STUDY OF THE FRICTION PHENOMENON IN THE WIPER-WINDSHIELD CONTACT

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Abstract: *the paper presents a series of experiments studying the friction between the wiper and the windshield and a series of considerations regarding the occurrence of the stick-slip phenomenon. The stand used was built so that a series of laboratory tests could be carried out under different load and speed conditions.*

In the first part of the study, the maximum and average friction forces, as well as the maximum and average friction coefficients, were determined. In the second part, the presence of the stick-slip phenomenon and the conditions for its manifestation were investigated. Observations were also made on the behavior of the system under these conditions.

Keywords: *friction coefficient, stick-slip.*

1. Introduction

We cannot talk about mechanical contact with movement without also talking about friction. Friction is present in any mechanical system with movement or a tendency to move. In situations where mechanical contact is used to transmit motion (such as mechanical couplings), friction is absolutely necessary. On the other hand, in other situations, where no movement is transmitted (bearings, wipers, rolling bearings, etc.), the presence of friction does nothing more than consume energy and facilitate the occurrence of wear. (in the case of mechanical couplings), friction is absolutely necessary. In the wiper-windshield coupling, friction is a very important phenomenon, because the wiper blade, which is made of an elastic material (the most commonly used being rubber), moves on the surface of the windshield (made of glass) under the action of the resultant of the driving forces and the friction forces.

Even though glass appears smooth, it, like any material, has microscopic asperities. When the slide moves on the glass surface under the action of a normal force, adhesion occurs in the contact between the asperities of the two materials, followed by a sudden slip, when the static friction force value is exceeded, a phenomenon called stick-slip. This phenomenon occurs frequently and produces vibrations and noise, which creates discomfort for passengers and implicitly wear. All this leads to inefficiency of the wipers, the windshield will not be cleaned properly, which reduces transparency and implicitly visibility.

The purpose of the study is to evaluate the friction coefficients and identify the conditions that favor the occurrence of the stick-slip phenomenon in the contact between the wiper blade and the windshield surface.

2. Description of the experimental stand

Studying the friction phenomenon in the wiper-windshield contact involved the use of a stand to simulate the movement of the wiper on the windshield surface [Ungureanu, 2012], [Vultur, 2012]. The design of this stand started from the idea of using a car windshield. However, with its curved surface, it was not possible to ensure uniform pressure along the entire length of the wiper blade. For this reason, it was decided to use a flat window at the back of the car. It was cut from the car body along with part of the steel metal frame and the motor mechanism to which it was attached. The assembly was adapted to be placed horizontally, using four metal legs.

The wiper arm was modified by inserting an elastic blade to allow the attachment of two incomplete-bridge Wheatstone strain gauges for measuring the driving force. To ensure a known constant force pressing the blade on the windshield, the spring responsible for generating the force pressing the arm on the windshield surface has been removed, and the pressing force is provided exclusively by the assembly's own weight and the weight of additional masses added on a special support, arranged perpendicular to the windshield surface.

By adding or removing these masses, the normal force (pressure force) exerted by the wiper blade on the windshield can be modified, implicitly influencing the friction force.

To carry out the experiment, in addition to the specially built stand, the following are required: an adjustable DC voltage source, necessary to regulate the speed of the wiper movement by changing the supply voltage of the electric motor (between 3 - 12V); an amplifier for the signal provided by the strain gauges, as they generate a low-amplitude signal, which requires amplification, and a digital oscilloscope to visualize and analyze the electrical signals coming from the strain gauges.

Figure 1: *Experimental stand: 1. Wiper assembly – windshield; 2. Adjustable 12 V power supply; 3. Amplifier for strain gauge marks; 4. Digital oscilloscope.*

3. Description of the experiment

Laboratory tests were conducted in a dry environment [Musca, 2014], using seven different masses to modify the normal force of the wiper pressing on the flat surface of the windshield (weights: 210 g, 318 g, 333 g, 433 g, 533 g, 888 g and 1198 g). For each table, tests were performed at three different speeds, obtained by changing the voltage applied to the arm's electric motor: low (4 V), medium (8 V) and high (12 V). All results were recorded using an oscilloscope, for arm oscillation periods of 1 s, 2.5 s, and 5 s.

The correct transformation of the data provided by the oscilloscope (voltages) into friction force requires a calibration of the strain gauge marks. For this purpose, the following steps were taken:

- The end of the wiper arm that attaches to the motor was fixed in a horizontal position in a vice;
- Several objects with different masses were successively attached to the opposite end;
- For each object, the force exerted (normal force) was calculated, and the values were noted in a table;
- The corresponding values read from the oscilloscope were also recorded in the same table;
- A graph was drawn to highlight the trend of the curve;
- Applying the linear regression method, the equation that allows the conversion of voltage values into friction forces was determined.

An example of a recorded diagram can be seen in the figure 2.

Figure 2: *Example of a diagram recorded on an oscilloscope – Dry surface, voltage 4 V, period T = 1 s*

The results of the laboratory tests were centralized in an Excel table.
Based on this data, four diagrams were created, as follows:

1. Normal pressure force/maximum friction force diagram;

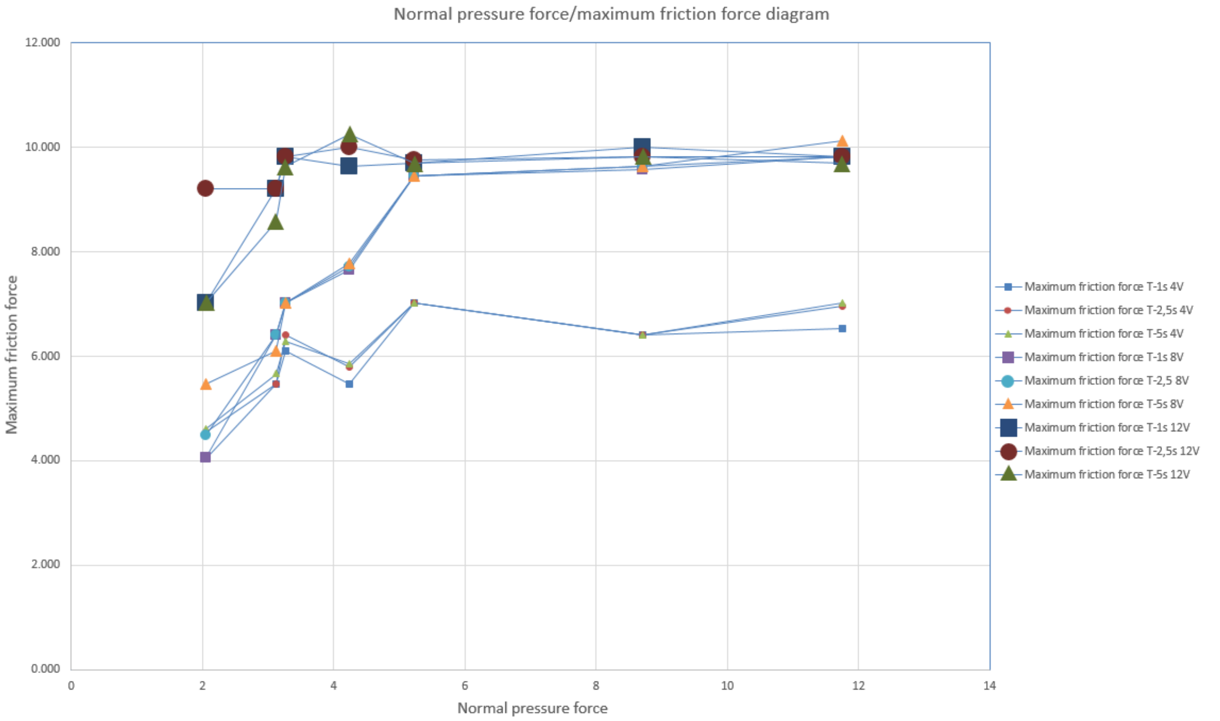

Figure 3: *Normal pressure force/maximum friction force diagram*

2. Normal pressure force/average friction force diagram;

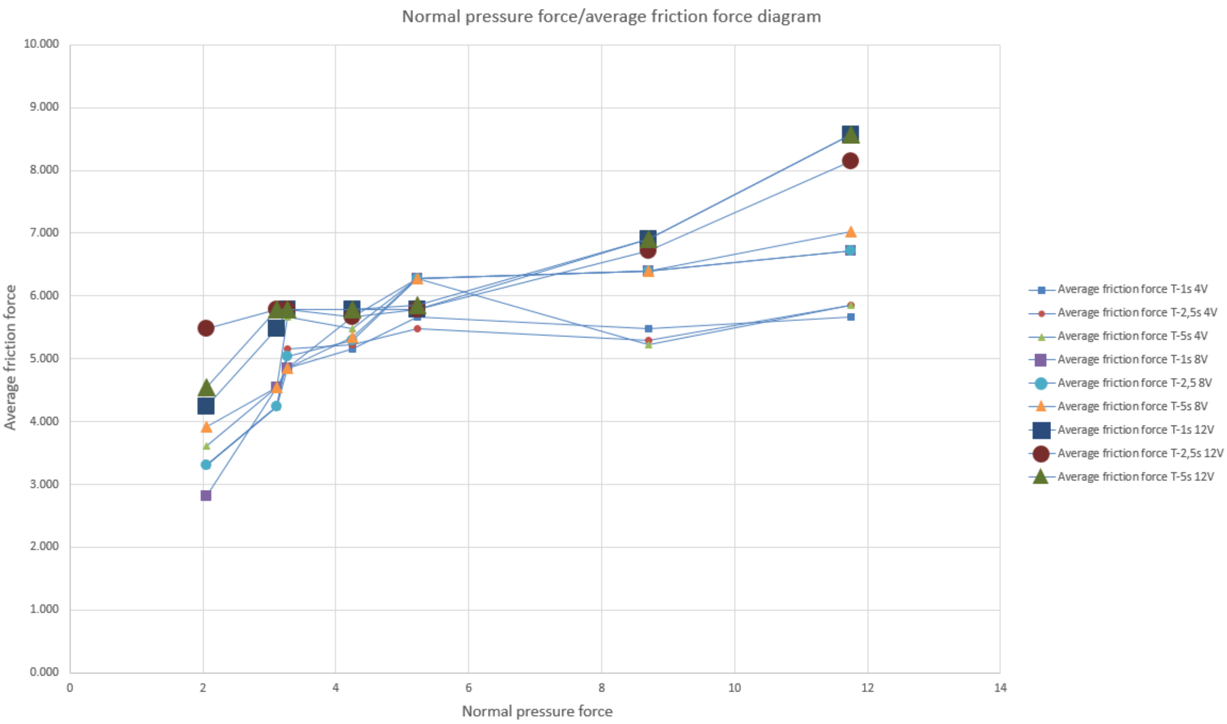

Figure 4: *Normal pressure force/average friction force diagram*

3. Maximum friction coefficient diagram;

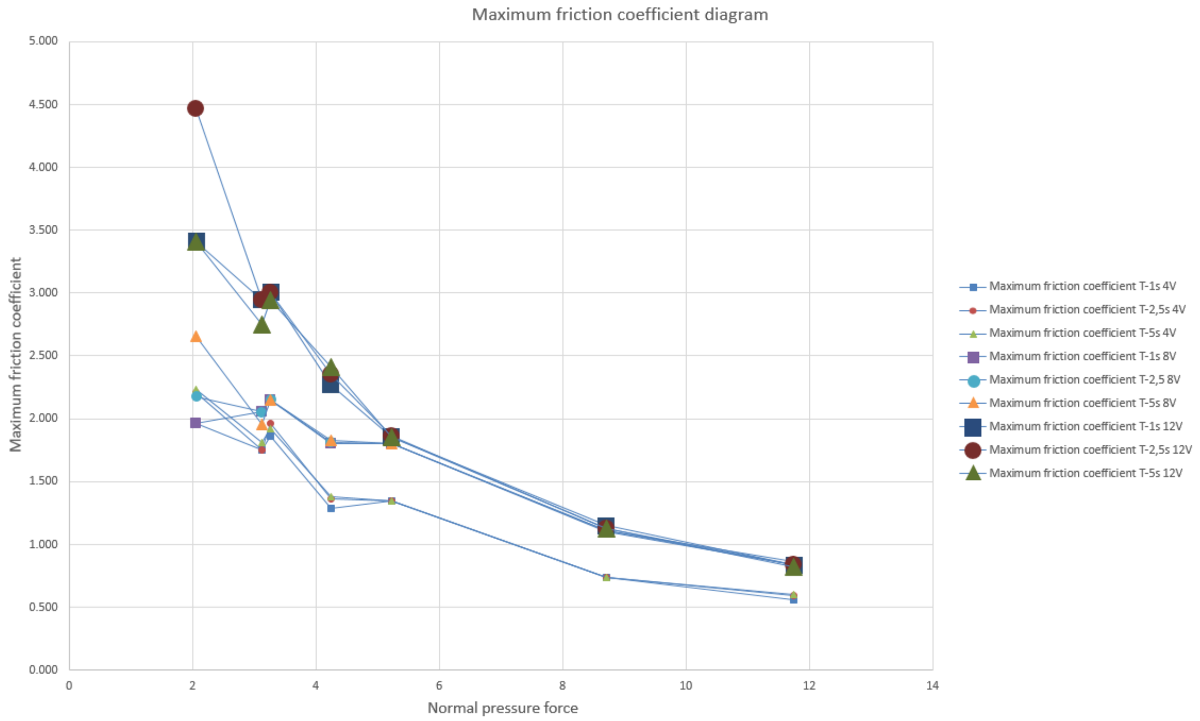

Figure 5: *Maximum friction coefficient diagram*

4. Average friction coefficient diagram.

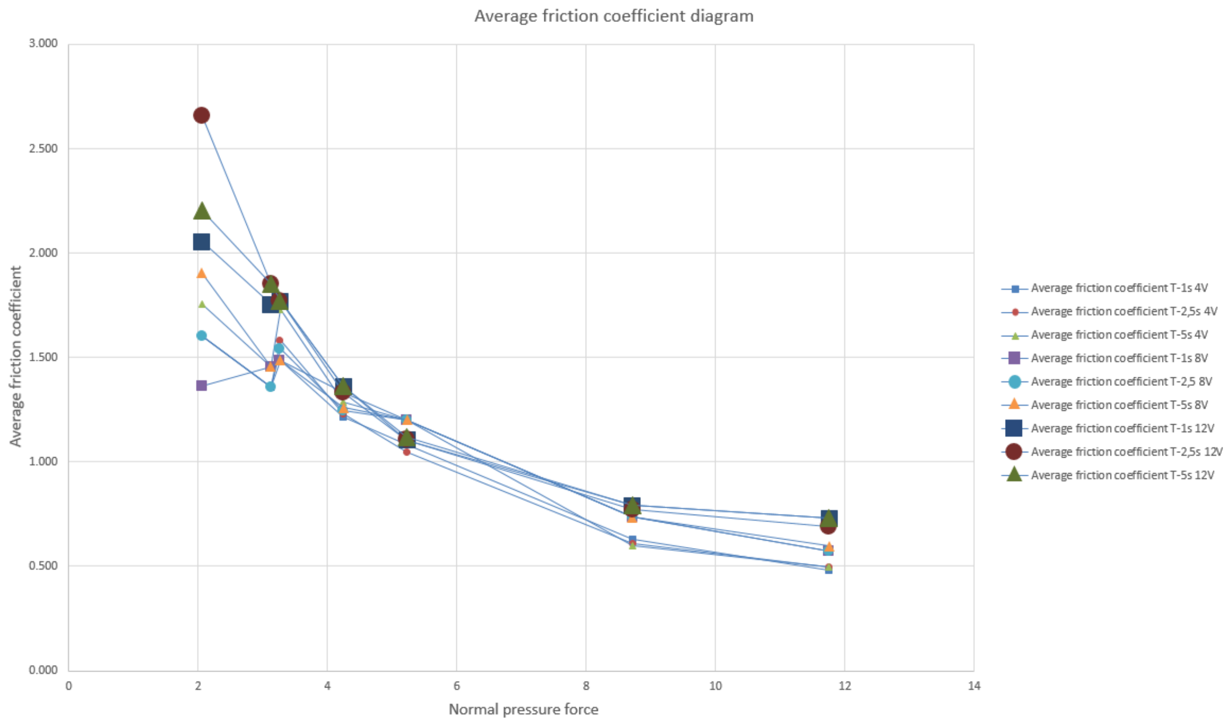

Figure 6: *Average friction coefficient diagram*

4. Data interpretation

4.1 Normal pressing force

From the analysis of the experimental results obtained, it can be concluded that one of the factors that favors the occurrence of the stick-slip phenomenon is the normal pressing force. Depending on this, the friction force trend curves and the friction coefficient curve were drawn.

It can also be observed that as the normal force increases, the friction force also increases, which is absolutely normal according to the law of friction (the friction force is proportional to the normal force) [Fuji, 2008].

At low speed (4 V) the curves tend to have lower values of the maximum friction force, and at high speed (12 V) the maximum friction force is higher. Increasing the speed increases the maximum friction force up to a point, but with uneven behavior.

Short oscillation duration (1 s) generally shows higher friction forces, medium duration (2.5 s) has a more stable behavior, and longer time (5 s) tends to lead to lower friction force values.

In the normal force/average friction force diagram, a trend of the curves similar to that of the maximum friction forces is observed, but they have a more uniform behavior.

The friction force sometimes decreases when the normal force increases, which indicates instability or a change in the contact surface.

The stick-slip phenomenon is present in the graph. This is indicated by an uneven behavior of the friction force, sudden jumps, abnormal decreases, suggesting that instead of smooth sliding, we have cycles of adhesion followed by sudden slips. These fluctuations are visible, especially in the T = 5-s (12 V) and T = 2.5-s (12 V) curves, where sudden decreases in the friction force occur, followed by increases. Some curves exhibit steep slopes, such as in areas of rapid increase in friction force, suggesting instantaneous slippage, followed by a period of adhesion. Normally a smooth friction behavior would show a steady increase in friction force as the normal force increases.

From the graphs it can be seen that during the "stick" the friction force remains constant for a period, indicating the static contact between the rubber and the glass. And during the "slip" the friction force drops suddenly, meaning that the surfaces have quickly slid past each other.

4.2 Friction coefficient

It is known that the coefficient of friction is defined as the ratio of the friction force to the normal force. Starting from the measurements, the maximum and average friction coefficient can be calculated. The maximum friction coefficient is understood to be the value of this parameter for the maximum friction force recorded. A graph is drawn for each category.

The graphs show a typical behavior for rubber-glass contact: at low friction forces, the surface deformation is relatively large, which leads to a high friction coefficient; as the friction force increases, the deformation stabilizes, and the coefficient tends to normalize.

At the beginning of the movement, the static friction force is much higher; once this is exceeded, rapid sliding occurs and the (dynamic) friction force drops sharply.

Similar to what is observed in the normal force/friction force diagrams: the stick-slip phenomenon is common in situations with high stresses and medium to high speeds.

The best observation of the stick-slip phenomenon can be made directly on the dynamic graph on the oscilloscope (friction force over time).

An example can be seen in Figure 7.

Figure 7: *Dynamic graph recorded by the oscilloscope (friction force as a function of time)*

5 Conclusions

Based on the graph and the observed behavior, the presence of the stick-slip phenomenon was found, especially at longer friction times.

The presence of this phenomenon was also observed during the experiment through the presence of vibrations and noise produced.

The oscillations of the friction force recorded are the main indicator of the phenomenon. It has been observed that the Stick-slip phenomenon leads to: inefficient movement control, causes additional wear of the material, inefficiency of the wiper and produces disturbing noise for the vehicle occupants. For these reasons, it is important to know the conditions of its occurrence and to prevent it.

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