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Use of lube oils in terms of the structural composition of marine piston engines

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Abstract
Lube oil is applied in a number of its functional solutions for modern engines. Therefore, when application changes are implemented, simultaneously, the existing diagnostic methods should be improved. The authors have attempted to analyze the existing trends of lube oil application as a diagnostic tool and have proposed their solution.

Introduction

Marine piston engine with self-ignition (hereinafter the “engine”) is a complex technical object designed for specific operational task in severe marine conditions. In order to provide, at the required level, engine reliability and durability, numerous phenomenon and relations between them should be identified, forming relation structures. The structures may be constructed e.g. according to functional relations or specific physical phenomenon which engine parts are subject to e.g. frictions or high temperature of combustion process producing heat loads.

Application of lube oils is related with the limitation of friction impact for engine assemblies which create the systems of compatible and mobile elements. Such systems form a structure that hereinafter are referred to as the tribological structure.

Tribological structure

The tribological structure indludes systems consisting of compatible engine parts in which a measurable parameter is a geometric change of the compatible elements due to their wear and tear. Clearance volume between the compatible elements affects the value of obtained work parameters. Due to clearance measurement (in some cases already while movement, e.g. as a result of wear and tear of piston rings) we may conclude regarding the engine technical condition (e.g. piston and cylinder system) [1].

The tribological systems are present in engines with bearing assemblies of significant sizes: (main bearing, crank-bearing), slide connections (piston and cylinder, crosshead slipper and its guide, crosshead bearing, piston rod and stuffing-box for under piston space) and in small or miniature elements (precise pairs of injection valves, fuel pumps, pneumatic and hydraulic control valves). Costs and possibility to replace the elements are significantly diversed, and consequences of their damage may sometimes have serious implications [1].

Engine producers while designing the modern groups of different engine types are driven by operational factors such as: vessel type and work type (long-range shipping, ferry shipping, supporting services e.g. hauling etc.), vessel size, speed, shipping conditions (area, weather, sea currents, shallow waters etc.), vessel operation time in different operation conditions (shipping with load or with ballast, planted ship movement, long halts in ports etc.). The above data constitute the grounds for engine selection of the work field allowing its rational and practical operation [2].

On the basis of the laboratory test and operation tests the producers foresee time periods and part, component and system wear values. Time periods after which the particular services are performed, resulting from the number of working hours or legal requirements, are also anticipated. All the services are aimed at the renewal of the engine operational potential. From the economical point of view, beneficial time selection means such selection of proper work time (durability) of particular engine elements so that they were mutual multiple which would facilitate the performance of the said planned services. As far as the reliability is concerned it may cause accumulation of negative factors, often leading to serious engine work interferences or to its damage.

Lube oil as engine functional system

It is deemed that lube oil is an engine functional system. The problem is that oil is not assigned to one engine assembly or other fixed structural design, but it moves and as particle stream of many chemical compounds constitute an element of numerous engine assemblies, of different work specificity, which form specific tribological systems.

Figure 1 presents a scheme for the selected elements of tribological systems of two-stroke crosshead engine.

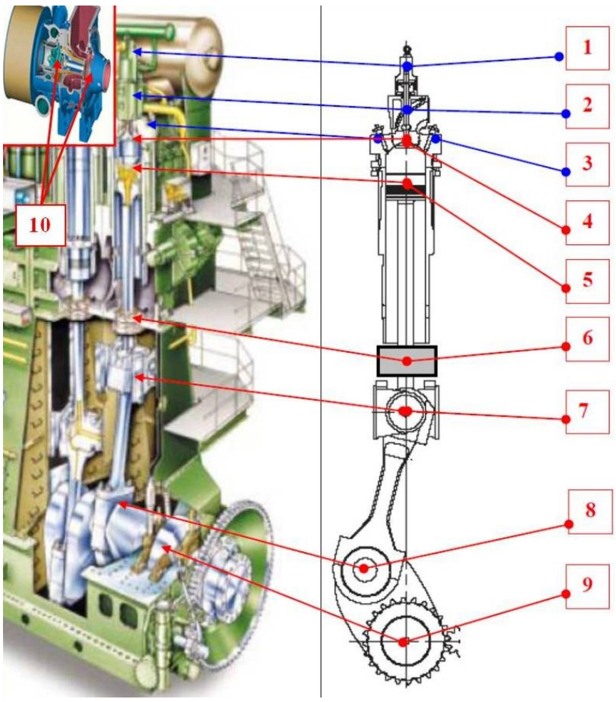

Fig. 1. Scheme for the selected elements of tribological systems of two-stroke crosshead engine [1]; 1 – hydraulic and pneumatic system for fume exhaust driver valve, 2 – guide for rod of valve head, 3 – injection valve, 4 – valve spindle – valve seat, 5 – bushing – piston, 6 – stuffing-box for piston rod, 7 – crosshead bearing, 8 – crank-bearing, 9 – main bearing of crankshaft

While identifying the work specificity of tribological systems the following division of the elements contained therein has been performed:

– elements of relatively large mass (compared to engine size) – e.g. main bearings of crankshaft, crosshead bearings, craft-bearings;
– elements of relatively small mass (compared to engine size) – e.g. cams for camshaft and fuel pump rollers, turboblower bearings, rod of valve head and bushings guiding valve head rod, mobile parts of hydraulic valves.

While engine operation in stochastic (also variable as to the number and value of present factors), severe sea conditions, tribological system elements are subject to different loads depending on mass volume of compatible elements and accelerations occurring in different external conditions.

Depending on the location in the engine structure, the tribological systems operate in different temperatures and pressures.

While analyzing functional engine structure, composed of numerous elements creating various organizational structures including engine assemblies, a division according to the further criteria may be performed:

- relatively low load and relatively low operation temperature (temperature ca. 70–100°C) – e.g. bearings for crankshaft;
- relatively high load and low temperature – e.g. crosshead-bearings, crank-bearings, main bearings of crankshaft;
- high operation temperature and low load – e.g. turboblower turbine, rod for valve head;
- high operation temperature, high unit loads – e.g. joint of rings and cylinder liner and oil combustion – e.g. cylinder liner.

Oil quality assessment methods and vessel reality

Oil quality assessment methods

Oil quality assessment methods are generally based on the phenomenological methods (measurement of actual physicochemical parameters). They determine oil state (of the adopted volume and weight) as a technical state of the engine functional system.

Taking into consideration the presence of a number of various work environments for tribological systems, it is possible to study changes in oil by quantum, dividing the oil change process into the phenomenon occurred in the tribological system and in a strictly defined time period of its work.

It allows for quantitative assessment of negative phenomenon affecting oil technical condition e.g. such as high temperature, impact of external conditions.

Both methods have advantages and disadvantages, particularly visible in real conditions of vessel operation. On a vessel, appointed engineer officers take oil samples (oils' samples) and provide them to the shipowner who orders samples' analysis to professional companies. Test results are returned together with recommendation regarding engine operation.

In the analyses, the basic values specifying engine oil state are: viscosity, combustion temperature, water content, impurity content, BN (Base Number) [3, 4, 5]. Often, the knowledge is not used rationally due to different education and knowledge level of engine operators.

Certain changes of the standard oil tests were also recommended. The tests should include the measures indicating engine oil condition such as [5]: viscosity, pH value, BN (Total Base Number), TAN (Total Acid Number), SAN (Strong Aid Number), pH value of aqueous extraction of oil, combustion temperature change, water and impurity content, metal content, microbs content (bacteria, mold or yeast). The test results constitute the valuable source of information for engine operators, improving their knowledge on oils, engines and their mutual relations. However, from the diagnostic point of view, a question about the accuracy and reliability of diagnosis should be asked.

Oil quality assessment methods in terms of the accuracy and reliability of diagnosis

Shall a diagnosis be reliable, the adopted and acceptable principles of test reliability should be complied with. Among the others, the tests should be based on accurate diagnostic information from properly selected points of oil system and proper measurement equipment [1].

It results from the analysis of the operated by the authors oil systems and the available schemes that engineers concentrate on oil processing and improvement of oil properties (cooling, purifying, filtering, losses refilled with fresh oil) in that part of oil system structure which is located before the inlet to the engine, and after leaving the operated tribological systems, the oil flows into a tank. In the tank streams of oil of various technical condition are mixed.

An oil system is composed of oil tank (tanks), pipelines, filters, coolers, centrifuges, transport pumps (Fig. 2) [6]. There is only one filter (5) at the inlet to the engine.

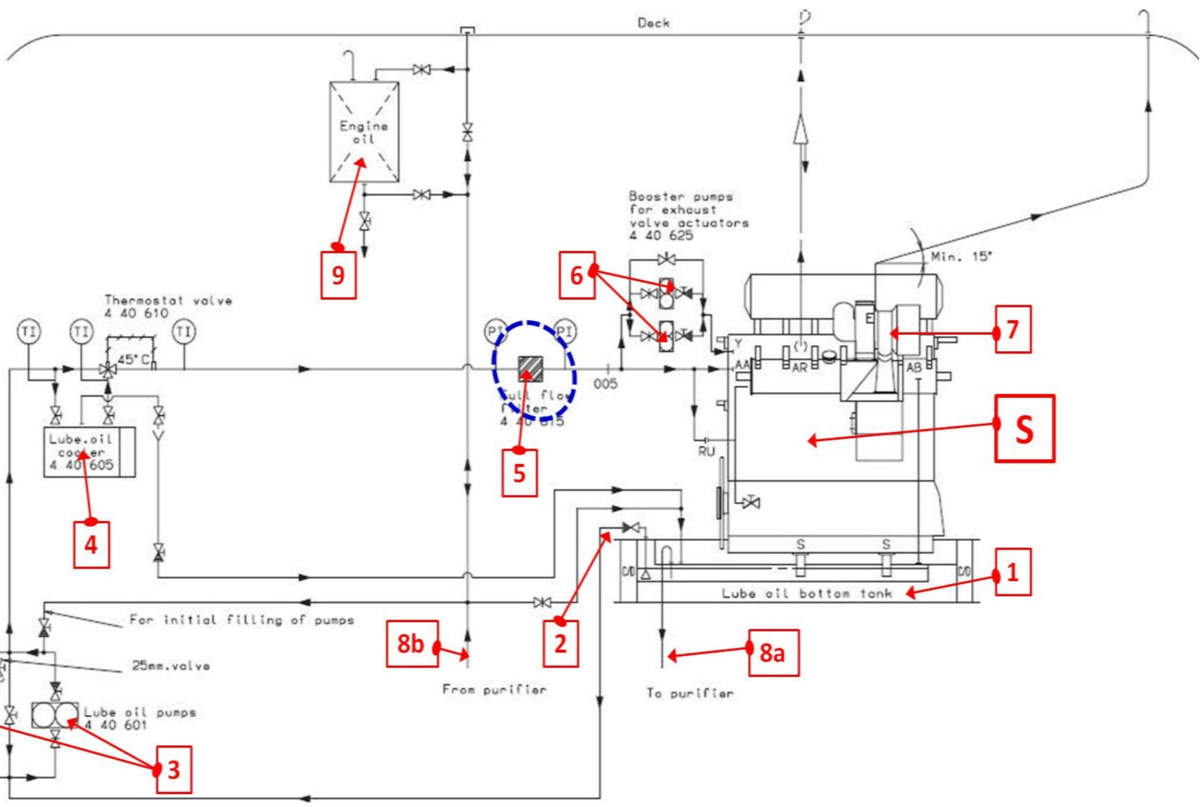

Fig. 2. Lube oil system scheme for engine S70 MC of MAN [6]: E – engine; 1 – lube oil bottom tank, 2 – oil provider from tank, 3 – lube oil pumps, 4 – oil coolers, 5 – filter, 6 – booster pumps for exhaust valve actuator, 7 – turboblower, 8a – exit from tank to purifier, 8b – exit from purifier to lube oil tank

Figure 3 presents an example of ME structural composition zoning into different environments for tribological systems.

Zone I covers the temperature and combustion process product zone, and the tribological systems operating there consist of: exhaust valve manifold, exhaust valve head, guiding bushing, piston with rings – cylinder liner.

Zone II covers the zone of relatively low temperature in relation to the combustion process temperatures: cylinder liner, piston rod – stuffing-box of piston rod, crosshead-bearing, crank-bearing, main bearing.

Zone III covers the turboblower zone: turboblower bearings operating in the area of relatively low temperatures in relation to the combustion process temperatures, exposed to water and air impurities, and turbine bearings exposed to fume temperatures and combustion product pollution.

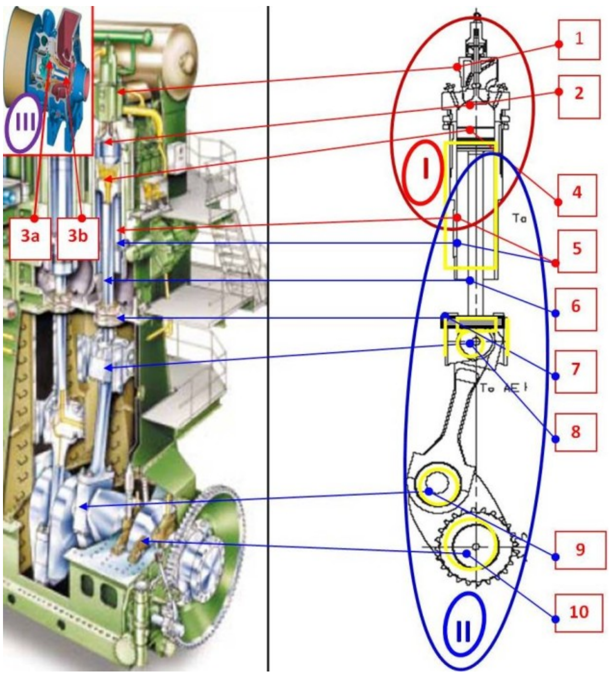

Fig. 3. ME structural composition zoning into different environments for tribological systems: **Zone I** covers the temperature and combustion process product zone: 1 – exhaust valve manifold, 2 – fuel injection valve, 3 – exhaust valve head, 4 – piston, 5 – cylinder liner; **Zone II** covers the zone of relatively low temperature in relation to the combustion process temperatures: 5 – cylinder liner, 6 – piston rod, 7 – stuffing-box of piston rod, 8 – crosshead-bearings, 10 – crank-bearing, 11 – main bearing; **Zone III** covers the turboblower zone: 3a – turboblower bearings, 3a – turbine bearings

Taking into consideration the accuracy of the points providing diagnostic data, the sampling points should be located at oil exhaust spots from the operated tribological systems. That would increase the reliability of diagnosis.

It would allow better oil change analysis to be conducted upon having left the tribological systems of various, specific operational conditions.

Conclusions

Assuming that lube oil is engine functional system, its specificity should be simultaneously determined. Liquid oil form results in that the oil provided to the providing points for tribological systems is divided into several streams. Every oil stream operates in different conditions. Mostly, upon having left the particular tribological systems, the streams join and mix in the oil tank.

During tests, mostly, the quality of the entire volume of oil is determined.

It is specifically dangerous in the modern engine constructions where there is a trend to apply oil in the number of various engine functional structures, e.g. as lube oil for main bearings, cylinder oil, hydraulic oil for exhaust valve drivers and fuel injection valves, lubricating turboblower bearings.

For this solution it is recommended to:

– prepare oil at the inlet to tribological systems (of the determined specificity);
– select sampling points at the exhaust from the particular tribological system in the manner that allows for qualitative and quantitative assessment of technical state change for different engine structures on the basis of oil parameter changes (also in terms of the entire oil volume).

Shipowners, looking after cost minimalisation, apply mainly the solutions included in the provisions. At the high inertia of procedures for oil sample testing and limited possibilities to perform such tests on a vessel, the applicability of lube oil as a diagnostic tool for engine are not fully utilized.

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