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A simplify method of assessment of magnetorheological fluids functional property

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Abstract

The article presents an innovative method of assessment one of the magnetorheological fluids properties. The way is based on a measure method of rheological properties for oils at low temperatures captured by ASTM D 2983-04a standard. Obtained results and also the way of assessment were compared with a method and results achieved on rotary rheometer with magnetic attachment. The research allows to indicate advantages and disadventages of the method for magnetorheological fluids presented in the article.

Key words: magnetorheological fluids assessment, dynamic rheology measurement,

INTRODUCTION

Magnetorheological fluids are rated among smart materials group because of the possibility of their rheology steering by magnetic field with changed intensity [2]. Component that is essential to change the fluids viscosity are ferromagnetic powders as iron or nickel [2,5].

Owing to the component the oils rheology can be changable. This behaviour takes place on account of metal powders that joining to chains at the same direction as lines of magnetic field. The force of metalic powders attraction depends on the field intensity.

The magnetorheological fluids are ordinarily liquids in hydraulic systems and devices as clutches and magnetorheological dumpers [2]. Parameters of the devices are depend not only on construction virtues, but also on the rheology fluids which work on. Currently, the producers of magnetorheology fluids give us mainly using parameters of the liquids. The parameters are very usefull for selection of the fluid to devices. Among the parameters we can single out: density, viscosity, solid phase content, flash point and range of maintanance temperaturę [2,4]. One of the main quantity, that can characterise magnetorheological fluids is yield stress dependence on magnetic field intensity. The function usually has logarytmic route and there is presented in the range of significant changes for yield stress. The illustrative chart of the function is presented on Fig.1.

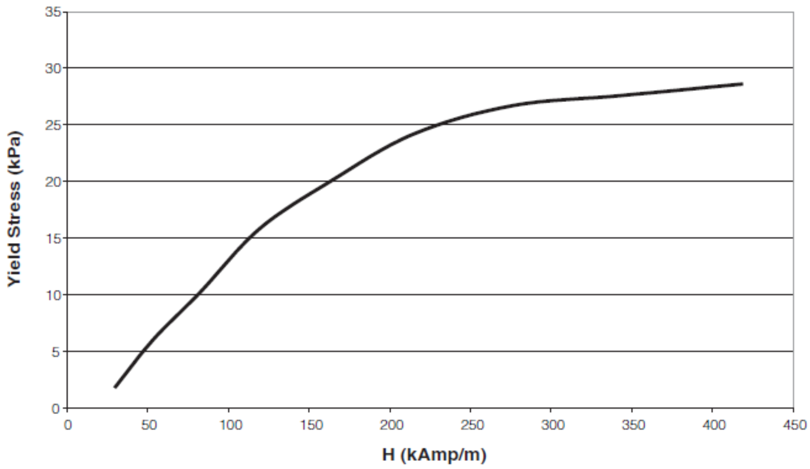


Fig. 1. The function of yield stress changes to magnetic field intensity for magnetorheological fluid.

Nevertheless, the dependence between yield stress and magnetic field intensity does not present changes that take places under stress velocity, what is the fundamental parameter for these liquids. Under external factor influence that is magnetorheological fluid motion, the stress under magnetic field will be lower than in the case the particles of liquid are not in motion. The chains of ferromagnetic particles done under static conditions are focused accordnig to lines of forces of magnetic field [5]. These will be broken by the liqiud in motion. The more flow intensive of magnetorheologic fluid the more difficult to rebuild the destroyed structuries of particles that are active in magnetic field.

The changes of rheological properties versus yield velocity increase for market's magnetorheological fluid are presented on Fig.2.

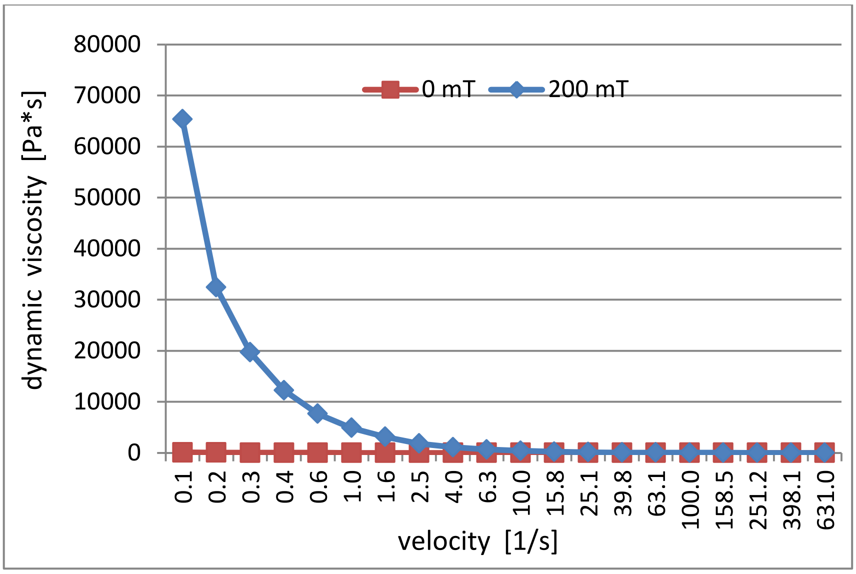


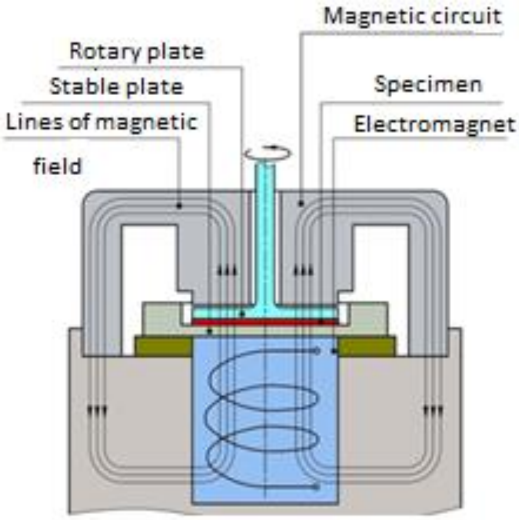
Fig.2 Characteristic of rheology changes under influence of yield velocity changes.

RESEARCH AND RESULTS

The research was conducted on rotary rheometer ARES TA Instrument dedicated to assessment of viscosity changes in magnetic field. The device is presented on Fig.3.

Fig.3. The rotary rheometer ARES TA Instrument.

The rheometer is equiped with special measurement plate – plate system. The distance between plates, where the magnetorheological liquid is poured is 1 mm. The system of measurement head is presented on Fig. 4.



Rys. 4. The diagram of an electromagnetic head of the rotary rheometer.

The research of rheological properties were conducted during yield velocity changes in the range of 0,1 - 630 s^{-1} at temperature 20 °C. The specimen of magnetorheological fluid was poured on the bottom plate. The upper plate that realise the rotary motion is connected with measurement system of viscosty. The measurement is done automatically.

The rheology characteristic of magnetorheologic fluid is determined as a medium value of three repeat research. The parameters as a dynamic viscosity, an yield stress and twisting moment were registered. On the basis of the research, the viscosity changes obtained with and without a magnetic field are presented below. The magnetic field intensity was 200 mT.

Taking into account the results we should notice the measurement error. A range of the error is from 11% to 18% of average measuring values. The obtained results with measurement errors are presented on Fig.5.

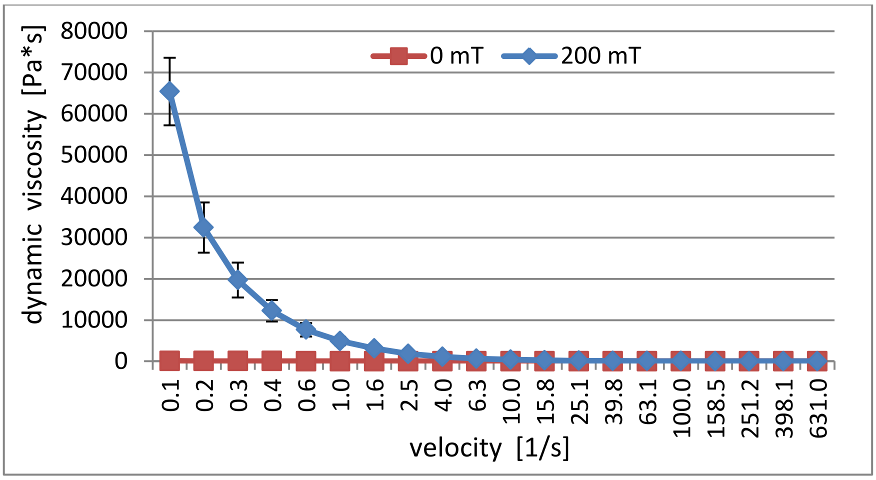


Fig.5 The changes of dynamic viscosity of magnetorheologic fluids depend on stress velocity in and without magnetic field.

To indicate the inaccuracy differencies and differencies for higher velocities, the Fig.6 presents the same results but it is showed at the logarithmic scale.

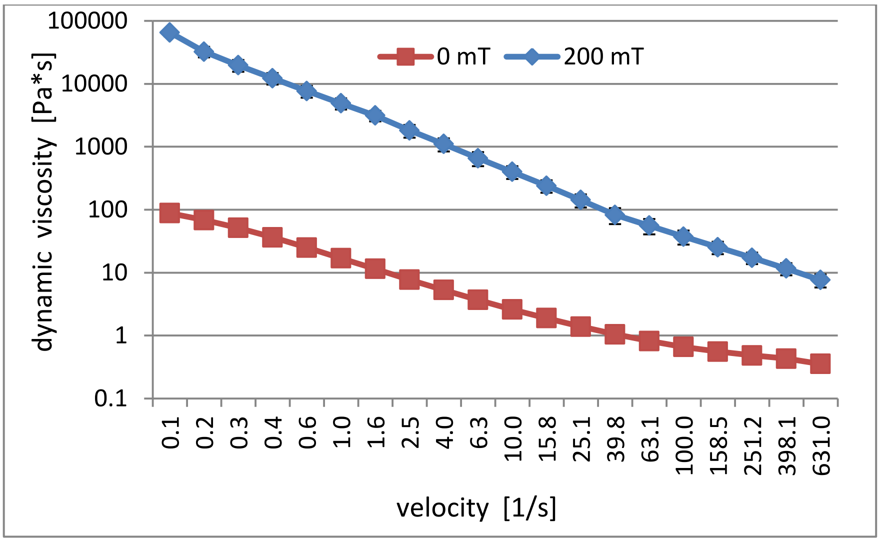


Fig. 6. The logarythmic changes of dynamic viscosity of magnetorheologic fluids depend on stress velocity in and without magnetic field.

Significant differencies of gained values with and without magnetic field are observed on Fig.6. It is the result of magnetic field and increasing velocity influence. We also can see only the measurement errors for viscosity values measured in magnetic field. On the curve that characterise the changes without magnetic field (red line) measuring errors are also pointed out but they are unvisible because of their small values (1% - 2% average measured values). If we compare the errors values in magnetic field and without this, we can state the errors values are increasing over 10 times for the measurement in magnetic field. These are summary errors come from weak reproducibility of ferromagnetic chains making and measuring error of the rheometer. That is why the results of dynamic viscosity in magnetic field should not be treated as highly precise. Therefore, it is suggested the other and easier measurement method that it does not demand so expensive apparatus. At the author's method, there is used the Brookfield viscometer. The device is also used to do research of viscosity determination of oils at low temperatures according to the Standard ASTM D 2983-04a [1].

The suggested method lies on measurements of dynamic viscosity for magnetorheological fluid. The liquid is placed in a glass test – tube that the capacity is 40 ml. The test – tube is put in special handle (Fig.8) made of balsa wood that is equiped to the rheometer. The handle is also a part of the device where source of magnetic field is placed. Neodymium magnets are attached to vertical walls in this way to generate the lines of magnetic field perpendiculary to the test tube. The lines of magnetic field also should go through the central part of test – tube with magnetorheological fluid.

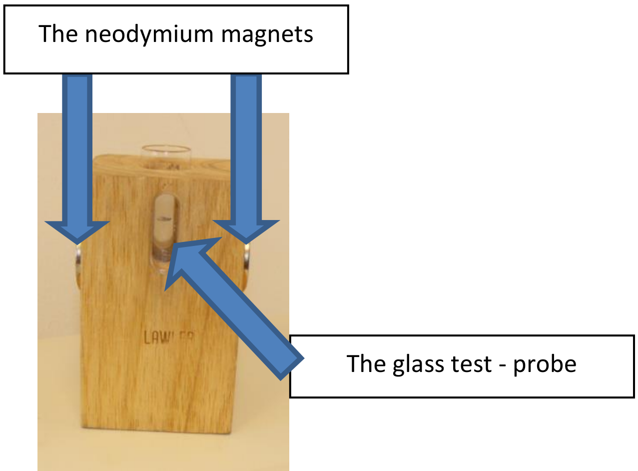
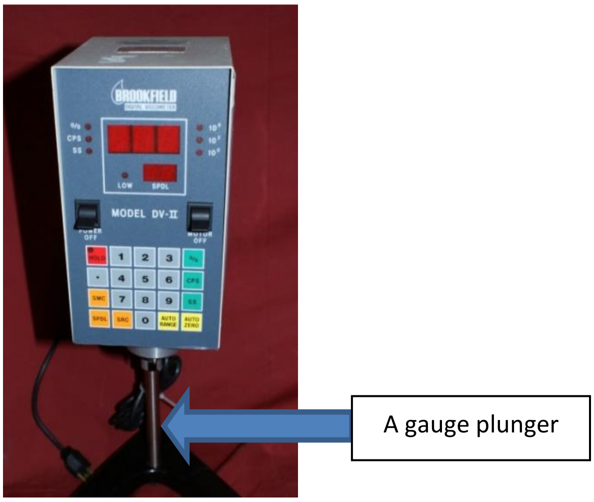


Fig.8. The wood handle with test – probe and attached magnets.

The resistance of internal friction in a fluid is measured owing to a special measuring system included a gauge plunger presented jointly with the Brookfield viscometer on the Fig.9. Taking into account the used magnetic field, the gauge plunger are made of paramagnetic material that do not react with magnetic field.



Rys.9. The Brookfield viscometer with a gauge plunger.

The innovative method of magnetorheological fluid assessment is quite simple because it demands only the gauge plunger sinking and recording the viscosity results after stress velocity changing. In spite of the maintenance simplicity, the method has huge advantages as possibility of magnetic field changing through the magnets replacement and possibility of viscosity measurement at different, especially low temperatures. These above-mentioned features do not ensure the rotary rheometer ARES with magnetic equipment.

The dynamic viscosity dependence on stress viscosity measured to the Brookfield apparatus is presented below on the Fig. 10. The viscosity was assess during magnetic field influence and without the field. The fig. 10 shows properties of the same fluid that is research on the ARES rheometer.

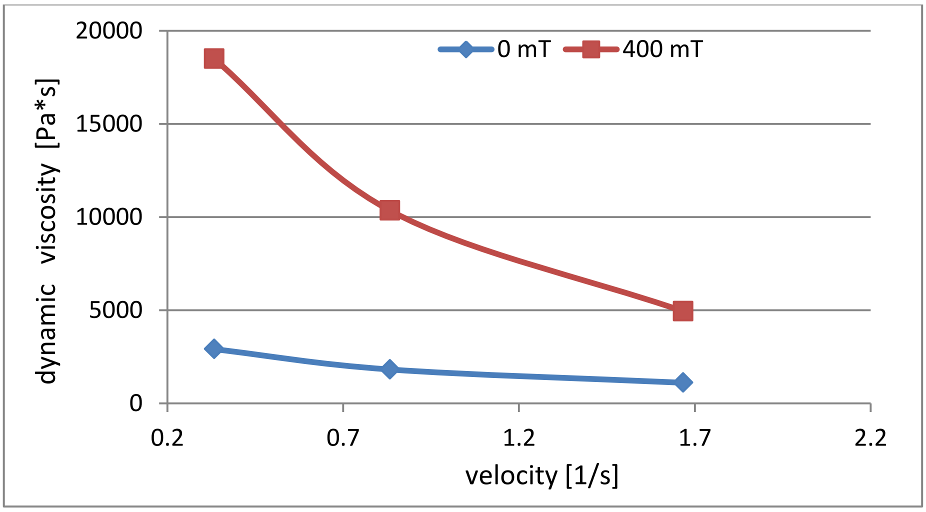


Fig. 10. The dynamic viscosity dependance on stress velocity with ant without the magnetic field.

The research of magnetorhrological fluid was conducted at temperature 20 ℃ at a range of stress velocity from 20 to 100 rpm. The charts were done for three stress velocities that allows to determine the viscosity changes under magnetic field influence.

The Brookfield viscometer that was used to do the research takes the measurement possible at the range of velocity from 0,005 turn/s to 1,67 turn/s. Using the lower range of stress velocity than the presented on Fig. 10 is possible when the intensity of magnetic field is lower. Otherwise, the maximum measuring range will be exceeded.

Summary

Taking into account the viscosity results obtained by Brookfield method and gained owing to the rotary rheometer ARES we can state that more precise results come from the Brookfield apparatus. The new method of magnetorheological fluids assessment has several advantages such as:

- very simple way to prepare and do the research,

- possibility of velocity and magnetic field intensity selection,

- possibility to do research at wide range of temperature.

Nevertheless, the disadvantage of the method is very narrow range of the velocity steering. This fact causes that it can be done only fragment of full viscosity characteristic of the magnetorheological fluid.

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