

DIMENSIONAL CHARACTERISTICS CHANGES OF MARINE DIESEL ENGINES DURING OPERATION

George NOVAC¹

¹Eng. PhD. Candidate, Naval Academy, Constantza

Abstract: This paper aims to study geometric parameters changes of marine diesel engines during operation. It presents the assembly operations of main naval engine components, and the values of dimensions measured during periodic overhauls, as result of mechanical wear. Values are tabulated and so compared, both to the assembly values, and the values of other wear measurements, extended over a period of time and hours of engine operation. The research is centered on two SULZER 7K80MC-C type engines, and wants to make a contribution for the realization of estimation software for marine engine components wear reported to the number of operation hours, for future improvements of the engine reliability.

1. INTRODUCTION

This paper contains a study of the major marine diesel engines moving component wear during operation. Main assembly operations and overhauls of cylinder liners, pistons and piston rings are described,, immediately followed by tables of measurements taken on these components. Two 7K80 MC-C engines were included in the study.

2. CYLINDER LINER OVERHAUL, REPLACEMENT AND ASSEMBLY OPERATIONS

Cylinder liner is shown in figure no. 1.

Characteristic data of the overhaul and assembly operations:

- Cylinder diameter, new $\varnothing$ 800 mm
- Cylinder liner, complete 4700 kg
- Cooling jacket 130 kg
- Edge distance – cylinder cover studs 2-3 mm
- Cylinder cover stud 110 kg
- Tightening torque – lifting tool bolts 200 Nm
- Piston cleaning ring diameter, new 798.3 mm

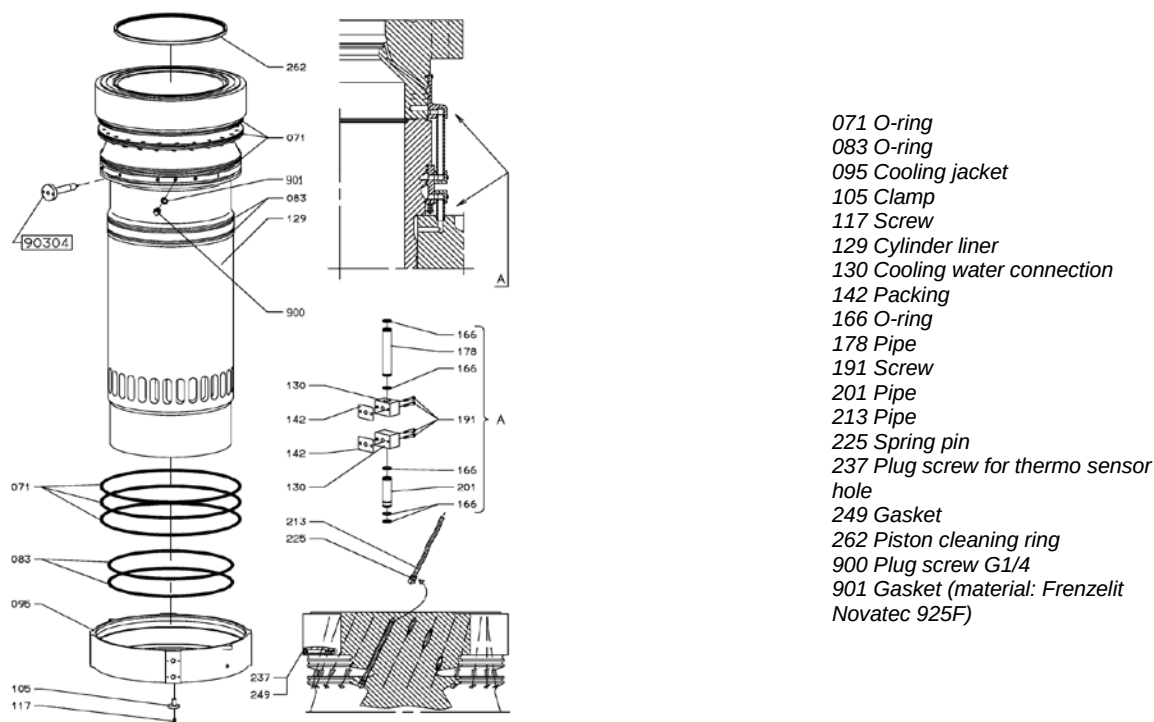


Figure no.1 Cylinder liner

For checking operation of the cylinder liner, the cylinder cover, the piston cleaning ring and the piston must be dismantled, then the cylinder liner and scavenge air ports cleaned. Measure the cylinder liner with an inside micrometer at the positions indicated on the measuring tool, and then fill in the specific table. (table 1.1, 1.2, 1.3, 1.4).

Measurements are taken in the fore-and-aft and athwartship directions according to the indication diagrams contained in each of the four tables.

For the overhaul operation the cylinder liner is lifted by crane from the engine room and landed on the wooden planks. For wear measurement the inside diameter is measured in accordance with the documentation provided by the manufacturer, in 11

indicated areas and after 2 directions F-A / E-M (as shown in the diagrams contained by tables.

The diameters of cylinder liners measured on the engines included in this study are listed in the following tables.

Table 1.1 1st Engine – 5th Piston – Date: 06.04.2008 – Functioning hours: 13278 h

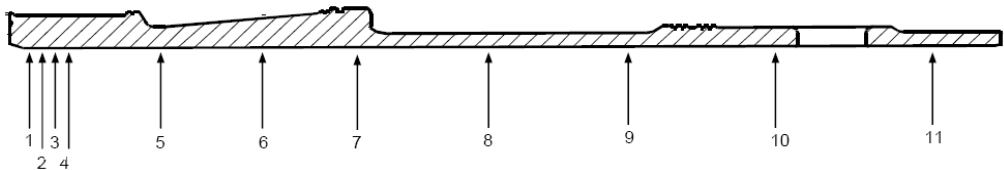
												
Measurement zone	1	2	3	4	5	6	7	8	9	10	11	
Diameter (mm)	F-A	799,81	800,18	799,89	799,88	799,55	799,78	799,83	800,08	800,22	799,93	799,82
	E-M	800,35	799,86	799,91	799,83	799,74	799,81	799,75	799,88	800,24	799,80	799,62
Average diameter		800,08	800,02	799,9	799,86	799,65	799,8	799,79	799,98	800,23	799,87	799,72
Wear %		0,010	0,002	-0,013	-0,017	-0,044	-0,025	-0,026	-0,002	0,029	-0,016	-0,035

Table 1.2 1st Engine – 3rd Piston – Date: 13.12.2009 – Functioning hours: 24942 h

Measurement zone	1	2	3	4	5	6	7	8	9	10	11	
Diameter (mm)	F-A	800,15	799,95	800,14	799,88	799,8	800,03	799,98	800,13	799,99	800,04	799,87
	E-M	799,97	800,1	799,9	800,04	799,81	799,88	800,1	799,82	800,03	799,79	799,99
Average diameter		800,06	800,03	800,02	799,96	799,81	799,96	800,04	799,98	800,01	799,92	799,93
Wear %		0,007	0,004	0,002	-0,005	-0,024	-0,005	0,005	-0,002	0,001	-0,010	-0,009

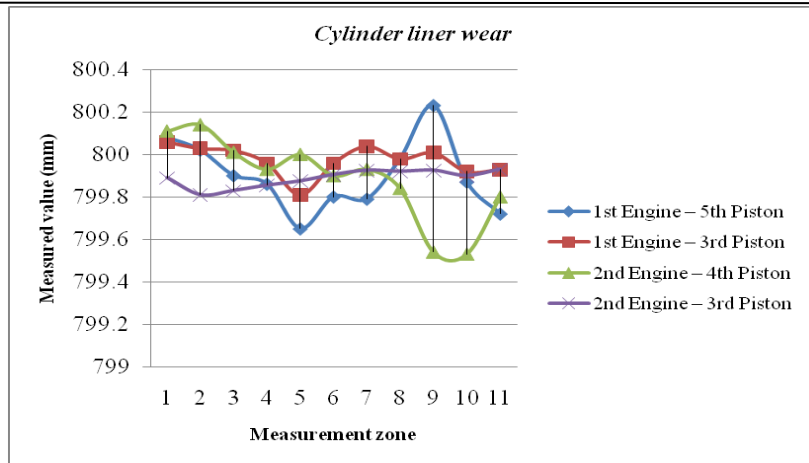
Table 1.3 2nd Engine – 4th Piston – Date: 27.09.2007 – Functioning hours: 19702 h

Measurement zone	1	2	3	4	5	6	7	8	9	10	11	
Diameter (mm)	F-A	800,05	800,14	800,01	799,84	799,98	799,93	799,99	799,89	799,52	799,68	799,82
	E-M	800,16	800,14	800,01	800,01	800,01	799,86	799,87	799,78	799,55	799,37	799,77
Average diameter		800,11	800,14	800,01	799,93	800,00	799,90	799,93	799,84	799,54	799,53	799,80
Wear %		0,014	0,017	0,001	-0,009	0,000	-0,013	-0,009	-0,020	-0,058	-0,059	-0,025

Table 1.4 2nd Engine – 3rd Piston – Date: 08.05.2007 – Functioning hours: 17092 h

Measurement zone	1	2	3	4	5	6	7	8	9	10	11	
Diameter (mm)	F-A	799,86	799,80	799,82	799,85	799,87	799,90	799,92	799,91	799,93	799,90	799,94
	E-M	799,92	799,82	799,84	799,86	799,88	799,91	799,93	799,93	799,92	799,90	799,92
Average diameter		799,89	799,81	799,83	799,855	799,875	799,905	799,925	799,92	799,925	799,9	799,93
Wear %		-0,014	-0,024	-0,021	-0,018	-0,016	-0,012	-0,009	-0,010	-0,009	-0,013	-0,009

The following graph summarizes the results of the previous tables, and contains the average values measured for the 4 pistons included in this study.



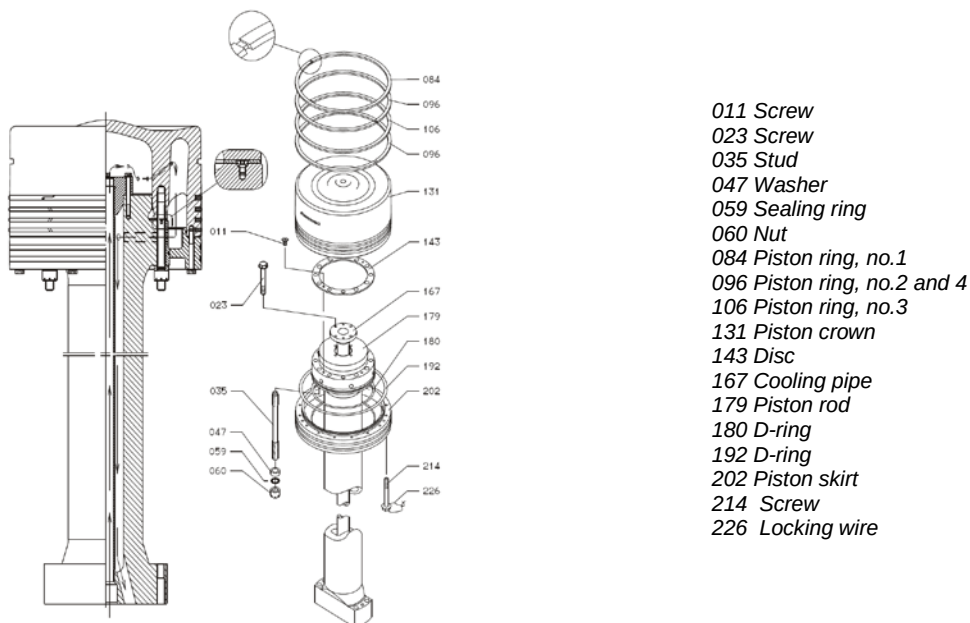
Graph no.1 Cylinder liner diameter according to the measured zone

3. PISTONS AND PISTON RINGS OVERHAUL, REPLACEMENT AND ASSEMBLY OPERATIONS

The piston and the piston rings are shown in figure no. 2.

Characteristic data of the overhaul and assembly operations:

- *Radial width (figure no.5):*
 - new piston ring 25 mm
 - worn piston ring 21 mm
- *Maximum vertical height (figure no.8):*
 - groove No. 1 18.8 mm
 - groove Nos. 2, 3 and 4 14.8 mm
- *Max. permissible burn-away (figure no.3):*
 - standard piston top 20 mm
 - Inconel piston top 8 mm
- *Height new rings:*
 - piston ring No. 1 17.9 mm
 - piston ring Nos. 2, 3 and 4 13.9 mm
- *Minimum ring gap (figure no.6,7)*
 - piston ring No. 1 5.6 mm
 - piston ring Nos. 2, 3 and 4 4.0 mm
- *Minimum free ring gap 50 mm*
- *Vertical clearance, new parts (figure no.4) 0.45-0.50 mm*
- *Piston complete weight 3300 kg*
- *Piston crown weight 865 kg*
- *Piston skirt weight 210 kg*
- *Piston cooling pipe weight 55 kg*
- *Piston rod weight 1950 kg*



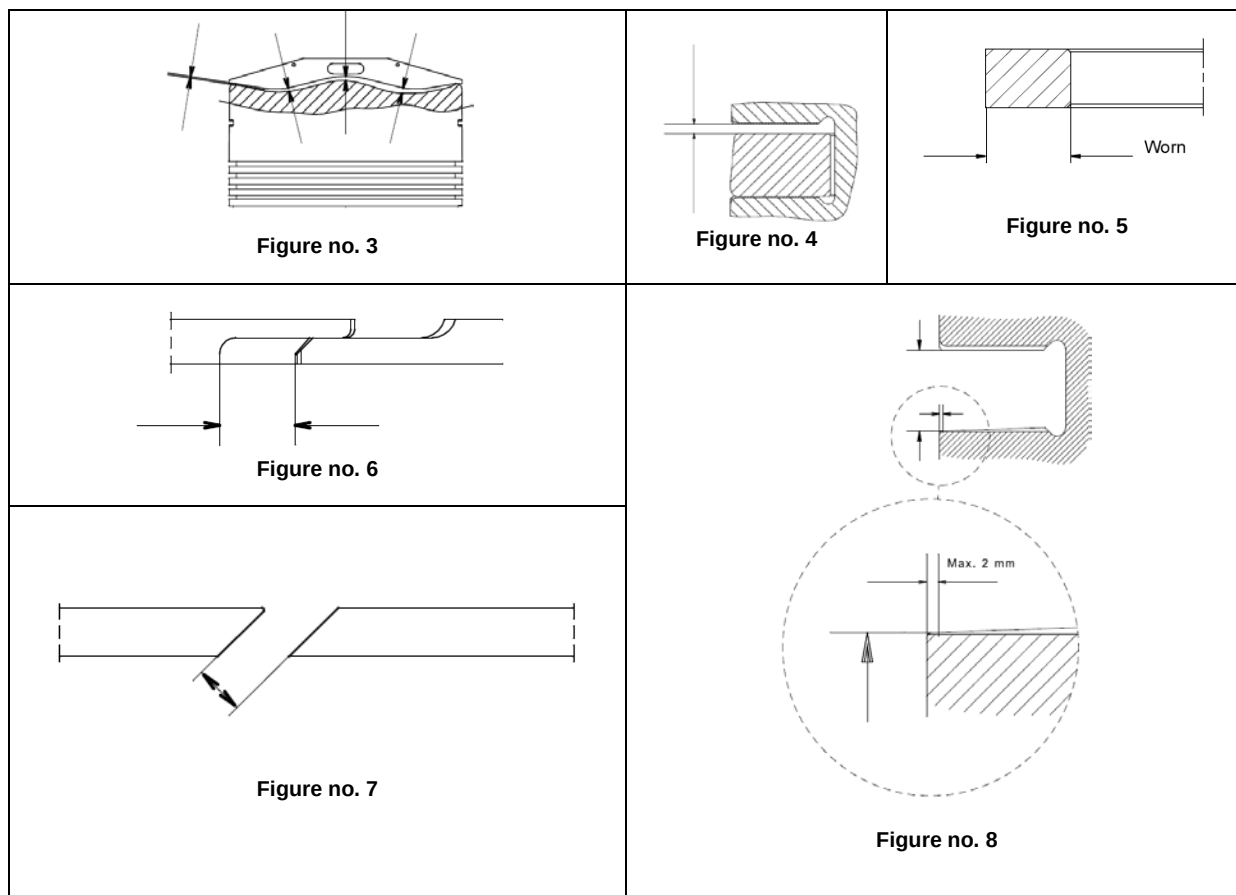
- 011 Screw
- 023 Screw
- 035 Stud
- 047 Washer
- 059 Sealing ring
- 060 Nut
- 084 Piston ring, no.1
- 096 Piston ring, no.2 and 4
- 106 Piston ring, no.3
- 131 Piston crown
- 143 Disc
- 167 Cooling pipe
- 179 Piston rod
- 180 D-ring
- 192 D-ring
- 202 Piston skirt
- 214 Screw
- 226 Locking wire

Figure no.2 Piston with segments

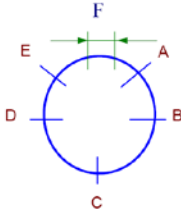
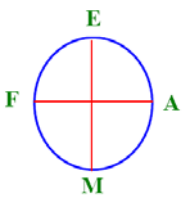
3.1. The piston head and piston rings cheking operations

For the piston rings cheking, the piston is removed and placed on a stand. The piston rings gap and other characteristic dimensions are measured before removing them from the piston, and if the measured values are not within the allowed range, they are replaced. The ring grooves are checked for burn marks or deformations after being cleaned and also the existence of chromium layer is verified.

Before installing new piston rings their free gap and height are measured. For measurement, the segment is inserted into a new cylinder liner, or at the bottom of a used one. Piston ring no.1 is horizontal measured (figure no.8) and piston rings no. 2,3 and 4 are tilted measured, as shown in the figure no. 9



The following are the measurements made on the piston rings, during overhauls or during other repairs, relative to the initial size of the components and to the number of operation hours of the engine.

Table 3.1 Measurements of the piston rings and grooves						
1st Engine – 5th Piston – Date: 06.04.2008 – Functioning hours: 13278 h						
		Piston ring no. 1	Piston ring no. 2	Piston ring no. 3	Piston ring no. 4	
New- N		N / M/ W	N / M/ W	N / M/ W	N / M/ W	
<u>Measured-M</u>		Dimension (mm)	Dimension (mm)	Dimension (mm)	Dimension (mm)	
<u>Wear-W</u>						
A	Width	25,0 / 24,53 / 0,47	25,0 / 24,78 / 0,22	25,0 / 24,79 / 0,21	25,0 / 24,81 / 0,19	
	Height	17,9 / 17,85 / 0,05	13,9 / 13,85 / 0,05	13,9 / 13,86 / 0,04	13,9 / 13,86 / 0,04	
B	Width	25,0 / 24,63 / 0,37	25,0 / 24,88 / 0,12	25,0 / 24,79 / 0,21	25,0 / 24,77 / 0,23	
	Height	17.9 / 17.82 / 0,08	13,9 / 13,86 / 0,04	13,9 / 13,86 / 0,04	13,9 / 13,85 / 0,05	
C	Width	25,0 / 24,60 / 0,40	25,0 / 24,88 / 0,12	25,0 / 24,88 / 0,12	25,0 / 24,79 / 0,21	
	Height	17.9 / 17.77 / 0,13	13,9 / 13,83 / 0,07	13,9 / 13,86 / 0,04	13,9 / 13,86 / 0,04	
D	Width	25,0 / 24,53 / 0,47	25,0 / 24,79 /	25,0 / 24,81 /	25,0 / 24,80 /	

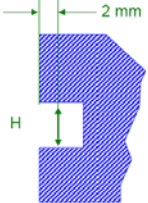
			0,21	0,19	0,20	
	Height	17,9 / 17,81 / 0,09	13,9 / 13,85 / 0,05	13,9 / 13,85 / 0,05	13,9 / 13,84 / 0,06	
E	Width	25,0 / 24,60 / 0,40	25,0 / 24,78 / 0,22	25,0 / 24,84 / 0,16	25,0 / 24,85 / 0,15	
	Height	17,9 / 17,83 / 0,07	13,9 / 13,85 / 0,05	13,9 / 13,84 / 0,06	13,9 / 13,84 / 0,06	
Average wear		Width	0,422	0,178	0,178	0,196
		Height	0,084	0,052	0,046	0,050
„F” measurement		min. 5,6 / 6,00	min. 4,0 / 5,0	min. 4,0 / 4,5	min. 4,0 / 4,6	
		Ring groove 1	Ring groove 2	Ring groove 3	Ring groove 4	
	Dimension	Max./M/wear until replacing	Max./M/wear until replacing	Max./M/wear until replacing	Max./M/wear until replacing	
F	„H”	18,8 / 18,40 / 0,40	14,8 / 14,40 / 0,40	14,8 / 14,40 / 0,40	14,8 / 14,30 / 0,50	
E	„H”	18,8 / 18,30 / 0,50	14,8 / 14,40 / 0,40	14,8 / 14,30 / 0,50	14,8 / 14,30 / 0,50	
A	„H”	18,8 / 18,40 / 0,40	14,8 / 14,40 / 0,40	14,8 / 14,30 / 0,50	14,8 / 14,30 / 0,50	
M	„H”	18,8 / 18,30 / 0,50	14,8 / 14,30 / 0,50	14,8 / 14,30 / 0,50	14,8 / 14,30 / 0,50	
AVERAGE WEAR until replacing		„H”	0,45	0,425	0,475	0,50

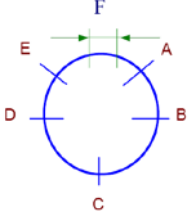
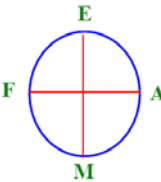
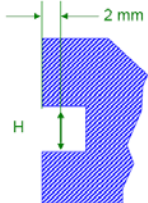
Table 3.2 Measurements of the piston rings and grooves						
1st Engine – 3rd Piston – Date: 13.12.2009 – Functioning hours: 24942 h						
		Piston ring no. 1	Piston ring no. 2	Piston ring no. 3	Piston ring no. 4	
		N / M / W	N / M / W	N / M / W	N / M / W	
<u>New- N</u> <u>Measured-M</u> <u>Wear-W</u>		Dimension (mm)	Dimension (mm)	Dimension (mm)	Dimension (mm)	
A	Width	25,0 / 24,80 / 0,20	25,0 / 24,86 / 0,14	25,0 / 24,95 / 0,05	25,0 / 24,96 / 0,04	
	Height	17,9 / 17,84 / 0,06	13,9 / 13,86 / 0,04	13,9 / 13,89 / 0,01	13,9 / 13,88 / 0,02	
B	Width	25,0 / 24,75 / 0,25	25,0 / 24,89 / 0,11	25,0 / 24,96 / 0,04	25,0 / 24,97 / 0,03	
	Height	17,9 / 17,84 / 0,06	13,9 / 13,87 / 0,03	13,9 / 13,87 / 0,03	13,9 / 13,87 / 0,03	
C	Width	25,0 / 24,75 / 0,25	25,0 / 24,87 / 0,13	25,0 / 24,98 / 0,02	25,0 / 24,97 / 0,03	
	Height	17,9 / 17,84 / 0,06	13,9 / 13,86 / 0,04	13,9 / 13,87 / 0,03	13,9 / 13,87 / 0,03	
D	Width	25,0 / 24,78 / 0,22	25,0 / 24,86 / 0,14	25,0 / 24,97 / 0,03	25,0 / 24,95 / 0,05	
	Height	17,9 / 17,83 / 0,07	13,9 / 13,85 / 0,05	13,9 / 13,88 / 0,02	13,9 / 13,87 / 0,03	
E	Width	25,0 / 24,80 / 0,20	25,0 / 24,87 / 0,13	25,0 / 24,97 / 0,03	25,0 / 24,96 / 0,04	
	Height	17,9 / 17,85 / 0,05	13,9 / 13,85 / 0,05	13,9 / 13,88 / 0,02	13,9 / 13,87 / 0,03	
Average wear		Width	0,224	0,130	0,034	0,038
		Height	0,060	0,042	0,022	0,028
„F” measurement		min. 5,6 / 6,00	min. 4,0 / 5,0	min. 4,0 / 4,5	min. 4,0 / 4,6	
		Ring groove 1	Ring groove 2	Ring groove 3	Ring groove 4	
	Dimension	Max./M/wear until replacing	Max./M/wear until replacing	Max./M/wear until replacing	Max./M/wear until replacing	
F	„H”	18,8 / 18,34 / 0,46	14,8 / 14,40 / 0,40	14,8 / 14,35 / 0,45	14,8 / 14,28 / 0,52	
E	„H”	18,8 / 18,34 / 0,46	14,8 / 14,40 / 0,40	14,8 / 14,32 / 0,48	14,8 / 14,27 / 0,53	
A	„H”	18,8 / 18,34 / 0,46	14,8 / 14,40 / 0,40	14,8 / 14,34 / 0,46	14,8 / 14,27 / 0,53	
M	„H”	18,8 / 18,35 / 0,45	14,8 / 14,30 / 0,50	14,8 / 14,32 / 0,58	14,8 / 14,27 / 0,53	
AVERAGE WEAR		„H”	0,4575	0,425	0,4925	0,5275

Table 3.3 Measurements of the piston rings and grooves

2nd Engine – 4th Piston – Date: 27.09.2007 – Functioning hours: 19702 h					
		Piston ring no. 1	Piston ring no. 2	Piston ring no. 3	Piston ring no. 4
New- N Measured- M Wear- W		N / M / W	N / M / W	N / M / W	N / M / W
		Dimension (mm)	Dimension (mm)	Dimension (mm)	Dimension (mm)
A	Width	25,0 / 24,50 / 0,50	25,0 / 24,40 / 0,60	25,0 / 24,50 / 0,50	25,0 / 24,40 / 0,60
	Height	17,9 / 17,70 / 0,20	13,9 / 14,00 / 0,00	13,9 / 13,80 / 0,10	13,9 / 13,80 / 0,10
B	Width	25,0 / 24,40 / 0,60	25,0 / 24,50 / 0,50	25,0 / 24,60 / 0,40	25,0 / 25,00 / 0,00
	Height	17,9 / 17,80 / 0,10	13,9 / 13,85 / 0,05	13,9 / 13,90 / 0,00	13,9 / 14,30 / 0,00
C	Width	25,0 / 24,60 / 0,40	25,0 / 24,45 / 0,55	25,0 / 24,65 / 0,35	25,0 / 24,65 / 0,35
	Height	17,9 / 17,90 / 0,00	13,9 / 14,00 / 0,00	13,9 / 13,80 / 0,10	13,9 / 14,00 / 0,00
D	Width	25,0 / 24,30 / 0,70	25,0 / 24,70 / 0,30	25,0 / 24,80 / 0,20	25,0 / 24,60 / 0,40
	Height	17,9 / 17,75 / 0,15	13,9 / 13,70 / 0,20	13,9 / 13,80 / 0,10	13,9 / 13,70 / 0,20
E	Width	25,0 / 24,30 / 0,70	25,0 / 24,80 / 0,20	25,0 / 24,60 / 0,40	25,0 / 24,60 / 0,40
	Height	17,9 / 17,80 / 0,10	13,9 / 14,00 / 0,00	13,9 / 13,85 / 0,05	13,9 / 14,00 / 0,00
Average wear		Width	0,58	0,43	0,37
		Height	0,11	0,05	0,07
„F” free gap measurement		min. 50 / -	min. 50 / -	min. 50 / -	min. 50 / -
		Ring groove 1	Ring groove 2	Ring groove 3	Ring groove 4
Dimension		Max./M/wear until replacing	Max./M/wear until replacing	Max./M/wear until replacing	Max./M/wear until replacing
F	„H”	18,8 / 18,10 / 0,70	14,8 / 14,10 / 0,70	14,8 / 14,10 / 0,70	14,8 / 14,10 / 0,70
E	„H”	18,8 / 18,10 / 0,70	14,8 / 14,05 / 0,75	14,8 / 14,05 / 0,75	14,8 / 14,05 / 0,75
A	„H”	18,8 / 18,10 / 0,70	14,8 / 14,15 / 0,65	14,8 / 14,05 / 0,75	14,8 / 14,05 / 0,75
M	„H”	18,8 / 18,10 / 0,70	14,8 / 14,05 / 0,75	14,8 / 14,10 / 0,70	14,8 / 14,10 / 0,70
AVERAGE WEAR until replacing		„H”	0,70	0,71	0,725

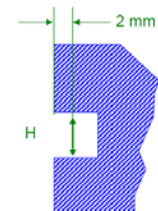
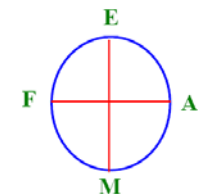
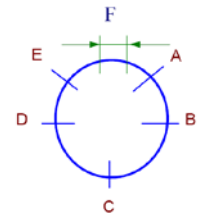
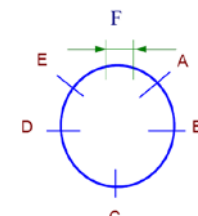
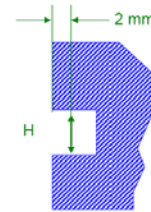


Table 3.4 Measurements of the piston rings and grooves

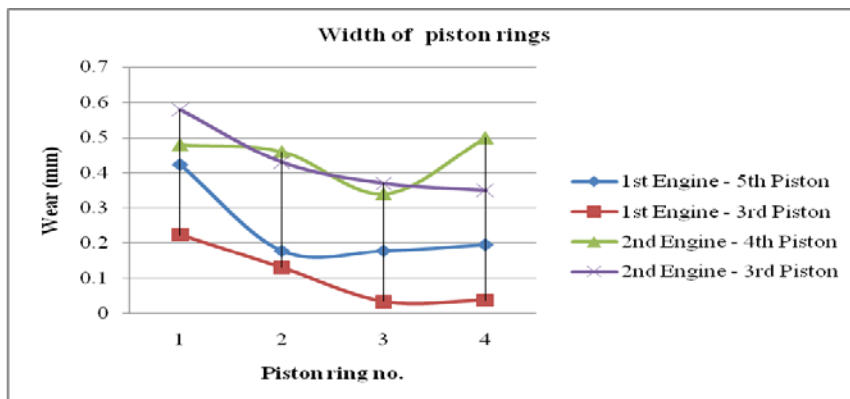
2nd Engine – 3rd Piston – Date: 08.05.2007 – Functioning hours: 17092 h					
		Piston ring no. 1	Piston ring no. 2	Piston ring no. 3	Piston ring no. 4
New- N Measured- M Wear- W		N / M / W	N / M / W	N / M / W	N / M / W
		Dimension (mm)	Dimension (mm)	Dimension (mm)	Dimension (mm)
A	Width	25,0 / 24,50 / 0,50	25,0 / 24,70 / 0,30	25,0 / 24,60 / 0,40	25,0 / 24,45 / 0,55
	Height	17,9 / 17,90 / 0,00	13,9 / 13,85 / 0,05	13,9 / 13,90 / 0,00	13,9 / 13,90 / 0,00
B	Width	25,0 / 24,40 / 0,60	25,0 / 24,40 / 0,60	25,0 / 24,70 / 0,30	25,0 / 24,50 / 0,50
	Height	17,9 / 17,80 / 0,10	13,9 / 13,90 / 0,00	13,9 / 13,90 / 0,00	13,9 / 13,90 / 0,00
C	Width	25,0 / 24,50 / 0,50	25,0 / 24,50 / 0,50	25,0 / 24,75 / 0,25	25,0 / 24,45 / 0,55
	Height	17,9 / 17,80 / 0,10	13,9 / 13,90 / 0,00	13,9 / 13,80 / 0,10	13,9 / 13,90 / 0,00
D	Width	25,0 / 24,60 /	25,0 / 24,60 /	25,0 / 24,70 /	25,0 / 24,60 /



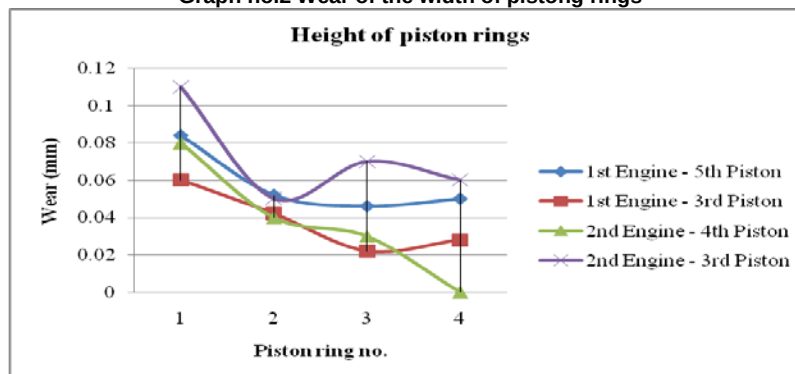
E	Height	0,40	0,40	0,30	0,40
		17,9 / 17,80 / 0,10	13,9 / 13,85 / 0,05	13,9 / 13,90 / 0,00	13,9 / 13,90 / 0,00
	Width	25,0 / 24,60 / 0,40	25,0 / 24,50 / 0,50	25,0 / 24,55 / 0,45	25,0 / 24,50 / 0,50
E	Height	17,9 / 17,80 / 0,10	13,9 / 13,80 / 0,10	13,9 / 13,85 / 0,05	13,9 / 13,90 / 0,00
	Average wear	Width 0,48 Height 0,08	0,46 0,04	0,34 0,03	0,50 0,00
„F” free gap measurement		min. 50 / 97	min. 50 / 101	min. 50 / 102	min. 50 / 105
		Ring groove 1	Ring groove 2	Ring groove 3	Ring groove 4
	Dimension	Max./M/wear until replacing	Max./M/wear until replacing	Max./M/wear until replacing	Max./M/wear until replacing
F	„H”	18,8 / 18,15 / 0,65	14,8 / 14,15 / 0,65	14,8 / 14,15 / 0,65	14,8 / 14,15 / 0,65
E	„H”	18,8 / 18,15 / 0,65	14,8 / 14,15 / 0,65	14,8 / 14,15 / 0,65	14,8 / 14,15 / 0,65
A	„H”	18,8 / 18,15 / 0,65	14,8 / 14,15 / 0,65	14,8 / 14,15 / 0,65	14,8 / 14,15 / 0,65
M	„H”	18,8 / 18,15 / 0,65	14,8 / 14,15 / 0,65	14,8 / 14,15 / 0,65	14,8 / 14,15 / 0,65
AVERAGE WEAR until replacing		„H” 0,65	0,65	0,65	0,65



Graphs no.2 and 3 includes the main results regarding the piston rings measurements.



Graph no.2 Wear of the width of pistong rings



Graph no. 3 Wear of the height of pistong rings

4. CONCLUSIONS

It can be noticed in all four measurements a cylinder liner deformation, by increasing the diameter to the top dead center of the piston, and a narrowing of the diameter in the 4-5-6 measurement zones. According to the engine operating manner or load conditions, for 8-9-10 measuring areas were recorded either enlarged cylinder liner diameter or smaller than the initial values. Also in normal operating conditions, wear on piston rings drops to the bottom of the piston, the first piston ring having the highest wear. The graphs, however, shows situations where the no. 3 and 4 piston rings had an increased wear, according to the operation and maintenance manner of the engine, or due to occurred functioning problems.

REFERENCES

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