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Rheological Properties of Soybean Oil with Nano Additives: A Comprehensive Analysis

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Author's contribution

The sole author designed, analysed, inteprted and prepared the manuscript.

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Short Research Article

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ABSTRACT

In this study, we have concluded the rheological behavior of the unadded and additived soybean oil with nanoadditives. The used soybean oil can be used for biodegradable lubricant. The mathematical model that best describes the rheological behavior is the power law model that also includes the nanoadditive concentration. Power-law modeling of the shear stress-strain rate dependence has a small correlation coefficient due to the hysteresis loop. If only the load curve is considered, the dependence has a tendency close to the linear one.

Keywords: Rheological; soybean oil; nano additives; properties; comprehnesive.

1. INTRODUCTION

The study is significant as it explores the potential of using biodegradable lubricants derived from vegetable oils, which have advantages such as non-toxicity and rapid biodegradability. The insights gained from understanding the effects of nano additives on

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the rheological behavior of soybean oil could lead to the development of more efficient and environmentally friendly lubricants. This is particularly important in the context of sustainable development and the increasing demand for eco-friendly products [1-5].

Biodegradable lubricants based on vegetable oils are of particular interest due to mainly economic advantages over biodegradable lubricants based on polyglycols or synthetic ester oils.

Both the relatively inexhaustible source, as well as the non-toxicity and rapid biodegradability of vegetable oils, are their main advantages.

The rheological behavior was studied for three classes of nano-additive lubricants (amorphous carbon, graphite and graphene) and for non-additive soybean oil. From the dependence of the dynamic viscosity on the shear rate and temperature, a mathematical model was formulated, also according to the power law, which also introduces the nanoadditive concentration into the relationship: [6-10]

$$\eta = \eta_0 \cdot \exp^{\,a(t-t_0)} \cdot e^{b\cdot c} \quad (1)$$

in which η_0 is the dynamic viscosity at temperature t0, considered the reference temperature, a is the coefficient of dependence of the dynamic viscosity on temperature (being a material constant), c is the concentration of the additive, in mass percent and b is a constant depending on the nature of the additive.

Analyzing the values of the material constants, it is found that the concentration dependence is weak for these friction and wear modifying additives.

Other compounds such as: hexagonal bromine nitride and graphene could also be used as bidegradable nano additive lubricants. Small nanometer particles of graphite, boron nitride, natural and synthetic minerals, MoS_2, WS_2 and polytetrafluoroethylene were used both as additives in lubricants and as solid lubricants [11-22].

2. MATERIALS AND METHODS

The experimental test bench is a Brookfield CAP 2000+ viscometer. It is a rotational viscometer that measures the flow behavior and viscosity of liquid and semi-solid materials, with cone-plane coupling as its working geometry.

The system is controlled by a specialized software, called CAPCALC 32, which has the possibility order of the stand, acquisition and data processing.

The viscometer has the possibility to make thermal determinations, namely the variation of rheological parameters with temperature, in the range of values 5°C – 75°C.

3. RESULTS AND DISCUSSION

Table 1 presents the determined relationships and statistical parameters (standard error and correlation coefficient), and Fig. 1 graphically presents the surfaces of the determined functions and the experimentally determined values.

For soybean oil, both unadded and with 1% additive, the Reynolds model of dynamic viscosity variation with temperature is found to satisfactorily approximate the experimental values, leading to correlation coefficients greater than 95%.

Table 1. Mathematical models for the dependence of dynamic viscosity on temperature and by the concentration of the additive

Nano additive	$\eta = \eta_0 \cdot \exp^{\,a(t-t_0)} \cdot e^{b\cdot c}$	Error standard	Coefficient of correlation
carbon	a=-0.042663... 0.038384 b=0.039285...0.068089	0.001057 0.0265	0.988
graphene	a=-0.042663...-0.038384 b=-0.039285...0.068089	0.001057 0.02652	0.988
graphite	a=-0.042663...-0.038384 b=0.014402...0.026520	0.00105 0.02652	0.988

** Constants a and b were determined for a 95% confidence interval*
*** η_0 =0.06 Pa*s , for all mathematical models and is the value of the dynamic viscosity of soybean oil at a temperature of 20ºC*

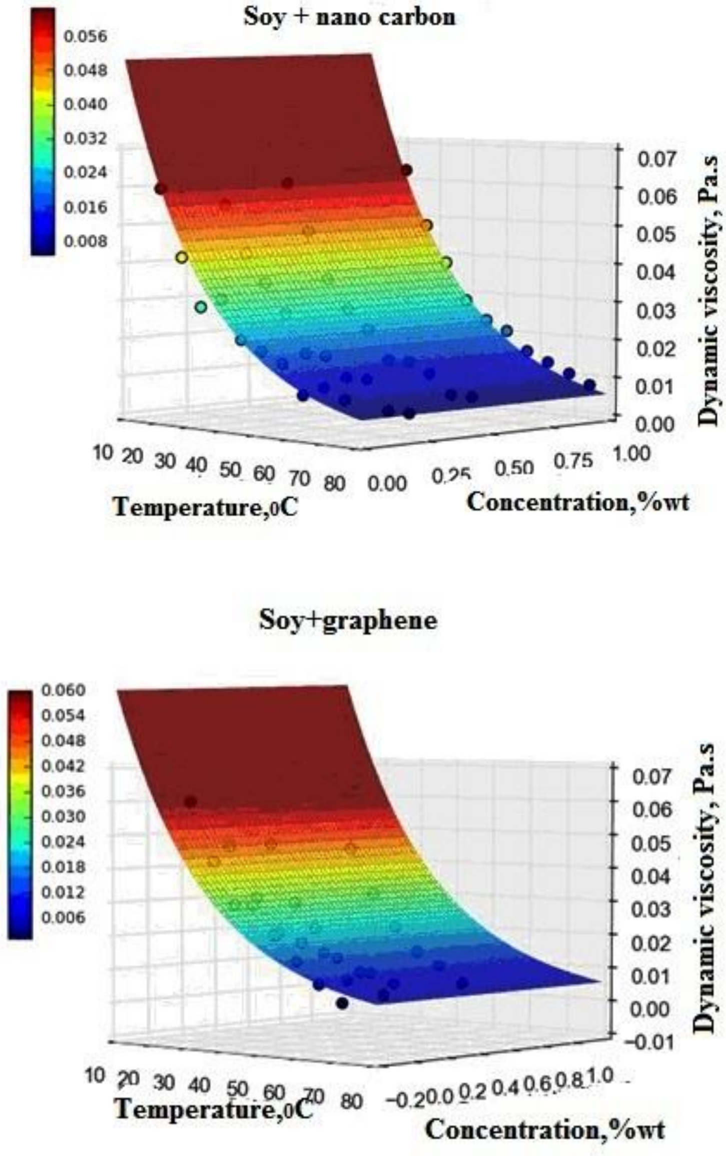

Fig. 1. 3D representation of the mathematical function of the dependence of dynamic viscosity on temperature and additive concentration

4. CONCLUSIONS

The nanocarbon did not change the viscosity but the other two lowered the temperature viscosity curve, regardless of the concentration.

It was found that the tested nanoadditives can be grouped into two categories depending on the influence of their nature:

- the additive that did not significantly change the viscosity of soybean oil and the shear stress - shear rate curve, the nanocarbon
- the additives that reduced the dynamic viscosity over the studied temperature range: graphite and graphene, these additives moving down the dynamic viscosity variation curves with temperature.

All nano-additive lubricants have an enhanced thixotropy after a certain shear rate value, 600 - 700 s^{-1} and up to 2000 s^{-1}, the extreme value for which determinations were made. Between 100 s^{-1} and 600 - 700 s^{-1}, the charge-discharge hysteresis is not significant, the dependence of the stress on the shear rate being almost linear, characteristic of fluids closer to Newtonian behavior.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc have been used during writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology

COMPETING INTERESTS

Author has declared that no competing interests exist.

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