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THE EVALUATION OF VISCOSITY PROPERTIES OF ENGINE OIL – MARINOL RG 1240 AFTER WORKING IN VARIOUS TYPES OF ENGINES

Małgorzata Malinowska

Gdynia Maritime University
Department of Marine Propulsion Plants
Morska Street 81-87, 81-225 Gdynia, Poland
tel.: +48 58 5586371, fax: +48 58 5586399
e-mail: m.malinowska@wm.am.gdynia.pl

Abstract

The lubricating oils are a liquid substance, consisting of a base (mineral, synthetic or vegetable) and selected additives. They can used for lubricate internal combustion engines, so they called – engine oils. For proper functioning of the engine, lubricating oil have to fulfil basic requirements: the main function is to enable the formation of a film of oil between the moving parts which reduces friction and wear, assisting in cooling, keeping the compression ratio, reducing corrosion, filling in all micro ridges on the surface of cooperating components, sealing the combustion chamber etc. The most significant property of any lubricating oil is viscosity, which is the measure of its resistance to gradual deformation by shear stress or tensile stress. The important feature is that property of viscosity changes during the exploitation process of oil, it may increase and decrease. That is why, for engines it is important not only to choose the type of oil correctly but also to frequent monitor the viscosity. In the article, the author shows how the viscosity of marine engine oils changes after working in different types of engines. The experiments were conducted using the method of the rheometer Haake Mars III of Thermo Scientific. The samples of engine oil – Marinol RG 1240 were collected after various periods of use in three different engine types Cegielski-Sulzer.

Keywords: *engine oil, viscosity, marine engine, lubricating system, rheometer, Marinol RG 1240*

1. Introduction

Lubricating oil is very important in all internal combustion engines to reduce friction in moving parts and to assist in cooling etc. [15]. The monitoring of lubrication system is important for minimizing environmental pollution and lowering engine friction [14, 17]. This issue concerns car and marine engines.

Various types of lubricants are available all over the world including mineral, synthetic, semi synthetic, and vegetable oils etc. The marine engine oil is a mixture that is produced in a process of crude petroleum distillation with special additives (such as corrosion inhibitors, oxidation inhibitors, anti-wear agents, load-carrying friction modifiers, foam suppressors, demulsifiers, metal deactivators etc.) [12].

Unfortunately, the engine oils degradation process is inevitable and it is very unpredictable phenomenon. Several factors such as contaminations, leaks, oxidation, evaporation, additive depletion, wear particles play an important role in degradation process [5]. To study the evolution of engine oil degradation, oil samples should be extracted periodically during engine exploitation. Second important problem in assessing the quality of the oil, is its refreshment (add new oil) after sample taken. It occurs unreal degradation process. In such a situation, it is difficult to determine the problem in the lubricating system. "Several simulations of engine oil degradation are conducted by artificial methods in order to study the trend of engine oil degradation. However, these artificial degradation methods cannot reproduce a real degradation process as most of the variables affecting the engine oil during its operation are absent here" [7].

The article analyses the effect of the purpose of engine on the viscosity in circulating engine oil. Three engines were compared: Cegielski-Sulzer 8AL20/24, Cegielski-Sulzer 6AL20/24 and Cegielski-Sulzer 3AL25/30. The number of working hours of oil samples was within limits of 600 to 1030 hours.

2. Viscosity

Viscosity is one of the most critical parameter that indicates the status of the lubricant and the tribological unit. It indicates the lubricating oils capability to provide a sufficient thickness of oil film between moving surfaces. It can be distinguished two definitions [18]:

- *dynamic viscosity (η)* – is the ratio of the shear stress between the lubricant layers to the transversal gradient of velocity;
- *kinematic viscosity (ν)* – is the ratio of dynamic viscosity to lubricant density.

Changes in lubricant properties due to oil oxidation, evaporation, fuel contamination, and additive depletion cause abnormal viscosity changes [18]. The viscosity of engine oil, during the exploitation process may increase and decrease. It changes along with [9, 10, 15]:

- *temperature* – for mineral oil, viscosity decreases significantly while the temperature grows. The growth of temperature causes the increase distance between molecules, which results in the decrease of coherence force and accordingly internal friction force;
- *pressure* – the viscosity of oil increases as pressure grows, and the change follows an exponential curve. The growth caused by the approach of liquid particles, and the increase of intermolecular interactions;
- *shear rate* – dependency is the effect of the type of property that the oil exhibits, whether it behaves like a Newtonian fluid or a Non-Newtonian fluid;
- *contamination* – viscosity of the engine oil varies in service, mainly due to contamination with soot produced by combustion of fuel and lubricating components, contamination with the fuel, oxidation, thermal degradation, and water content [6, 16].

Reasons for viscosity increase [16] (see. Fig. 1):

- oxidation – this process is very dependent on temperature, contamination, and the availability of oxygen.
- contamination by residual fuel – this occurs if coagulation of asphaltenes from bunker fuel takes place within the engine oil and it is the main reason for viscosity increase of engines operating on heavy fuel oil (*HFO*);
- insolubles – significant increases of insolubles in engine oil can result from poor combustion, insufficient capacity of filters, faulty operation of purifiers, and also ingress of sulphuric acid into the oil because of low cylinder liner temperature, poor mechanical condition of the engine etc.;
- water or coolant – contamination with water forming an emulsion will increase the lubricating oil viscosity;
- admixture with another lubricant – mixing with higher viscosity oil will cause an increase in the viscosity of the total oil charge.

Reasons for viscosity decrease (see Fig. 1):

- the main cause of viscosity reduction is the dilution by light fuels, use of lower viscosity lubricating oil for topping up or by contamination with cleaning fluids [16].

If the viscosity is too small, it is difficult to form a solid oil film, and then cannot achieve the role of reducing friction with the risk of engine seizure. However if the viscosity is too large, it will cause the engine to start difficult, and also makes the oil cannot be cycle normally, resulting in equipment lubrication failure finally [2, 16]. However, decrease in engine oil viscosity is potentially more harmful to the engine than an increase of viscosity. In summary, the inappropriate viscosity of lubricating oil leads to excessive wear, unnecessary fatigue, or even catastrophic engine failure [1].

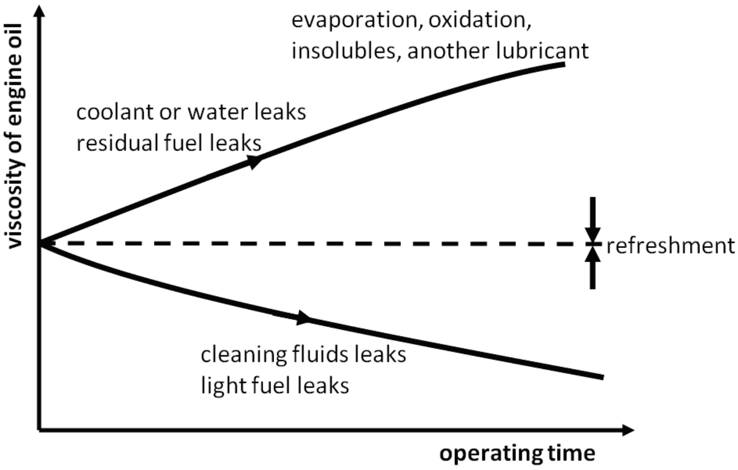

Fig. 1. Changes in viscosity of engine oil during exploitation [8]

Therefore, for engine, it is important not only to choose the type of oil correctly but also to monitor its viscosity. If a change in the oil viscosity is detected, further analysis of the oil can identify the cause of the disturbance of its properties. Variation in the oil viscosity is often the first indicator of a global problem of the tribological unit. Tab. 1 presents the list of the limited variations of the viscosity, which are used to monitor engine oil [3, 4, 13].

Tab. 1. Critical and preventive limits for engine oil for the viscosity at 100°C [13]

Limit	Limits for engine oil are indicated for the viscosity at 100°C
Critical (upper)	+20%
Preventive (upper)	+10%
Preventive (lower)	-5%
Critical (lower)	-10%

It is also worth noting that another problem in assessing the quality of the oil, is its refreshment (add new oil). It occurs unreal degradation process. In such a situation, it is difficult to determine the problem in the lubrication system [7].

3. Samples oil

The research was conducted using motor oil samples of Lotos Company – Marinol RG 1240. The trials differed in terms of overwork in three different engines:

– Main Engine Cegielski-Sulzer 8AL20/24 of 552 kW placed on the sailing vessel “Dar Młodzieży”,
– Auxiliary Engine Cegielski-Sulzer 6AL20/24 of 410 kW placed on the sailing vessel “Dar Młodzieży”,
– Laboratory engine Cegielski-Sulzer 3AL25/30 of 396 kW.

In all cases, engine oil was collected using a drain valve mounted on the oil supply system. The operating hours are shown in Tab. 2.

Marine motor oil Marinol RG 1240 is TPEO (*Trunk Piston Engine Oil*) and it is designed for lubrication of marine anhydride light fuel engines. It is formulated on the base of deeply refined, solvent dewaxed and hydro refined oil distillates received from crude oil. They contain a properly selected package of washing and dispersing additives as well as auto-oxidising, anticorrosion, antirust, and anti-wear attributes. Parameters Marinol presents in Tab. 3. The oil fulfils the API CD requirements (*American Petroleum Institute*, category CD) for marine engines [18].

Tab. 2. Operating hours of tasted oils

Samples	Source	Hours of operation
Sample 0	New Marinol RG 1240	0
Sample 1	Main Engine Cegielski-Sulzer 8AL20/24	1000
Sample 2	Auxiliary Engine Cegielski-Sulzer 6AL20/24	650
Sample 3	Auxiliary Engine Cegielski-Sulzer 6AL20/24	880
Sample 4	Auxiliary Engine Cegielski-Sulzer 6AL20/24	1030
Sample 5	Laboratory Engine Cegielski-Sulzer 3AL25/30	600
Sample 6	Laboratory Engine Cegielski-Sulzer 3AL25/30	750

Tab. 3. Parameters of engine oil – Marinol RG 1240 [18]

Requirements	Research methods by	Unit	RG 1240
Kinematic viscosity at 100°C	ASTM D-445	mm^2/s	14.3
Pour point	ASTM D-5950	°C	-24
Flash point	PN-EN ISO 2592	°C	260
Base number	ASTM D-2896	mgKOH/g	12.5
Viscosity index	ASTM D-270		96
Corrosion effect at 100°C, 3h, Cu	PN-EN ISO 2160 ASTM D-130	degree	1

4. Experiment

The experiments have been performed at -10 to 100°C range for all samples, researchers used the rheometer Haake Mars III of Thermo Scientific company (device is shown in Fig. 2). Shear rheometer utilizes a controlled instrument, to induce stress. The tests were conducted using the cone-plate system. During tests, the parameters of rheometer were as follows:

– temperature range from -10°C to 100°C, resolution about 0.35°C,
– shear rate γ = 100 1/s.

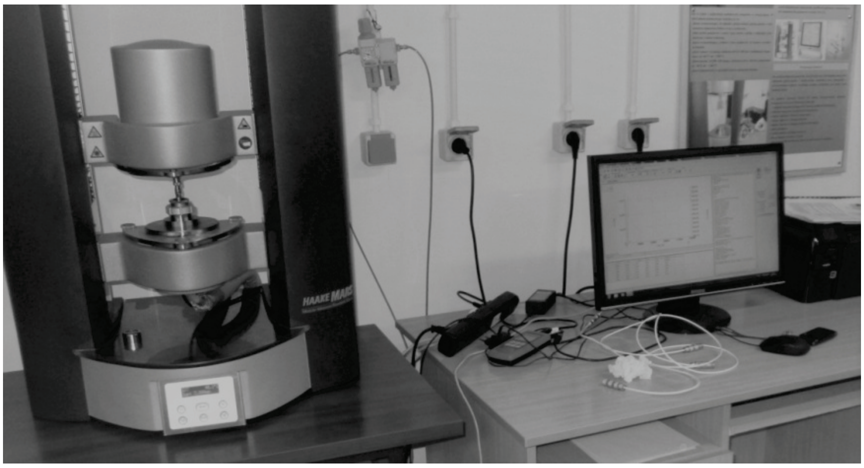

Fig. 2. Rheometer Haake Mars III of Thermo Scientific Company

Designated points of the viscosity – temperature relationship, constitute the mean value of three measurements. Lubricating oil Marinol RG 1240 operates typically of liquids and in all tested samples the viscosity decreases while the temperature rises at completely tested range (Fig. 3).

It is difficult to distinguish the differences between oils characteristics from the graph shown in Fig. 3, thus for the typical temperatures (-10°C, 0°C, 10°C, 20°C, 40°C, 60°C, 100°C) the results are shown in Tab. 4. The percentage discrepancy in dynamic viscosities is also indicated to evaluate the values of viscosity regarding the critical limits, which are − 10% and + 20% of the value of fresh oil viscosity (see Tab. 1). Since a variation of this magnitude, represent a reduction in lubrication properties of engine oil.

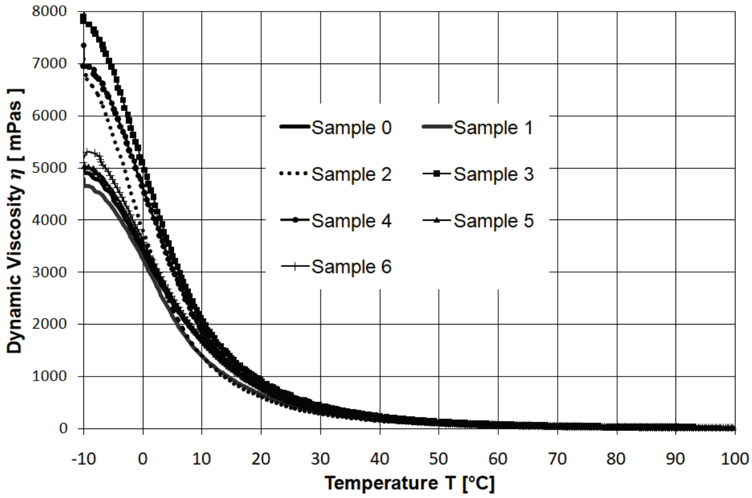

Fig. 3. Graph of the dynamic viscosity – temperature changes for Marinol RG 1240 for different measurement samples

Tab. 4. Test results of viscosity – temperature changes and percentage discrepancies in reference to fresh oil

Samples	Unit	-10°C	0°C	10°C	20°C	40°C	60°C	100°C
Sample 0	**mPas**	**4.98**	**3.318**	**1.628**	**0.764**	**0.1813**	**0.0598**	**0.01181**
Sample 1	**mPas**	**4.69**	**3.252**	**1.402**	**0.648**	**0.165**	**0.055**	**0.01173**
discrepancy	%	*-6.0*	*-2.0*	*-13.9*	*-15.2*	*-9.0*	*-8.0*	*-0.7*
Sample 2	**mPas**	**7.585**	**3.946**	**1.462**	**0.67**	**0.1693**	**0.0496**	**0.01303**
discrepancy	%	*52.0*	*18.9*	*-10.2*	*-12.3*	*-6.6*	*-17.1*	*10.3*
Sample 3	**mPas**	**8.075**	**4.519**	**1.778**	**0.76**	**0.1855**	**0.0725**	**0.01387**
discrepancy	%	*61.8*	*36.2*	*9.2*	*-0.5*	*2.3*	*21.2*	*17.4*
Sample 4	**mPas**	**8.123**	**5.094**	**2.042**	**0.886**	**0.2181**	**0.0644**	**0.01401**
discrepancy	%	*62.8*	*53.5*	*25.4*	*16.0*	*20.3*	*7.7*	*18.6*
Sample 5	**mPas**	**5.148**	**3.498**	**1.711**	**0.779**	**0.192**	**0.063**	**0.01323**
discrepancy	%	*3.2*	*5.4*	*5.1*	*2.0*	*5.9*	*5.4*	*12.0*
Sample 6	**mPas**	**5.098**	**3.612**	**1.693**	**0.762**	**0.191**	**0.0632**	**0.01367**
discrepancy	%	*2.2*	*8.9*	*4.0*	*-0.3*	*5.4*	*5.7*	*15.7*

The behaviour of viscosity-temperature relationship of the measured samples is very different. The biggest discrepancies between fresh oil (sample 0) and samples of used oil are visible for temperature below 0°C. The disparity for sample 4, at −10°C temperature was even 63%. This is extremely important for cold start of engine. For temperature above 20°C, the discrepancies do not exceed 20%, for all samples.

The engine oil from the Main Engine of "Dar Młodzieży" (engine – Cegielski-Sulzer 8AL20/24) is one of the samples, which the viscosity decreases at all temperatures. For a temperature of 100°C, discrepancy accounts for just 0.7 %. It can be concluded that the quality of engine oil is monitored and lubrication system is taken care of. It is possible a problem for cold start of engine, because of decrease of viscosity at 10°C by 13.9% and 20°C by 15.2%.

The following 3 samples of oil after 650 hours, 880 hours and 1030 hours of use from the Auxiliary Engine of "Dar Młodzieży" (Cegielski-Sulzer 6AL25/30) were investigated. For temperature 100°C, the viscosity increases of 10.3% (sample 2), 17.4% (sample 3) and 18.6%

(sample 4). The last sample of this type of oil is very close to the critical limit (+20%); therefore, it is recommended to change the engine oil. For the other measured temperatures, the viscosity--temperature relationship behaves in the different way. Sample 2 has a decrease in viscosity for temperatures in the range from 10°C to 60°C, discrepancy from -17.1% to -6.6%. For sample 3, the viscosity reduction is only at one temperature 20°C, which is 0.5%. For sample 4, in all temperatures the viscosity increases in reference to fresh oil. The different behaves of viscosity curves show that engine oil was refreshed (added fresh oil) after first sample taken. It occurs unreal degradation process. In such a situation, it is difficult to determine the problem in the lubricating system of auxiliary engine. All type of contaminations may be present in the lubricating system of this auxiliary engine: fuel, fresh water, seawater, insolubent, other lubricant etc.

The smallest changes of viscosity-temperature relationship are noted for oil from laboratory engine (Cegielski-Sulzer 3AL25/30). The increase in viscosity is observed in the temperature 100°C, for the sample 5 i.e. 12% and for the sample 6 i.e. 15.7%. This is above preventive limit (+10%), therefore it is recommended broader analysis this engine oil. This engine works very little hours during the year and most of the time it is unused. Thanks to the spectroscopy analysis of trace elements [11], it is known that the largest contaminations of the oil are air pollutions. All external particles (dust, dirt, smoke) are sucked together with air into the crankcase, and they contaminate the oil.

5. Conclusion

The article analyses the effect of the purpose of engine on the viscosity in circulating engine oil. Three engines from Cegielski-Sulzer were compared: Main Marine Engine of „Dar Młodzieży" 8AL20/24, Auxiliary Marine Engine of „Dar Młodzieży" 6AL20/24 and laboratory engine 3AL25/30. The number of working hours of oil samples was within limits of 600 to 1030 hours.

Lubricating oil degradation is a very complex, unpredictable and complicated process. It is very important to monitoring and analysing quality of engine oil. Lubricating oil analysis has become an effective mean to provide early warnings in the failure progression because it contains valuable information regarding the aging and damage of oil-wetted moving components. First most crucial factor, which can indicated problem in lubricating system it is viscosity of oil. The viscosity is the measure of internal friction in a fluid, which acts as a resistance to change of molecule position in moving fluid exposed to shear stress. It has a profound impact on the combustion efficiency of diesel engines, thus having a notable influence on their expected life.

If a little change in the oil viscosity is detected (especially in viscosity-temperature relationship), further analysis of the oil can identify the cause of the disturbance of its properties. It may be helpful to add measurements another parameters, such: total base number, flash point, wear debris concentration, water, and soot contents, etc.

High viscosity value in oil indicates that contamination or oxidation are deteriorating the lubricant, whereas, low viscosity value indicates decrease in the dilution property of the oil. Variation in the oil viscosity is often the first indicator of a global problem of the tribological unit.

After the refreshment of lubricating oil occurs unreal degradation process. In such a situation, it is difficult to determine the problem in the lubrication system.

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