

Analysis on Auger Pump Performance During Handling High Viscous Liquid

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ABSTRACT – Viscosity is one of the factors affecting the performance of the auger pump. An auger pump is positive-displacement (PD) pump that moves fluids and semi-solid material along the screw axis using one or more screws. The study is about the analysis of the performance of the auger pump when transferring various viscosity liquids. In the study, a pumping device with auger shaft is designed. The sample liquids chosen for the experiment oil and concentrated detergent that poses various viscosity. The viscosity is being identified roughly by Zahn Cup Method with the temperature kept constant at 26°C throughout the measurement. The performance of the auger pump can be accessed by altering the motor speed in order to get various reading for the flow rate and pressure. It is found in the study; flowrate is affected by viscosity with the increasing motor speed. The study proves that the auger pump can operate with viscosity of 770 cSt liquid.

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INTRODUCTION

Machining process is an important manufacturing step during production of industrial parts and components [1-4]. Currently, lubrication/cooling system of a lathe machine is not capable in supplying high viscous liquid, which is not suitable enough to cool the workpiece [1-4]. During machining process, contact between tool-chip-workpiece (shearing, sliding, rubbing etc.), release energy in the form of heat, especially during metal machining [5-10]. Thermal deformation may occur if one element reaches an excessively high temperature, which might have a detrimental impact on the work or damage the equipment [7-8].

Application of cutting fluid during machining process is one of the important methods in improving the quality of product through reduction of friction and cooling down the tool to preserve its rigidity during machining process [1-4]. A lot of study had been done towards the matter and it is still found that the efficiency of cutting fluid to penetrate the cutting zone between tool and workpiece is extremely low. It is due to the high pressure contact between tool, workpiece and chip [1-4]. Current conventional method of supplying cutting fluid is just cooling down cutting zone, without the attention of reducing the friction [3-4]. Meanwhile, application of minimum quantity lubrication is still showing low efficiency due to low momentum of mist to penetrate the high-pressure zone [1-2]. Thus, to increase the efficiency of cutting fluid penetration, it is required to supply cutting fluid with higher pressure and focus towards the cutting zone itself rather than flooding it. Additionally, it is needed to utilize high viscous liquid to prevent the liquid to turn into mist once it leaves the supply nozzle [1-4]. It is assumed that, with the application of auger pump, it is possible to supply high viscosity cutting fluid and increase the cutting fluid pressure to be supplied towards the cutting zone.

Screw pumps are a type of volumetric pump that is frequently utilized in the industrial and oil and gas industries [8-11]. They outperform other types of pumps in these applications in terms of efficiency, head capacity, and reliability. Furthermore, they have significant benefits such as minimal hydraulic pulses, smooth transmission, and low noise. They are often built to function with high viscosity fluids, such as oils, and to deliver high amounts of pressure. Mechanical losses are introduced through friction between the rotor and the stator, as well as between the screws, lowering efficiency [12-16].

Additionally, losses in the pump can be identified and categorized as mechanical loss, volume loss and hydraulic loss. Mechanical loss consisted of bearing loss, sealing loss and disc friction loss, while volume loss consisted of leakage loss in shaft sealing and wear ring. The hydraulic loss consisted of bending loss, friction loss, diffusion loss, and impact loss. There are a few losses that happened in the pump system when handling viscous liquids. These losses that occurs in the system resulting in a decrease of pump efficiency and directly affected the pump performance [17-23].

The behavior of pump could be varies based on its mechanism [20-27]. In the study, an auger screw pump is designed and fabricated for the application of high viscosity liquid. The performance and efficiency of the designed pump will then be analyze towards supplying high viscosity liquid, especially for the sake of machining process.

METHODOLOGY

VISCOSITY MEASUREMENT (ZAHN CUP METHOD)

Zahn Cup method is used to determine the viscosity of each of the experimental liquids. Zahn Cup method use Zahn numbers to express the viscosity of a liquid measured. Zahn numbers is the time taken for a fixed volume of 44 ml liquid to flow through the viscosimeter and usually expressed in the unit of seconds. The Zahn Cup method includes dipping the cup into the liquid at a certain temperature. The cup will then be pull out and the time taken for the liquid to be fully drop is immediately taken. For this experiment, the Zahn Cup three is used because of its availability and the Zahn seconds for the sample falls under this category. The viscosity of the sample is determined by measuring the time taken when the steady flow through the orifice breaks. The time taken will then be used to find the Zahn seconds using the Equation 1. The samples are tested within three set of data to obtain an average and valid value of time taken while conducting this experiment.

$$v = (11.7) (t-7.5) \quad [1]$$

Where, t represents the time taken in (s) and v represent the kinematic viscosity in (cSt).

Before conducting the experiment, make sure the cup is clean and is free of residual by cleaning the device with a suitable solvent and then dry. The steps to conduct the Zahn Cup test is shown in Figure 1.1 until Figure 1.4 and materials needed to conduct Zahn Cup test.



Figure 1. Apparatus and materials



Figure 2. Temperature measurement



Figure 3. Immersion



Figure 4. Time measurement starts

The Zahn Cup experiment is conducted by observing the flow of the liquid until there is a breakage of the liquids leaving the Zahn cup. The measurement of the stopwatch is ended at the same time as the first liquid breakage is observed. The validity of this test is repeated thrice, and the average time is calculated as shown. The result of the experiment is shown in Table 1.

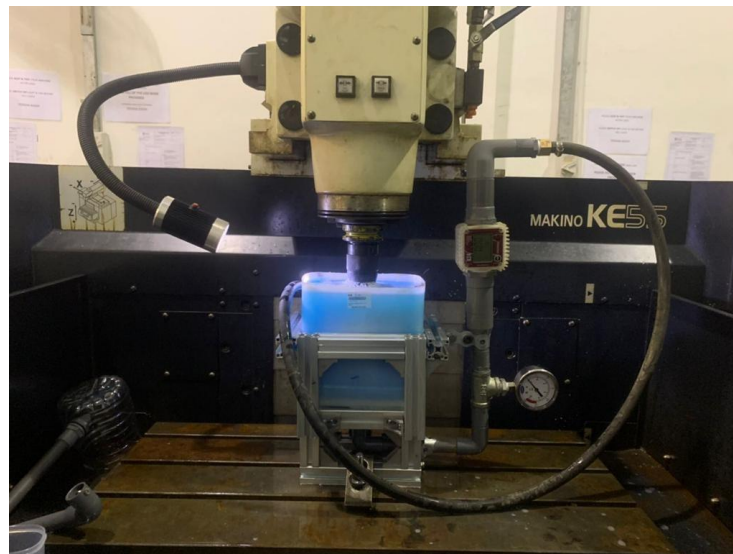
Table 1 Viscosity of the Viscous Liquid Mixtures

Types of Viscous Liquid	Kinematic Viscosity (cSt)
100% Water	1.2
25% Detergent	23.4
50% Detergent	47.9
75% Detergent	242.2
100% Detergent	773.4
100% Cooking oil	1130.2

The lowest viscosity of the fluid is as expected comes from the 100% water sample, which consist of purely water as it took the shortest time for the liquid to show its first breakage. Based on the experiment, the viscosity of 100% water is 1 cSt. It can also be observed that the viscosity is gradually increasing as more percentage of detergent is added into the mixture. The viscosity of 25% detergent mixture is 23 cSt while the viscosity at 50% detergent is 48 cSt. Then, the viscosity at 75% is 242 cSt while 100% is 773 cSt. As expected, 100% cooking oil shown the highest viscosity as it took the longest time taken for the liquid to shows its first breakage while conducting the experiment with the viscosity of 1130 cSt.

PUMPING SYSTEM TEST

The experiment is being conducted to access the performance of the auger pump while transferring various viscous liquids. The parameters that need to be accessed to determine the performance of the auger pump is the flowrate, pressure, motor speed for various types of the liquids.

**Figure 5.** Pumping system test

RESULT AND DISCUSSIONS

FLOWRATE ANALYSIS

Table 2 shows the flowrate measurement for various liquid viscosity and plotted in Figure 6.

Table 2. Flowrate of the Various Liquid Viscosity

Types of viscous liquid Speed (Rpm)	Flowrate (L/min)					
	Water	25% Detergent	50% Detergent	75% Detergent	100% Detergent	100% Cooking oil
100	2.4	2.0	1.6	1.2	0.8	0.5
200	3.6	3.3	2.8	2.5	1.8	1.2
300	4.8	4.5	4.2	3.6	3.0	2.0
400	6.2	5.6	5.1	4.5	4.0	3.4
500	7.5	6.8	6.3	6.0	5.4	4.7

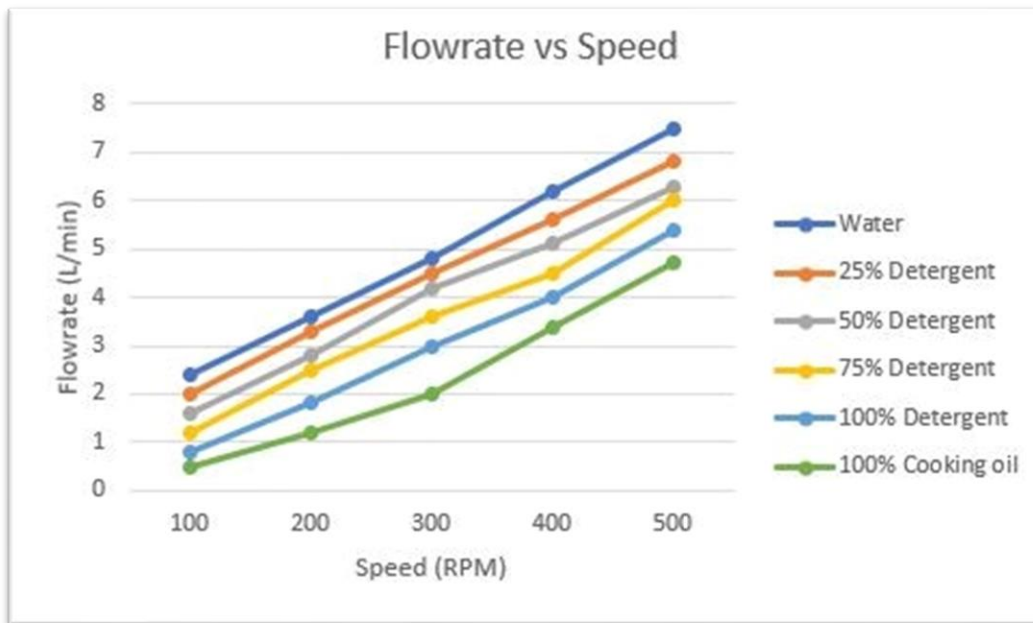


Figure 6. Flowrate vs speed for various liquid viscosity

Based on the experiment, it could clearly be seen that the flowrate increases as the motor speed increases for all the experimental liquids. It can be observed that water has the highest flowrate with 7.5 l/min at a speed of 500 rpm and a lower flowrate is shown by 100% of cooking oil with the value 5.4 l/min of flowrate. This is expected, as 100% cooking oil has the highest viscosity among the experimental liquids. Based on Poiseuille's law as shown in Equation 4.1., the flowrate is inversely proportional to viscosity. This indicated with an increase of viscosity, the flowrate will decrease. This is clearly shown as the viscosity of the liquid increases, there is a significant decrease of flowrate, with 100% of cooking oil has the lowest flowrate.

$$Q = \frac{\pi Pr^4}{8vl} \tag{2}$$

Where, Q represent flowrate in (m³/h), π represent pi, P represent pressure in (Pa), r represents radius of pipe in (m), η represent kinematic viscosity in (cSt), and l represent length of pipe in (m). Thus, it can be assumed that the pump shows a high performance while handling 100% cooking oil, the pump used is suitable and efficient in handling higher viscous liquids. Similar agreement of finding had been explain in previous study [28] for various viscosity solvent liquid.

PRESSURE ANALYSIS

Based on Table 3 and plotted in Figure 7 **Error! Reference source not found.**, it can clearly be seen that the pressure for 100% cooking oil is the highest compared to the other viscous liquid with pressure 0.388 MPa for speed 500 rpm while the lowest one is water with 0.129 MPa. An increase in viscosity will drastically lead to an increment of the pressure. The relationship between pressure and viscosity are directly proportional. It can also be observed that the pressure for all

the liquids depends on a viscosity of the liquid. Basically, cooking oil have a relatively high viscosity with 1130 cSt. Similar finding is shown in [28], with agreement for the effect of solvent viscosity and pressure of liquid pumped.

Table 3. Pressure of the Various Viscous Liquid

Types of viscous liquid Speed (Rpm)	Pressure (MPa)					
	Water	25% Detergent	50% Detergent	75% Detergent	100% Detergent	100% Cooking oil
100	0.022	0.043	0.065	0.086	0.129	0.172
200	0.043	0.065	0.086	0.129	0.172	0.259
300	0.086	0.108	0.129	0.172	0.237	0.302
400	0.108	0.129	0.172	0.194	0.280	0.345
500	0.129	0.172	0.216	0.237	0.323	0.388

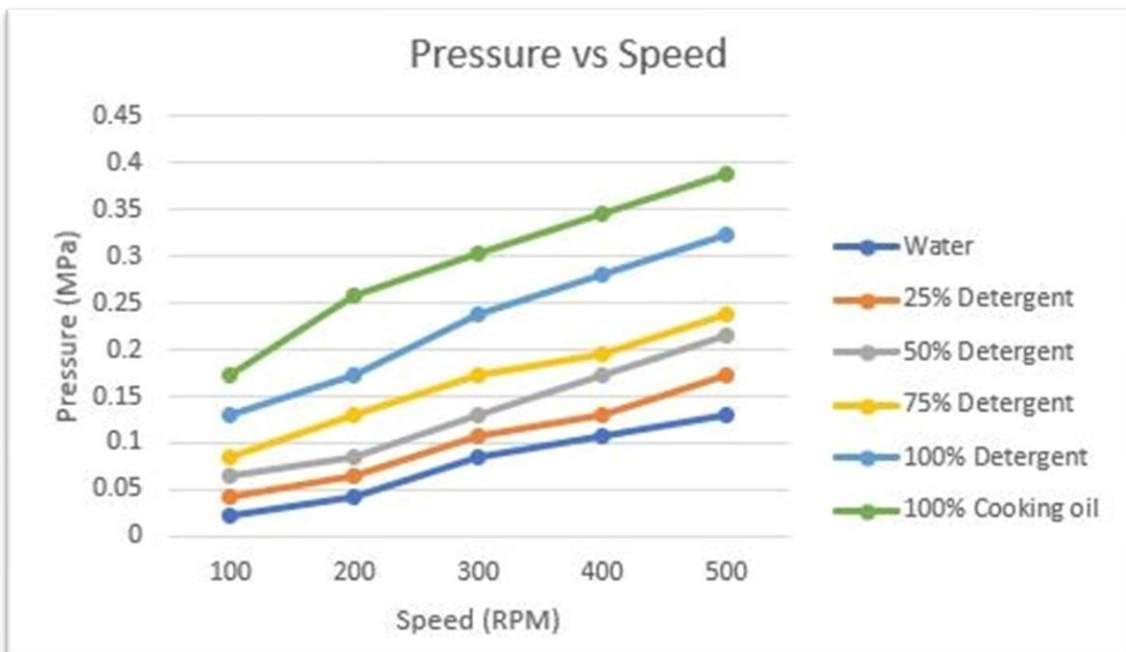


Fig. 7. Pressure vs speed for various viscosity liquid

CONCLUSION

In conclusion, the study had analysis the performance of the auger pump while handling viscous liquids. Besides, the pumping system is designed and fabricated in order to access the performance of the auger pump. The viscosity test is conducted by using Zahn cup method to identify the viscosity of various liquid that have been used to conduct this experiment such as water, cooking oil and the mixture with the percentage of detergent varies starting from 25% up to 100%. Lastly, the experiment is being performed by altering the speed of the milling motor. The flowrate and pressure of the experimental liquids is being measured using the flowmeter, and pressure gauge.

Based on the data obtained from the experiment, viscosity test is identified by theoretical calculation. Based on the results obtained, the flowrate decrease and pressure are increases as the viscosity of the liquids increases. For 100% cooking oil, the system still can operate even though the viscosity up to 1130 cSt. When a fluid moves through pipes, it will experience frictional resistance and thus leads in the dissipation of energy from the transported liquids. Thus, it can be observed at the higher viscosity liquids of 100% detergent and 100% cooking oil consume lower flowrate compared to 25% detergent mixture. Thus, the auger pump used in the experiment is efficient to be used to transfer viscous liquid as high as 1130 cSt.

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