ANALYSIS OF FAILURES OF CYLINDER LINES OF THE LOW-SPEED MARINE DIESEL ENGINES TYPE 6RLB66

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Summary. The paper presents the results of operational reliability of the cylinder liners, which were characterised little frequent of failures. The low-speed marine diesel engines type 6RLB66 have been produced on the licence of firms Sulzer and applied for main propulsion of bull carriers type B542. The sudden failures of cylinder liners caused badly operating troubles and large economic losses. On the base of operational and construction dates have been tacked attempt of causes and conditions of failures. There has been too executed statistical analysis of acquisition dates and have been showed of manners of operating which maybe to diminish of failures.

The results of examination can be helpful in the processes of designing and manufacturing and operating this type of marine engines.

1. Introduction

In the paper have been presented of analyse failures of cylinder lines of low-speed engines type 6RLB66 of main propulsion of bulk carriers. In these engines the cylinder lines damaged very often [1]. The sudden failures of cylinder lines, which eliminated from using, are teaser in operating. When cylinder lines damaged should: exchange cylinder lines on spare or sometimes exploit the engines witch from reduction of speed. Such failures caused large economic losses on motive: costs purchased of new cylinder lines, costs bring of spare cylinder lines and costs out of operation of ship.

The investigations of engines have been make in actual condition of operating on the base gather information. The results of investigations can be helpful in the processes of designing and manufacturing at verification service and formulate of recommendation increase the reliability of diesel engines.

2. The object of investigations

The RL series engines are single-acting, reversible two-stroke marine diesel engines with exhaust-gas turbocharging and loop scavenging for direct propeller drive.

Examine engines type 6RLB66 has been manufactured on the licence firm in 1984 and 1985 years. They served for main propulsion of bulk carriers type B-542, which have been manufactured by home shipyard in 1985 and 1986 y. Characteristic particulars of engines 6RLB66:

- diameter of cylinders – 660 mm,
- stroke – 1400 mm,
- horse power at 124 r. p. m. – 8160 kW.

The cylinder liners are arranged in hanging position in the cylinder jackets (fig. 1). The scavenge-air inlets and exhaust-gas outlets on the cylinder jackets are located on the exhaust side, where the scavenge-air receiver is mounted.
A water guide ring fitted inside each cylinder jacket at its upper part which forces the cooling water to take a certain path. This results in more intensive cooling of the exhaust ducting.

The piston cooling water system is independent of cylinder cooling system. The piston cooling water is supplied to, and drained away from, the pistons through telescopic pipes.

Equally distributed lubricating quills are screwed into the periphery of the cylinder liners. The lubricating quills are seated with their shoulders against the sealing faces in the cylinder liner. The accumulators are screwed onto the outer ends of the lubricating quills, these accumulating the oil supplied by the cylinder lubricating pumps before it passes on through the lubricating quills the running surfaces of the cylinder liners at the correct time.

![Fig 1. Schematic diagram of the cylinder liner: 1 - cylinder liner, 2 - bore for lubricating quill, 3 - cylinder jacket, 4 - rubber ring for the ports, 4a - rubber ring for the ports, 4b - lower rubber ring, 4c - rubber ring for water guide jacket, 5 - filling piece, 6 - cover, 7 - water guide ring, 8 - screw plug for vertical cooling water bore, 9 - lube oil supply for lower part of cylinder liner, 10 - soft iron joint, A - exhaust ports, S - scavenge pots, NO - upper lubricating groove, NU - lower lubricating groove, K - check hole](image)

The fault of loop scavenging engines is asymmetrical heat load of cylinder line, cylinder head and piston. The engines are sensitive on the sudden changes heat loads and mechanical loads.

The necessary ducts for scavenging air and the exhaust are cast into the cylinder jackets. For the protection of the cylinder liners abrupt cooling down and temperature fluctuations of more than ± 3°C engines are avoided when regulating the cooling water temperature.
3. Method of investigations

In the investigation engines type 6RLB66 has been examination the abrupt and gradual damages of cylinder lines, which have been replaced. Such failures were signalled: temperature rise of cooling water on the departure from cylinder line, leaks or loss of cooling water, fall of peak firing pressure or compression pressure and knocks in cylinder (fig 2a). Some not signal failures have been stated during periodical survey, special survey in shipyard or visual inspection (fig. 2b). Same failures have been not signalled because was damaged signalling aids. Fig. 2 shows that most of all failures was signalled by means of temperature rise of cooling water on the departure from cylinder line and most of all no signalling failures have been ascertained during of periodical survey.

![Diagram](image)

**Fig. 2. Failures of cylinder lines: a) signalled, b) not signalled; TW – temperature rise of cooling water on the departure from cylinder line, LW – leaks or loss of water, K – knocks in cylinder, CP – fall of peak firing pressure or compression pressure, TE – temperature of exhaust gas, PS – periodical survey, SS – special survey, VI – visual inspection**

There has been accepted information about failures 65 cylinder lines. In operating was occurred 3 condition states of examined engines: state of full ability, state of partially ability and state of disability to work. The investigations have been carried according to plan \((n, W, r)\), which encircled \(n = 65\) cylinder lines. The failure cylinder lines have been exchanged on news \(W\) and investigations have been ended when as soon as exchanged of \(r\) cylinder line.

The well-ordered realisations of time of examined cylinder lines for step of failures shows fig 3.

![Graph](image)

**Fig. 3. The well-ordered realisations of time of examined cylinder engines type 6RLB66 lines for step of failures**
The predominant kind failures of cylinder lines were macrocracks and microcracks of wall of cylinder lines. The cracks showed in lower (62%) and high parts (38%) of cylinder lines in the vertical and horizontal plane (fig. 4a) and also in various directions (fig 4b). The most of all failures of cylinder lines stepped in lower part, vertically and from the port side (at exhaust ports – fig. 5).

![Diagram](image)

**Fig. 4. The location a) and direction cranks of cylinder lines b): B – bow side, P – port side, S – stern side, SB – starboard side; A – askew, H – horizontally, V – vertically**

![Diagram](image)

**Fig. 5. The place formations of cylinder lines: C – collar, CH – cooling hole, EP – exhaust ports, IP – inlet ports, LH – lubricating hole, SS – sliding surface**

The much number of cranks of cylinder lines at exhaust parts resulted from occurring a high temperature and velocities of flow of exhaust gas when exhaust parts was drawing. The periodical changes of temperature caused heat loads of walls of cylinder line and piston and also viscosity drop of lubricating oil. The high velocity of flow exhaust gas in during of exhaust gas is blowing oil from surface cylinder line and piston.

From failures of cylinder lines have been ascertained of failures of pistons, cylinders heads, injectors and lubricating system (fig 6). I these elements stepped in a lot of stances early failures. Fig. 6 shows that failures of cylinder lines ascertaining generally together with failures of pistons. The participate failures and wear of elements of piston in their unserviceable conditions shows fig 7. From fig. 7 resulted that most of all unserviceable conditions of piston determined of used of piston rings and cracks of piston skirts. The leakage of cooling water to inside of cylinder line from cracked or leaky of piston perhaps to carry into crack of cylinder line [4]. These cracks of cylinder lines, which
formed in lower parts of cylinder lines, caused failures of cylinder lines. The failures and wear of piston ring scavenges of hot gases between cylinder line and piston.

Fig 6. The unserviceable conditions of element in which perhaps ascertained early failures: CH – cylinder head, I – injector, L – lubricating system, P – piston

Fig. 7. The main participate failures and wear of elements of piston in their unserviceable conditions shows: UPR – used of piston rings, CPS – cracked of piston skirt, LPS – leaky of piston skirt, SPS – seized of piston skirt, CPR – cracked of piston ring, SPR – seized of piston ring, BPC – burned of piston crown, IPR – immobilised of piston ring, UPC – used of piston crows,

4. The select results of reliability test

The mean time of work of cylinder lines from failures have been determined in the following formula:

\[ \Theta^*(t) = \frac{1}{m} \sum_{i=1}^{m} t_i \]  

(1)

where:

- \( m \) – number of failure cylinder lines,
- \( t_i \) – time of work of cylinder line number \( i \) from instant of failure.

The standard deviation of error-free running time from failures can be determined in the following form
The coefficient of variation have been determined in the following way [2]:

$$\nu^* = \frac{\sigma^*}{\Theta}$$  \hspace{1cm} (3)

The life $\gamma$–percentages have been determined in the following way:

$$R(t_r) = \frac{Y}{100}$$  \hspace{1cm} (4)

The results of numerical indexes of reliability have been matched in table 1. The mean time of work of cylinder lines from failures in with reference for expectation life is small.

Table 1. The results of numerical index reliability of cylinder lines of engines type 6RLB66

<table>
<thead>
<tr>
<th>No</th>
<th>Name and mark</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mean time of work of cylinder lines from failures $\Theta$</td>
<td>$\Theta^* = 14,935$ h</td>
</tr>
<tr>
<td>2</td>
<td>Standard deviation of error-free running time from failures $\sigma$</td>
<td>$\sigma^* = 14,133$ h</td>
</tr>
<tr>
<td>3</td>
<td>Coefficient of variation $V$</td>
<td>$V^* = 0,946$</td>
</tr>
<tr>
<td>4</td>
<td>Life $\gamma$–percentages $t_\gamma$</td>
<td>$t^<em>_{90} = 944$ h, $t^</em>_{50} = 11,039$ h</td>
</tr>
</tbody>
</table>

5. Conclusions

The construction of examined cylinder lines with loop scavenging and their modernisations are unsuccessful. For the reduction cracks of cylinder lines one should: to avoid large heat loads of cylinder lines, to avoid large different of temperatures in time manoeuvres and changes of service load, maintain the pistons in good technical state. For the maintain the cylinder lines in state of ability one should often diagnosed their state by means measurements of parameter firing pressure or compression pressure. The best diagnostic symptom for detect of failures of cylinder lines is temperature rise of cooling water on the departure from cylinder line. This temperature ought constantly monitoring.

For the lightening of side thrusts on the exhaust parts it advisable is use list of a ship [3].

The results of these investigations one should to take as leaderless and they will continue. It is necessary to investigations of quality of conformance of cylinder lines and influence of service conditions of engines on the failures.

Literature
