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ADJUSTMENT OF CYLINDER LUBRICATING OIL OF MARINE SLOW-SPEED ENGINES

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Abstract

The article refers to the common task of lubrication system. The fast development of the world's maritime sector, makes competition among countries increasing. Because of the deterioration of the global economy, the shipping companies, ship-owners want to reduce freight rates, to meet safety requirements, as well as improving conditions of exploitation and operating the machines to prevent the pollution of the marine environment. While exploiting the diesel engine in general and Sulzer diesel engines in particular, ship owners are always eager to reduce the operating cost and still ensure the engine running are safe and reliable. Provide an example of how to calculate the amount of cylinder lubricating oil according to the theory of slow-speed marine engines. The article refers to the costs of the operation and exploitation of ship, offer solution to reduce extraction costs by optimizing the amount of lubricating oil for the cylinders. The analyses in the article are based on Sulzer RTA engines. The article also refers to the level of actual lubrication oil for the cylinders of slow-speed marine engines during operation and exploitation based on the practical experience of the chief engineers, who had ever worked with these engines. The optimal adjustment of cylinder lubricating oil of Sulzer RTA diesel engines to reduce the operating cost but still ensure the engine running are safe and reliable and the problems need to be noted in the process of adjustment.

Keywords: *cylinder lubricating oil system, slow-speed engines, optimal adjustment, Sulzer diesel engines*

1. Introduction – the necessity of adjusting the level of cylinder lubricating oil

The strong growth of the world's maritime sector makes and competition among countries is increasing. Along with the deterioration of the global economy, the shipping companies, ship-owners want development to need reduced freight rates, to meet safety requirements, as well as improving conditions of exploitation, operating the machine to prevent the pollution of the marine environment. While exploiting the diesel engine in general and Sulzer diesel engines in particular, ship owners are always eager to reduce the operating cost and still ensure the engine running are safe and reliable. According to a report by the ship operators also as ship owners, the operating costs of the vessel is shown in Fig. 1, in which we see the cost of cylinder lubricating oil occupy a relative proportion (3%) [5, 6]; while costs such as crew costs, engine maintenance, maintenance of the ship it is difficult to change. So operation cost for ship can be reduced by reducing cost for marine engine diesel fuel and cost for cylinder lubricating oil. The article mentioned here is reducing the cost of cylinder lubricating oil by determining the exact amount of lubricant oil level.

Therefore, determining the exact amount of cylinder lubricating oil is a very important. As the design instruction for the previous manufactured engines, cylinder lubricating oil level of Sulzer engines is smaller than 1.4 g/kWh [2-4]. Nowadays, the engines designed and manufactured upon new technology that allows exploiting the engine with the oil flow for cylinder is 1.1 g/kWh. In fact, as reported by the direct operators on board, the oil level is about 1.6 g/kWh, because the professional qualifications of exploitation, operators are not equal and the same. After experts analysing, evaluating on this engine's practical running and pointing out that the amount of cylinder lubricating oil can be reduced to 0.9 g/kWh and still ensure the longevity of cylinder and ring. Thus, this new oil level can entirely save up to 0.5 to 0.7 g / kWh.

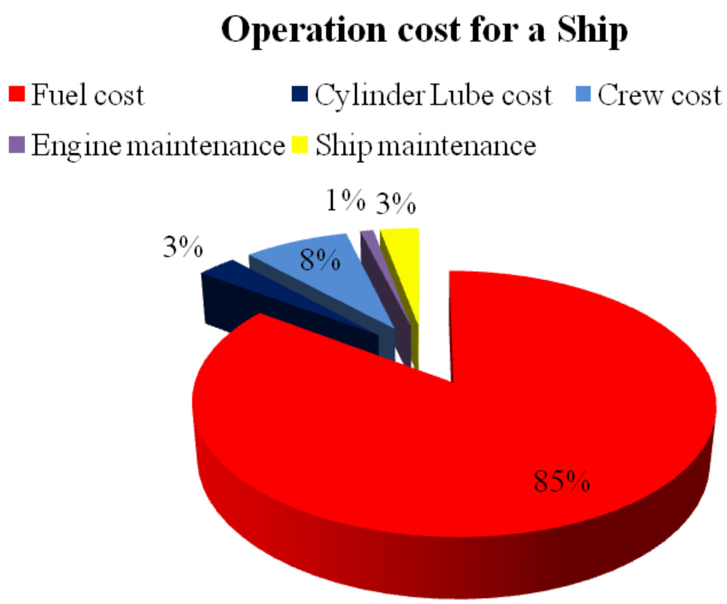

Fig. 1. Operation costs for a Ship

With this saved oil, level can directly affect the engine exploiting cost, especially the engines with large cylinder diameter. In case with the Sulzer 7RTA84T-D diesel engine with a capacity of 29400 kW, when reducing the amount of oil supplied from a typical oil level of 1.6 g/kWh to the new oil level as in the engine instructions at 1.1 g/kWh that could save $ 100,000 per year than cylinder lubrication oil price is $ 1,300 / ton. But also with this oil price, while reducing the oil level supplying from 1.6 to 0.9 g/kWh that could save $ 140,000 per year.

Thus, the reducing of cylinder lubricant oil amount is considered as one of the main methods to reduce the engine exploiting cost that can save 3-5% in fuel costs. This depends on the type of engine, engine power, the engine speed, as well as the relationship between the fuel price and cylinder lubrication oil price.

2. An overview of the lubrication systems

The movement of various engine parts under high speed and load conditions creates the requirement for an engine lubrication system. Without some lubricant, friction between parts would quickly wear and generate heat causing severe engine damage and eventually destroyed. The lubrication system has important functions to good engine operation and durability [1]. Lubrication systems in a diesel engine accomplish the following tasks:

- reduce friction between moving parts, which minimizes engine wear, and the creation of heat,
- cools a variety of internal engine parts and removes some heat from the engine,
- removes dirt, abrasives and contaminants from inside the engine,
- assists sealing of the combustion chamber by forming a film between the piston rings and the cylinder wall,
- absorbs shock loads between bearings and gears thus, cushioning and protecting engine parts while minimizing engine noise production,
- stores an adequate supply of oil for lubricating internal engine parts,
- minimizes corrosion of internal engine components.

The cylinder liners on a two stroke marine engine are lubricated using separate injection pumps which use a different specification of oil (see Fig. 2). The oil, which is led to drillings in the liner, is able to deal with the acids produced by the burning of high sulphur fuels.

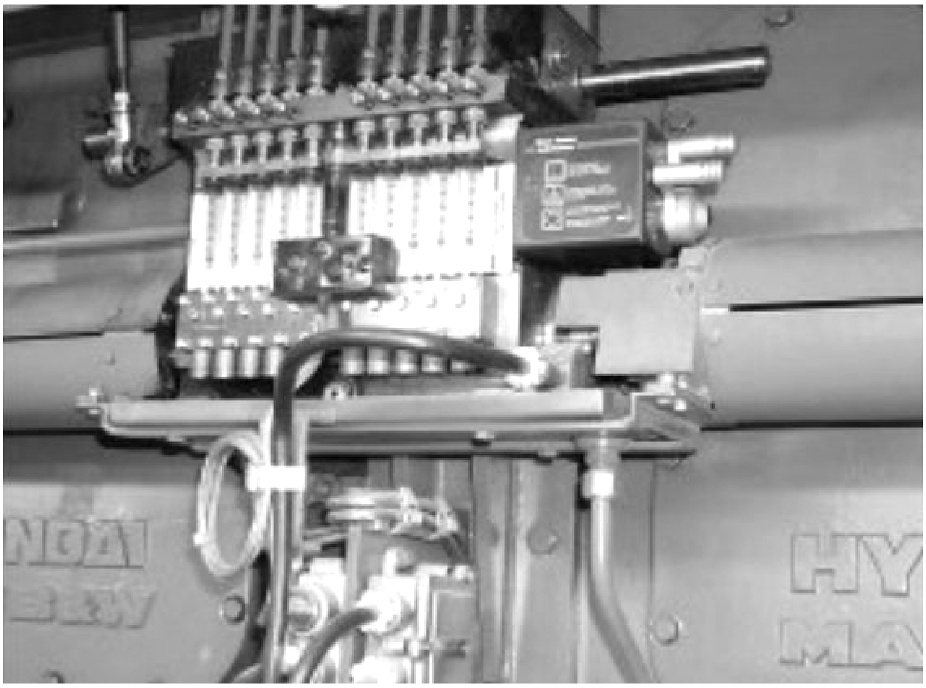

Fig. 2. Lubricating oil pump for cylinders of slow-speed marine engines

3. The amount of cylinder lubricating oil according to the theory

Currently, marine slow-speed diesel engine occupies a large market share in the world. These engines are two-stroke diesel engines equipped with lubrication oil system for each cylinder. Each engine will have an instruction about the amount of cylinder lubricating oil based on operating hours and load. These parameters are generally calculated according to the formula or test and recorded in the engine's profile.

An example of the cylinder oil feed rate calculation is presented below. Considering a Sulzer 10RTA-flex96C type engine with the new lubricating pump design and operating at 40.0 MW with the following parameters set [5, 6]:

- type: 10RTA -flex96C,
- max. continuous power: 54920 [kW],
- max. continuous speed: 100.0 [rpm],
- minimum speed: 21 [rpm],
- stroke number: 2,
- number of cylinders: 10,
- stroke: 2500 [mm],
- cyl. bore diameter: 960 [mm],
- mean indicated pressure: 19.3 [bar],
- the cylinder oil density: 0.90 kg/l at 40°C,
- the upper quill set to position 1 with a discharge capacity of 0.27 ml/stroke (should be calculated according to Tab. 1),
- the lower quills set to position 3, with a volume discharged 0.47 ml/stroke (should be calculated according to Tab. 1),
- the pump speed factor (PSF) adjusted to 1.0.

If the output frequency, read-out from the frequency converter, is 50 Hz, the lubricator pump shaft speed can be calculated by the equation No. 1. Distribution between the upper and lower quills is adjusted with the cylinder lubricating pump setting disc is presented in Tab. 2 (setting position 1 to 6 will change the pump stroke).

$$n_{lp} = f_R \cdot k_r [rpm], \tag{1}$$

where:
n_{lp} – the lubricator pump shaft speed,
f_R – frequency read-out from the converter,
k_r – frequency ratio depended on engine type – see Tab. 1.

Tab. 1. Frequency ratio of some Sulzer slow-speed diesel engines

RTA / RT-flex cylinder bore [cm]	Frequency Ratio – k_r [Pump shaft speed / motor supplied frequency]
48T-B, 52	0.57
58T-B, 60, 62	0.763
50, 68T-B, 72	1
84T-B	1.53
96C	2

Tab. 2. Setting disc position

Setting disc position	1	2	3	4	5	6
Old design [ml/stroke]	0.212	0.290	0.397	0.544	0.736	0.941
New design [ml/stroke]	0.27	0.36	0.47	0.63	0.83	1.10

The ratio of the lubricating pump shaft speed to the motor frequency is known as the Frequency Ratio (FR) and is presented in Tab. 1. This ratio depends on the engine bore and the necessary pump capacity. The cylinder oil feed rate can be calculated on the base of equation No. 2 [5, 6].

$$O_{fr} = \frac{(q_u + q_1) \cdot i \cdot n \cdot \rho \cdot 60}{P} \left[\frac{g}{kWh} \right], \tag{2}$$

where:
q_u – upper quill discharged volume [ml/stroke],
q_l – lower quill discharged volume [ml/stroke],
i – number of units (cylinders),
n – horizontal shaft speed [rpm],
P – engine load [kW].

According formula 2, the theoretical cylinder oil feed rate for the detailed engine will be:

$$Feed\ rate = \frac{(0.27 + 0.47) * 10 * 100 * 0.92 * 60}{40{,}000} = 1.02 \ \ [\frac{g}{kWh}] \ .$$

4. Adjusting the amount of cylinder lubricating oil

Based on the experience of the authors and the chief engineers, which have worked on big ships equipped with Sulzer RTA engines, the following resume can be stated: when cylinder supplied a lubricating oil level is as in the instruction (about 1.0-1.4 g/kWh), engines worked well with small & stable abrasion speed. With this level, abrasion speed in maximum is smaller than 0.04 mm / 1000 running hours. However, when experimenting with the Sulzer 10RTA-flex96C diesel engine, the chief engineers decreased oil level from 1.3 g/kWh to 1.0 g/kWh for cylinder number 2 of this engine, then measure the cylinder abrasion at the position of the highest ring when piston is at top dead centre (TDC) after running period. Researching results show, that abrasion level is almost constant as to the oil level of cylinder number 2 at 1.3 g/kWh – see Fig. 3 [5, 6]. This result makes the engine operator more confidence when deciding to reduce cylinder lubrication oil level.

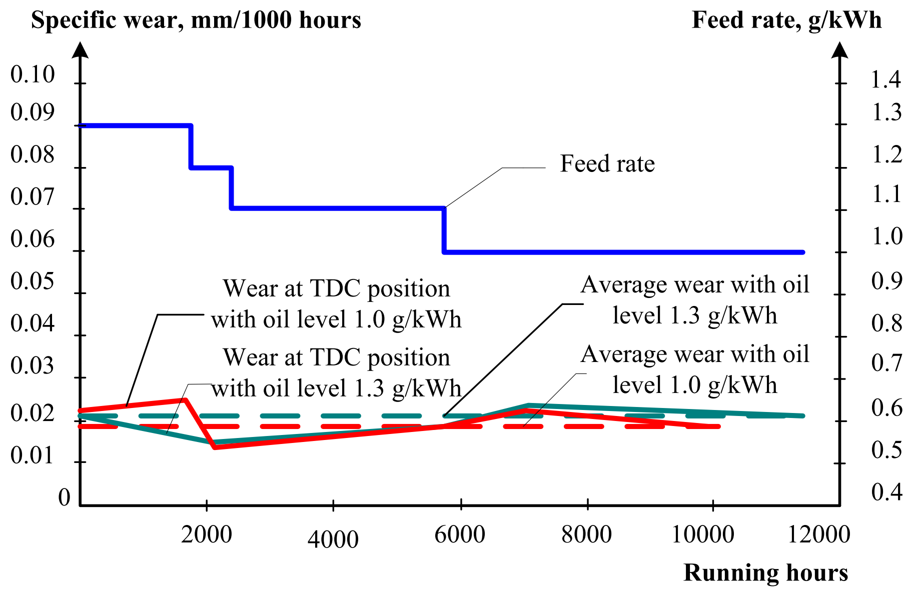

Fig. 3. The abrasion level while reducing the oil level of cylinder number 2 from 1.3−> 1.0 g/kWh of Sulzer 10RTA-flex96C diesel engine

Reducing the amount of lubricating oil to the cylinder from 1.3 g/kWh to 1.0 g/kWh, while ensuring the reliability and safety of the equipment, has helped reducing the cost of ship operator. From that help ship-owners reduce freight rates, increase competitiveness in the field of freight. This is a key issue for many ship owners, while the world economy is still in recession, dragging the maritime economy is difficult, for survival and development, the ship owners need to reduce cost ship operators.

In addition, the researches show that when the lubricant oil level reduced to the 1.0 g/kWh, the longevity of cylinder and ring was not be affected – see Fig. 4. Therefore, the replaced materials cost would not be increased. Moreover, researching results also indicate that when oil level reduced to 0.8 g /kWh, nothing occurred to the abrasion speed as well as other damages to the engine cylinder & ring.

Fig. 4. The cylinder surface and ring status of Sulzer 10RTA96C diesel engine when the oil level at 1.0 g shirt / kWh

5. Other problems of engines lubricating

During making the abrasion speed of cylinder into small values, during the exploiting process, temperature on the cylinder surface should be always maintained greater than the dew point temperature. This helps prevent corrosion on the working surface of the cylinder by acids formed from burned products. Moreover, the alkali level in lubricating oil, also known as total alkalinity level is an important factor, for ensuring the engine can work safely [1]. The reduced oil level is applicable to all types of fuel with a sulphur content of over 1.5%, so there is no need to increase the cylinder oil level when sulphur content in fuel is increased.

Besides, to achieve the abrasion level as small as mentioned above, the engine equipped with electronics oil supplying equipment, which supplies cylinder lubricant oil to nozzle, is installed on the cylinder to the oil at different levels, and oil supplying times on the cylinder surface are automatic based on the pressure difference between oil pressure with burned gas pressure inside cylinder. Oil is equally distributed on the cylinder surface by rings and grooves on the cylinder surface. This oil supplying system operates reliably without much maintenance. On the other hand, the system automatically adjusts the cylinder oil level subject to engine charge without the operator's intervention that shown in Fig. 5 [5, 6].

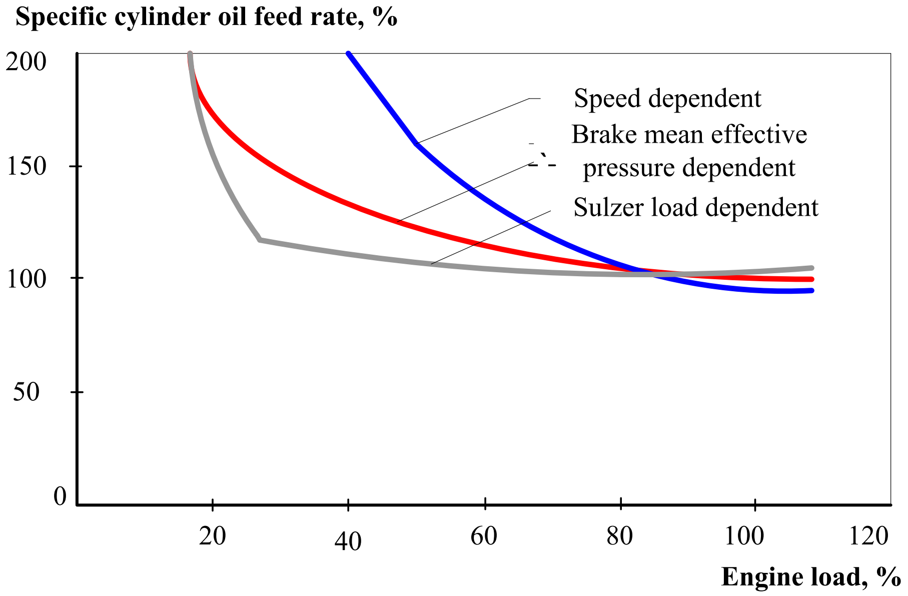

Fig. 5. The cylinder lubricant level subject to engine charge

For ship owners and operators who want to optimize the oil level, before reducing, the operators should ensure that the engine is in good status. This reduction should be divided into small steps for about 1000 running hours. Before each reduction, the engineer should pay attention to the following factors:

- observe the mirror surface of cylinder and ring through the scavenging port on the cylinder,
- analyse the concentration of metal particles and total alkalinity level in oil after lubricating in in drain tank of cylinder lubricating oil,
- measure the abrasion level of the cylinder through the scavenging port,
- measure the gap ring through the scavenging port, which reflects the ring attrition.

4. Conclusions

From the actual research results, the reduction of the oil level-supplying cylinder can be applied for all marine slow-speed engines. The above results of experimental researching have contributed greatly to the reduction of engine cost and enhanced economic efficiency for ship owners. The researching results from the presented paper can be also a useful reference for chief engineer when exploiting Sulzer marine engines equipped with electronic cylinder lubrication system.

The reducing of cylinder lubricant oil amount is one of the main methods to reduce the engine exploiting costs. The reducing costs can be a source of savings of 3-5% in fuel costs (hundreds dollar per year). This depends on the type of engine, engine power, the engine speed, as well as the relationship between the fuel price and cylinder lubrication oil price.

The research shown, that abrasion level of the engine's cylinder is almost constant after controlled reduction of oil level. This result makes the engine operator more confidence when deciding to reduce cylinder lubrication oil level. In addition, the researches show that when the lubricant oil level is reduced the longevity of cylinder and ring was not be affected. However, the reduced oil level is applicable only to all types of fuel with a sulphur content of over 1.5%. To keep engine working in safety and reliability, the reduction process should be gradually done in many different times and before each reduction, need to interest in the notes as mentioned above.

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