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ANALYSIS OF MODERN METHODS FOR ENSURING LUBRICATION OF THE CYLINDER-PISTON GROUP

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Summary

Introduction. *Recently, new systems have appeared on marine engines cylinder liner lubricants from different manufacturers. World leaders the following manufacturers are involved in the production of these systems: Wärtsilä Retrofit pulse lubrication system (RPLS); MAN B&W Lubrication engine control system (LUBECS) and Hans Jansen. Major innovations and technical developments in cylinder systems lubricants boil down to the following: saving cylinder oil; reduction of wear of cylinder liners; – reducing the risk of cold corrosion of cylinder liners; maximum possible operating time in "Slows teaming" mode and "Extra Slow steaming" (mode of long-term operation of ship engines on low loads 50% MCR and ultra-low loads from 10% to 50% MCR).* ***Purpose.*** *Analysis of the approaches of the above-mentioned manufacturers to solving problems of high-quality functioning of cylinder lubrication systems allows us to trace current trends in ensuring optimal lubrication regimes for modern marine diesel engines with increased piston stroke. Solving these problems (according to ship tests of the manufacturers in question) leads to a reduction in cylinder oil consumption by approximately two times.* ***Results****. Overview of cylinder oil injection systems into the cylinder, determination of the approaches of a well-known manufacturer of lubrication systems and the difference in supply principles, designed for training ship mechanics – understanding the differences and features of lubrication systems in modern operating conditions (different types of engines, manufacturers, and differences in classes of ships) will help to avoid breakdowns of main engines and financial losses for shipowners.* ***Conclusions.*** *We will consider the methods by which these problems are solved and the assigned tasks are solved in this article.*

Key words: *cylinder liner; lubricants; marine engines.*

АНАЛІЗ, СУЧАСНИХ СПОСОБІВ, ЩО ЗАБЕЗПЕЧУЮТЬ ЗМАЩУВАННЯ ЦИЛІНДРОПОРШНЕВОЇ ГРУПИ СУДНОВИХ ДИЗЕЛІВ

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Анотація

Вступ. *Останнім часом з'явилися нові системи змащення для циліндрових втулок суднових двигунів від різних виробників. Світовими лідерами у виробництві даних систем є такі виробники: Wärtsilä Retrofit pulse lubrication system (RPLS), MAN B&W Lubrication engine control system (LUBECS) та Hans Jansen. Основні інновації та технічні розробки в циліндрових системах змащення зводяться до наступного: економія циліндрового масла; зменшення зносу циліндрових втулок; зменшення ризику холодної корозії циліндрів; максимально можливий час роботи в режимах «Slows teaming» та «Extra Slow steaming» (режим тривалої роботи суднових двигунів на малих навантаженнях 50% MCR і наднизьких навантаженнях від 10% до 50% MCR).* ***Мета.*** *Аналіз підходів вищезазначених виробників до вирішення завдань якісного функціонування систем змащення циліндрів дозволяє простежити сучасні тенденції щодо забезпечення оптимальних режимів змащення сучасних суднових дизельних двигунів із збільшеним ходом поршня. Вирішення цих проблем (за судновими випробуваннями розглянутих виробників) призводить до зниження витрати циліндрового масла приблизно в два рази.* ***Результати.*** *Огляд систем впорскування циліндрового масла до циліндру, визначення підходів відомого виробника систем змащення та різниця в принципах подачі, крім того розуміння відмінностей та особливостей систем змащення в сучасних умовах експлуатації (різні типи суднових дизельних двигунів, виробників, а також відмінності в класах суден) допоможуть уникнути поломок головних двигунів і фінансових втрат для судновласників.* ***Висновки.*** *Проаналізувавши всі сучасні конструктивні рішення та інженерні підходи виробників суднових двигунів, а також особистий досвід – були сформульовані загальні рекомендації щодо оптимізації процесів змащення циліндропоршневої групи та методи вирішення цих проблем.*

Ключові слова: *втулка циліндра; мастило; суднові двигуни.*

Introduction. The new systems have been designed on marine engines cylinder liner lubricants from different manufacturers in order to minimize oil consumption, decrease level of wear and damage to marine engines and reduce the economic losses of the ship-owners. The following well-known leading manufacturers such as Wärtsilä RPLS; MAN B&W LUBECS; Hans Jansen are involved in the production of these systems concerned in this paper.

Most of the projects and technical improvements in cylinder systems lubricants may be determined as the following: saving cylinder oil; reduction of wear of cylinder liners; reducing the risk of cold corrosion of cylinder liners; maximum possible operating time in “Slow steaming” mode and “Extra Slow steaming” (mode of long-term operation of ship engines on low loads 50% MCR and ultra-low loads from 10% to 50% MCR).

Modern operating conditions of ship engines require highly qualified and experienced engineering staff who are ready to respond to any deficiency or trouble-shooting matter. If problems arise during operation with the condition of the cylinder-piston group, the manufacturer should be aware of the problems concerned with his products in order to take all possible measures and actions to prevent and stop the process of deterioration of the engine condition.

The present work makes ample use of the maritime experience and test trials conducted on board of M/V “Primerose” and APL “Salalah”. The results of this practical research were systematized and clearly illustrated in the figures given in the previously published scientific work [23]. The theoretical background and practical references to manuals for engine room department were widely used while preparing this paper. The results of this research will be useful for training and upgrading the knowledge of future and active marine engineers.

1. Analysis of modern cylinder lubrication systems for marine diesel engines be Wärtsilä RPLS, MAN B&W LUBECS and Hans Jansen.

1.1 The main design solutions developed by Wärtsilä regarding the lubrication of the cylinder-piston group of diesel engines come down to the following points.

The RPLS system for supplying cylinder oil through high pressure quills (non-return valves) is shown in Figure 1 [24, 25] and includes a separate hydraulic oil system to operate the hydraulic actuator using a solenoid valve (Figure 2) [24, 25].

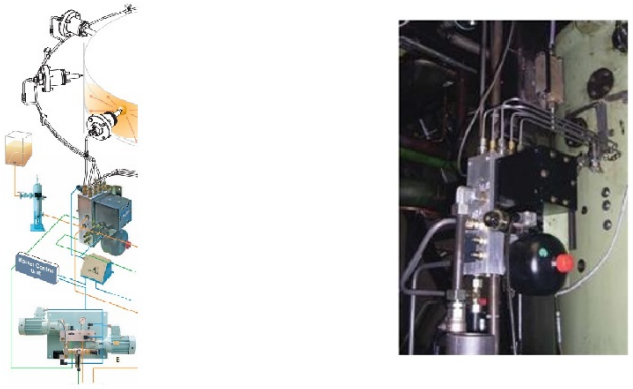

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Fig. 1. System for supplying cylinder oil to parts of the Wärtsilä cylinder-piston group: a) general layout of the system; b) installation diagram on a diesel engine

In addition, the RPLS system includes system for determining the position of the engine crankshaft and injecting oil at exactly specified moment considering the crankshaft speed, load and a given feed (set by the processor).

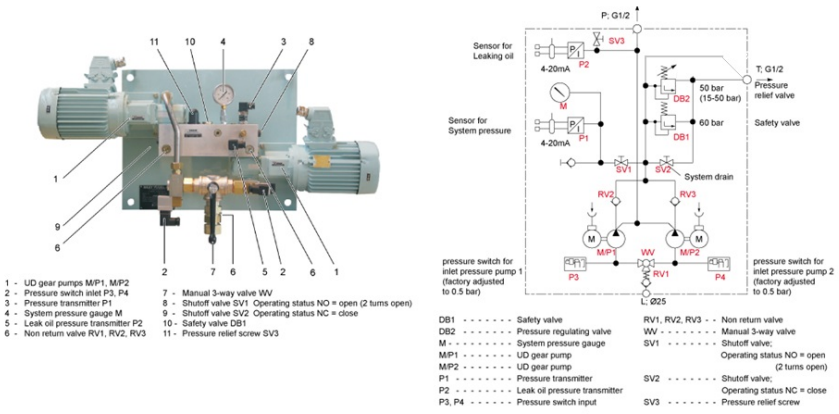

Fig. 2. Functional structure of the hydraulic oil system

1.2 Engineering and design solutions from MAN B&W LUBECS.

The LUBECS system developed by MAN B&W supplies cylinder oil through non-return valves under high pressure by injecting at each control point with plungers driven by hydraulic oil from a signal solenoid valve to a cylinder lubricator installed on each cylinder.

The cylinder lubricator is industrially installed on the hydraulic cylinder control unit (HCU) which does not require a separate control and monitoring system (additional processors) and is built into the main control panel system (MOP). The MAN B&W hydraulic control unit is shown in Figure 3 [8].

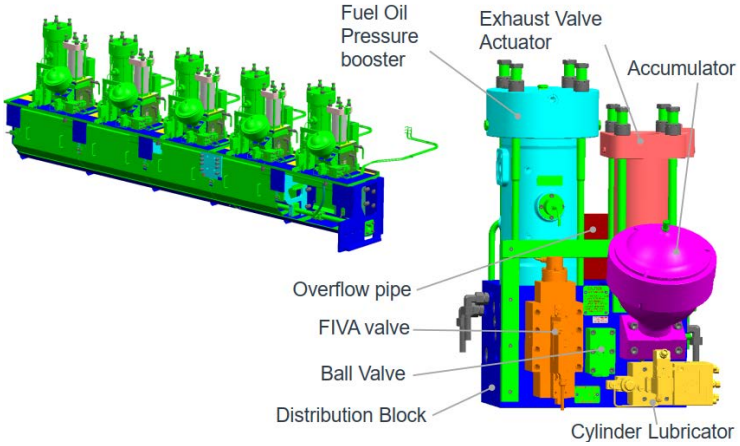

Fig. 3. Complete set of hydraulic control unit for cylinder lubrication system LUBECS from MAN B&W

Oil is supplied to the diesel cylinder by a lubricator the diagram of which is shown in Figure 4 [3].

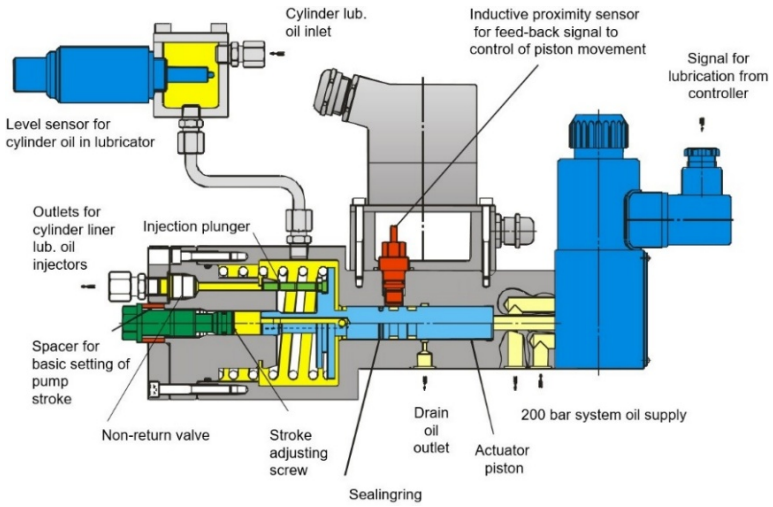

Fig. 4. Lubricator for lubrication system LUBECS from MAN B&W

1.3. Engineering and design solutions from Hans Jensen

This system was tested by one of the container shipping companies. According to the agreement with the shipowner, the functional components of this system have been installed on new ships since summer 2014.

The Hans Jensen lubrication system traditionally supplies cylinder oil through non-return valves under high pressure, while the cylinder oil is supplied to the space above the piston but not to the piston rings, up to the cylinder liners with swirling cylinder oil flows (SWIRL principle). The Hans Jensen lubricator is shown in Figure 5 [4].

Fig. 5. Lubricator from Hans Jensen

2. Analysis of general solutions in the cylinder liners lubrication.

Currently, leading manufacturers of marine engines are intensively developing lubrication systems for cylinder-piston groups largely based on their engineering innovations considering the experience of operating marine diesel engines in marine conditions. Systems for monitoring and adjusting the cylinder oil supply are constantly

and regularly updated (via software) and the companies constantly monitor compliance with these requirements.

Analysis of cylinder lubrication systems by Wärtsilä (RPLS), MAN B&W (LUBECS), Hans Jensen gives the opportunity to witness the progress of engineering concept of system developed and resorts to identifying common solutions and trends in systems:

– installation of non-return valves before inlet of cylinder oil to the cylinder;

– use of a hydraulic drive system (hydraulic actuator) of dosing pumps (Lubricators Hydraulic Units);

– ensuring accurate injection of cylinder oil into exactly specified torque by the Central Processor (Controller) considering the speed, engine load and the amount of oil designated for each system (mandatory includes a crankshaft position sensor);

– ensuring cylinder oil savings by skipping piston strokes (except for Hans Jensen systems under development).

3. Analysis of peculiarities and principles in providing lubrication of cylinder-piston elements group.

3.1 Wärtsilä (RPLS) strategy

The RPLS cylinder lubrication system developed by Wärtsilä solves the following problems:

– injection direction control;

– injection of cylinder oil at precisely specified time by processor considering the position of the cylinder rings at the ratio: 40% – top rings; 40% – bottom rings and 20% piston skirt.

The direction of cylinder oil injection is demonstrated in Figure 6. Savings are achieved by skipping piston strokes. According to tests on a steamship the description does not register more than 6 piston strokes in case of light loads, that is the established minimum consumption g/(gKWh) per number of piston strokes (mandatory injection). The minimum declared cylinder oil consumption is 0.8 g/(gKWh).

Fig. 6. RPLS cylinder oil injection direction

3.2 MAN B&W strategy

The LUBECS cylinder lubrication system developed by MAN B&W as well as Wärtsilä solves the same problems in a similar way: injection of cylinder oil at exactly specified time by the processor without precise distribution to the upper and lower rings of the piston. The injection direction is shown in Figure 7 [3].

Savings are achieved by skipping piston strokes (no more than 12 piston strokes in case of light loads, i.e. the established minimum flow rate g/(kWh) which is mandatory injection). The minimum declared cylinder oil consumption is 0.6 g/(KWh).

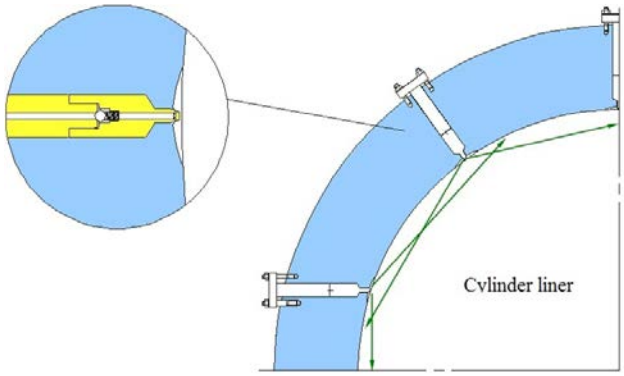

Fig. 7. Cylinder oil injection direction of the LUBECS system

3.3 Hans Jensen strategy

Hans Jensen's latest cylinder lubrication system developed and tested in 2013 and launched in 2014 runs different route in providing cylinder liner lubrication. The basic principle is that cylinder oil injection occurs at each stroke of the piston and cylinder oil flows above the piston onto the cylinder liner with swirling flow of the injected cylinder oil (SWIRL principle) using non-return valves under high pressure hydraulic system and additional air charge impulse. The injection direction is presented in Figure 8.

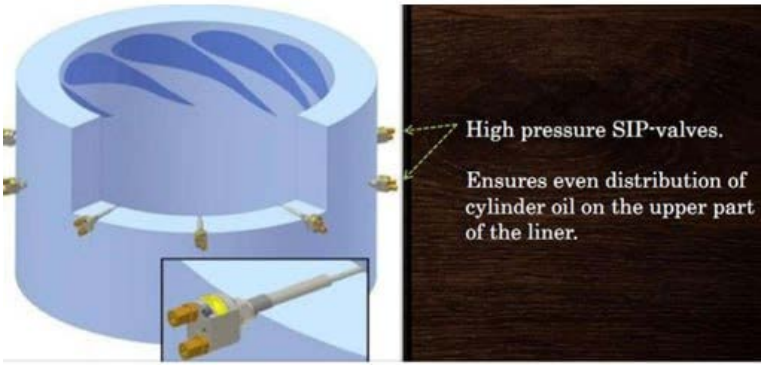

Fig. 8. Hans Jensen cylinder oil injection direction

Figure 9 shows the surface covered with an oil film on traditional cylinder lubrication system, and in Figure 10 from Hans Jensen.

Fig. 9. Surface covered by an oil film on a traditional cylinder lubrication system

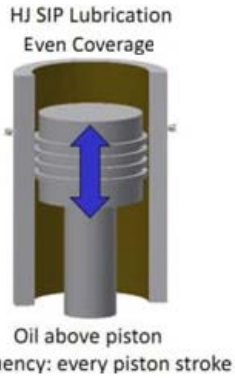

Fig. 10. Surface covered by an oil film on the system Hans Jensen cylinder lubricant

The declared cylinder oil consumption is shown in Figure 11 according to the results of tests on the M/V "Primrose" and one has to admit that comparison was made with the old mechanical lubricator system.

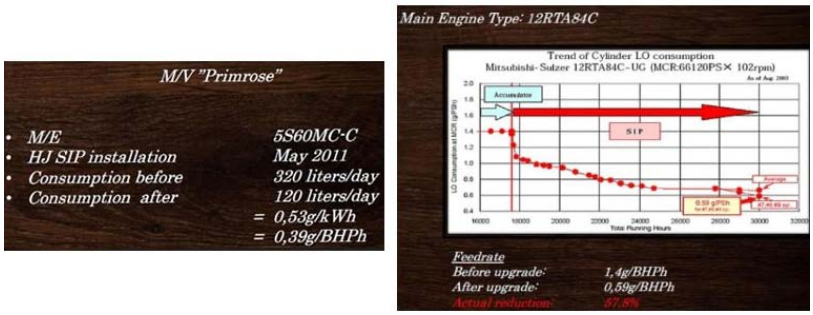

Fig. 11. Cylinder oil consumption during test trials of the m/v "Primrose"

4. “Slow steaming” mode (long-term operation mode at low load of marine engines) and recommendations from manufacturers Wärtsilä and MAN B&W.

Due to economic reasons marine engine manufacturers are aimed at achieving trouble-free operation under (50% MCR) and ultra-light (<50% MCR) load operating conditions of marine engines to reduce fuel consumption and maximum decrease of the cylinder oil consumption.

Low load conditions on WÄRTSILÄ engines led to the following problems of the cylinder-piston group:

– cold corrosion of cylinder liners;

– increased wear of cylinder liners and damage to cylinder rings; unfortunately, it should be noted that the loss of one bushing on this engine has its own feature – in the event of failure to replace the problematic cylinder liners being detected in time leads to the loss of half of the engine cylinder liners (as there is not enough time for replacement due to the ship’s schedule or any other reasons).

An example of damage to cylinder rings on 12RT-Flex 96C engine is shown in Figure 12.

Fig. 12. Example of damage to cylinder rings on an engine

Wärtsilä currently makes the following recommendations to solve these problems:

– continuous inspections of piston rings and cylinder liners;

– at least once every three days increasing the load to 70% MCR and more, for a period of one-two hours to get rid of solid deposits and unburned fuel residues will be carried out (the load should be increased gradually);

– replacement of the cylinder lubrication system with an RPLS system;

– installation of the MAPEX system (Monitoring & Maintenance, Performance, Enhancement with Expert Knowledge).

The MAPEX system determines in real time:

a) Monitoring the stability of the cylinder oil film cylinder liners.

b) Alarm activation in case of local overheating of the cylinder liners.

c) Monitoring of cooling water temperature and alarm activation in case of parameters exceeding the set modes.

d) Informing in case of failure of one or more injectors.

e) Monitoring the temperature of the air charge and signaling in case of exit from the established modes.

Figure 13 shows examples of real-time temperature readings for cylinder liners, cooling water and air charge.

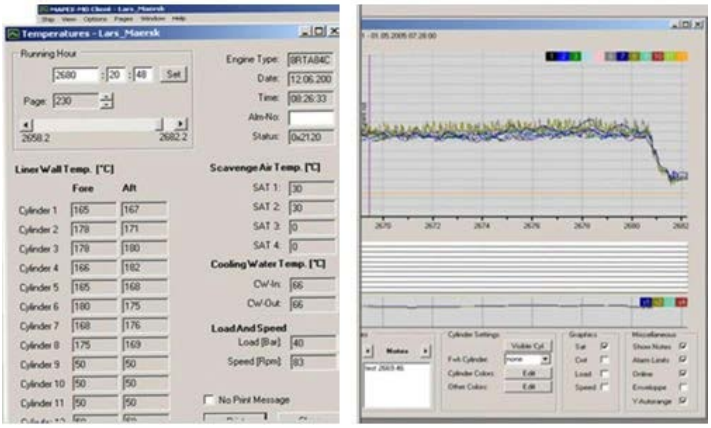

Fig. 13. Example of temperature readings of cylinder liners, cooling water, air charge in real time of the MAPEX system

Figure 14 shows examples of notifications about parameters of the MAPEX system going beyond acceptable limits.

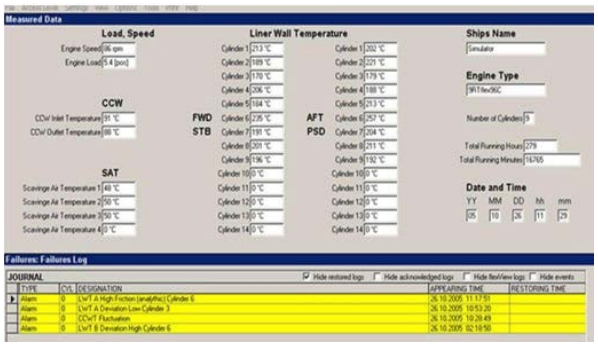

Fig. 14. Example of signaling in the MAPEX system

Problems considered in light load modes of marine diesel engines identified by MAN B&W:

– cold corrosion of cylinder liners (especially long-stroke engines)

Figure 15 [1] shows an example of cold corrosion of cylinder liner on S50ME-B9.2 engine.

Fig. 15. Example of cold corrosion of an engine cylinder liner

– partial removal of metal in the locks and damage to the piston rings and damage to the cylinder rings.

Figure16 shows an example of cylinder ring damage on an S80ME-C9 engine.

Fig. 16. An example of damage to cylinder rings on an S80ME-C9 engine

According to service bulletins and operating experience of MAN B&W engines, the following recommendations have been suggested:

– continuous inspections of piston rings and cylinder liners;

– at least once every two days increase the load to 50% MCR and more, for a period of one-two hours to get rid of solid deposits and unburned fuel residues should be carried out (the load has to be increased gradually, an example is shown in Figure 17);

– replacement of cylinder lubrication systems with LUBECS system;

– pay special attention to the adaptive cylinder oil control (ACC) factor in settings and adjustments of the supply of cylinder oil to the cylinder liners. The ratio of the metal coefficient and base number (BN) in the analysis of oil taken from the underside piston space. Figure 18 [10] shows the dependence of the metal level on BN and the recommended safe work zones according to the analysis readings.

Manual load-up procedure	Duration
Load up, 10 → 40% load	30 minutes
Load up, 40 → 75% load	60 minutes (SL08-501)

Fig. 17. Recommended loading time characteristics

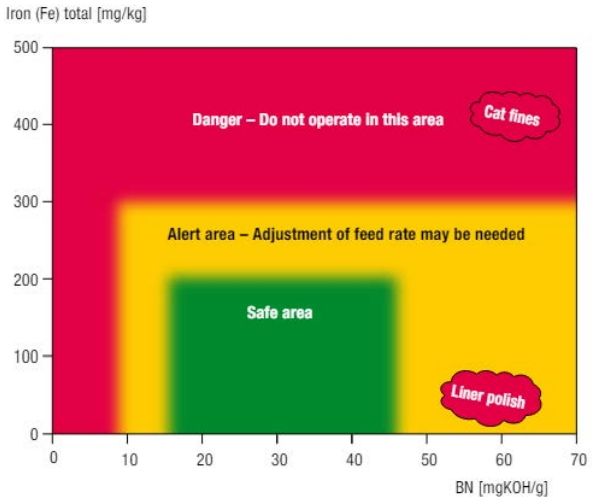

Fig. 18. Dependence of the metal level on BN and recommended safe work zones based on analysis readings taken in the underside piston spaces

Recommended oil consumption is calculated using the formula:

$$ACC \times S = FR$$

where: ACC – 0.2–0.35 – is set experimentally after determining the metal coefficient and BN in the analysis of oil taken from the underside piston space; S-sulfur (the amount of sulfur in the fuel %); FR – feed rate (recommended oil consumption g/(KWh)).

At the same time, it must be considered that the recommended oil consumption should not be lower than 0.6 g/(KWh) (the LUBECS system will automatically set the consumption to at least 0.6 g/(KWh)).

It should be noted that the manufacturer MAN B&W recommends changing the cylinder lubricant to a TBN factor of 100 for long-stroke engines.

In order to combat cold corrosion of cylinder liners MAN B&W has developed a new cooling system for cylinder liners.

It is a 4-pipe cooling system for cylinder liners (G-type engines and future generations Mark 9). Figure 19 [1] shows the general layout of the new cooling system installed on the engine.

The system consists of two additional cooling water pipes along the entire engine and additional pump and control valve that controls the sleeve cooling water temperature reaching 120°C and maintaining the temperature of the cylinder cover and exhaust valve at 80–90°C. The high temperature of the cylinder liner is maintained only in low load modes of the marine engine.

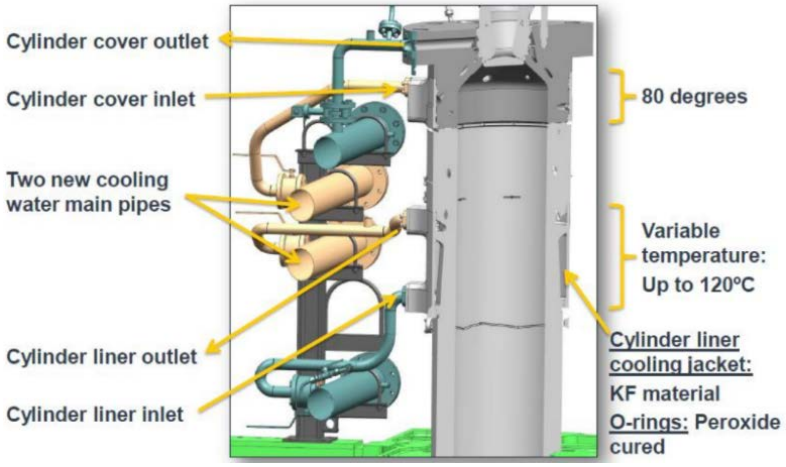

Fig. 19. General layout of new MAN B&W cooling system

Conclusion. General recommendations for optimizing processes of lubrication of the cylinder-piston group of marine diesel engines. Having analyzed all the design solutions and engineering approaches of marine engine manufacturers, general recommendations for optimizing the lubrication processes of the cylinder-piston group may be defined as the following:

– continuous inspection of cylinder rings and cylinder liners;

– increase in the operating temperature of the cooling water behind the jacket space by 5–10°C of cylinder liners (within the limits allowed by the manufacturer);

– at least once every two days increasing the load to 50% MCR (70% MCR) and more, for a period of one-two hours to get rid of unburnt fuel residues (the load increase should be done gradually);

– constant control over the amount of cylinder oil supply when switching to fuels with different sulfur content. Adjustment should be carried out from a higher feed rate to a smaller one gradually with constant inspections of cylinder rings and cylinder liners and on the basis of an oil analysis in the piston underside space (MAN B&W) or MAPEX (Wärtsilä);

– quality control of fuel atomization (injectors);
– control of load distribution across cylinders.

Modern operating conditions of ship engines require highly qualified and experienced engineering teams. If problems arise during operation with the condition of the cylinder-piston group, the Chief Engineer is obliged to inform the manufacturer immediately and take all possible measures and actions to prevent and stop the process of deterioration of the engine condition, with regard to the recommendations of manufacturing companies as well as personal experience.

If damage to the cylinder rings is detected on one of the cylinders or the automatic system turns off the fuel supply to one of the cylinders (for example, on RT-flex engine, when the sensor for the amount of fuel supplied to the cylinder is jammed, the automatic system turns off the fuel supply completely to this cylinder), maximum engine load should be immediately limited on MAN B&W engines to 55% MCR, RT-flex (Wärtsilä) to 70% MCR until the problem is resolved. Mind that pirate navigation areas require an increase in the ship's speed or poor navigation conditions in the navigation area cannot guarantee compliance with these recommendations and, therefore, the experience and qualifications of the Chief Engineer in these difficult conditions will play a decisive role.

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