PISTON FAILURES OF MARINE TYPE 6RLD66 DIESEL ENGINES

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Abstract

The paper presents results of operational research on the of reliability of pistons, which have bee often been subjected to critical damage, sudden and gradual. The low-speed marine diesel engines type 6RLB66 have been produced under Sulzer licence and used for main propulsion of bulk carriers (type B542). Sudden failures of pistons have caused bad operating troubles and large economic losses. Analysis of failures and wear was based on investigation of records ship's document, computer records and on observation of engines and their of sub-assemblies during ships' stays in ports and shipyards Selected functional and numerical coefficients of reliability were estimated by determining the relations between time of correct work and failures of combustion engines pistons.

Keywords: *marine engines, pistons, wear, sudden and gradual failures*

1. Introduction

The paper presents an analysis of failures of pistons of low-speed engines, type 6RLB66, used as the main propulsion of bulk carriers. In these engines pistons have been often [2, 3, 4]. Sudden failures of pistons, which eliminated engines from operation, are troublesome for shipowners. When the is a piston failure, it should be exchanged, piston rings replaced by spare ones or sometimes the engine runs with its speed reduced [2, 3, 5]. Such failures cause large economic losses due to the costs of a new piston, costs of delivering the spare piston and costs of the ship being not in operation.

The investigations of engines have been performed in the actual operating conditions, on the basis of collected information. The results of investigations should contribute to decreased frequency of failure occurrence and improvement of the readiness, effectiveness and reliability of marine engine units and subassemblies.

2. Object of researches

Investigated engines type 6RLB66 one manufactured under Sulzer licence in 1984 and 1985 years. They served for main propulsion of bulk carrier's type B-542, which have been manufactured by home shipyard in 1985 and 1986 year. Characteristic particulars of engines 6RLB66:

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

The RL series engine is a single-acting, reversible two-stroke marine diesel engine with exhaust-gas turbocharging and loopscavenging for direct propeller drive. The cylinder jackets and frames are bolted onto the bedplate by means of tie rods.

The continuous part of the scavenge-air receiver serves as scavenging duct. The inner part is subdivided according to of the cylinders by transverse partitions. Small center longitudinal duct leads the air supplied by the auxiliary blower into the scavenging spaces of the cylinders.

The cylinder jackets, cylinder covers, turbocharger, pistons and fuel injection valves are cooled by fresh water. The scavenge-air cooler can either be supplied by sea or fresh water. The engine drives neither the lubricating oil nor the cooling water pumps.

The piston consists of the piston crown, the piston skirt and the piston rod. These three main parts are fastened together by waisted studs and their nits. The waisted bolt nuts are secured against slackening by locking discs.

The pistons crown, which contains the grooves for the compression rings is exposed to the highs temperature of the combustion gases and must therefore be cooled. The cooling of the piston crown is effected by fresh water enters and leaves trough telescoping pipes.

In the center of the piston crown a tapped hole is provided for fastening the piston suspension device. The lower three-compression piston ring grooves are chromed on one side the upper two ring grooves are hard chrome plated on both sides.

The piston skirt serves to guide in the cylinder liner and to keep the exhaust ports closed over turbocharger. It is equipped with bronze wearing rings, which are required particularly during the running in period, of the initial service.

The piston rod widens out at its upper end into a flange. Onto this flange the piston waisted trough studs and their nuts fasten skirt and crown.

3. Results of investigations

The paper formulates the following statement: *damage and wear of pistons and piston rings do depend on their working time.*

Type 6RLB66 engines has been examined: abrupt and gradual failures of pistons that had been replaced (Fig. 1). Such failures were signalled by the temperature rise of cooling water at the outlet from cylinder liners, leaks or loss of cooling water, fall of the peak firing pressure or compression pressure and knocks in cylinders. Some non-signalled failures were observed during periodical surveys, or special survey in a shipyard or by visual inspection. Same failures were not signalled because signalling aids were damaged.

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Fig 1. View of a cracked of piston skirt

Fig. 2 shows that most of the failures were signalled by the values of compression pressure, maximum combustion pressure means and outlet temperature.

a) b)

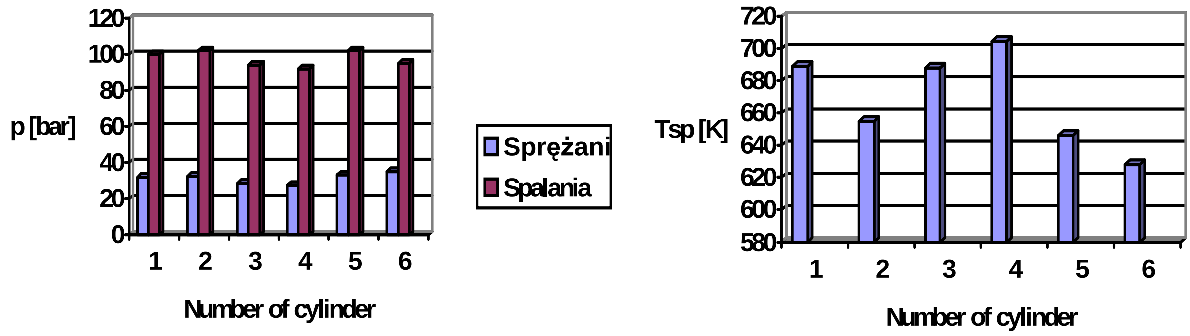

Fig. 2. Values of compression pressure and maximum combustion pressure a) and outlet temperature T_{sp} engine b) RLB66 at engine speed 188 rpm and load 76%: p – pressure

Figure 2 shows that in cylinders 3 and 4 there were low values of compression pressure and high values of outlet temperature of the engine. After a disassembly of pistons it was found that all piston rings suffered excessive wear over the limit values and there leakages of cooling water.

Three conditions of examined engines were distinguished: state of full ability, state of partial ability and state of disabilitto be operated. Investigations followed the plan (n, R, t), which embraced n = 61 pistons and n = 41 sets of piston rings. Damaged pistons were repaired (R), and the research was finished as soon as the correct time of piston reached the value t. Failures of pistons occurred mostly together with damage to cylinder liners.

The moment of failure one identified with his result, that is to say with consequently of state of unfitness, with exchange or with repair of piston. The well-ordered realisations of the correct time of work to instant failure of examined pistons are shown in Figure 3. Figure 4, in turn, shows well-ordered realizations of restoration time for the examined pistons. In the examined engine most pistons were exchanged on account of cracks in the piston skirt or piston crown. There were mostly long cracks of piston skirts.

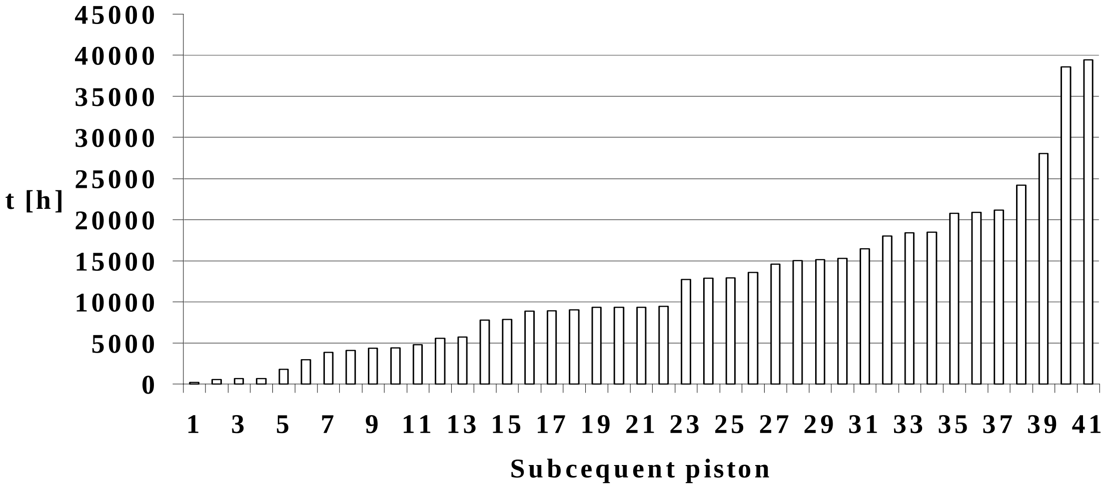

Fig. 3. Well-ordered realizations of time to failure of examined pistons engines, type 6RRLB66

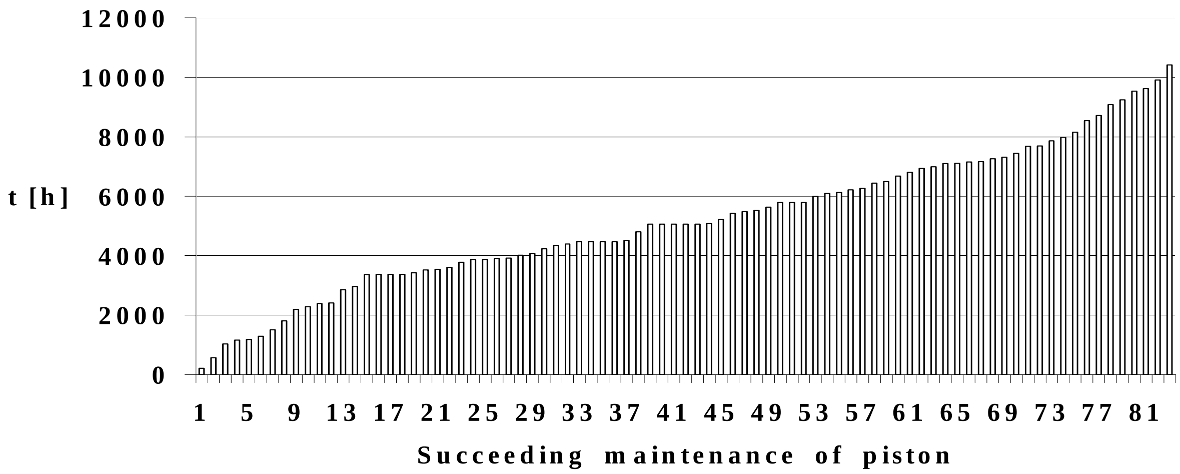

Fig. 4. Well-ordered realizations of time of restorations of examined pistons

The research also included the wear of pistons and piston rings. Changes in dimensions of pistons and pistons rings were determined by geometrical measurements. The sizes of pistons and piston rings are shown in Figures 5÷7.

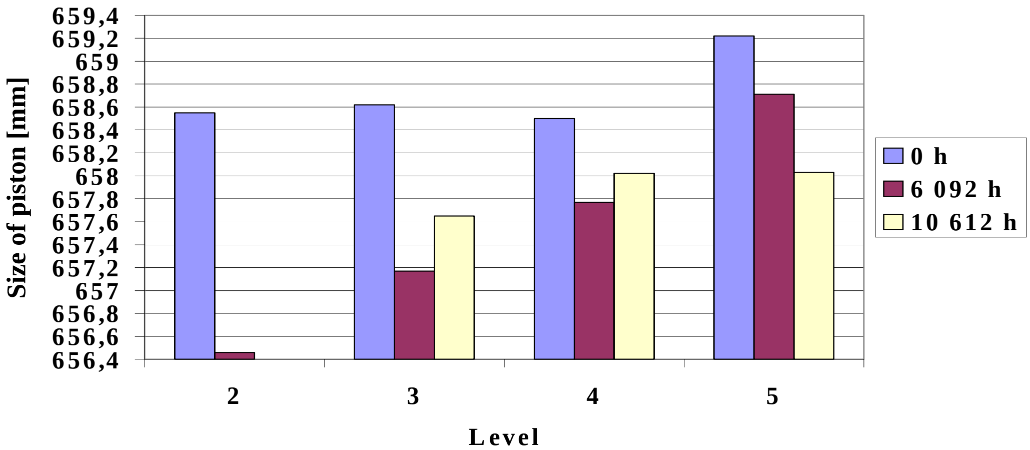

Fig. 5. Changes of piston dimensions in direction along the axis of engine for different times of work

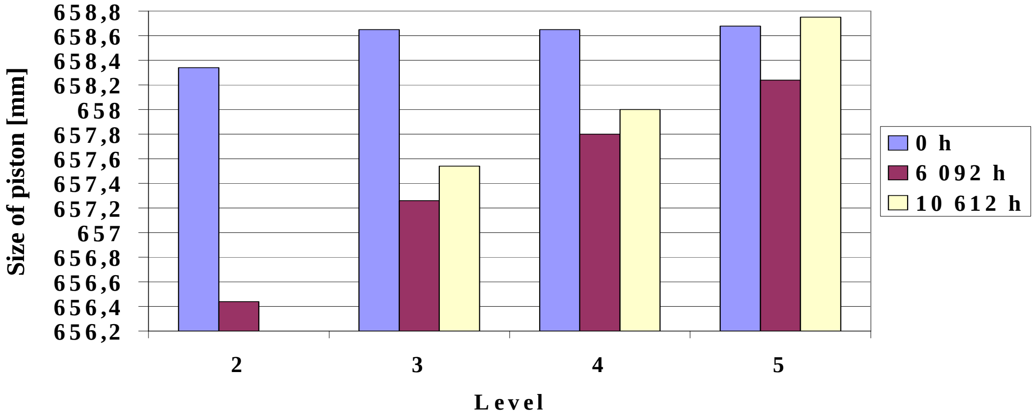

Fig. 6. Changes of pistons dimensions in the direction perpendicular to engine axis for different working times

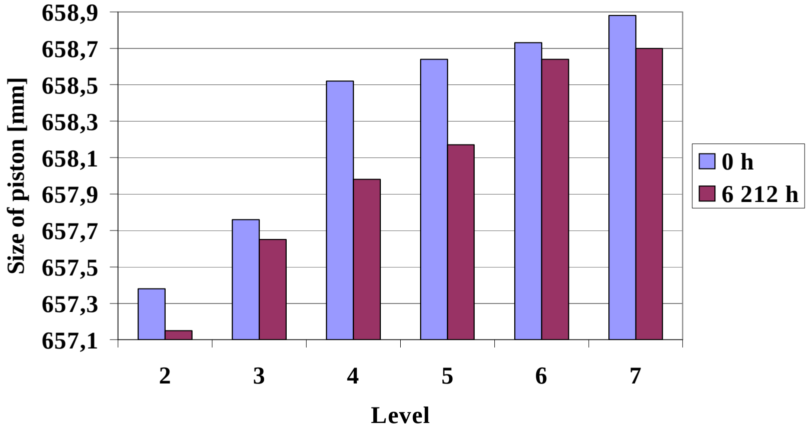

Fig. 7. Changes of pistons dimensions in the direction perpendicular to engine axis for different times of measurements

Figures 5÷7 imply that the wear of piston and piston rings is intensive in its top part.

From the available data quantitative coefficients of reliability were calculated for the examined; the compatibility between empirical and theoretical distributions were examined, too.

For renewable objects the basic functional characteristic of reliability is failure flux parameter $\omega^*(t)$:

$$\omega^*(t) = \frac{r}{n \cdot \Delta t} \tag{1}$$

where:

r – number of failures in researched sample in time $<t, t + \Delta t>$,
Δt – length of partition of time of research.

The results of calculations are given in Figure 8.

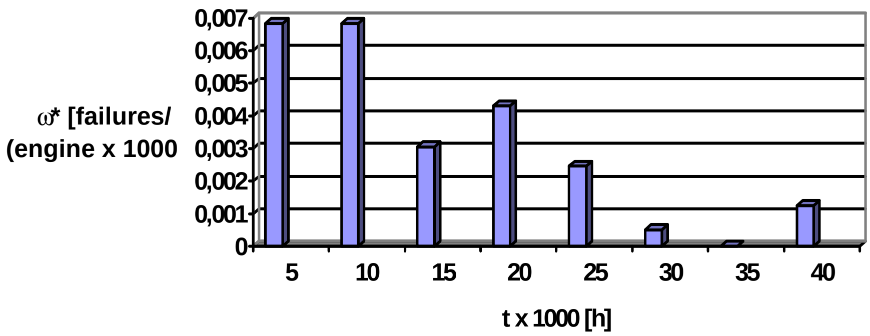

Fig. 8. Diagram of the flux failures parameter $\omega^*(t)$ of pistons of engines type 6RLB66

The average durability of investigated pistons is described by this equation:

$$\bar{t} = \frac{1}{n}\sum_{i=1}^{n} t_i \tag{2}$$

where:

t_i – time of work i of piston (piston rings) to instant of failure,
n – number of pistons (piston rings) damaged.

Standard deviation time of correct work to the instant of failure is calculated from this formula:

$$\sigma_T^* = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(t_i - \bar{t})^2} \tag{3}$$

The average value of correct work time to failures of investigated engine pistons was 12 109 h with a standard deviation of 9 308 h. The durability of piston rings amounted to 5 392 h of work with a standard deviation of 2 469 h.

4. Conclusions

In 65% of cases piston and cylinder liner damage were found in one unit. In 70% of failures of pistons wear or seizures of pistons rings were ascertained to cause blow-by of exhaust gases, increase of temperature and deterioration of lubrication conditions.

In 39% of cases defective injector valves were the cause of deposit formation: carbon deposits, lakes and cokes. In 70% of cases it was found that pistons suffered damage in the time interval 3500 ÷ 10 000 working hours. In the process of piston wear at first a decrease of sizes of pistons and piston rings was noted, then the operating time increase. It was a result of processes of adhesive wear and formed carbon deposits.

The durability of examined pistons was low and its scatter resulted from different conditions of operating and different trading regions.

The construction of examined pistons and cylinder liners with loop scavenging after modernisation is far from perfect. The producer of RLB engines has attempted recently to modernize the construction and production technologies and changes in the operational methods were introduced to minimize failures. Honing is used in final step of cylinder liner manufacturing.

References

[1] Grześkowiak, J., Kotkowski, K., Wołyńska-Mrowicka, E., Heppel, K., Nosal, S., *The efect of some selected factors on the running – in performance of a node modeling the marine engine cylinder liner – piston ring sliding pair*, EXPLO-DIESEL & GAS TURBINE ’01. Gdańsk – Międzyzdroje – Kopenhaga 2001, s. 115 – 122.

[2] Monieta, J., *Analysis of failures of cylinder liners of the low-speed marine diesel engines type 6RLB66*, Journal of KONES 2001, No. 1 – 2, s. 93 – 99.

[3] Monieta, J., *Failures of cylinder liners of the low-speed marine diesel engines Sulzer type RLB*. Collection of Research Papers of The Baltic Association of Engineering Experts No. 3 Kaliningrad 2003, p. 3 – 6.

[4] Monieta, J., *Metoda oceny eksploatacyjnego zużycia tulei cylindrowych okrętowych silników spalinowych napędu głównego*, Journal of KONES 2003 Vol. 10, No. 1 – 2, s. 209 – 216.

[5] Włodarski, J. K., *Eksploatacja maszyn okrętowych. Tarcie i zużycie*, Wyd. Wyższej Szkoły Morskiej w Gdyni, Gdynia 1998.