Semi-permanent Use of Lube Oil and Engines without Oil Change and No Waste Oil by Clean Engine Technology

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Abstract

Our recent study, field data and experiences show that semi-permanent use of engines can be realized by permanently keeping engines clean. This is because clean engines result in maintaining initial high thermal efficiency and almost no wear for a long time. This is a clean engine technology, and it has been in practical use in many marine diesel engines and in other fields. This paper reports the process in which we have arrived at semi-permanent use of engines in 3 steps.

Keywords : Semi-permanent Use, Lube Oil, Engine, Saving Resources, Environmental Protection

1. Introduction

Our recent study, field data and experiences show that semi-permanent use of engines can be realized by permanently keeping engines clean. This is because clean engines result in maintaining initial high thermal efficiency and almost no wear for a long time. This is a clean engine technology. It is very useful for saving natural resources and protecting environment.So far, we have reported on semi-permanent use of lube oil (LO) and no waste oil in [1]~[5] and some others. The technology is called kidney system. This is because it always keeps LO clean as animals' kidney always keeps their blood clean. Also, a technology for clean fuel oil (FO) has been successfully developed, because effective FO cleaning is required when low-grade FO is used. At first, semi-permanent use of engines was not expected. This paper reports the 3 steps towards the clean engine technology.

In the 1950s, Dr. Seiji SUMIMOTO advocated semi-permanent use of LO by removing sludge from used LO. He developed a chemical for cleaning LO. Then, he established a company, Sumimoto Scientific Institute Co. Ltd. (SSI) and started business to clean LO for semi-permanent use. Chemical cleaning of LO was done outside engines. The 1st author, Mr. Morio SUMIMOTO, one of sons and the successor of Dr. S. SUMIMOTO, invented a new type of filter of high performance in the early 1980s. Then, he has successfully developed a clean LO system, namely, the kidney system and an effective FO cleaning system.

The 2nd and the 3rd authors, university staffs, would like to emphasize that we are making study for the world, not for the company SSI. All the papers with our names as authors have been and shall be written by the university staffs. It is, therefore, the university staffs that are responsible for the reports. However, they are not responsible for any troubles in practical use of the technology. This is because they have nothing to do with the business of the company. Their study is strictly scientific.

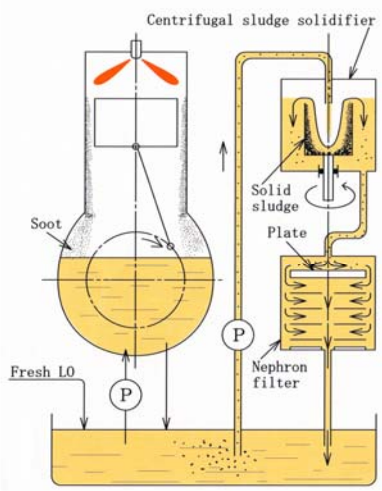


Fig.1 Kidney System

2. LO System and LO Sludge

2.1 Kidney system

Fig.1 shows the kidney system in large marine diesel engines. In general, the conventional system cleans LO by centrifugal sludge separator. The kidney system is composed of a set of the new type of filters and a centrifugal separator which is very small and simple in structure, compared with the conventional one.

As shown in Fig.1, the new type of filter has about 100 sheets of filter paper of circular shape in a cylindrical case. Every sheet has a hole at its center. As a whole, these holes form a flow path at the center of the paper sheets. As shown, contaminated LO flows down into the filter from the upper inlet, then strikes the support plate and changes flow direction toward the inner surface of the filter case. Then again, LO changes flow direction and flows between the sheets of the filter paper towards the center. Sludge particles sit on the filter paper and get removed while LO flows between the paper sheets. Thus, cleaned LO flows out of the filter through the flow path along the center. The smallest unit of animals' kidney is an organ, called nephron and, therefore, the new type of filter is called nephron filter. Most LO sludge comes from PM. Particles of 0.05~1μm in accumulation mode occupy almost all mass of both exhaust PM and LO sludge before coagulation [4][6]. Particles of about 1~1000 nm make Brownian motion [7]. They are considered to hit the filter paper and get removed by the nephron filter. Both large and small sludge particles are almost completely removed in the kidney system. Therefore, LO is permanently kept clean and there is neither oil change nor waste LO. The centrifugal separator of the conventional LO system cannot remove sludge particles smaller than 1μm. Therefore, sludge is accumulated and LO is degraded as engine running goes on. As a result, the used and contaminated LO must be repeatedly changed with fresh LO at some interval. Thus, the used LO is thrown out as waste LO.

2.2 Useful and harmful LO sludge, and Reason for semi-permanent, not permanent use of LO

LO sludge is impurities which are harmful to LO functions, such as lubrication, engine cooling, cleaning, and so on. In general, np insoluble (insoluble in normal pentane) is LO sludge and about 10 wt% of the sludge is oxidized sludge of LO and FO [1][8]. There are two kinds of oxidized LO, namely, useful and harmful [9]. Useful one is LO whose molecules are at the very beginning stage of oxidation and have about the same molecular mass as those of fresh LO. On the other hand, molecules of harmful oxidized LO are fully oxidized and have very large molecular mass with complicated chemical structure. The useful oxidized LO is soluble in base LO. It is considered that it forms a boundary layer on the lubricating surface and increases load carrying capacity of LO [5][10]. On the other hand, harmful oxidized LO is insoluble in LO and very sticky. Therefore, it sticks on the lubricating surface and catches solid particles which are harmful to lubrication. The harmful and sticky oxidized LO also sticks on the nephron filter and it is completely removed as shown later. In case of the conventional filter, however, the sticky oxidized LO blocks the mesh holes of the filter. The centrifugal separator of the conventional LO system cannot remove the harmful oxidized LO because of almost no difference of density between base LO and the oxidized LO. LO is lost as time goes on due to LO oxidation, evaporation, oil-up from crank case to combustion chamber, thermal cracking, leakage, and so on. Therefore, the lost LO must be compensated for sometimes. This is why LO can be used semi-permanently, not permanently.

3. Field and Basic Research Results

3.1 No need of detergent in kidney system

Fig.2 shows a comparison between the field results of 3 ships of the same design, except for different LO systems respectively; (1) no LO cleaning system, (2) the conventional centrifugal separator and (3) the kidney system. The 3 ships travelled almost the same route. Fig.2 shows that np insoluble was kept at about 0.1wt% of LO for 10,000h in the kidney system, and it was kept further without waste LO also after the test. On the other hand, LO contamination rapidly increased in other cases and the used LO was changed with fresh LO. Many other field data shows that np insoluble ranges from 0.01~0.2% in the kidney system. This may mainly depend on number of the nephron filters, namely, the total surface area of filter paper. These results show that the LO kidney system can permanently keep LO clean as expected. The results also show that detergent is not needed in the kidney system and that it is even harmful.

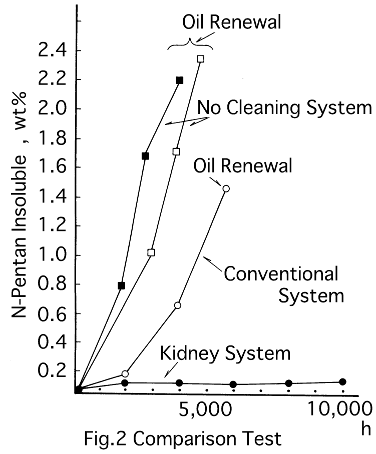


Fig.2 Comparison Test

3.2 No need of anti-oxidant in kidney system

Fig.3 shows that the harmful oxidized LO is completely removed by the nephron filter. This is an example of IR (infrared) analysis of used LO. It is well known that oxidized LO absorbs infrared radiation around 1710 waves /cm as shown by the broken line in Fig. 3. The hard line is a result of IR analysis of used LO in the kidney system. There is no absorption of radiation around 1710 waves /cm. An analysis shows that rate of LO oxidation in 4 stroke marine diesel engines is usually 0.01~0.03 wt% of LO content in normal condition [1]. As already described, fully oxidized LO is harmful. But it is negligibly small in amount, and Fig.3 shows it is completely removed by the nephron filter. Therefore, anti-oxidant is not needed in the kidney system and even harmful.

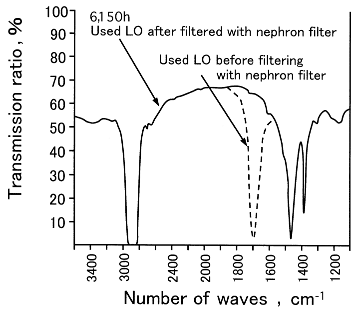


Fig.3 Oil Analysis with Infrared Spectrometer

3.3 No need of strong dispersant in kidney system

A comparison of spot tests between LO of medium duty and that of heavy duty was conducted [2]. Heavy duty means that the dispersant is strong. The result shows that sludge in LO of medium duty dispersant is completely removed after filtering 30 passes by the nephron filter. On the contrary, sludge in LO of heavy duty dispersant is not removed at all after 30 passes. This is because the strong dispersant breaks sludge into too fine particles to be removed even by the nephron filter. Therefore, strong dispersant is not needed and even harmful in the kidney system. However, it seems that dispersant of medium strength is needed because sludge coagulates and precipitates during engines stop. Then, maybe sludge is precipitated without dispersant where LO flow is stagnated.

3.4 Higher load carrying capacity of used and well filtered LO

A test result shows that used LO cleaned by the nephron filter has higher load carrying capacity than fresh LO by about 30 % [1]. It has been known since old time that used LO well filtered and cleaned is superior to fresh LO in load carrying capacity. This fact, however, seems to have been known in the limited field, for example, in the military field such as airplanes and submarines. Basic research at university obtained almost the same result [3].

3.5 No problem of blackened LO

A basic study on blackening of LO under high temperature was made at university [3]. Appearance of LO becomes black in a short time by heating in a pot with electric heater. The black appearance remains unchanged even after filtering by the nephron filter. This may be because LO molecules are thermally broken into too fine particles to be removed by the nephron filter. Load carrying capacity of the heated and blackened LO is higher than that of fresh LO if filtered by the nephron filter. This may be because the harmful oxidized LO is removed and the useful one remains. It is reported that there are some other factors for blackening LO. For example, black sludge is generated when FO mixes into LO and they are incompatible [11]. However, such sludge is removed by the nephron filter.

4. Clean FO Technology and Field Results [2]

There is so much sludge in low-grade FO, and there is an example of an extremely contaminated exhaust valve. The analysis shows that the sludge on the valve comes from LO. The sludge contains Ca, Zn and P which are main elements of LO additives. Two kinds of units for the clean FO system have been successfully developed. They are called floating high suction (FHS) and sludge breaker (SB), respectively. FHS supplies clean FO to engines from near surface of FO service tank. SB completely removes FCC catalyst particles by breaking soft sludge around the hard FCC catalyst particles.

5. Advance to Long-Life Engine

Two hurdles must be overcome to realize semi-permanent use of engines;(1) maintaining thermal efficiency of newly built engines and (2) almost no wear for a long time. Through reviewing and rearranging the old and some new data as well as some experiences as a whole, it is sure that semi-permanent use of engines has been now realized by the clean engine technology.

5.1 Maintaining initial thermal efficiency

Three cases are to be presented here. (1) A car equipped with the nephron filter was tested. The result was that thermal efficiency was kept for more than 10 years. (2) It was generally recognized that turbocharged 4 stroke engines for electric power reduced their power to about 70 % of the initial power in a year. Based on our experience in large turbocharged 2 stroke marine diesel engines and a test of the car above, it was assumed that fouling of engines caused the power loss. Therefore, a field test was made on a turbocharged 4 stroke diesel engine for electric power. The engine was equipped with the LO kidney system, the clean FO system and the fire rings which prevent combustion gas from blowing into the crank case. As expected, the thermal efficiency was kept constant for a year. The overhaul after a year of running showed that every part of the engine was as clean as that of a newly built engine. Fig.4 ~ Fig.7 show some parts of the engine after running a year. They are very clean. (3) A field test was conducted on 2 trucks in service in 2002 [2]. Before installing the nephron filter, these engines were completely cleaned by using a special chemical for engine flushing. This is because the conventional flushing can never wash away the old sludge firmly adhered on engines. As a result, thermal efficiency was recovered just after the special flushing and it was kept since then on.

Fig.4 Crank Case

Fig.5 Combustion Chamber Side of Cylinder Head

Fig.6 Radial Turbine

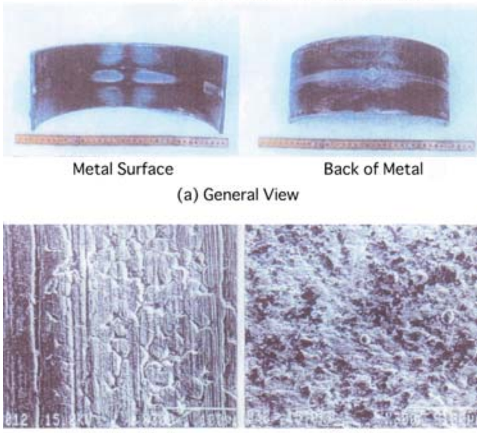
(a) New Condition (b) Used for 4 Years

Fig.7 Floating High Suction System

5.2 Almost no wear

Fig.8(a) shows a general view of crank pin metal of an engine with the conventional LO system. There is much sludge not only on the lubricating surface but also on the back. The enlarged view of the metal in Fig.8(b) shows that there are many sludge particles on the LO path and there are some scratches on the lubricating surface.

The scratches were possibly caused by solid and hard particles. This may be one of main causes of metal wear. Also, some pieces like flakes are observed on the metal. The flakes are considered to be caused by the sludge on the back of the metal. The sludge particles are considered to have repeatedly pushed up the metal from the back. Thus, the metal is considered to have been subject to repeated stress and fatigue fracture at many points. The fatigued flakes of metal will be eventually removed off and this is possibly another main cause of metal wear.



Metal Surface Back of Metal

(a) General View

Lubricating Surface Oil Path

(b) Enlarged View

Fig.8 Crank Pin Metal with Conventional LO System

There was an example of a damaged crank pin metal of an engine with the conventional LO system. In this case, a part of the metal was pushed up from the back by a lump of sludge and the metal was locally forced off. Fig.9 shows a crank pin metal of the engine equipped with the kidney system, FHS and fire rings. The engine was found very clean after running a year. There was almost no wear of the metals in this engine [2]. Fig.10 shows some main bearings of an engine for a field test of constant LO quality. There was almost no wear for 16,524h. This is to be discussed again later in 5.4.

Fig.9 Crank Pin Metal of an Engine Equipped with the FHS, Fire Ring and the Kidney System

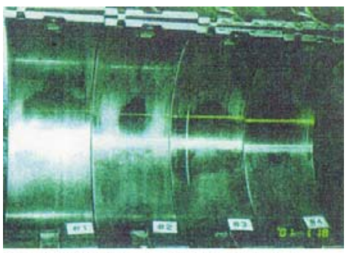


Fig.10 Main Bearing with LO Control using the Kidney System and the Others

5.3 Some recent data and experiences in field

Some typical data reported in our papers are shown in the previous part of the paper. They are rearranged in a logical way in order for us to understand the clean engine technology. Some recent data and experiences are to be presented here to help us further understand the new technology.

Four cases in Fig.11 ~ 14 show that the engines equipped with the clean engine system are very clean in comparison with the conventional system. (1) Fig.11 shows the crank case of two large 4 stroke marine engines of the same type. The clean engine is the one already shown in Fig.4. (2) Fig.12 shows the valve control side of the cylinder head of two medium size 4 stroke diesel engines. The engine with the conventional system was run using a fuel of relatively high quality FO. The photo was taken after running 4000 h. The other one with the kidney system was run using a low quality FO and the photo was taken after running 10,000 h. (3) Fig.13 shows the frame of a small high speed diesel engine equipped with the nephron filter. The photo was taken after running 10,000 h. The crankcase and bearings are very clean. (4) An engine equipped with the kidney system was over hauled according to the rule. As shown in Fig.14, there is much sludge around the FO injection valve and the exhaust valves. The sludge is localized around the FO valve. This might be because the ship had used FO containing much sludge. Except for the exhaust system, however, the engine was relatively clean as a whole. Finally, three experiences are to be presented. (1) An engine was equipped with the LO kidney system, and run for electric power in an island. There was almost no wear for more than 6,000 h running. (2) An electric power diesel engine for a lighthouse [3] was rewarded a testimonial for constant power for a long time. (3) Recently, a 4 stroke diesel engine equipped with the LO kidney system has been running for about 20,000 h, keeping np insoluble under 0.1 wt%. The thermal efficiency has been kept constant and there is almost no wear in all the sliding parts. Every part of the engine is very clean. Now, we can judge whether a 4 stroke engine is clean or not by only looking at a photo of the combustion chamber.

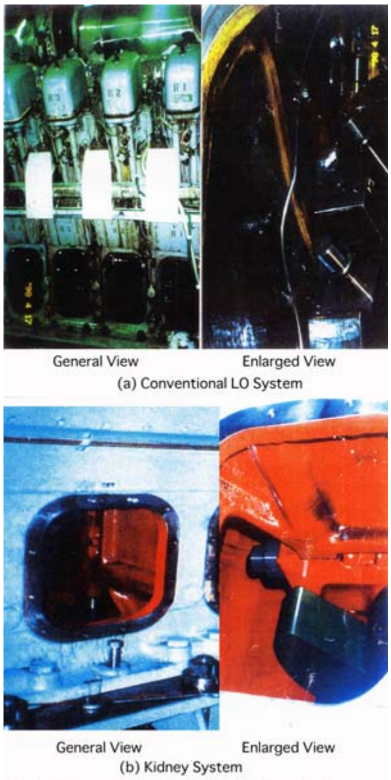


Fig.11 Comparison of Crank Case between Conventional and Kidney System

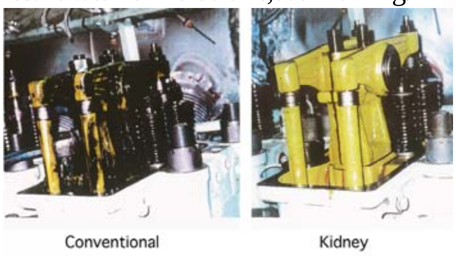


Fig.12 Comparison of Cylinder Head between Conventional and Kidney System


Fig.13 Frame of an Engine with Nephron Filter

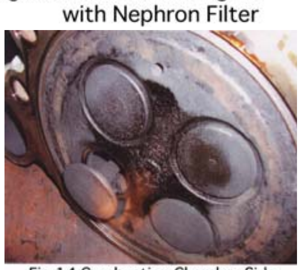


Fig.14 Combustion Chamber Side of Cylinder Head

5.4 Long life engine and new era of tribology

Our data and experiences as a whole show that semi-permanent use of engines without oil change and no waste oil is now realized. Let us review Fig.10. This was the result of a field test. The purpose of the test was to know what would come out from keeping LO quality constant. In order to keep viscosity constant, for example, all LO in service was changed with fresh LO because of a little high viscosity some time. This LO change should not have been made. Instead, some LO of low viscosity should have been added. This is because LO becomes of higher quality and of higher viscosity in the kidney system both in theory and in practice.

It must be emphasized that the clean engine technology has made a new era of tribology. It is recognized that the present-day tribology is very difficult for ordinary mechanical engineers to cope with. This is because the modern tribology depends too much on additives, or on chemistry. In other words, the modern tribology is chemical tribology. Ordinary mechanical engineers are not good at chemistry, especially at organic chemistry. As a result, it seems that chemical engineers are far dominant over mechanical engineers in this field. The modern tribology has been built on the old idea that sludge inevitably increases in LO as machine running goes on. Furthermore, almost all engineers believe that LO is rapidly oxidized and degraded. However, this is not the fact. The amount of LO oxidation is negligibly small in engines as discussed in 3.2. Many reports and books discuss rapid oxidation of LO by chemical chain reaction. Other than us, only two researchers report on small amount of LO oxidation [8][9].

From mechanical engineers' point of view, it is sure that viscosity is the fundamental factor of LO quality. Just recently, we have found that oil makers share our idea. There is a fact that 49 kinds of LO originally planned have been reduced only to 6 at a plant of TOSTEM Thailand [12]. Now, the fact is that there is almost no wear only if np insoluble is less than about 0.1 wt%, and almost no additives are not needed, even harmful. We believe this is the beginning of a new era of tribology.

6. Conclusion

Semi-permanent use of lube oil and engines without oil change and no waste oil has been established by the clean engine technology. Two points are absolutely required for semi-permanent use of engines. They are maintaining the initial thermal efficiency of newly built engines and almost no wear for a long time. Advantages of the clean engine technology are as follows, no oil change and no waste oil, no dirty and hard work to dispose of waste oil in ships, reduction of LO consumption to 1/10 ~ 1/5 in marine diesel engines, reducing FO consumption in a long time span, no need of main additives.
The R&D of semi-permanent use of LO happened to begin with large marine diesel engines. These engines use the lowest-grade FO among internal combustion engines, and therefore, LO is subject to the worst condition of contamination. Therefore, practical use of the LO kidney system is easier in other fields than in marine diesel engines. For example, the technology can easily realize no radiation contaminated LO from steam turbines at atomic energy electric power plants.
The clean engine technology has made a way to a new era of tribology in which most additives are not needed, but even harmful. It is sure that the new tribology gives mechanical engineers a powerful hand to cope with tribological problems. This is because the new tribology requires almost no knowledge of the complicated chemistry of additives. We hope that tribologists will change the conventional concept of tribology and study the new tribology of almost no wear due to minimum sludge. We also hope that more useful and effective technology will be developed by challenging engineers and researchers.

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