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AUTOMATED DETERMINATION OF FRICTION COEFFICIENT

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Abstract

The presented research is designed to meet a particular challenge facing the industry. Its aim is to automate the process of friction coefficient determination, using a method that enables quick and easy repeatability of measurements developed by S.C. Plasmaterm S.A in Târgu Mureș.

Keywords: *friction coefficient, measurement system, automation.*

1. Introduction

A current challenge in the forming industry is to ensure the long life of forming tools, which is the function of the friction occurring between the tool and the sheet metal during the forming process. Hence, new materials and new surface engineering technologies are being developed. However, one cornerstone of developing such materials and surface treatments is the accurate measurement of such surface characteristics. [1] *Plasmaterm SA* is involved in a novel surface engineering process of forming tools and has developed a friction coefficient measurement method. To be able to realize the measurements in an automated way, a cooperation with the *Sapientia Hungarian University of Transylvania*, Mechanical Engineering Department was established. The main goal of this project was the design and implementation of a system that would automate friction coefficient measurement.

2. The experimental measuring equipment

The measurements make use of the Faville le Vally method [2], which is based on the potential energy loss of the body. The method involves the use of a pendulum that is initially set to a well-defined position with respect to the vertical direction (α0). Next the pendulum is allowed to fall freely, thus it will pass the vertical line and reach a maximum angle (α). The maximum deflection angle is then measured. Since in each case α > α0, the energy difference is due to the friction between the pendulum axis and its support. As described above, the friction coefficient is determined by the following equation:

$$\mu = \frac{m}{F} \cdot \frac{R}{D} \cdot \frac{\sqrt{2}}{2} \cdot \frac{\cos(\alpha_0) - \cos(\alpha)}{\alpha - \alpha_0} \qquad (1)$$

where:

μ	– friction coefficient
m	– weight at the end of the lever arm [kg]
F	– the force applied to the test piece [N]
D	– diameter of the test piece [m]
R	– the length of the arm [m]
α	– maximum deviation angle
α_0	– start angle

To determine the friction coefficient in an automated way, the system in **Figure 1** is proposed. Three main parts of the equipment can be distinguished: the hardware that ensures the initial loading and the rotation of the sample, the controller to control the measuring process and the interface/data acquisition, which will be realized using a PC.

The equipment hardware must ensure the loading of the sample and the specific motion of the pendulum, as well as accurate data acquisition. In order to be able to measure up to 400°C, the heat-up of the sample must also be per-formed.

Figure 2 (the frame of the equipment is not shown) demonstrates the hardware components.

The sample (6) is placed between the "V" shaped counter pieces (7). Those are opened using a pneumatic cylinder supported by a linear guiding (4). After closing the counter pieces, the required load is generated by a pneumatic cylinder (5). The sample holder is placed on a load cell (8) in order to ensure the closed loop control for the air pressure regulator. The pendulum, consisting of part (9) and the weight (3), rests on the handle, and provides the torque for the sample rotation. The coupled rotation of the pendulum and sample is tracked by an incremental encoder (2). Based on the transmitted values, the friction coefficient is determined.

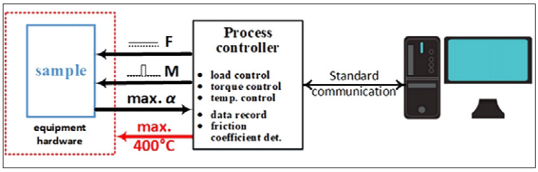

Figure 1. *Equipment setup for friction coefficient determination*

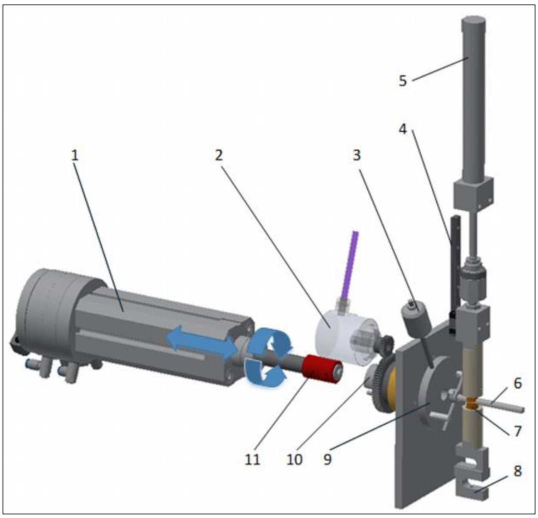

Figure 2. *The equipment hardware for friction coefficient determination*

The pneumatic circuit for the system (**Figure 4**) is designed to make the system as simple as possible.

The main components of the pneumatic system:

– Air pressure control unit (**Figure 4.1.**). This element is responsible for the adjustment of the operating pressure using dry air.
– Positioning (**Figure 4.2.**). The positioning module is responsible for positioning the specimen. There is a translational (1) and a rotary (2) motion carried out with a pneumatic cylinder and two 5/2 (3) valves.

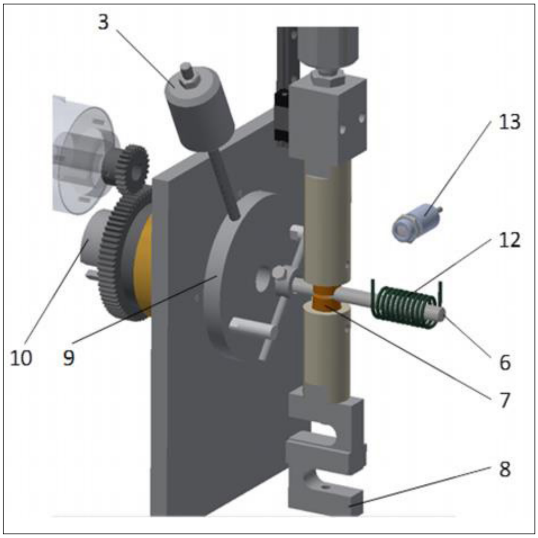

Figure 3. *The placement of the induction coil and temperature sensor for high temperature measurements*

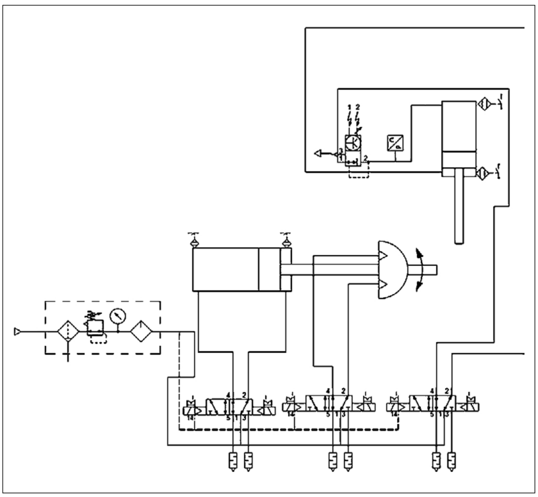

Figure 4. *The pneumatic circuit of the system*

– Clamping module (**Figure 4.3.**). The clamping is responsible for tightening of the specimen. Clamping is performed by a translational cylinder (1), the force is regulated by a proportional pressure regulator (2). An analog pressure sensor (3) is used to measure the pressure.

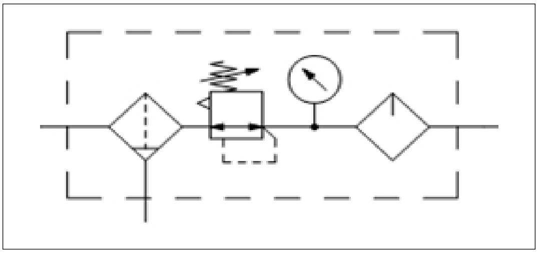

Figure 4.1. *Air pressure control unit*

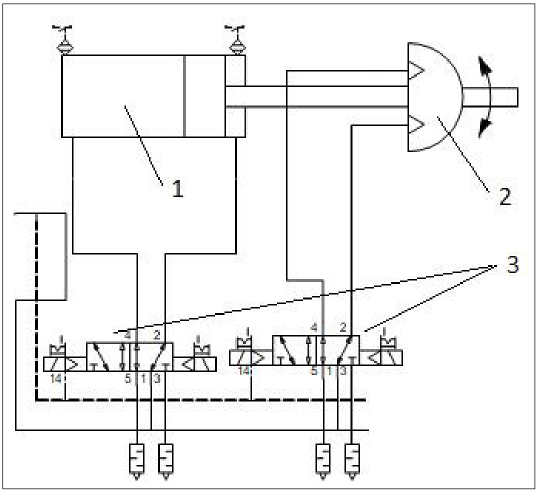

Figure 4.2. *The positioning module*

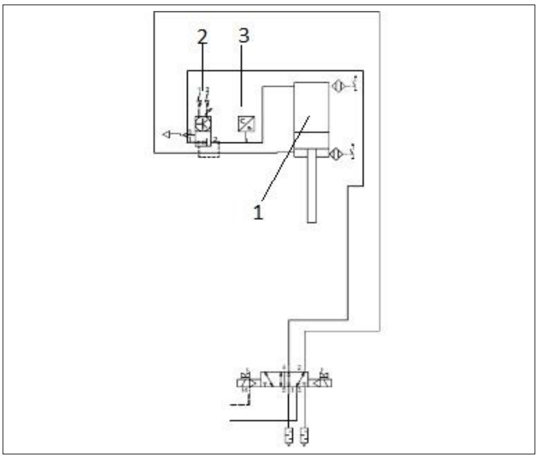

Figure 4.3. *The clamping module*

The system is controlled (**Figure 5.**) by a Rexroth L10 Logic Controller (PLC). A remote controller is connected to the base module of the PLC, which controls the measuring system in manual mode. The cylinder end position switches, cylinder control valves, a load cell, a pressure gauge sensor, and a proportional pressure regulator are connected to the digital and analogue ports of the module.

The system also includes a data display program (**Figure 6.**) that communicates with the PLC via its own protocol. In addition to displaying data, the program also saves the displayed data to a database for later processing.

The **Figure 9** shows the result of a series of 15 measurements. The sample and the "V" shaped counter pieces are made of steel. The minimum deflection was 87.82 ° and the maximum deflection was 89.02 °. Knowing the average of the 15 measurements (88.46°) and knowing the starting angle, the diameter of the sample, the loading force, the length of the lever arm and the weight of the body at the end of the pendulum, the coefficient of friction can be calculated via equation (1).

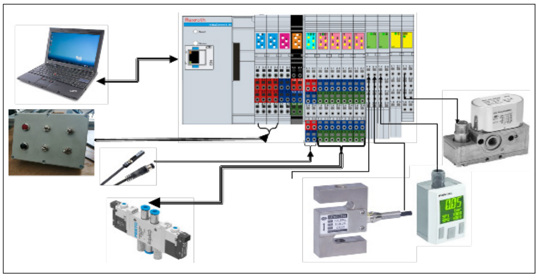

Figure 5. *The control system*

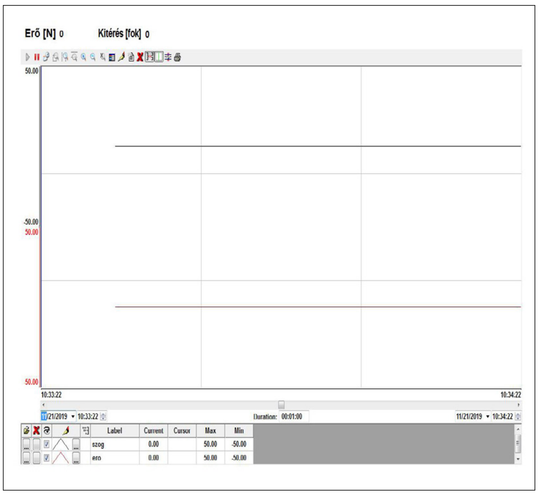

Figure 6. *The data display interface*

Figure 7. *The full system with the frame*

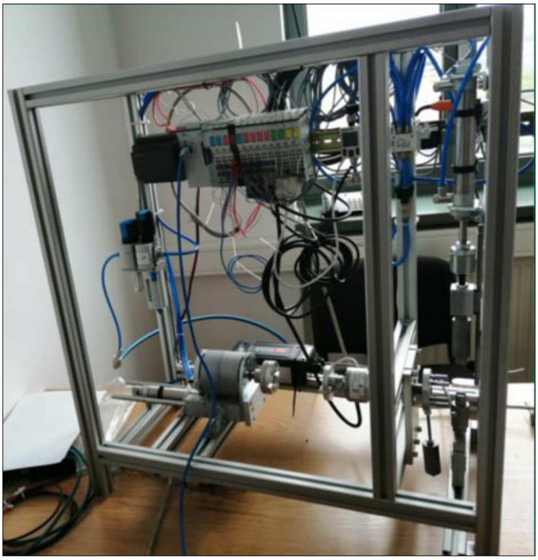

Figure 8. *The implemented system*

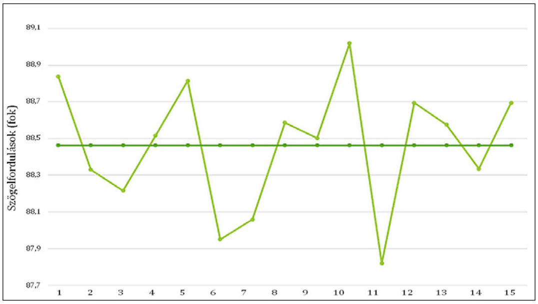

Figure 9. *Some measurements.*

3. Conclusions

In conclusion, we have designed and developed an automated friction coefficient measuring system that allows the user to perform quick and easy measurements and to evaluate the results. The above presented automated measuring method can be further improved by the use of a heating unit, consisting of an induction coil (12) and a noncontact IR temperature sensor (13) as presented in **Figure 3**. The coil is placed around the sample and the measurement is started if the sample has reached the desired temperature.

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