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DEVICE FOR ADHESION TESTS OF LUBRICANTS

Key words

Control system, measuring system, grease.

Abstract

The article presents a device for adhesion tests of lubricants with different chemical compositions to steel substrates. The control system of the device and technical parameters of the actuator and the measuring unit are described. The authors also present an algorithm method for adhesion tests of lubricants. Additionally, the data acquisition subsystem of adhesion forces cooperating with the device is presented. The examples of the obtained results from the verification tests for grease and oil compositions are given.

Introduction

Exploitation requirements of machines and technical equipment are mainly focused on the prolonging service life of a technical object. This requirement is correlated to lubricants applied in a node of friction. The development of innovative lubricants consists in the improvement of many specific physicochemical properties such as the adhesion of cooperating elements of a node of friction and others [1, 2]. The adhesion effect is related to the cohesive effect [3], such as for grease with its internal tenacity. This relationship is a result of the intermolecular interactions caused by the Van der Waals forces [4]. Exploitation properties of lubricants are formed by the appropriate selection of components, such as improving additives, which enhance the adhesion of grease applied in a node of friction [5].

The testing devices used in these tests are hydraulic and electromechanical testing systems, such manufacturers as Zwick Roell [6], Instron [7], Chatillon [8] or others. These machines are characterised by a wide range of the forces applied. It usually does not meet the requirements of the tests in small load conditions (under 500 N). Products subject to small load tests are usually tested on specialised devices that guarantee that the forces applied are maintained with great accuracy and in small measurement ranges [9, 10].

The article presents the specialized device enabling the implementation of adhesion tests of lubricants composed of varied components. The developed device allows application of force and its measurement with high resolution. The measured values are automatically transferred via Ethernet to a remote PC. For recording and archiving of measurement data on the PC, a proprietary developed software made in the LabVIEW environment is used [11].

1. Description of the device

The developed control system (Fig. 1) enables the application and measuring of force. The device is equipped with a Magelis operator panel with a touch screen [12], a controller which is composed with a Modicon programmable logic controller (PLC) [12] and an actuator, changeable measuring heads, and a measuring transducer F/U (force to voltage). An additional element of the system is a computer PC with software for recording and archiving made in LabVIEW.

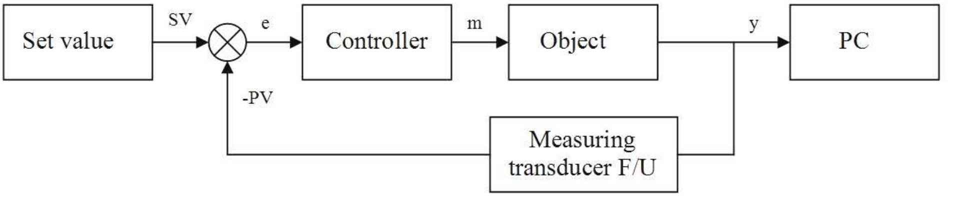


Fig. 1. Block diagram of the control system; SV – set value; PV – present value; e – error; m – manipulated variable; y – output signal; PC – computer PC

Magelis (HMI STO 511) with the communication protocol Modbus RTU [13] was used as the control units with a touch screen panel. The software was developed in the user's desktop environment Vijeo Designer [12].

To control and regulate the test object in the device, the central unit of the family Modicon PLC (M258) working with an efficiency (22 ns/inst) was used. The controller is equipped with 26 inputs and 16 outputs, and it supports a range of communication protocols such as Modbus RTU, Modbus Ethernet TCP/IP, and CANopen. PLC is programmed in the SoMachine environment. In addition, the controller module contains a 16-bit unit A/D, which converts the analogue signal received from the transducer F/U. The converter consists of a strain gauge force sensor (CL17pm, ZEPWN) with a range from –150 N to +150 N (relative uncertainty of measurement better than 0.13%) and a measuring amplifier with an output range from –10V to +10V. A force sensor is placed under the lower part of the head (Fig. 2). The actuator in the system is a stepper motor with a full step equal to 1.8º (BRS368). The stepper motor is controlled by a stepper motor driver, which was characterized by a choice of the distribution of step ranging from 200 to 10000 and a working mode selection of a motor [12]. The type of stepper motor driver (SD328), through the ability to exchange data with PLC via CANopen bus, allows for the use of its five basic modes of operation (displacement). Application of force is done automatically by using a stepper motor and an electromechanical linear actuator of an EGSK (FESTO) type with a range of motion up to 200 mm. The linear drive is coupled with the movable part of the measuring head (Fig. 2). The device uses two sets of interchangeable measurement heads Ø 100 mm for testing oil (Fig. 2) and Ø 10 mm for testing grease.

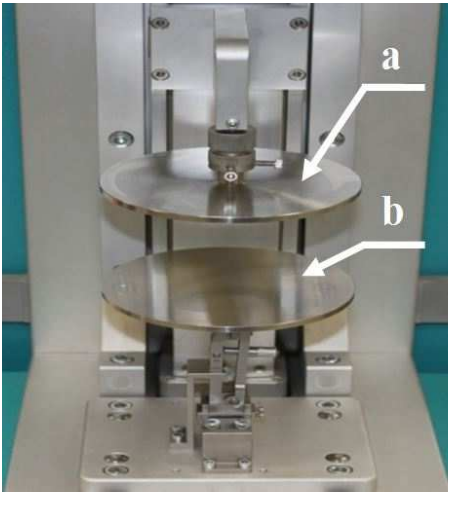


Fig. 2. View of the set measuring head for testing oil; a – the upper part of the head (moving); b – the lower part of the head (static; measuring)

An additional element of the device is a PC that contains a copyright software developed in the LabVIEW environment. The PC receives the

”on-line” measurement data from a PLC using Ethernet protocol Modbus TCP/IP. Dedicated LabVIEW software allows one to record additional visualization of the collected measurement data (Fig. 3), and it is automatically archived in the text files.

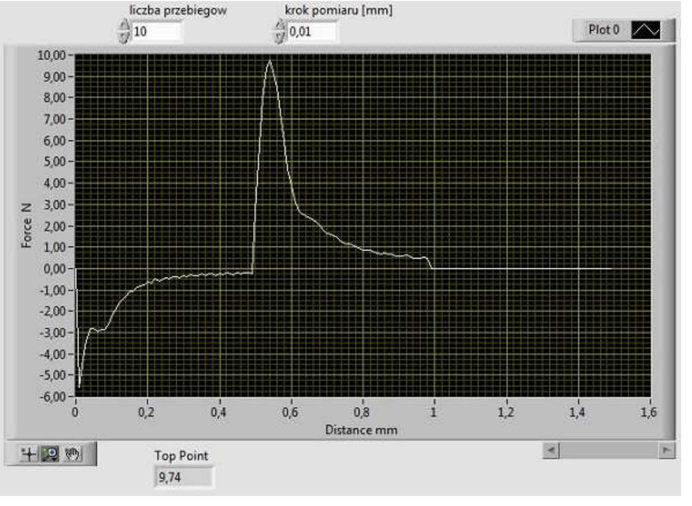


Fig. 3. Window in the LabVIEW for an adhesion lubricants test

2. Algorithm of lubricants tests realises by the system

The algorithm (Fig. 4) enables the application of force with its simultaneous measurement and parallel recording of displacement with a given sampling step.

The algorithm procedure during initialization, provides the ability to set the parameters of the process: P1 – the starting position of force measurement; P3 – position of extreme heads separation; v1 – approach speed to the position P1; v2 – approach speed to the position P2; v3 – approach speed to the position P3; t1 – maintenance position P1 time; lp – number of measurements to execute in one cycle research; kp – sampling step.

The next operation of the displacement of the movable part of the head is carried out to the P2 position at a v2 speed. The P2 position is calculated automatically as a fixed value to the P1 position. After reaching the target position, there is a reduction to the value of the speed v1. With this speed, a precise approach of moving part of the head to the P1 position and closer to the static part of the head is achieved, upon which the test object is placed. After reaching the position P1, it is maintained for a t1 time. During this time, the stabilizing force and the steady distribution of the oil film in a predetermined measurement gap occur.

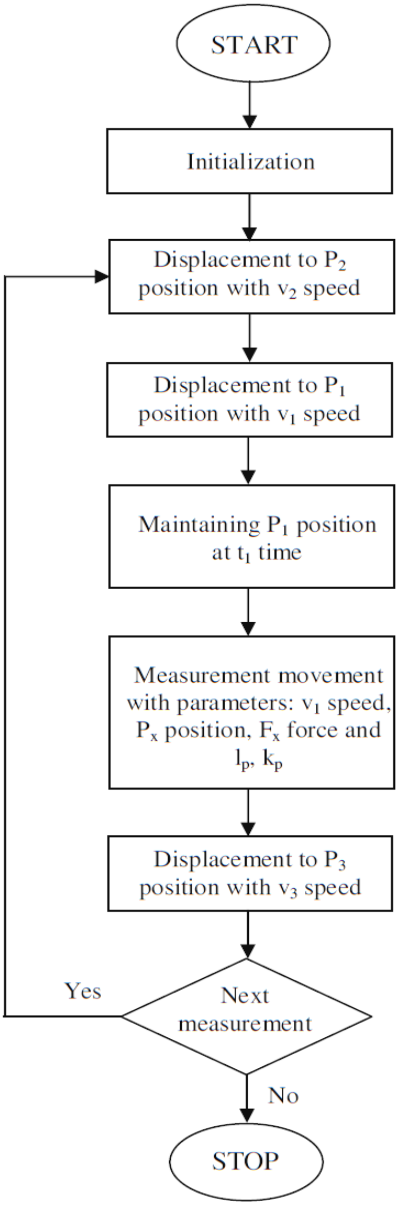
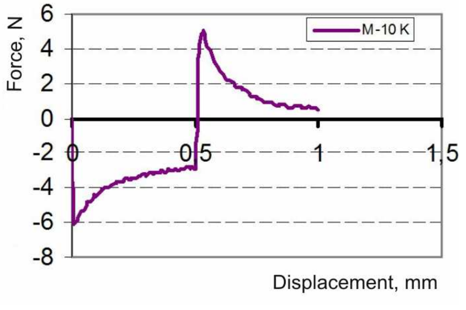


Fig. 4. Diagram of an algorithm for the testing properties of lubricants

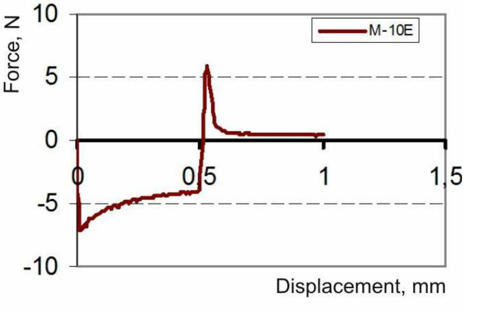
The measurement gap is determined experimentally, and it is the distance between the bottom and the top part of the head. After the termination of the t1 time, there is a change in the direction of the displacement of the movable part of the head, and it moves away from the part of the measuring head at a v1 speed. During this movement, an automatic measurement of the force Fx and its position Px until the execution of a given number of measurements lp with the established sampling step kp is done and recorded. After reaching a predetermined number of measurements, automatically fast head separation of the movable part to the position P3 at a speed v3 occurs, which terminates the single measurement cycle. In the following, the algorithm shows the ability to choose the next cycle measurement or stop a testing process. If the requirements for the implementation of research do not change, then the start of the next cycle measurement with the same operating parameters and automatic displacement of the movable part of the head to the position P2 occurs. However, if the operating parameters need to be changed or the required number of measurements has been made, then the automatic measurement procedure and testing algorithm parameters of lubricants are completed.

3. Verification tests results

The developed and manufactured measuring device was used for the testing to the adhesion (interaction) of lubricant compositions between the steel substrates. The research uses an original methodology, the aim of which is to record the course of force versus displacement of the movable part of the steel head from the static part. The object of the research was a lubricant placed between the elements of the head. Examples of curves are shown in Figure 5. On the resulting graphs, we can distinguish the portion of the waveform compression forces associated to overcoming the forces of intermolecular interactions that accompany the step of approaching the moving parts of the head to the static part.



a)



b)

Fig. 5. Breaking force characteristics of the layer of grease as a function of displacement [14]; a – grease M-10K; b – grease M-10E

This step is carried out until a gap of experimentally determined size is received. In the next stage, the upper part of the head is moved away from other part at a constant speed until the breaking of the lubricant film. This phenomenon is observed in the graphs as a sudden decrease in the value of the measured tensile force. The received graphs allow the identification of the force needed to establish the gap between the elements of the steel head and to determine the maximum amount of force required to separate elements of the head joined by lubricating composition. The results presented for the example of two types of lubricants allow us to conclude that the addition of ester (E) of grease and the addition copolymer (K) grease differentiate the properties of lubricant compositions specified by value tearing forces of the lubricating layer.

The tests helped to determine that the value of the breaking force is changed for different chemical composition of lubricants. For example, in case the maximum content of the additive in the lubricant (M-10K), the breaking force increases by about 27% while a compression force increases by more than 18%. In the case of the ester lubricant containing an additive (E) (M-10E), the tearing force is increased by 6%, while the compression force is increased by more than 3%. The results of the verification tests of composition based on oil are shown in Figure 6. The obtained characteristics allow one to estimate the amount of force required to determine the gap between the elements of the head, as well as to determine the maximum amount of force required to disengage of the head elements connected by a lubricating composition.

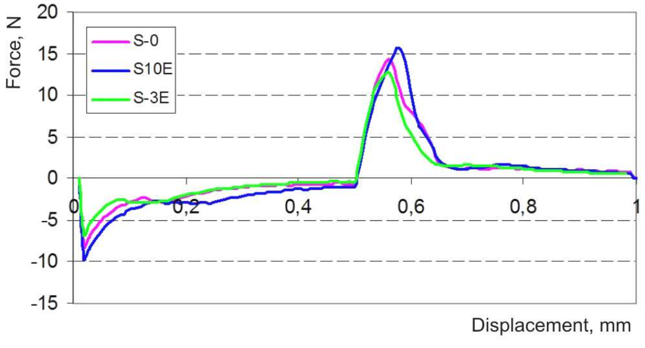


Fig. 6. The characteristics of a tearing force of the lubricant layer (composition based on a synthetic oil and additive E) as a function of displacement [14]

Summary

The specialized device for testing the adhesion of lubricants with different chemical composition was developed, which enables a programmable test in a cycling mode.

The algorithm for testing lubricants developed and used in the device allows the identification of the forces of cohesion and adhesion of lubricants with different chemical composition, which is confirmed by the results of the verification tests.

As an additional subsystem cooperating on-line with the device, copyright software has been used that was developed in the LabVIEW environment and implemented on a PC. The purpose of this software is the collection of on-line measurement data and archiving in the form of text files.

The presented solution in the form of a specialized device with little modification of the measuring head can be used to execute adhesion standard tests of the identification cards [15, 16].

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Urządzenie do badania adhezji środków smarowych

Słowa kluczowe

System sterowania, układ pomiarowy, smar plastyczny.

Streszczenie

W artykule zaprezentowano urządzenie umożliwiające realizację badania adhezji środków smarowych o różnym składzie chemicznym do podłoża stalowego. Przedstawiono opis systemu sterowania urządzenia. Podano parametry układu wykonawczego i pomiarowego systemu sterowania. Zaprezentowano autorski podsystem akwizycji danych pomiarowych sił adhezji, współpracujący z urządzeniem. W artykule przedstawiono algorytm metody badań adhezji środków smarowych oraz podano przykładowe wyniki z badań weryfikacyjnych smaru plastycznego i kompozycji olejowej.