



DEVELOPMENT AND VALIDATION OF A MEASURING EQUIPMENT FOR TESTING THE CONSISTENCY OF LUBRICATING GREASE

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Abstract

We designed a penetrometer to measure the consistency of lubricating grease, the consistency value of which corresponds to the value given by the manufacturers. This is shown to be an important tool for testing lubricating grease in tribology laboratory practice, as the measuring instrument can be used to measure any lubricating grease consistency.

Keywords: constraints, kinematic pairs, constraint equations.

1. Introduction

Lubricating greases are consistent lubricants consisting of a base oil, a thickener (metallic soap) and an additive.

The consistency plays a role in determining the flow properties of lubricating greases, i.e. the hardness and fluidity of the grease.

The consistency of greases can be quantified by the degree of penetration.

Requirements for lubricating greases:

- long life;
- good adhesion;
- sealing ability;
- corrosion protection;
- anti-wear effect;
- low mechanical loss, good wear protection even under heavy load conditions (EP effect);
- ensuring proper lubrication at extremely low or high temperatures.

The consistency of lubricating greases is classified by the National Lubricating Grease Institute (NLGI), see in [Table 1. \[1–6\]](#).

In this thesis we design and build a penetrometer to measure consistency and check its accuracy.

Table 1. NLGI grades of lubricating grease [7]

Degree of consistency according to NLGI	Penetration after 60 fractures, at 25 °C, in 0.1 mm	The consistency of the grease
000	445–475	liquid
00	400–430	liquid
0	355–385	very soft
1	310–340	soft
2	265–295	moderately soft
3	220–250	solid
4	175–205	semi-rigid
5	130–160	rigid
6	85–115	very rigid

2. Measuring the consistency of lubricants

2.1. Methods of measuring the consistency of lubricants

The consistency is measured using a penetrometer. The measurement is carried out by immersing a standardised 150 g cone of the penetrometer in the lubricating grease for 5 seconds at

room temperature 25 °C. The depth of immersion indicates the consistency value.

The measuring apparatus, [Fig. 1](#), consists of a base, a standard size cone, [Fig. 2](#), a cone stem with a tape holder and a graduated tape attached, [Fig. 3](#).

To keep the tape taut, we used a tension rod attached to a tape holder, [Fig. 3](#). The crossbar holds an electromagnet for releasing and guiding the meter body. An optical sensor module was used to lower the meter body, [Fig. 4](#). An NI USB-6008 data acquisition card was used to process the incremental transmitter signals.

2.2. Data collection, visualisation

For detection, an incremental transmitter is used, in which the transmitter is a graded tape and the receiver unit is an optical sensor module.

We used a ribbon from an inkjet printer.

Since the parameters of the tape are not known, a microscope and a 0.01mm scale are required to sample the size of the graduation on the tape.

A magnified image of the tape was photographed using a camera mounted on the microscope. Then, at the same magnification, a magnified image of the scale was photographed. The images were superimposed on a computer using a pixel graphics image editing program called GIMP, which can be used to count the number of scale periods per period of the tape, [Fig. 5](#).

The optical sensor module receives an analogue signal, converts it into a digital signal and a USB-6008 data acquisition card is used to process this signal.

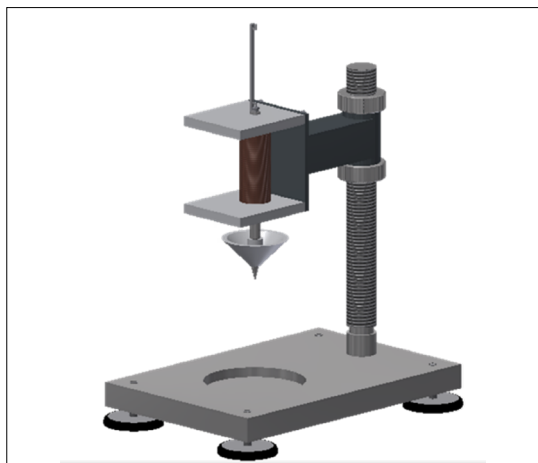
For 1 period on the tape, there are 16 scale divisions, since 1 division is 0.01 mm, so 1 period on the tape is 0.16 mm. The sensor will send a signal every 0.16 mm to the USB 6008 data acquisition card, which will count it and transmit it to the computer.



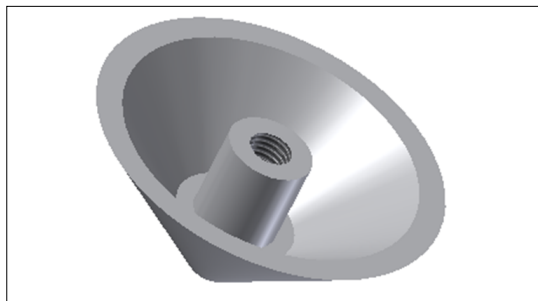
[Fig. 3](#). Assembled measuring body.



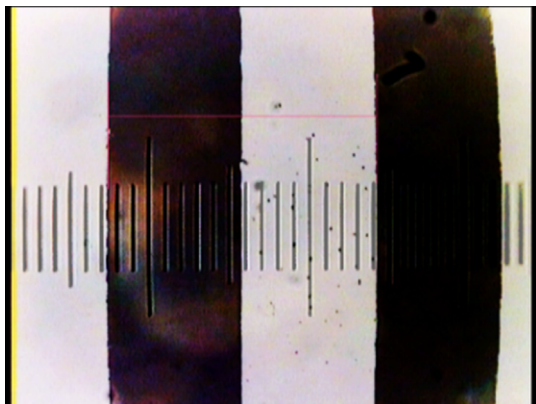
[Fig. 4](#). Optical sensor module.



[Fig. 1](#). Measuring device.



[Fig. 2](#). Standard cone.



[Fig. 5](#). Magnified superimposed image of the tape and the scale

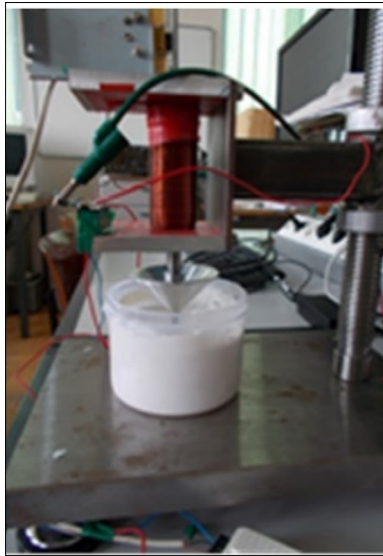


Fig. 6. Penetrometer during measurement.

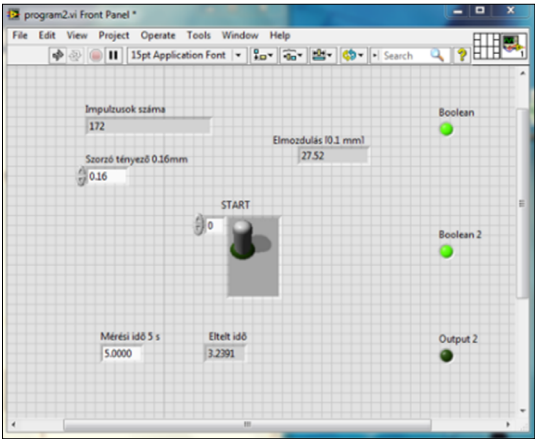


Fig. 7. Interface.

Table 2. Values of lubricating greases

	AXA GR 1	MULTIS EP 2	UNIREX N3
Measured averages	280.32	279.78	223.04
Scattering square	132.51	61.38	191.55
Scatter	11.52	7.83	13.84
Manufacturer penetration averages	315.00	280.00	235.00
Difference between measurement and manufacturer's data	-34.68	-0.22	-11.96

The data acquisition card is used to feed the sensor and control the relay in the coil circuit. The USB-6008 data acquisition card is programmed in a LabView programming environment.

During the programming three tasks are performed:

- control the relay;
- control the duration of the measurement for 5 seconds;
- calculation and display of the measurement value.

2.3. Implementation of measurement

Three different grades of NLGI grease were used for the measurement:

1. AXA GR1 grease, NLGI 1, soft grease, used for lubrication of tap bearings, joints, reducers, sledges, cam mechanisms, etc.;
2. MULTIS EP2, NLGI 2, moderately soft, multi-purpose grease, used for lubrication of sliding, ball and roller bearings under pressure, wheel bearings, universal joints, running gears and various shock absorbers or vibrating sub-parts;
3. UNIREX N3, NLGI 3 solid lubricating grease, suitable for maintenance of rolling elements and bearings at high temperatures, lubrication of electric motors.

The penetration of the greases was measured at rest. To carry out the measurement, the surface of the grease was smoothed, Fig. 6.

On the computer, the program is opened in the LabView programming environment and a window called Front Panel, Fig. 7, is displayed, where the parameters required for the measurement are set. The tip of the cutting cone is positioned over the grease. In the control panel, the program is started and the START switch is used to start the measurement. After 5 seconds, the displacement display shows the displacement of the gauge in the grease in tenths of a millimetre.

This measurement was performed 5 times for each of the greases. An arithmetic mean was calculated from the measured data. The averages of the measured data are given in Table 2.

2.4. Processing the measurement results

The processing of the measurement data can be found in Table 2, and displayed in Fig. 8.

Table 1 also includes the penetration values given by the manufacturer. We have examined whether there is a significant difference between our measured penetration data and the values given by the manufacturer. We used the t-distrib-

Table 3. Hypothesis testing

	Difference between measurement and manufacturer's data	Hypotheses		
1	−34.68	H0: $x_k=0$		
2	−0.22	H1: $x_k\neq 0$		
3	−11.96			
Average, x_k	−15.62			
Scatter	14.30			
$t_{critic}, 0.95$	4.30265273			
$t_{examined}$	−1.891363374			
Decision	−1.891363374	€ (−4.30; 4.30) >>> H0 true € (−4.30; 4.30) >>> H1 true		

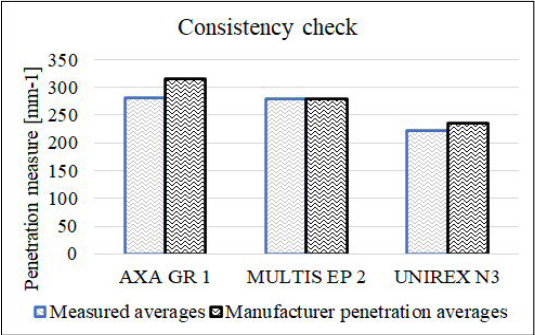


Fig. 8. Consistency check

bution method to test whether the difference was significantly different from zero.

We checked by hypothesis testing, Table 3, that there is no significant difference between our measured penetration data and the manufacturer's values with 95% probability, so the equipment measures well.

3. Conclusions

The penetrometer is an important tool for performing tribology laboratory grease analysis.

The consistency of the lubricating grease measured with a penetrometer corresponds to the value specified by the manufacturer.

The instrument can be used to measure the consistency of lubricating grease.

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