STUDIES ON FLOW PERFORMANCE OF CRUDE PALM OIL IN TRANSPORTATION HANDLING USING DIFFERENT TYPE OF MECHANISMS

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ABSTRACT

Crude palm oil (CPO) has high tendency to solidify. This drawback has make the CPO become solidify in the pipelines and will cause loss of millions of ringgit per year. The objectives of this research were to identify suitable temperature condition for best flow performance of CPO (least frictional force exists) and to identify physical parameter to create resonance frequency using ultrasonic equipment. There are two methods that were employed for the improvement of the CPO in transportation handling which are by using jacketed steam and ultrasonic equipment. This work reports viscosity data, determined with viscometer for CPO over the temperature range of 30ºC - 60ºC and also the viscosity data that was determined for CPO over the ultrasonic frequency of 3MHz, 6MHz and 9MHz. From the result obtained, the viscosity of the CPO decreases nonlinearly with increasing temperature as has been found in other ordinary liquids. Then, all solid CPO were observed to be totally dissolved at temperature 50ºC. By using ultrasonic equipment, the result shows that viscosity decreases approximately linearly with increasing ultrasonic frequency at constant temperature. All the methods used shows satisfactory results, where the flow of the CPO in transportation handling will increase. The research findings shall ease problems to CPO transporter or pipeline users and it would contribute significantly in cost reduction of CPO storage and handling.

ABSTRAK

Minyak kelapa sawit mentah mempunyai kecenderungan yang tinggi untuk membeku. Kelemahan ini telah membuatkan minyak kelapa sawit mentah membeku di dalam paip dan akan menyebabkan kerugian berjuta-juta ringgit setiap tahun. Objektif kajian ini adalah untuk mengetahui suhu yang sesuai untuk aliran minyak kelapa sawit mentah (mengurangkan daya geseran) dan untuk mengenalpasti parameter fizikal untuk membuat frekuensi resonansi menggunakan peralatan ultrasonik. Terdapat dua kaedah yang digunakan untuk memperbaiki aliran minyak kelapa sawit mentah semasa proses penghantaran iaitu dengan menggunakan jaket berwap dan peralatan ultrasonik. Laporan ini merekodkan data kelikatan minyak kelapa sawit mentah yang ditentukan dengan menggunakan viskometer untuk suhu antara 30ºC - 60ºC dan juga data kelikatan untuk minyak kelapa sawit mentah pada frekuensi 3MHz, 6MHz dan 9MHz. Daripada hasil yang diperolehi, kelikatan minyak kelapa sawit mentah menurun secara tidak seragam dengan peningkatan suhu seperti yang biasa terjadi pada cecair biasa yang lain. Kemudian, minyak kelapa sawit yang membeku tersebut didapati mencair secara keseluruhan pada suhu 50ºC. Dengan menggunakan alat ultrasonik, hasilnya menunjukkan bahawa kelikatan minyak kelapa sawit mentah menurun secara seragam dengan meningkatnya frekuensi alat ultrasonik pada suhu yang sama. Semua kaedah yang digunakan menunjukkan hasil yang memuaskan, di mana aliran minyak kelapa sawit mentah semasa proses penghantaran semakin meningkat. Hasil kajian ini adalah untuk mengurangkan masalah aliran minyak kelapa sawit mentah semasa proses penghantaran atau di dalam paip dan ini akan mengurangkan kos simpanan dan pengendalian minyak kelapa sawit mentah.

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LIST OF ABBREVIATIONS

cm	-	Centimeter
cP	-	Centipoises
CPO	-	Crude palm oil
FFA	-	Free fatty acid
kHz	-	Kilohertz
mg	-	Milligram
MHz	-	Megahertz
min	-	Minute
ml	-	Milliliter
MPOB	-	Malaysian Palm Oil Board
Pa.s	-	Pascal second
ppm	-	Part per million
rpm	-	Revolutions per minute
SI	-	Système International

LIST OF SYMBOLS

a	-	Acceleration
C12:0	-	Lauric acid
C14:0	-	Myrstic acid
C16:0	-	Palmitic acid
C18:0	-	Stearic acid
C18:1	-	Oleic acid
C18:2	-	Linoleic acid
d	-	Delta
F	-	Force
m	-	Mass
m	-	Meter
P	-	Poise
s	-	Second
t	-	Time
T	-	Temperature
V	-	Volume
B	-	Beta
ºC	-	Degree celsius

μ	-	Viscosity
Δ	-	Delta

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

The first oil palm plantation in Malaysia started in 1917 when oil palm trees first introduced to Malaysia as an ornamental tree. Sabah is the largest palm oil producer in Malaysia, It has about 1.2 million hectares of some of the highest-yielding oil palm plantations (21.4 metric tonnes per hectare) producing 5 million metric tonnes of palm oil yearly.

Malaysia is a world's larger producer of palm oil and currently accounts for 47.9% or 11.9 million tonnes of the world palm oil production. Of the 11.9 million tonnes of palm oil produced in 2002, some 91.4% of it was exported (MPOB, 2003). In 2004, Malaysia produces 14 million metric tonnes of palm oil annually (world output 30.6 million metric tonnes) from about 4.0 million hectares of oil palm. In 2008, Malaysia produced 17.7 million metric tonnes of palm oil on 4.5 million hectares of land. In 2010, production is expected to increase to 18.7 million tonnes, an increase of 20.9% during the five-year period, and to 20.15 million tonnes in 2015 and to 21.8 million tonnes in 2020 (Ramli & Mohd Alias, 2006).

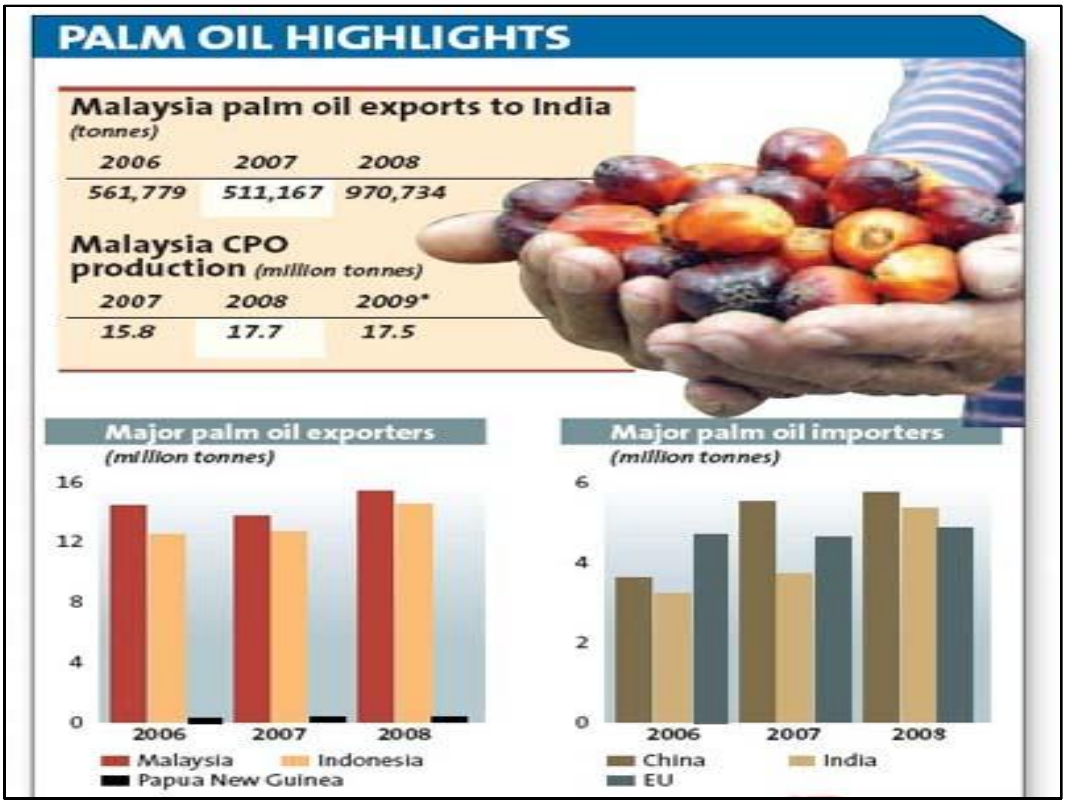

Figure 1.1: Palm oil highlights.

Oils is a collective term for more or less viscous, generally organic-chemical liquids. Depending on their chemical composition, a distinction may be drawn between fatty, essential, mineral and silicone oils. Fatty oils include liquid, semisolid and solid products of vegetable and animal origin. They are also known as sweet oils.

Palm oil is dark yellow to yellow-red oil of vegetable origin obtained by pressing or boiling the flesh of the fruit of the oil palm (*Elaeisguineensis*). Palm oil differs from kernel oil, the latter being obtained from the kernels of the oil palm.

Palm Oil is the world's most widely used vegetable oil, consumed mainly for cooking and food preparation; now it is rapidly increasing its presence in the industrial sector, especially within the biofuels energy market. It's a highly traded product, produced by and large, in Malaysia and Indonesia, for shipping all over the world. It is used very much within the limelight these days as a potential substitute for rapeseed oil to generate biodiesel in Europe.

Palm oil produced two products which are Palm Stearin and Palm Olein. Example of the Palm Stearin is margarine and the Palm Olein is cooking oil. The demand for liquid oils has increased in recent years, mainly for salad and cooking uses and an important property for such oils is low cloud point, which is the temperature at which turbidity appears when the oil is cooled under standard conditions. Liquids oils with a low cloud point are desirable because of the widespread use of household refrigeration.

The solidification temperature is of considerable significance in the transport of fatty oils and fats. They must remain liquid during loading, during the voyage and during unloading. Transportation of the oil is no easy task. It's a very meticulous process as the oil is no longer pump-able if it solidifies on account of a temperature drop. Often, through the processes of loading, transport and unloading, transporters gradually raise the temperature of the storage unit within transport from 26.5°C to 50°C to keep the product in a liquid, pump-able state. It has to be done right, because if the oil does solidify, there's no turning back. Although it can be reheated for cooking purposes within the kitchen, forced heating in the tanks, in such a close vicinity to the heating coils, will cause the oil to singe, discolor and become rancid.

Palm oil has relatively high solidification point about a range of 41 – 31^{o}C. In its native countries it has a liquid consistency, but in temperate latitudes it is fatty and has to be heated. So, the oils must be heated by a few degrees Celsius per day, to prevent the risk of rancidity and other negative changes arises.

Table 1.1 shows a rough estimate of appropriate temperature ranges for CPO during the transport conditions. Temperature may deviate from these values, depending on the particular transport conditions.

Table 1.1: Temperature of CPO on the particular transport conditions.

Designation	Temperature range
Loading travel temperature	40^oC
Favorable travel temperature	35^oC
Solidification temperature	35^oC
Pumping temperature	50^oC

Some of the common methods used to enhance the use of palm oil and palm oil products at low temperatures are the adding of additives (known as pour point depressant, wax crystal inhibitor and cold flow improver) and blending with other more unsaturated oils (Ooi *et al*., 2005). Of the two, additives are usually the preferred method as it is more economical.

1.2 Problem Statement

During raining season or at seasonably low temperature, where the surrounding experienced relatively cold weather, the crude palm oil (CPO) tends to solidify. Crude palm oil has high solidification point, which is 32^oC. Below that 32^oC, CPO will start to solidify. When the crude palm oil solidified, it will cause a problem in pumping the crude palm oil through the pipelines and also difficult to transport during the cargo handling. Crude palm oil has poor cold stability and also has relatively high pour point, which cause them to solidify in pipelines (Ooi *et al*., 2005) and in the tanks while the cargo handling. If the oil solidifiers in the tanks, it cannot be liquefied again even by forced heating. These problems are due to Palm Stearin rather than Palm Olein. Palm oil produced two products which are Palm Stearin and Palm Olein. This is because Palm Olein contains the unsaturated fat compared to the Palm Stearin. Example of the Palm Stearin is margarine and the Palm Olein is cooking oil.

Due to these problems, company will face high cost of handling, pumping and transporting the CPO to the market. Companies will loss of millions of ringgit per year. According to Ooi *et al*. (2005), cloudiness, precipitation, poor flowability, poor pumpability and solidification are some of the common problems suffered by vegetable oils at low temperatures. Palm oil, which is more saturated than other vegetable oils, is the most affected. The poor cold stability of palm oil has limited its applications in among other things, cooking oil, salad oil, lubricant and biodiesel.

1.3 Objectives

There are some objectives for this research study:

- To identify suitable temperature condition for best flow performance of CPO (least frictional force exist).
- To identify physical parameter to create resonance frequency using ultrasonic equipment.

1.4 Scopes of Study

In order to achieve the objectives, the following scopes have been identified:

- Flow characterizations of the crude palm oil.
- Effects of Temperature control using jacketed steam.
- Usage of Ultrasonic Equipment to improve liquid flow.
- Effects of using the two methods on viscosity of the crude palm oil.

1.5 Rationale & Significance

There are some purposes why we are needed to study to improve flow performance of crude palm oil in pipeline using difference mechanisms/parameters.

These because of in order to:

- To ensure that the CPO is not solidified in the pipelines, tanks or lorry tankers.
- The study will enhance in reduce the cost of operation and maintenance.
- To ensure that palm oil plants and associated equipment are not damaged due to this solidified palm oil.
- To ensure that the operation time of palm oil transportation is not impeded by this problem.
- The preferred method shall be selected based on economic value.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter will discuss about what is the palm oil, the palm oil composition, and the uses of the palm oil. For the next section, it will discuss about the two mechanisms that had been used in this research (ultrasonic equipment and jacketed steam) and the viscosity measurements. Then, it will also discuss about pigging process that is used in the CPO industries before or after pumping the CPO.

2.2 Palm Oil

Palm oil is derived from the pulp of the fruit of the oil palm *Elaesisguineesis*. Palm oil is one of the few vegetable oil high saturated fats. It is thus semi-solid at typical temperate climate room temperatures, though it will more often appear as liquid in warmer countries. Palm oil is naturally reddish because it contains a high amount of beta-carotene. Good palm oil must have lower amount of mono and diglycerides compositions.

Palm oil is a common cooking ingredient in Southeast Asia and the tropical belt of Africa. Its increasing use in the commercial food industry in other parts of the world is buoyed by its cheaper pricing and the high oxidative stability of the refined product.

Figure 2.1: Palm Oil.

2.3 Palm Oil Composition

Palm oil is extracted from the mesocarp of the oil palm fruit. Mesocarp consists of about 70 to 80% by weight of the fruit and about 40 to 45% of oil. The extracted oil is known as crude palm oil (CPO).

Palm oil is composed mainly Triglycerides, mono and diglycerides. The unsaponifiable matter in the palm oil such are free fatty acids, moisture, dirt and minor components of non oil fatty matter. Palm oil is a large natural source of tocotrienol, part of the vitamin E family.

2.3.1 Triglycerides

Triglycerides are a chemical compound of one molecule of glycerol bound to three molecules of fatty acid.

$$
\begin{array}{llllll}
CH_2-OH & + & R1\text{-}COOH & & CH_2-COOR1 & \\
| & & & & & \\
CH-OH & + & R2\text{-}COOH & \leftrightarrow & CH-COOR2 & +\ 3H_2O \\
| & & & & & \\
CH_2-OH & + & R3\text{-}COOH & & CH_2-COOR3 & \\
\text{Glycerol} & & \text{Fatty Acid} & & \text{Triglyceride} & \text{Water}
\end{array}
$$

Triglyceride properties depend on the different fatty acids that combine to form triglyceride, while the fatty acids themselves also different depend on their chain length and degree of saturation. The short chain fatty acids has lower melting point and more soluble in water compared to the longer chain fatty acids which has higher melting point. Then, the melting point is dependent on the degree of non saturation. This shows that the unsaturated fatty acids will have a lower melting point compared to saturated fatty acids although it has similar chain length.

Table 2.1 shows the fatty acid composition in the palm oil. The most predominant fatty acids in the palm oil are C16:0 (saturated palmitic acid) and C18:1 (unsaturated oleic acid).

Table 2.1: Fatty Acids Composition in the Palm Oil

Substances	Content
C12:0 Lauric	0.2%
C14:0 Myrstic	1.1%
C16:0 Palmitic	44.0%
C18:0 Stearic	4.5%
C18:1 Oleic	39.2%
C18:2 Linoleic	10.1%
Others	0.9%

2.3.2 Mono and diglycerides and FFA

The triglycerides are break up to form free fatty acids thus yielding mono and glycerides and FFA by a process known as hydrolysis. The process occurred in the presence of heat and water.

Hydrolysis can be presented as below:

CH_2 – COOR1	+			CH_2 – OH		
|				|		
CH-COOR2	+	H_2O	↔	CH-COOR2	+	R1COOH
|				|		
CH_2 – COOR3	+			CH_2 – COOR3		
Triglyceride		Water		Diglyceride		FFA

Mono and diglycerides are about 3 to 6% by weight of the glycerides in the oil. Goods oil is having a lower amount of mono and diglycerides. This is because mono and diglycerides act as emulsifying agents inhibiting crystal formation and making filtration difficult.

2.3.3 Moisture and Dirt

Normally, moisture and dirt in the palm is about 0.25%. Good milling will reduce the moisture and dirt in the palm oil.

2.3.4 Minor Component

Minor component in the palm oil are carotineoids, tocopherols, sterols, polar lipids and impurities. They are classified into one category because they are fatty in nature but are not really oils.

The impurities which are contained in crude palm oil (CPO) are shown in table 2.2:

Table 2.2: Composition of CPO.

Substances	Content
Free Fatty Acid (FFA)	3 – 5%
Gums (phospholipids, phosphotides)	300ppm
Dirt	0.01%
Shell	Trace
Moisture and Impurities	0.15%
Trace metal	0.50%
Oxidation products	Trace
Total Carotenoids	500 – 1000 mg/ke

The fatty acid composition of the Malaysian palm oil shows that its unsaturation (mean 50.1%) is intermediate between that Sumatran and Brazilian palm oil. The Sumatran oil has an average unsaturation of 48.4% while that of the Brazilian oil is 51.4% (Siew, Tang, Flingoh, Chong & Tan, 1993).

2.4 Uses of palm oil

Due to its physical characteristics, palm oil can be used and prepared in a number of processes without the need to hydrogenise it. This has advantages as hydrogenation can produce undesirable trans fatty acids which may lead to diseases, including cardiovascular problems and diabetes.

The composition of palm oil, together with its natural consistency, appearance, pleasant smell and its resistant nature makes it an ideal ingredient in the development and production of a variety of edible oils, in particular margarines and fats. Palm oil is also ideal when making the following products such as dry cake mix used for baking biscuits, cakes and sponge cakes, soaps, sauces, fat substitutes used when making condensed milk, powdered milk, non lacteous cream used in coffee and ice-cream.

Also, palm kernel meal, a byproduct of palm oil, is used in the production of concentrated foods and as a supplement in animal food.

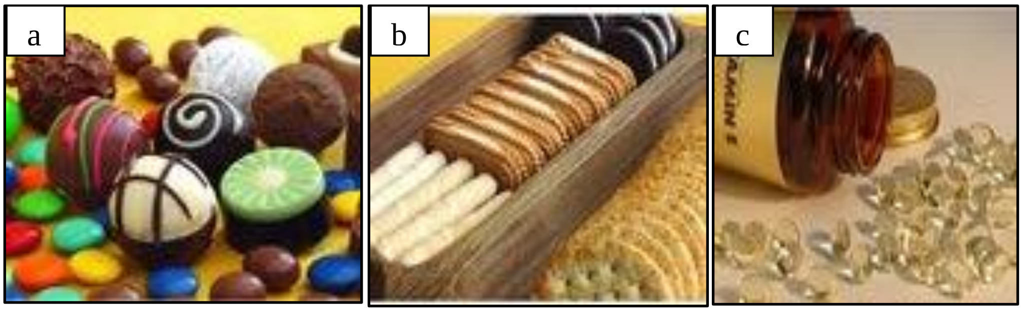

Figure 2.2: (a) cakes and sponge cakes, (b) biscuits and (c) food supplements

Figure 2.3: (a) soaps, (b) cosmetics and (c) paints

Palm oils are used in the production of oleochemical products such as fatty acids, fatty esters, fatty alcohols, which all contain glycerol and fatty nitrogen. Recently, palm and kernel oils have been increasingly used as biodiesel fuel.

In 1900, Rudolf Diesel used vegetable oil as fuel for his car, from which the motor engine subsequently took its name. Years later, palm oil was successfully developed as a biofuel for cars. Using palm oil as a biofuel is more environmentally friendly and it's more advantageous than other combustible fuels such as petrodiesel and standard petrol.

Colombia has pledged to produce biodiesel using palm oil mixed with diesel. This will eventually play an important role in providing energy fuels which can power thousands of cars and machines with motor engines across Colombia. Using palm oil as a biodiesel brings benefits and is environmentally friendly. It also generates employment and contributes to the demand for renewable energy sources.

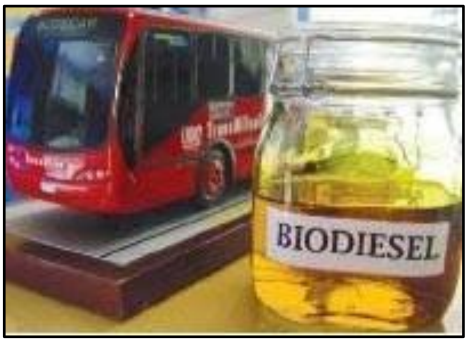

Figure 2.4: Biodiesel

2.5 Ultrasonic Equipment

Ultrasonic or ultrasound, derived from the Latin words "ultra," meaning beyond, and "sonic," meaning sound, is a term used to describe sound waves that vibrate more rapidly than the human ear can detect. Ultrasonic wave is a sound wave having frequency higher than human audibility limits (Mason & Lorimer, 1988). According to Gooberman (1968), sound wave with frequency above 20 kHz is usually considered as ultrasonic. Other researchers (Saggin and Coupland, 2004) reported ultrasound is a qualitatively similar to audible sound, but the vibrations occur at much higher frequencies (>20 kHz). The use of ultrasonic wave has gain consumers interest in various fields (Adnan *et al*., 2008) such as in medical and in an industry.

The ultrasonic has been used to provide information about the dynamic rheological properties of oils. By measuring longitudinal ultrasonic wave over a wide range of frequencies, it is possible to determine the dynamic bulk viscosity of the oils (Sidek *et al*., 1996).

Ultrasonication offers great potential in processing of liquids and slurries by improving the mixing and chemical reactions in various applications and industries. Ultrasonication generates alternating low-pressure and high-pressure waves in liquids, leading to the formation and violent collapse of small vacuum bubbles. This phenomenon is termed cavitation and causes high speed impinging liquid jets and strong hydrodynamics shear-forces.

Ultrasonic technology was for over 40 years employed in the steel industry, initially with flaw detection and later joined by wall thickness measurement. For the past 15 years the plastics industry has used ultrasonic testing in the field of wall thickness measurement of pipe extrusions. Nowadays, ultrasonic can be used in various field of applications and industries.

Figure 2.5: Ultrasonic Equipment.

2.6 Jacketed Steam

Jacket is an outer covering for anything, especially, a covering of some nonconducting material such as wood or felt, used to prevent radiation of heat, as from a steam boiler, cylinder, pipe and so on. Steam is the elastic, aeriform fluid into which water is converted when heated to the boiling point. Steam jacket is a space filled with steam between an inner and an outer cylinder, or between a casing and a receptacle as a kettle.

Steam jacketed piping is fabricated from standard fittings to provide an internal pipe for the molten sulfur or other material and external jacket for the steam. The heat transfer coefficient for this system is very high. Typically, a jacket system will maintain the product near the steam temperature where there is little or no flow in the pipeline.

2.7 Viscosity Measurements

Viscosity is one of the most important physical properties of a fluid system. Viscosity is a measure of the resistance of a fluid which is being deformed by either shear stress or tensile stress. Viscosity changes with shear rate, temperature, pressure, moisture and concentration (Sunny Goh Eng Giap, 2010). Informally, viscosity is the quantity that describes a fluid's resistance to flow. The less viscous the fluid is, the greater its ease of movement (fluidity).

Formally, viscosity (represent by the symbol μ) is the ratio of the shearing stress (F/A) to the velocity gradient ($\Delta v_x/\Delta z$ or dv_x/dz) in a fluid.

$$\mu = \frac{F}{A} \div \frac{\Delta vx}{\Delta z} \qquad \text{or} \qquad \mu = \frac{F}{A} \div \frac{dvx}{dz}$$

The more usual of this relationship, called Newton's equation, states that the resulting shear of a fluid is directly proportional to the force applied and inversely proportional to its viscosity. The similarity to Newton's second law of motion ($F = ma$) should be apparent.