\frac{H}{\pi F_C} + \frac{R_{SS} H}{F_C}}$$

where the pressure force  $F_C$  is a variable function dependent on the system acceleration,  $F_C = f(a_s)$ .

### 3. EXPERIMENTAL DETERMINATIONS

In the experimental part of the paper we will follow a series of parameters related to the operation of an electromagnetic relay while it is subjected to

The striction resistance is calculated, based on the infinite conductivity sphere model, with relation:

$$R_S = \frac{\rho}{\pi r}$$

where  $\rho$  is the resistivity of the material from which the contact is made and  $r$  is the radius of the point contact.

The calculation of the  $R_P$  resistance is made on the basis of the specific surface resistivity of  $R_{SS}$ , which depends on the contact material, the chemical composition of the disturbing film and its thickness  $d$ .

For a contact made of cooper with a disturbing copper oxide film, according to the literature, the calculation relation is:

$$R_{SS} = 315 \cdot 10^{10} \cdot d^{2.68}$$

For a punctiform contact with  $r$  radius, the resistance value of the disturbing film is given by relation:

$$R_P = \frac{R_{SS}}{\pi r^2}$$

In conclusion, the contact resistance  $R_C$  is given by relation:

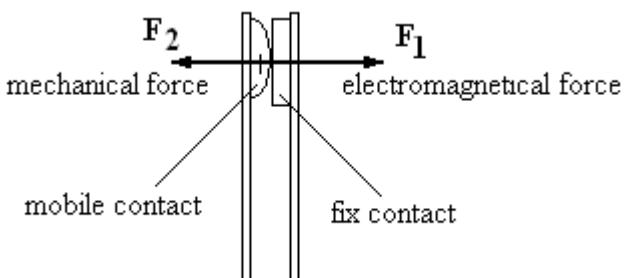
$$R_C = R_S + R_P = \frac{\rho}{\pi r} + \frac{R_{SS}}{\pi r^2}$$

Taking into account the value of  $r$  defined above, we have:

$$R_C = \rho \sqrt{\frac{H}{\pi F} + \frac{R_{SS} H}{F}}$$

The above relation defines the dependence of the contact resistance  $R_C$  on the push force  $F$  on the point contact.

The forces acting on the contact system of a relay, as long as it is not subjected to vibrational movements, are shown in Fig. 2.



an oscillatory vibration movement perpendicular to the contact assembly.

The analysis will be performed on a normally open contact ND of the relay when a 5A load current passes through it.

The determinations will be realized on an experimental stand, containing a vibrating table that can be operated on each axle independently. For the present study, the vibrating table was driven only on the x-axis. An accelerometer is mounted on the vibrating table.

The image of the experimental system is shown in Fig.3.

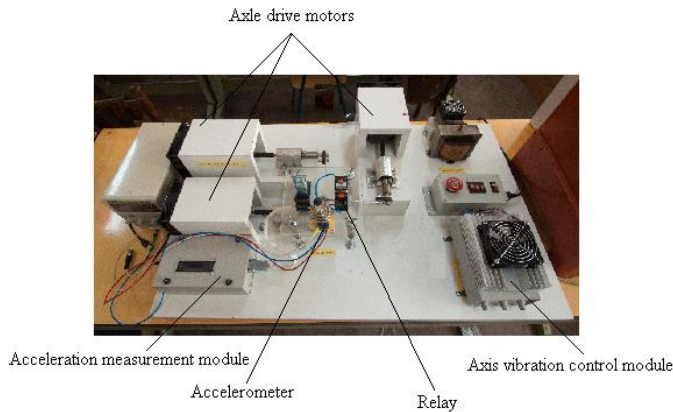


Fig.3 The experimental system

The amplitude of the oscillatory motion with the stand is 1.5 mm. The oscillation frequency, directly proportional to the engine speed, can be adjusted on each axle with a potentiometer located on the front panel of the vibration control module.

The acceleration of the vibrating mass system with the study relay mounted on, it is measured with an accelerometer placed on it. The system acceleration value is show on the display of the acceleration measurement module.

The voltage drop on the relay contacts is visualized by means of an oscilloscope. The electric schema of the voltage drop measurement diagram on the relay contacts is shown in the next figure.

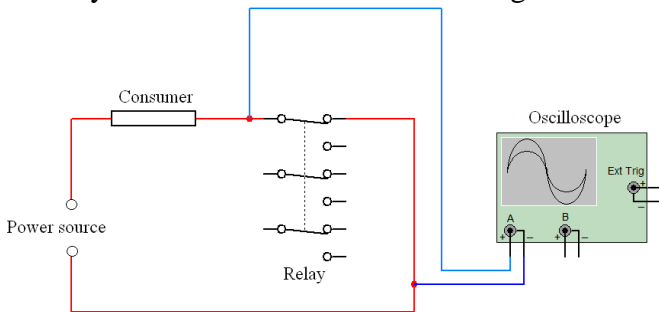


Fig.4 Electrical scheme for voltage drop measurement

The speed of the vibrating table drive motor on the x-axis was measured with an electronic

tachometer, as a result of which the oscillation frequency of the vibratory table was measured. In Fig.5,6 and Fig.7, the voltage drops for two oscillation frequencies are shown.

From the Fig.6 it can be seen that from an oscillation frequency of about 41 Hz the phenomenon of interruption of the electric contact occurs.

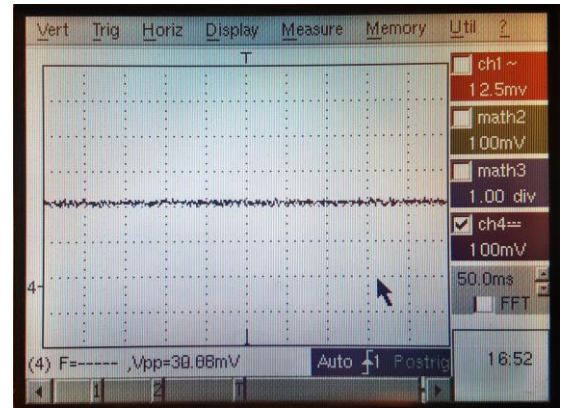


Fig.5 The voltage drop on the relay contact at the oscillation frequency of 10 Hz

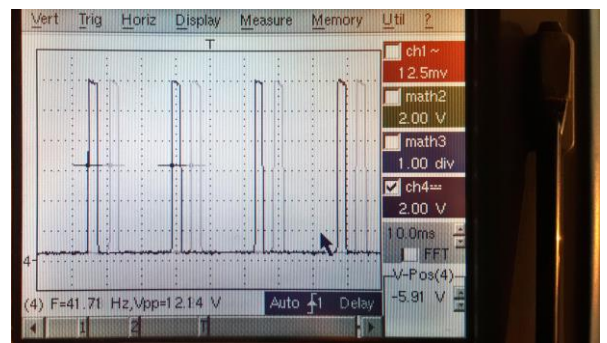


Fig.6 The voltage drop on the relay contact at the oscillation frequency of 41.71 Hz

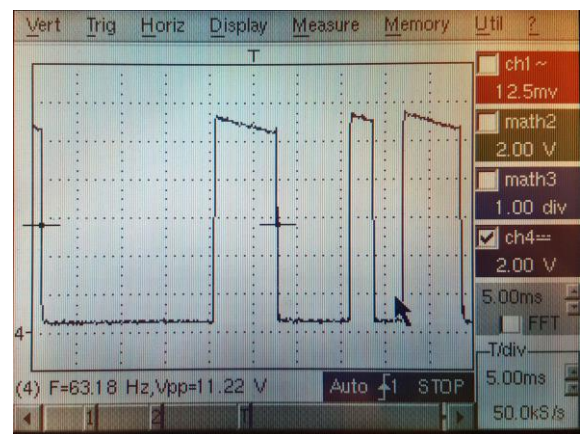


Fig.7 The voltage drop on the relay contact at the oscillation frequency of 63.18 Hz

The effective interruption of the electrical contact increases as the frequency of the oscillation increases, the thermal phenomena due to the electric arc that appears are increasingly important. This

may result in deformation of the contact element or its total destruction.

The results of the measurements are presented in the following table:

Tabell1. The results of the experimental measurements

Nr. of det.	Frequency of oscillation [Hz]	Acceleration [m/s <sup>2</sup> ]	Contact voltage drop [mV]	Contact resistance [mΩ]
1	10	0.2	30,06	6.12
2	14	0.25	30.70	6.14
3	15	0.4	33.66	6.732
4	15.16	0.5	34.31	6.862
5	16	0.65	29.34	5.868
6	23.33	0.75	27.91	5.582
7	30	1.2	26.8	5.360
8	31.66	1.5	25.54	5.108
9	34	1.8	32.66	6.532
10	38	2	30.23	6.046
11	42	2.5	29.57	5.914
12	49	3	26.15	5.23
13	52	3.5	777.8	155.56
14	53.50	4	791.2	158.24
15	59	4.5	811.4	162.2
16	66	5	831.1	166.22
17	73	5.5	863.5	167.30
18	75	6	870.3	174.06
19	90	6.5	861.9	172.38
20	93.33	7	891.1	178.22

Based on the above results, the system acceleration variation curve was plotted according to the oscillation frequency shown in the following figure.

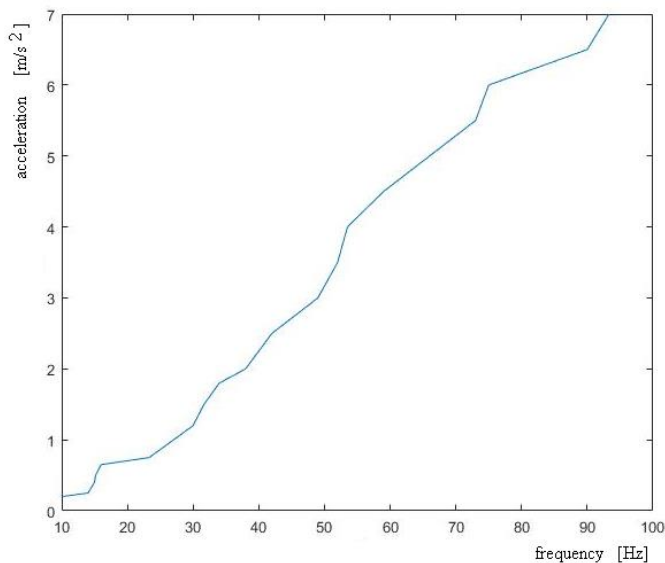


Fig.8. The system acceleration according to oscillation frequency.

Also based on the experimental results we studied the variation of the resistance on the RC

relay contact according to the acceleration of the system, obtaining the diagram presented in Fig.8

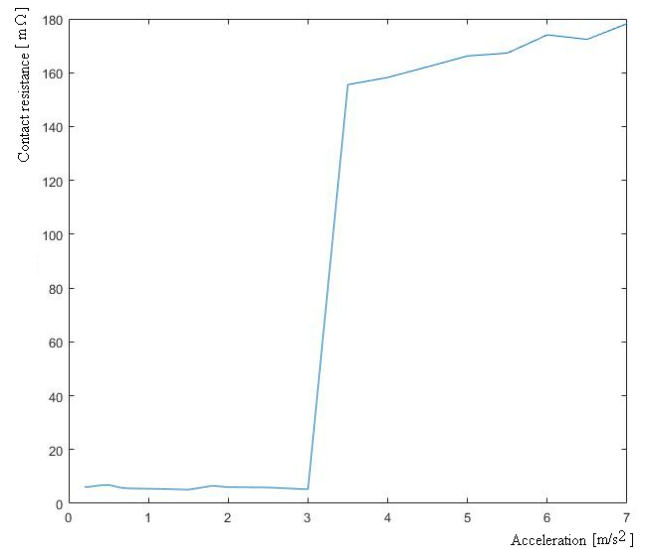


Fig.9. The contact resistance depending on system acceleration

The graph shown in Fig. 10 it is correlated a number of three variables, the system acceleration, the voltage drop across the contact and the contact resistance.

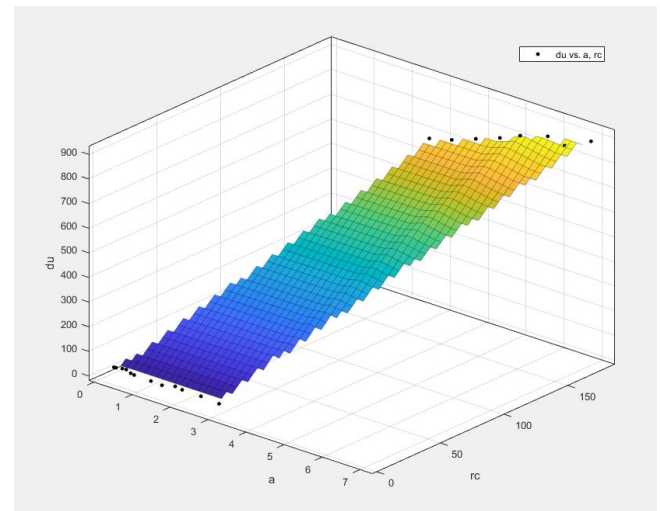


Fig.10. The variation of voltage drop across contact due to system acceleration and contact resistance.

#### 4. CONCLUSIONS

From the upper analysis we can see that the contact resistance  $R_C$ , ultimately depends by the acceleration of the oscillatory movement, in the sense that with the increase of the oscillation acceleration it increases.

Extremely, if the inertial force applied to the contact, which depends by the acceleration of the vibrator system, increases more than the force  $F$  of the pressing on the contact, it is possible to appear interrupter of the electric contact, which can lead to the occurrence of the electric arc periodically

between the contacts, which ultimately causes overheating of contacts, with all its negative effects

In conclusion in the industrial environment, contact equipment such as relays, contactors, etc. used in environments where they are subject to vibration, must be protected against them by specific measures, one of them is the judicious mounting of them, according to the direction of the vibration.

The analysis of the phenomenon was carried out in the present study on a single axis of vibration, considered the most unfavorable. We consider that the study is necessary to be continued by analyzing the phenomena that arise from composite vibrations and other axes.

## 5. REFERENCES

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