EXPERIMENTAL SETUP FOR THE STUDY OF SLIDING FRICTION IN BELT TRANSMISSIONS

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Abstract: *The present paper aims to describe the testing equipment, methodology and some experimental results regarding sliding friction in belt transmissions. The mechanical structure of the experimental setup consists in two shafts and a belt transmission. The speed of the shafts is measured using incremental optical sensors. The driving shaft torque and the driven shaft resistive torque are measured using special devices made of elastic lamellas and strain gauges. The resistive torque of the driven shaft can be adjusted in order to highlight the sliding effect in belt transmissions. Using an Atmega 2560 microcontroller, the sensors information is shown on an alphanumerical display.*

Keywords: *experimental setup, belt transmission, friction,*

1. Introduction

Belt transmissions were used for centuries to set in motion mechanisms. In the industrialization age, this type of transmissions became indispensable, being necessary to transmit power from the steam engines to different types of machines, to synchronize mechanisms and to connect shafts with various positions, [HABASIT, **].

Belt transmissions are often used due to some main advantages as: low costs, transmit motion to multiple shafts, endurance, various positions of the transmission's shafts etc. The efficiency of this type of transmissions should be near 90%, [KUBAS, 2017], [FIRBANK, 1970]. Often this value is smaller due to insufficient control of belt tension, misalignment of the pulleys and belt contamination. Beside low efficiency, the belt endurance decreases drastically and the driving mechanism must be turned off and reviewed.

Sliding between belt and pulleys can also influence the transmission's efficiency and endurance. Due to friction, the belt is heating and the material stiffness decreases, resulting in an important wear of the belt.

Research studies regarding clean belt transmissions are presented in [ČEPON, 2009], [ČEPON, 2010]. The authors present empirical relations for friction, belt slip, bending stiffness, the contact between belt and pulley. The abovementioned study however, doesn't take into consideration all factors that affect sliding.

Due to these aspects, a study of belt transmissions is necessary in order to estimate the sliding friction in this type of transmissions.

2. The experimental setup

The experimental setup consists in an electric motor which drives a belt transmission. The transmission is made from two shafts with pulleys mounted on them. The shafts are connected by a wide belt made of rubber with fiber reinforcement. On the output shaft of the transmission, a mechanical brake made of a disc and a brake shoe is placed. The assembly disc-brake shoe ensures a resistive torque for the studied transmission.

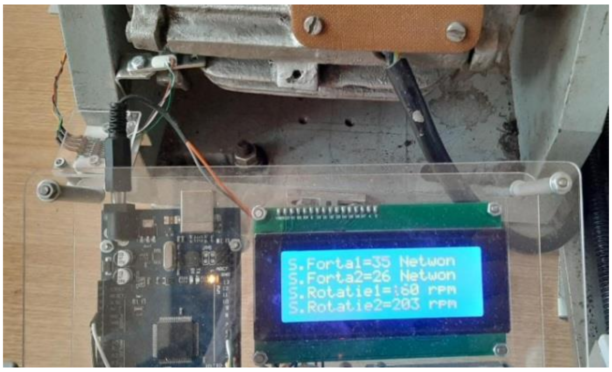

Figure 1. *The experimental recorded values*

To highlight the sliding in the transmission, two optical sensors are used to indicate the speeds of the shafts. Each shaft has a transparent disc with equidistant dark spots on the circumference mounted on it. The dark spots block the light from the optical sensors with a frequency proportional to the shaft's angular speed.

The driving torque and the output torque are measured using special devices made of elastic lamellas and strain gauges. The output torque is determined by measuring the displacement of the disc-brake shoe assembly. The shaft of the electric motor is placed on two external radial ball bearings. The housing of the motor has the possibility to rotate. An elastic lamella - strain gauge device is used to block the rotation of the motor housing and to measure the driving torque.

The information from the sensors is indicated and can be read from an alphanumerical display, as shown in Figure 1. The display is connected to an ATMEGA 2560 microcontroller which processes the signals from the sensors and controls the display.

The mechanical structure and the sensors positions on the experimental setup are indicated in Figure 2.

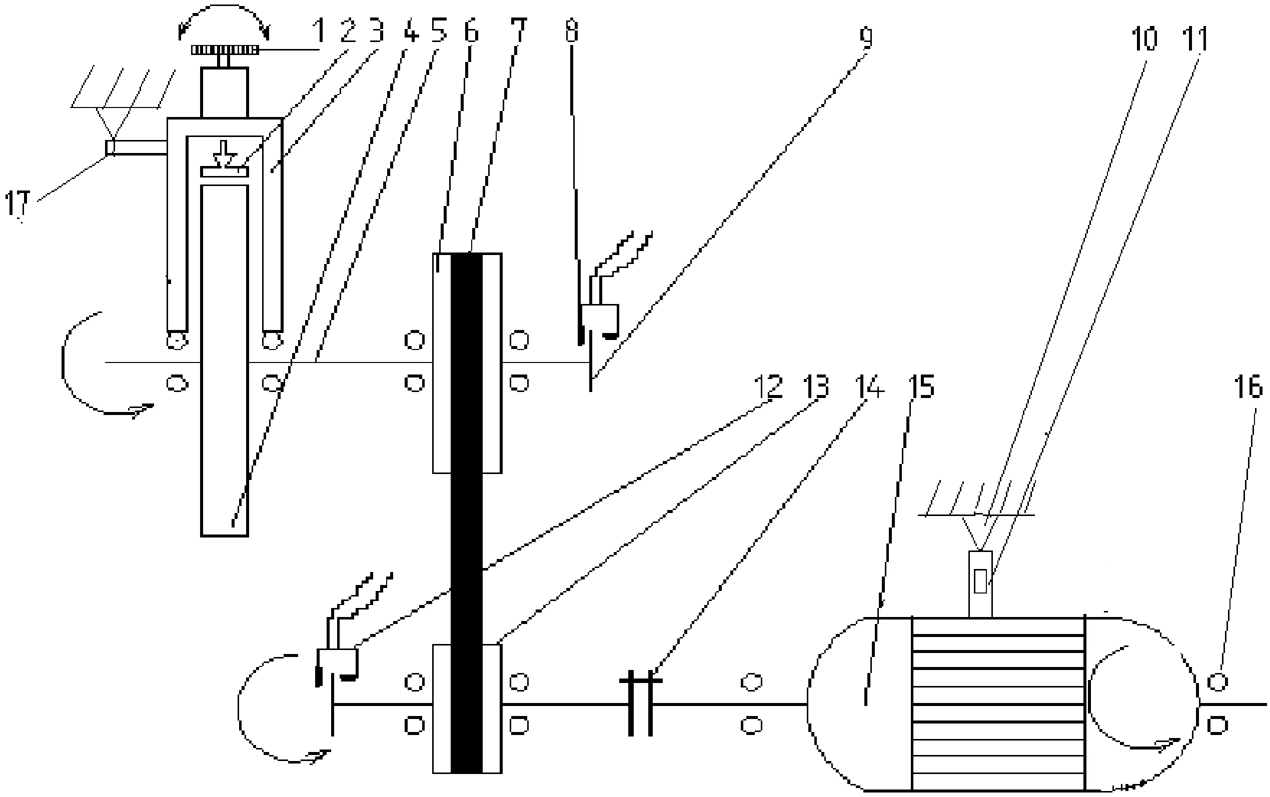

Figure 2. *The experimental setup [VĂRVĂREANU, 2019]*

The experimental setup structure consists of the following elements, indicated in Figure 2:
1-screw for brake adjustment;
2-brake shoe
3-brake housing
4-brake disc
5-output shaft
6-output shaft pulley
7-belt
8-output shaft optical sensor
9-disc with dark spots
10-support
11-strain gauge – lamella assembly
12-driving shaft optical sensor
13-driving shaft pulley
14-coupling
15-electric motor
16-bearings
17-strain gauge – lamella assembly

3. Testing methodology

In order to highlight the sliding effect in belt transmission the following steps must be taken:

The brake shoe mustn't touch the brake disc in order to obtain a minimum friction torque within the transmission. Once the braking system is inactive, the electric motor is turned on using the command button. The numerical values of the shafts speeds, the reaction force of the motor and the braking force are indicated on the experimental setup display. The values are also recorded.

The braking force adjustment is made using the screw 1, which presses the brake shoe onto the brake disc. The value of the friction force is measured and indicated on the display. The speed values and the reaction forces are recorded and represented graphically. Several loading steps were made and the experimental values are represented graphically as further shown.

The evolution of the motor rotation speed depending on power was represented in Figure 3. For tests, a three phase electric motor was used. The motor has 0.35 kW and 1420rpm rotation speed.

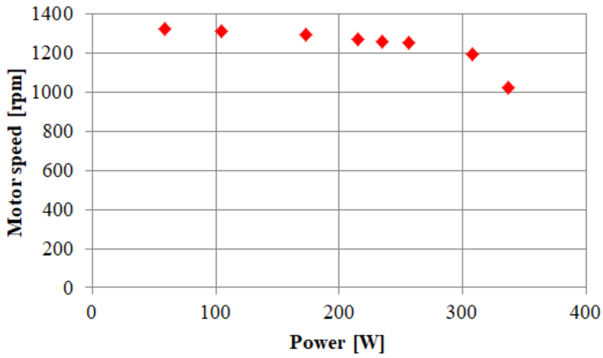

Figure 3. *Driving motor speed-power correlation*

The power loss in transmission was calculated as difference between the driving shaft's power and that of the driven shaft. The evolution of the power loss with the brake force was represented in Figure 4.

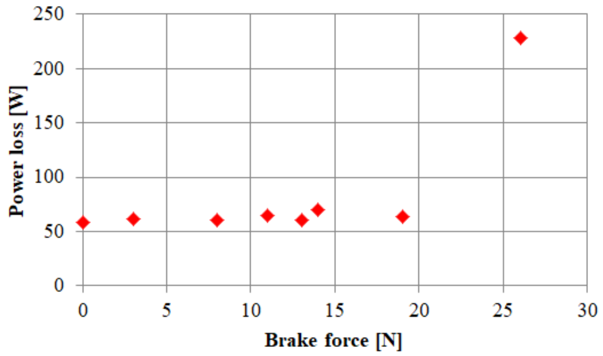

Figure 4. *The evolution of the transmission power loss with the braking force*

Sliding occurrence in the transmission was highlighted by representing the relative evolution of the output shaft rotation speed correlated with the driving shaft rotation speed. The correlation between the output shaft speed variation and the motor power is represented in Figure 5.

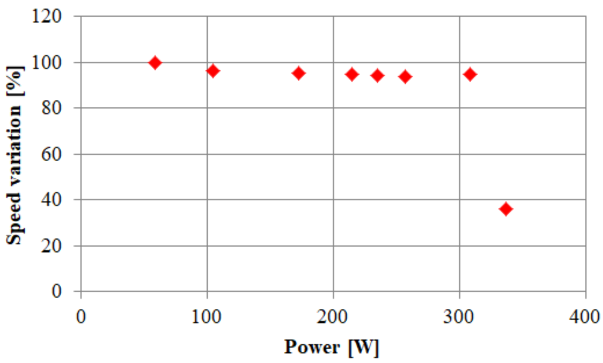

Figure 5. *The correlation between the output shaft speed variation and input power*

Also, the correlation between output shaft speed variation and braking force magnitude was represented, as shown in Figure 6.

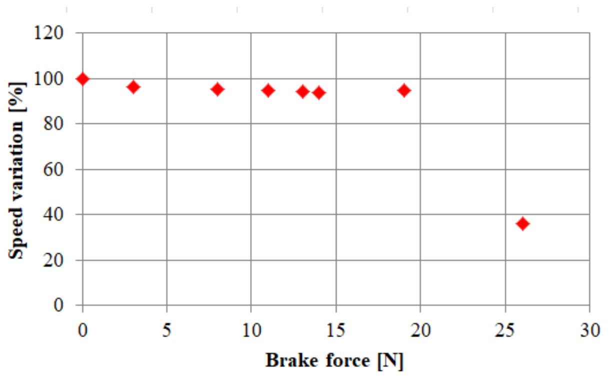

Figure 6. *Output shaft speed variation – brake force correlation*

4 Conclusions

An experimental setup was conceived and built to highlight the sliding effect in flat belt transmissions. The test rig consists of two pulleys mounted on different shafts. The driving shaft is connected to an electric motor by a coupling, while the driven shaft is hindered in motion by a disc - brake shoe assembly.

The rotational speed of the shafts was measured using optical sensors and the torque of the shafts is determined by recording the reaction forces.

Several braking force levels were chose to record the numerical values and the results were represented. The experimental tests revealed that the sliding is negligible at loads smaller than 250W in power input, and significant for higher loads.

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