# THE INFLUENCE OF OIL REFILLING STRATEGY ON THE AMOUNT OF OIL IN TRUNK PISTON MARINE DIESEL ENGINE LUBRICATING SYSTEM

**Andrzej Młynarczak**

*Gdynia Maritime University, Department of Marine Power Plant*
*Morska Street 81-87, 81-225 Gdynia, Poland*
*tel.: +48 58 6109 324*
*e-mail: mlynek@am.gdynia.pl*

***Abstract***

*The issues connected with the amount of lube oil in engine oil system are real problems in marine diesel engines maintenance process. The amount of lube oil in circulation influences its quality and consequently the wear of lubricated parts. That amount still changes and is connected with lubricating oil refilling strategy. The results of simulation carried out for SULZER 8S20U and PIELSTICK 12PC2-5V engines allowed to determine the influence of lubricating oil refilling strategy on the amount of lube oil in circulation. Frequent topping-up at regular intervals can be arranged to maintain the sump working capacity at the chosen percentage of the design maximum (for example 90 per cent), while a significantly delayed topping-up might allow the working capacity to be reduced to as low as about 50 per cent of the maximum. Thus a significantly reduced lubricant amount may have a disadvantageous influence on engine elements wear (i.e. piston rings, cylinder liners) and consequently cause the growth of the engine overhaul costs, although in far perspective, it would be difficult to connect that fact with the amount of oil in circulation. On the other hand in small output trunk piston engines without sump tanks, delayed topping-up and operation with minimum oil level could give some economic and ecological advantages resulting from reduced oil consumption. But in marine conditions (rolling and trim changes) it would be very hazardous for the engine safety operation.*

***Keywords:*** *marine diesel engine, lube oil , refilling strategy*

## 1. Introduction

Constant development of marine engines causes the quality of its construction elements to be better and better. One of these elements is lubricating oil which depending on kind of engine (crosshead engine, trunk piston engine) has various tasks to perform.

As the time is passing, lubricating oil in marine engine lubricating oil system loses its properties. The refilling process is one of the lubricating oil maintenance methods. The amount of fresh oil added to lubricating oil system always balances its consumption, but the way of refilling depends on marine engineer. He can add small portions of fresh oil in short time intervals or big ones in long time intervals. It is always possible to maintain constant amount of oil in lubricating oil system by continuous refilling.

In author's opinion the refilling strategy can influence the most important oil quality properties (viscosity, mass concentration of solid impurities, total base number). These properties influence the wear of tribologic system elements i.e. piston-ring-cylinder of trunk piston engines and working period of lubricating oil in engine lubricating system. These factors determine costs of spare parts, maintenance and lubricating oil.

Research results leading to determine the influence of lubricating oil-refilling method on mass concentration of solid impurities and total base number were presented in previous works [6-8]. But when choosing the best refilling strategy an engineer should take into consideration the fact that the above mentioned strategy affects not only oil properties (mass concentration of solid impurities and total base number) but also the amount of lube oil in engine oil system. The latter one influences safe work of engine and oil quality as well. The article aim is to determine the influence of lubricating oil-refilling methods on the amount of lube oil in engine oil system.

## 2. The influence of the amount of lube oil in circulation on oil properties

The influence of the amount of oil in lubricating system on oil quality was investigated by many scientists years ago [3, 9, 10]. The amount of oil in lubricating system has an effect on solid impurities velocity escalation and cleaning efficiency [9]. In case of small and mean output trunk piston marine diesel engines oil systems, which usually are characterized by cleaning efficiency below 10 kg/h, the amount of oil is recommended to be increased because solid impurities stability level decreases as a result. If cleaning system efficiency increases the effect of oil amount in lubricating oil system on solid impurities stability level decreases. Decreasing the lubricating oil amount which is permissible in high efficiency cleaning systems, may somehow cause increasing the velocity of alkalinity additives consumption and consequently increasing the deposits in combustion chamber and engine elements wear i.e. pistons, piston rings, cylinders.

The influence of the oil amount in circulation on solid impurities velocity escalation is different in the presence of water in lube oil. Water catalyses oxidation process and consequently raises organic impurities (also acids) forming velocity, decreases lubricant detergency-dispersion properties and as a result raises deposit formation on engine elements. In that case reducing lubricant amount in oil system causes lowering of organic impurities forming velocity (as a result of shortening water time in the oil). However, according to research results presented in [3], oxidation products formed in marine diesel engine crankcase are only about 2% of their total amount. Oil contamination depends mainly on hydrocarbons oxidation products formed inside engine combustion chamber. Therefore increasing lubricant amount in lubricating oil system finally has advantageous influence on oxidation process, additives consumptions and wear velocity of engine elements [13].

Casale, Davidson and Lane [1, 2] claim, that wide variations of sump level from the design-intended optimum are undesirable. In fact, the amount of oil in circulation influences the stress imposed upon the lubricant. A working capacity of at least 85-90 per cent of design maximum is advisable. The minimum should be not less then 60 per cent. Fig. 1 illustrates that point of view.

Frequent topping-up (t) at regular intervals can be arranged to maintain the sump working capacity at the chosen percentage of the design maximum (in the example – 85-90 per cent), while a significantly delayed topping-up (T) might allow the working capacity to be reduced to as low as 60 per cent of the maximum. Thus a significantly reduced lubricant amount may have a disadvantageous influence on engine elements wear (i.e. piston rings, cylinder liners) and consequently cause the growth of the engine overhaul costs, although in far perspective, it would be difficult to connect that fact with the amount of oil in circulation [2].

On the other hand in small output trunk piston engines without sump tanks, delayed topping-up (T) resulting in higher lubricant level drop (see Fig. 1), decreases lubricate oil consumption. Research results show that the smallest oil consumption (both per hour and elementary) occurs for minimum crankcase level [5]. Raising oil level from minimum to maximum causes oil consumption raise of about 25 per cent, but variations between minimum and average level are insignificant for oil consumption. So, delayed topping-up in wet crankcase engines and operation with minimum oil level could give some advantages resulting from reduced oil consumption.

Any oil consumption results in emission of particulates - hydrocarbons, metals deriving from oil additives for example calcium or zinc. Most of these particulates manifest serious hazardous properties, mainly carcinogenic ones [4]. Therefore the limitation of lube oil consumption is one of the essential steps towards the reduction of environmental protection. So, as a consequence of delayed topping-up strategy_not only lube oil cost cutting but also ecological effect might be achieved. However the author feels that it would be a hazardous approach in marine conditions because of rolling of a ship. Firstly, in these conditions the estimation of oil level in engine

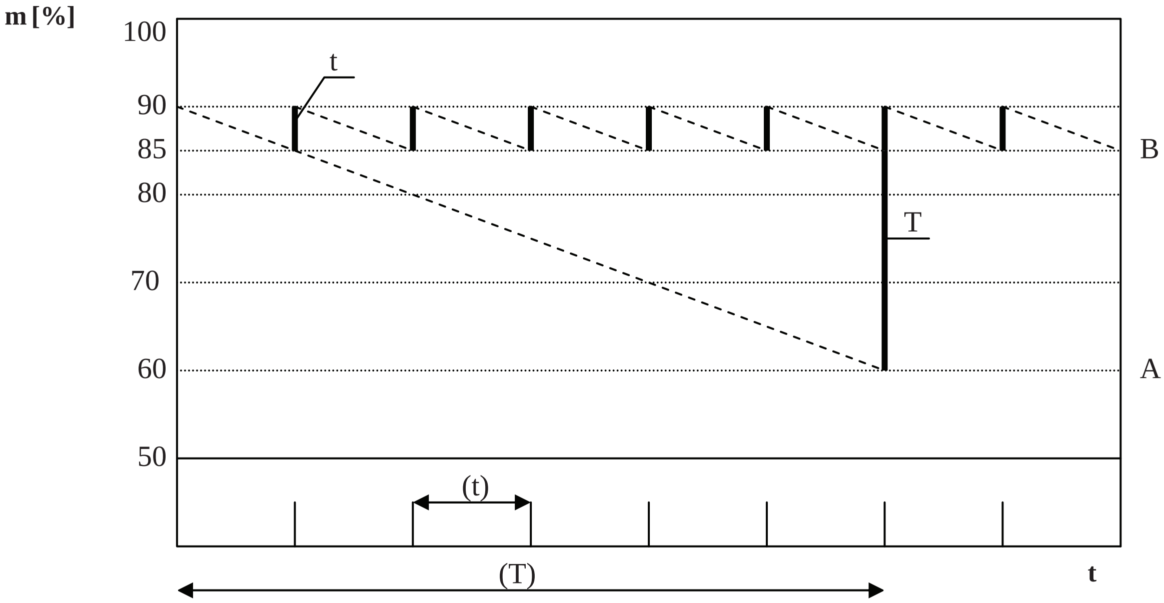


*Fig. 1. Topping-up practices in trunk piston marine diesel engines [2]*

crankcase can not be accurate and there is a risk of engine operating with insufficient oil amount which can lead to serious failure (seizing of cooperating elements). Secondly, as mentioned above, increased lube oil amount in circulation advantageously influences oxidation process, additives consumptions and wear velocity of engine elements.

## 3. The influence of oil refilling strategy on the amount of oil in circulation [6]

In real operation of trunk piston marine diesel engines the refilling process goes on periodically after consuming some oil and the amount of oil in circulation still changes. In that case we can say about the average operating mass of oil $\overline{m}$ which is defined by the following formula:

$$\overline{m} = \frac{1}{\Delta t}\int_0^{\Delta t} m dt = m_o - \frac{G_o \cdot \Delta t}{2}, \tag{1}$$

where:
$\overline{m}$ - average operating mass of lube oil in circulation [kg],
$m_o$ - initial mass of lube oil in circulation [kg],
$G_o$ - lubricating oil consumption per hour [kg/h],
$\Delta t$ - time between the following refillings [h].

Analysing equation (1) we can notice that the average operating mass of oil in circulation, among other things, depends on time between refillings $\Delta t$ - that is on the used refilling strategy. That strategy can be defined by parameter $d$ which determines the amount of added oil related to initial oil amount in circulation. Equation (2) shows its definition:

$$0 < \Delta t < \frac{m_o}{G_o} \text{ for } d = \frac{G_o \cdot \Delta t}{m_o}. \tag{2}$$

Considering expression (2) equation (1) takes the following form:

$$\overline{m} = m_o \cdot \left(1 - \frac{d}{2}\right). \tag{3}$$

As an example, Fig. 2 and 3 present the average operating masses of oil in the circulation of PIELSTICK 12PC2-5V and SULZER 8S20U marine engines, according to formula (3) for different refilling strategies.

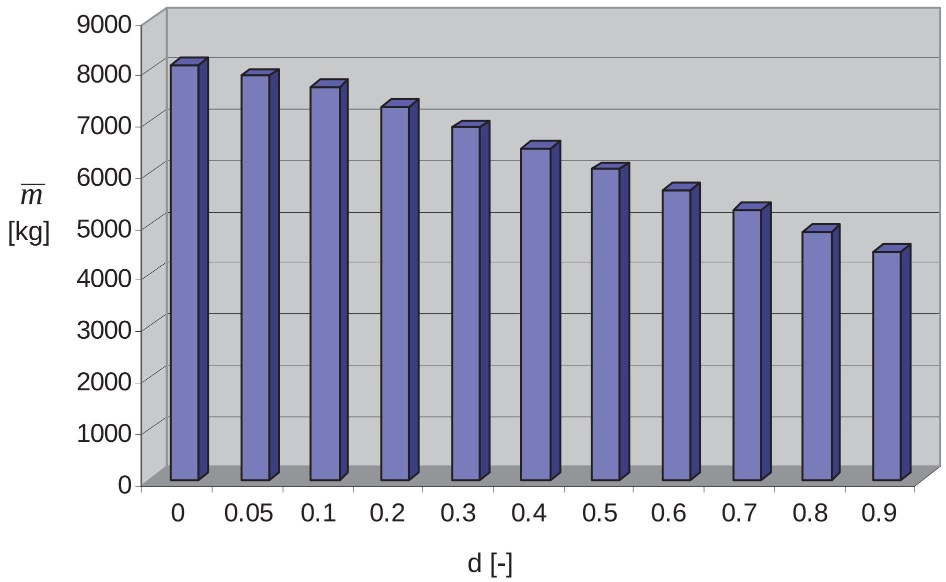


*Fig. 2. Changes of average operating oil mass in PIELSTICK 12PC2-5V engine circulation versus refilling strategy*

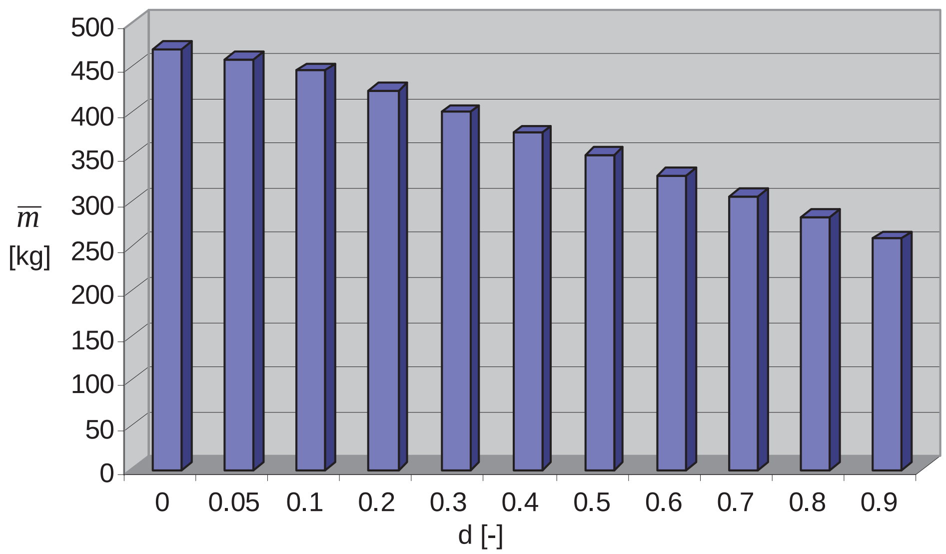


*Fig. 3. Changes of average operating oil mass in SULZER 8S20U engine circulation versus refilling strategy*

In case of continuous oil refilling ($d = 0$ on Fig. 2 and 3) the average operating mass of oil in circulation remains at constant design maximum level. In real operation of marine engines continuous refilling is impossible. The refilling process goes on periodically after consumption of some oil. It is illustrated in Fig. 2 and 3 for $d$ parameter values changing from 0,05 to 0,9. These values determine the masses of added oil related to initial oil masses in the engine oil system. Analysing Fig. 2 and 3 we can notice that used topping-up practices influence the average amount of oil in circulation. Raising added oil portions (raising time between the following refillings) it is possible to diminish the average operating oil mass in circulation.

In practice the range of $d$ parameter changes is strictly limited by minimum sump level (determined by engine maker), which ensures continuous lubrication of engine elements in marine conditions (rolling, trim changes), that is safe operation of the engine. For SULZER 8S20U engine the minimum amount of oil in sump tank during engine operation is 380 l [12] whereas for PIELSTICK 12PC2-5V engine it is 4500 l [11]. Consequently, the maximum related amounts of added oil will be the following: for SULZER 8S20U engine - $d_{max} \approx 0{,}3$ and for PIELSTICK 12PC2-5V engine - $d_{max} \approx 0{,}5$.

## 4. Conclusions

1. Wide variations of sump level from the design-intended optimum are undesirable. More amount of lubricating oil in circulation diminish the stress imposed upon the lubricant, oxidation process velocity, alkalinity additives consumption and advantageously influences the cleaning system efficiency.
2. In real operation of trunk piston marine diesel engines the refilling process goes on periodically and the amount of oil in circulation still changes depending on realized refilling (topping-up) strategy. Bearing in mind the average oil mass in circulation, which should be the highest, the method of the smallest portions of added oil $d \to 0$ at short intervals appears to be the best.
3. In marine engines without sump tank delayed topping-up and operation with minimum oil level could give some economic and ecological advantages resulting from reduced oil consumption. But in marine conditions (rolling and trim changes) the estimation of oil level is inaccurate, so for the engine safety operation it would be a very hazardous practice.

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