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A Study on Power Law Parameter for Non- Newtonian Behavior of Silver/ Heat Transfer Oil Nanofluid

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ABSTRACT

This study deals with predicting a correlation for power law parameter for Non- Newtonian behavior of silver/ heat transfer oil nanofluid by using the acquired data of the previous work by Aberoumand et al. In this work the data of figures related to apparent viscosity versus shear rate were used to derive a formulation to predict power law parameter as a rheological parameter for silver/ heat transfer oil nanofluid. Based on this correlation, power law parameter depends on volume fraction and bulk temperature variables.

Key words: Silver/ Heat Transfer oil Nanofluid, Power Law Parameter, Non- Newtonian Behavior

INTRODUCTION

In the last decade, nanofluids as the suspension of nanometer size particles and base fluids have been suggested and applied in almost all of the fluid mechanics and heat transfer problems. The ability to enhance viscosity of common fluids is behind of this fact. This significant property has encouraged researchers to use nanofluids in so many engineering fields [1- 12]. Many innovations have also been introduced in disease diagnosis, heat exchanger design and enhanced oil recovery by using these nanofluids. Nanofluids also can be utilized for enhancing heat transfer and improving energy efficiency in thermal systems. They may be used in automotive and heavy duty engines as engine coolants. Some military devices require high heat flux cooling and at this level, using conventional fluids is challenging. So, using nanofluids can provide required cooling for these applications. Generally, nanofluids consist of typical nanometre-sized particles in a base fluid like water, oil, ethylene glycol and etc [1–3]. Thermo physical properties of these fluids such as thermal conductivity and viscosity are usually related to the diameter of nanoparticles which should be usually below 100nm. Viscosity is one of the rheological properties of fluids which shows the resistance of fluid to flow and is expressed in cp or mPa.s. Nanofluid viscosity is a very important property in nanofluids usage especially in heat transfer and fluid mechanics applications. To study on the viscosity of nanofluids, the effect of nanoparticle concentration [1, 2, 4-8], bulk temperature [2, 5-8] and diameter of nanoparticles [1, 2, 8] have to be considered. Among all conventional base fluids, oil based nanofluids have been introduced by researchers as a nanofluid which is able to behave in both of Newtonian and Non- Newtonian modes. So, it was found as an important problem to know about the power law parameter of oil based nanofluids. According to this point, our previous experimental work was selected [9] and the data of previous work by Aberoumand et al. were collected for calculating the power law index. In addition, based on the data of [9] and least squire method, a correlation has been introduced for predicting the power law parameter of silver/ heat transfer oil nanofluid.

METHODOLOGY AND DISCUSSION

In order to determine the power law parameter of the applied nanofluids in [9], the viscosity data of [9] have been collected. Then, the procedure of data evaluation and predictive model for power law parameter of silver/ heat transfer oil nanofluids in any temperature and volume fraction have been described as follow: All the viscosity data of [9] consisted of apparent viscosity ($\frac{\tau}{\gamma}$) versus γ.

By fitting power curves on these data, power shaped formulas could be obtained for any curve which has constant temperature and volume friction:

$$\frac{\tau}{\gamma} = k_1 \gamma^{k_2} \tag{1}$$

Also based on the theory the shear stress is defined as:

$$\tau = \mu \gamma^n \tag{2}$$

Eq. 1 results in:

$$\tau = k_1 \gamma^{k_2 + 1} \tag{3}$$

The left hand sides of Eq. 2 and 3 are equivalent then it could be inferred from these equations that:

$$\mu = k_1 \text{ and } n = k_2 + 1 \tag{4}$$

According to the above applied methodology, the power law parameters related to the all experimental data of [9] are calculated and shown in Table 1.

Table -1 The Power Law Parameters of Various Experimental Data of Silver/ Heat Transfer Oil Nanofluids of [9]

φ %	T (C°)	n	φ %	T (C°)	n	φ %	T (C°)	n	φ %	T (C°)	n
0	25	1	0.011	25	0.92	0.044	25	0.87	0.171	25	0.55
0	30	1	0.011	30	0.82	0.044	30	0.81	0.171	30	0.7
0	35	1	0.011	35	0.88	0.044	35	0.96	0.171	35	0.89
0	40	1	0.011	40	0.92	0.044	40	0.97	0.171	40	0.96
0	50	1	0.011	50	0.78	0.044	50	1.00	0.171	50	0.98
0	60	1	0.011	60	0.85	0.044	60	1.04	0.171	60	0.89

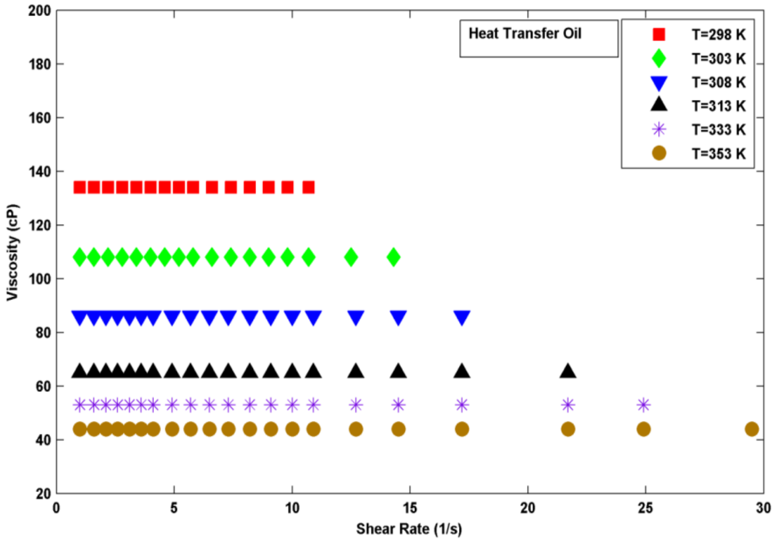

Fig.1 Viscosity vs. shear rate of heat transfer oil

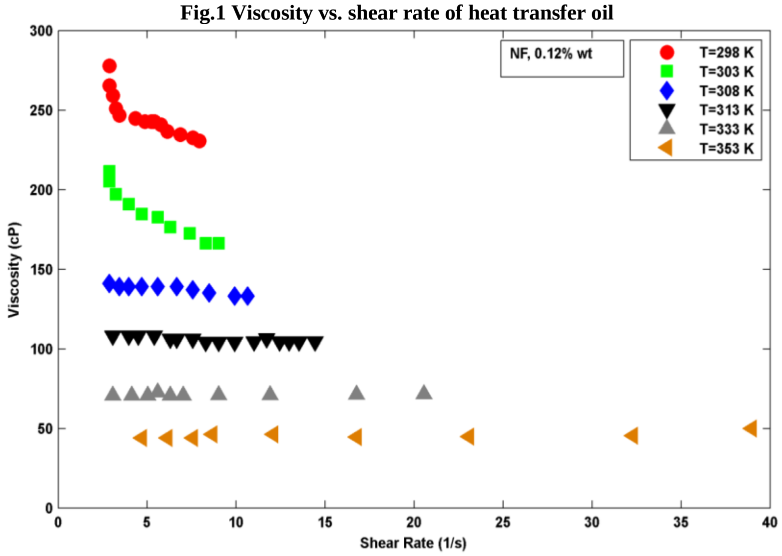

Fig.2 Viscosity vs. shear rate of Ag/ heat transfer oil nanofluid with 0.12% wt (0.011 %Vol.)

As it can be seen from Table 1, the behaviour of power law parameters of the applied nanofluids (in different temperatures and volume concentrations) does not follow a certain order; but as it is obvious, this parameter is dependent to a combination of temperature and nanoparticle concentration of nanofluids. In the other hand, the power law index is a function of temperature and volume concentration.

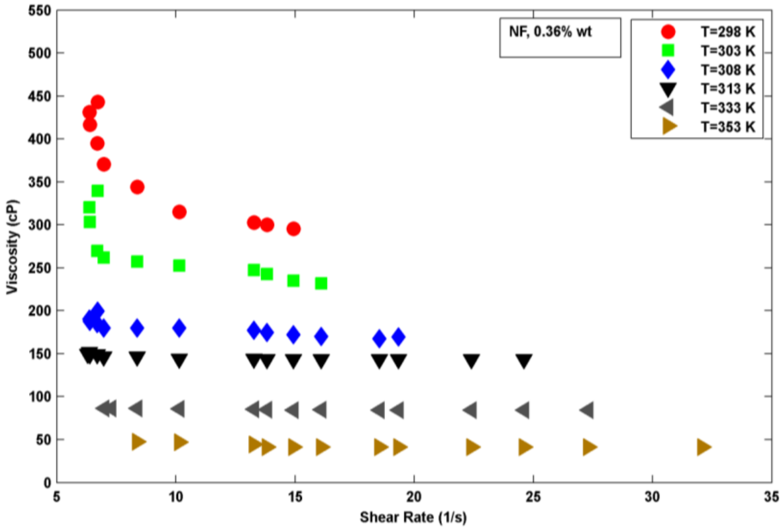

Fig.3 Viscosity vs. shear rate of Ag/ heat transfer oil nanofluid with 0.36% wt (0.044 %Vol.)

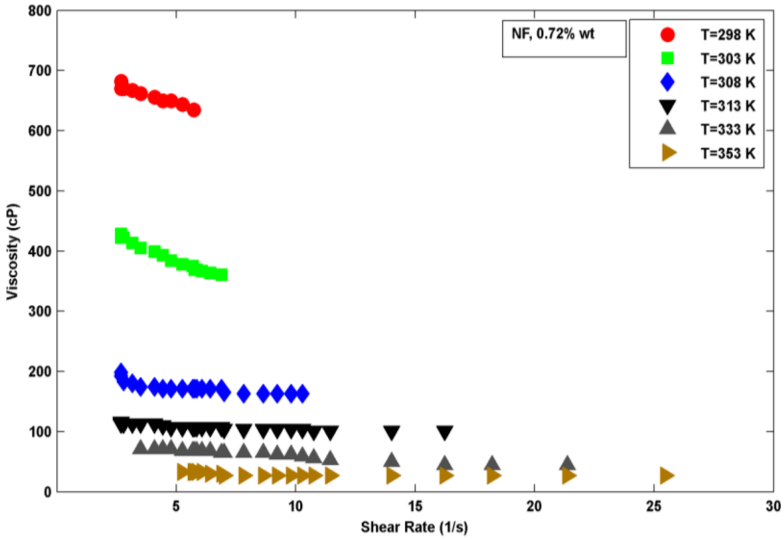

Fig.4 Viscosity vs. shear rate of Ag/ heat transfer oil nanofluid with 0.72% wt (0.171 %Vol.)

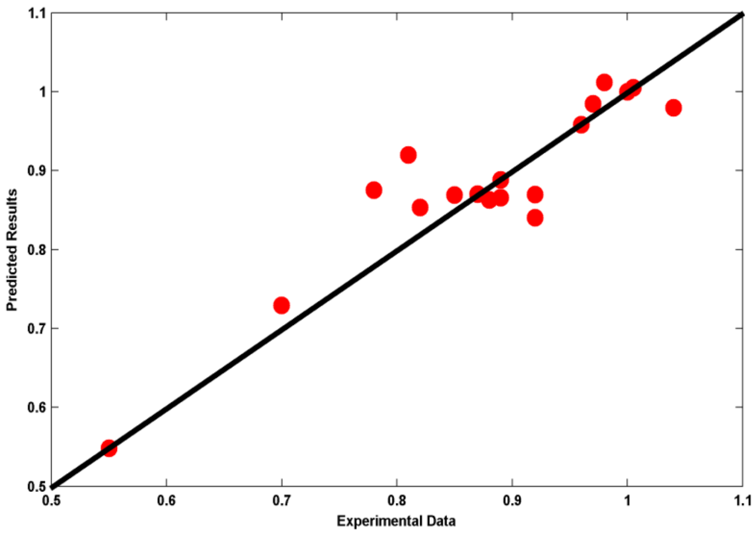

Fig.5 Comparison between experimental power law index and the proposed correlation for power law index

PROPOSED CORRELATION

Based on the experimental data and the least squire optimization method, a correlation for predicting the power law index has been proposed:

$$n(\varphi,T) = a_1 + a_2T + a_3\varphi + a_4T^2 + a_5T\varphi + a_6\varphi^2 + a_7T^2\varphi + a_8T\varphi^2 + a_9\varphi^3 \quad (5)$$

Where: a_1= 1, a_2 = -3.538e-016, a_3 = -29.04, a_4 = 3.694e-018, a_5 = 0.5141, a_6 = 472.3, a_7 = -0.005152, a_8 = -0.1134, a_9 = -2172, R-Squire= 0.88

According to the Eq. 5, the power law index is dependent to the temperature (Cº) and volume fraction of nanofluids. This equation can be used for silver/ heat transfer oil nanofluids and a comparison between predicted values for power law index and the calculated ones provided in Table 1 is presented in Fig. 5. Note that this correlation is valid for temperatures between 25º to 60º and low volume concentrations to 0.171%.

CONCLUSION

The experimental data of viscosity of silver/ heat transfer oil nanofluid in three different volume fractions were collected and by theoretical approach, the power law indexes for the experimental data have been calculated in various temperatures and volume concentrations. Moreover, a correlation regarding to the applied nanofluids for predicting power law parameter as a function of volume concentration and temperature has been proposed and the accuracy of the correlation has been assessed reaching to approximately 88% precision with the experimental data.

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