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High speed radial marine diesel engine suitability maintenance model

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ABSTRACT

For the application of the general theory of maintenance suitability (reparability) on high speed radial marine diesel engines research maintainability results are presented for the engine type M 504 B2, which are the most important part of the propulsion subsystem for the missile gunboat Navy (RTOP-11 and RTOP-12). A large number of empirical data is taken from the practice and statistically processed and analysed scientifically. The aim of this study was to determine the function of motor reparability special purpose in demanding operating conditions of the Adriatic archipelago. It is scientifically proven that the normal distribution best approximates the empirical function of maintenance suitability respectively the reparability, and the mean time of the maintainability suits the mean time of the repair engines subsystems. The research results are applicable to other similar marine engines, as well to other platforms diesel engines.

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Generally for ships it is said that they are complex technical systems, because they are composed of a large number of subsystems and elements. The ship is a complex technical system, open and realistic system with its dynamic and deterministic properties. It consists of tens of thousands of subsystems, assemblies and elements of different exploitation reliability and maintenance suitability, but also of different importance for the operational availability [1], [3]. Technical system operational availability stands for probability that the system, when used under the specified conditions, will function satisfactory at any point of time, where time observed includes the usage time *tk* and malfunction time *tz* of the technical system. Operational availability O_r is determined with a following relation [2], [4]:

$$O_r = \frac{t_k}{\left(t_k + t_z\right)} \qquad (1)$$

When studying the reliability problem, as well as maintenance suitability of complex technical systems, time is a key factor or a key category in assessing the ability of certain technical system, in the present case high speed radial marine diesel engine M 504 B2, in fulfilling the functions for which it is intended, including failures and problems that occur in the repair and maintenance of engines.

System time usage t_k is actually the time when the exploitation reliability of technical systems is expressed, while malfunction time t_z is the time when suitability maintenance of the technical system is expressed.

Warships, as specific marine ships, are normally presented in two conditions: operational and non-operational status, and therefore under the maintenance suitability imply actually probability that the warship which appeared with malfunction, to be returned to the operating state during scheduled malfunction which makes active repair time, logistics time and administrative time. Operational availability respectively the return of warship to the operating state depends primarily on the type of warship and marine subsystems state; therefore, in extension the attention will be aimed to the particular category of warship and ship subsystems and their mutual interconnections, which basically can be serial or parallel.

Analogously, according to (1), the engine maintenance suitability imply actually probability that the engine, on which a failure appeared, is to be returned to the operating state estimated time of motor malfunction t_{zm}. Therefore, the maintenance suitability of the engine M 504 B2 also designed the engine's ability as reparability system to maintain (through preventive maintenance) or to return (through corrective maintenance) engine operational availability O_{rm}, which is determined by the aforementioned relation (1). It is absolutely clear, that to return the projected capacity after the failure, during corrective maintenance t_{kodr} must be less or equal to the engine malfunction time t_{zm}, ie. that the following relation is valid [4], [5], [6], [8]:

$$t_{kodr} \leq t_{zm} = t_{lm} + t_{am} + t_{avkm} \quad (2)$$

where is:
t_{kodr} – corrective maintenance time [h],
t_{lm} – engines logistic time [h],
t_{av} – engines administrative time[h],
t_{avkm} – engines corrective maintenance active time [h].

Engines logistic time t_{lm} includes the time of purchase and completion of spare parts, engines administrative time tam includes time in which the person responsible for the maintenance makes administrative activities necessary for the successful implementation of maintenance, and engines maintenance active time t_{avkm} includes: time during the dismantling and preparation t_{dmp}, the time required for defecation perceived failure t_{dk}, the time of repair and assembly t_{okm} and the time required for functional engine testing after assembly.

Accordingly, the following relation is valid:

$$t_{avkm} = t_{dpm} + t_{dk} + t_{okm} + t_{im} \quad (3)$$

where is:
t_{avkm} – engines corrective maintenance active time [h],
t_{dmp} – time during dismantling and preparation [h],
t_{dk} – the time required for defecation perceived failure [h],
t_{okm} – the time of repair and assembly [h],
t_{im} – the time required for functional engine testing after assembly [h]

Following the foregoing, the table 1 is made showing the corrective maintenance active medium time t_{avkm}^{sr} of individual subsystems engine M 504 B2.

Data on corrective maintenance active time are shown in table 1 and were collected during research of reliability high speed radial diesel engine M 504 B2, in cooperation with the staff of the NCP from Šibenik Group (NCP – Repair shipyard "Šibenik" d.o.o. – repairs, maintenance, modifications, new yachts up to 75 m/1,500 t), which are

Table 1 Corrective maintenance active medium time of individual subsystems engine M 504 B2

Subsystem	Failure	t_{dmp} [h]	t_{dk} [h]	t_{okm} [h]	t_{im} [h]	t_{avkm}^{sr} [h]
Turbocharger	Rotor	60	8	80	32	180
	Control valve	16	3	32	3	54
	Labyrinth	80	5	120	3	208
	Gas router	40	24	56	24	144
	Seal marine	2	1	3	0	6
	Regulation screw	6	2	8	1	17
	Housing	32	5	40	26	103
Reversing clasp	Suport clasp	48	16	56	16	136
	Housing clasp	80	6	110	1	197
Cylinder block	Fuel leakage	8	3	16	1	28
	Compression leakage	56	8	80	1	145
	Emulsion in the cylinder	56	8	80	8	152
	Cylinder block fuel leakage	40	16	70	8	134
Piston assembly	Piston damage	70	6	90	24	190
Initiation system	Guide valve breakage	16	2	20	3	41
	Guide valve blocked	16	2	24	3	45
Bloc-pump fuel	Fuel lath	48	8	68	5	129
Speed velocity regulator	Spring regulator breakage	16	3	24	1	44
Exhaust pipe	Emulsion leakage	32	1	54	1	88
	Torn screw	40	1	50	1	92
Injector	Nozzle burned	9	3	12	3	27
	Nozzle leakage	9	3	14	3	29
High pressure fuel pump	Fuel leakage	32	5	40	2	79
	Managing mechanism blocked	56	8	60	8	132

directly involved with the organization, supervision and implementation of all maintenance engine M 504 B2 [13]. On the basis of the table 1.1 a diagram is made of cumulative values of corrective maintenance active medium time $t_{avkm}{}^{sr}{}_{i}$ i = 1,2 ... 10 per individual engine subsystems M 504 B2, as shown in Figure 1.

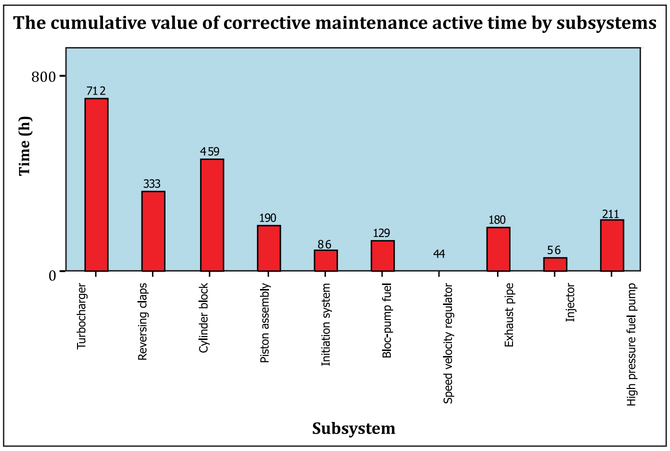

Figure 1 Cumulative value of corrective maintenance medium active time by engines subsystems

Based on the Figure 1 a percentage diagram is made of shared time $t_{avkm}{}^{sr}{}_{i}$, shown in Figure 2.

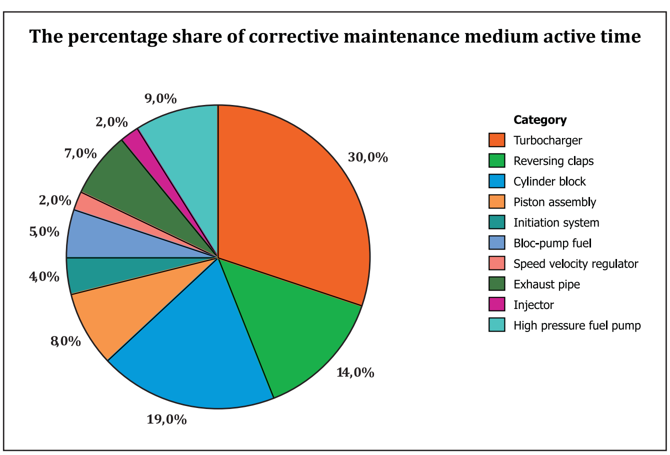

Figure 2 The percentage share time t_{avkmsr} by subsystems

According to Figure 2 it is obvious that the 63% of corrective maintenance medium active time $t_{avkm}{}^{sr}$ is focused on three subsystems: turbocharger (30%), the cylinder block (19%) and reversing buckle (14%). Thus, the total active medium time during corrective maintenance $t_{avkm}{}^{sr}$ of all 69 failures on six engines according to table 1. amounts 2400 operating hours, while the amount on three aforementioned subsystems is 1512 operating hours. For the purpose of comparison below are the operating times shown for preventive maintenance of diesel engine M 504 B2 as defined by the engine manufacturer [11]:

- Dismantling the engine from the boat – 130 hours,
- Overhauling the engine – 7494 working hours,
- Engine service – 1260 operating hours,
- Buckle revision – 748 hours,
- Turbocharger service – 340 hours,
- Bench test – 550 hours,
- Assembly on board – 240 hours.

As in the analysis of reliability, the best way to analyse the benefits of maintaining the ship's diesel engine M 504 B2 is to determine the function of maintainability *M(t).*

1 Maintaining benefits analysis for the ship's diesel engine M504 B2

The key difference between the engine reliability analysis and engine maintainability analysis is the fact that reliability is actually probability that the engine failure will not occur in a particular (specified) time which in the case of a diesel engine M 504 B2 is 2000 hours. Maintainability is actually probability that the engine can be restored to corrective condition in a particular (specified) time, which in this case engine malfunction t_{zm}. In this case engine malfunction time should not be higher than 2000 – 890 = 1110 hours, under condition that the provided operational availability of 44% is satisfactory. Following the foregoing it can be said that the engine suitability maintenance is based on the engine malfunction time t_{zm}, and by analogy, the perfectibility of the engine is limited to the engine maintenance active time (or engine repair active time). In this context we distinguish corrective maintenance active time t_{avkm} and preventive maintenance active time t_{avpm}. Assuming that the maintenance time of the system t is a random variable which is independent of the engine operating time t', then the function M (t) is defined by the expression [6]:

$$M(t) = \int_0^t f(t)\,dt \tag{4}$$

M(t) is a function of the maintenance suitability, and the function *f(t)* is the probability density function for the total engine malfunction time t_{zm}. Analogously the foregoing, the function $M_R(t)$ is defined by expression [6]

$$M_R(t) = \int_0^t f_R(t)\,dt \tag{5}$$

$M_R(t)$ is a function of engine repairability, and $f_R(t)$ is the probability density function for the repair active time. From previous researches it is certain that failure intensity function λ_i of a individual subsystem shown in table 1 is not constant, then the probability density function *f(t)* which are taken into account in the benefit analysis of maintaining the ship's diesel engine M 504 B2, we conclude the following: Normal distribution, Lognormal distribution and Weibull distribution.

The normal distribution

Maintenance suitability function *M(t)* is determined by the following expression [4]:

$$M(t) = \frac{1}{\sigma\sqrt{2\pi}} \cdot \int_{-\infty}^{t} e^{-\frac{1}{2}\left(\frac{t-M}{\sigma}\right)^2} dt \qquad (6)$$

where is:
t – maintenance time random variable,
M – maintenance time medium value,
σ – maintenance time standard deviation.

Lognormal distribution

Maintenance suitability function *M(t)* is defined by the expression [4]:

$$M(t) = \int_{0}^{t} \frac{1}{t\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{\ln t - m}{\sigma}\right)^2} dt \qquad (7)$$

where is:
t – maintenance time random variable,
m – maintenance time natural logarithm medium value
σ – maintenance time natural wastage logarithm standard deviation

Weibull distribution

In the case of Weibull distribution function maintenance suitability *M(t)* is defined by the expression [4]:

$$M(t) = 1 - e^{-\left(\frac{t}{\eta}\right)^{\beta}} \qquad (8)$$

where is:
t – maintenance time random variable,
β – shape parameter,
η – scale parameter.

Starting from the above mentioned maintainability function forms *M(t)*, it shall be determined the empirical function of maintainability, respectively the reparability engine function $M_R(t)$ based on the data in table 1 and relations for parameter estimation of reparability function which is determined by the following relation [2], [4]:

$$M_R(t_i) = \frac{\sum_{j=1}^{i} n_j}{N+1} \qquad (9)$$

where is:
n_j – the number of cases when the maintenance procedures dues, t_j,
N – total number of maintenance procedures, the total sum of all n_j.

For the calculation according to relation (9), empirical values t_j have to be sorted in ascending order from the smallest t_1 to the largest time t_n.

2 Determining the empirical value of reparability functions for engine M 504 B2

Based on the data given in Table 1, a Table 2 has been made in which are shown: corrective maintenance active medium time by engine subsystem elements $t_{avkm}{}^{sr}{}_j$ in ascending order, where is j = 1, 2 ... 24, and repair frequency for each individual element by its subsystems f_j, which arises from the appearances incidence of failure.

Table 2 Average corrective maintenance engine active medium time $t_{avkm}{}^{sr}{}_j$

Engine elements	Medium time $t_{avkm}{}^{sr}{}_j$ [h]	Appearance incidence of failure f_j
Seal marine	6	1
Regulation screw	17	3
Nozzle burned	27	1
Fuel leakage	28	1
Nozzle leakage	29	11
Guide valve breakage	41	1
Spring regulator breakage	44	1
Guide valve blocked	45	3
Control valve	54	1
Fuel leakage	79	9
Emulsion leakage	88	1
Torn screw	92	2
Housing	103	2
Fuel lath	129	1
Managing mechanism blocked	132	2
Cylinder block fuel leakage	134	3
Support clasp	136	16
Gas router	144	1
Compression leakage	145	1
Emulsion in the cylinder	152	1
Rotor	180	2
Piston damage	190	1
Housing clasp	197	2
Labyrinth	208	2

Figure 3 shows the incidence diagram of average corrective maintenance active medium time $t_{avkm}{}^{sr}{}_j$ by its individual subsystem element, which is created and based on Table 2.

According to Figure 3 there are particularly highlighted three active times t_{avkm} with the highest incidence: 29 hours (11 times), 79 hours (9 times) and 136 hours (16

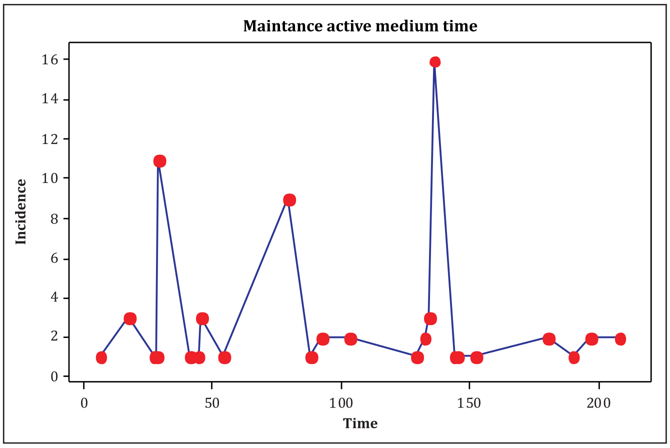

Figure 3 Incidence diagram of corrective maintenance active medium time $t_{avkm}^{sr}{}_j$ of its individual subsystem element.

times), while the incidence of the other active times ranges between one and three times. From Table 2, and according to the following:

$$MTTP = \frac{1}{6}\sum_{j=1}^{24} f_j \cdot t_{avkmj}^{sr} \qquad (10)$$

one can calculate the medium time of engine repair (MTTP), which amounts to 1,111 hours, and is equal to the engine malfunction time t_{zm} which amounts 1110 hours. Based on Table 2, 3 and Figure 3 it can be concluded that the corrective maintenance medium active time t_{avkm}^{sr} varies from case to case and depends on the type of failure that caused the engine to malfunction. Hence, the time t_{avkm}^{sr} is not constant, it is statistically changing and representing a random variable. Therefore it is necessary to determine the empirical function engine subsystems reparability $M_R(t_i)$ based on the collected empirical data from Table 2. The calculated data presented in Table 3 and Figure 4.

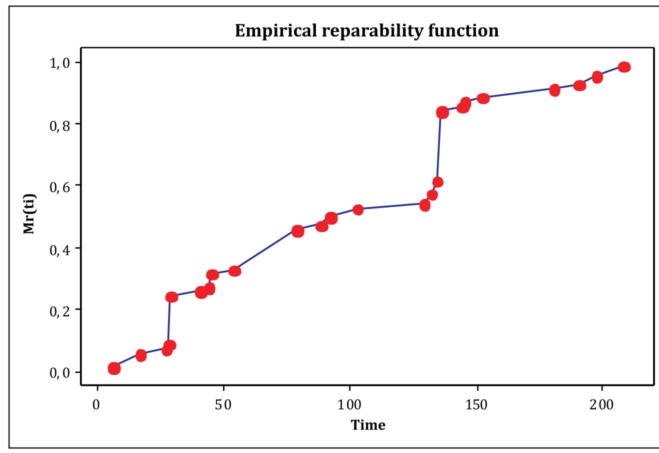

Figure 4 Empirical engine subsystems reparability function

Table 3 Empirical engine subsystems reparability function

Engine elements	Medium time $t_{avkm}^{sr}{}_j$ [h]	Appearance incidence of failure f_j	$M_R(t_i)$
Seal marine	6	1	0,0142857
Regulation screw	17	3	0,0571429
Nozzle burned	27	1	0,0714286
Fuel leakage	28	1	0,0857143
Nozzle leakage	29	11	0,2428571
Guide valve breakage	41	1	0,2571429
Spring regulator breakage	44	1	0,2714286
Guide valve blocked	45	3	0,3142857
Control valve	54	1	0,3285714
Fuel leakage	79	9	0,4571429
Emulsion leakage	88	1	0,4714286
Torn screw	92	2	0,5
Housing	103	2	0,5285714
Fuel lath	129	1	0,5428571
Managing mechanism blocked	132	2	0,5714286
Cylinder block fuel leakage	134	3	0,6142857
Support clasp	136	16	0,8428571
Gas router	144	1	0,8571429
Compression leakage	145	1	0,8714286
Emulsion in the cylinder	152	1	0,8857143
Rotor	180	2	0,9142857
Piston damage	190	1	0,9285714
Housing clasp	197	2	0,9571429
Labyrinth	208	2	0,9857143

The form of empirical engine subsystems reparability functions shown in Figure 4 indicates which function best describes empirical data. In this case it is assumed that it was a normal distribution. Based on research results shown in Figure 4, respectively the forms of empirical reparability subsystems function of high speed diesel engine M 504 B2, it can be assumed the following:

- The normal distribution best approximates the empirical reparability radial high speed marine diesel engine function.
- The maintenance time medium value M corresponds to the medium time of engine repair – radial high speed marine diesel engine by subsystems ($MTTR_{ps}$).

Analytical assumptions testing was conducted, then results were checked with the help of the software package Minitab 16 and Anderson-Darling test.

3 Theoretical determination model of corrective maintenance active time distribution

In order to define the distribution that best approximates the empirical collected data, it is necessary to determine the value of the cumulative distribution of theoretical models, Normal and Lognormal distribution, ie. the value of *F (x).* The decision about selecting the best distribution will be given by using the Kolmogorov-Smirnov test.

The probability density function for the normal distribution has a shape according to [2], [4]:

$$f_n(t) = \frac{1}{\sigma\sqrt{2\pi}} \cdot e^{-\frac{1}{2}\left(\frac{t-M}{\sigma}\right)^2} \tag{11}$$

Where *t* is a random variable that defines the time to failure elimination, M medium time to eliminate defects (parameter position) and standard deviation *σ*, which defines waste of time to eliminate defects around the average value (scale parameter).

Cumulative distribution function is according to [2], [4]:

$$f_n(t) = \frac{1}{\sigma\sqrt{2\pi}} \cdot \int_{-\infty}^{t} e^{-\frac{1}{2}\left(\frac{t-M}{\sigma}\right)^2} \tag{12}$$

Applying transformation;

$$z = \frac{t-\hat{M}}{\hat{\sigma}} \tag{13}$$

cumulative distribution function can be written as:

$$F(z) = \frac{1}{\sqrt{2\pi}} \cdot \int_{-\infty}^{z} e^{-\frac{1}{2}z^2} \tag{14}$$

Cumulative distribution function given by 14, can be calculated after the value of the parameter *z* from the designated tables available in the literature. By analytical procedure the parameters $\hat{M}$ and $\hat{\sigma}$ can be obtained by:

$$\hat{M} = \frac{\sum_{i=1}^{n} t_i}{n} \tag{15}$$

$$\hat{\sigma} = \sqrt{\frac{\sum_{i=1}^{n}\left(t_i - \hat{M}\right)^2}{n-1}} \tag{16}$$

where *n* is the number of completed intervention to eliminate cancellation.

Using the expression 15 and 16, the empirical research data collected by research and presented in Table 3 we get the parameters of the normal distribution corrective maintenance high speed radial engine M 504 B2 active time.

$\hat{M}$ = 96.61 hours

$\hat{\sigma}$ = 56.038 hours

The same values are obtained using the software Minitab 16.

Mean of t_i = 96,6087

Standard Deviation of t_i = 56,0389

The probability density function for lognormal distribution has the form according to [2], [4]:

$$f_{\ln}(t) = \frac{1}{ts\sqrt{2\pi}} \cdot e^{-\frac{1}{2}\left(\frac{\ln t-m}{s}\right)^2} \tag{17}$$

Where *t* is a random variable that defines the time to eliminate failure, m medium value of time elimination defects natural logarithm (scale parameter) and *s*, the standard deviation, which defines natural logarithm waste of time elimination defects around the average value (shape parameter). Since the lognormal distribution results from the normal distribution of replacing *ln t* instead *t*, the cumulative distribution function $F_{\ln}(x)$, is obtained as in the case of normal distribution, using relation.

$$z = \frac{\ln t - \hat{m}}{\hat{s}} \tag{18}$$

and the parameters $\hat{m}$ and $\hat{s}$ are obtained by:

$$\hat{m} = \frac{\sum_{i=1}^{n} \ln t_i}{n} \tag{19}$$

$$\hat{s} = \sqrt{\frac{\sum_{i=1}^{n}\left(\ln t_i - \hat{m}\right)^2}{n-1}} \tag{20}$$

Where n is the number of completed interventions to eliminate cancellation. Using the formulation 19 and 20,based on the empirical data research collected and presented in table 3 we get the parameters for lognormal distribution of corrective maintenance high speed radial engine M 504 B2 active time.

$\hat{m}$ = 4.29684

$\hat{s}$ = 0.7869558

The same values are obtained using the software Minitab 16

Mean of ln t_i = 4,32968

Standard deviation of ln t_i = 0,786956

By applying the analytical methodology and expressions 12., 13, 14, 17, 18 it can be calculated the cumulative value function $F_n(t)$ and the $F_{ln}(t)$. Calculation results of cumulative functions, analytically and using Minitab 16 software, are given in table 4. The table shows the size D_n and D_{ln} representing the absolute value of the difference between the value of the empirical cumulative distribution function and theoretical cumulative distribution function $F_n(t)$ and the $F_{ln}(t)$.

From the calculation results shown in table 4., we see that the maximum value amount of the difference of cumulative normal distribution function for is D_{nmax} = 0.17552 while the lognormal distribution amounts D_{lnmax} = 0.20688. After defining the maximum values D_{nmax} and D_{lnmax}, the numerical values are calculated for the implementation of the Kolmogorov-Smirnov test, to determine the theoretical model data distribution of corrective maintenance high speed radial diesel engines M504 B2 active time. Using the well-known relation to the implementation of the Kolmogorov-Smirnov test, the level of significance of α = 0.01 and n = 69 follows

$$D_{max} < \frac{d_\alpha}{\sqrt{n_1}} = \frac{1.63}{\sqrt{69}} = 0,1962$$

Since D_{max} = 0.20688 is greater than D_{max} = 0.1662 it is not accepted the assumption that the received research data for corrective maintenance of diesel engines M 504

Table 4 The values of cumulative functions

Actively growing time (t_i)	M_R (t_i)	Fn (t)	Fln (t)	D_n	D_{ln}
6	0,0142857	0,052951	0,00063	-0,03867	0,013656
17	0,0571429	0,077717	0,028612	-0,02057	0,02853
27	0,0714286	0,107091	0,09447	-0,03566	-0,02304
28	0,0857143	0,110419	0,102486	-0,0247	-0,01677
29	0,2428571	0,11382	0,11068	0,129037	0,132177
41	0,2571429	0,16052	0,216843	0,096623	0,0403
44	0,2714286	0,17392	0,244103	0,097509	0,027326
45	0,3142857	0,17854	0,253151	0,135746	0,061135
54	0,3285714	0,223525	0,332533	0,105046	-0,00396
79	0,4571429	0,376676	0,520151	0,080467	-0,06301
88	0,4714286	0,438955	0,574417	0,032474	-0,10299
92	0,5	0,467228	0,59643	0,032772	-0,09643
103	0,5285714	0,545401	0,650856	-0,01683	-0,12228
129	0,5428571	0,718373	0,749733	-0,17552	-0,20688
132	0,5714286	0,736159	0,758929	-0,16473	-0,1875
134	0,6142857	0,74769	0,764844	-0,1334	-0,15056
136	0,8428571	0,75895	0,770592	0,083908	0,072265
144	0,8571429	0,801136	0,792014	0,056007	0,065129
145	0,8714286	0,806077	0,794525	0,065351	0,076903
152	0,8857143	0,838532	0,811148	0,047182	0,074567

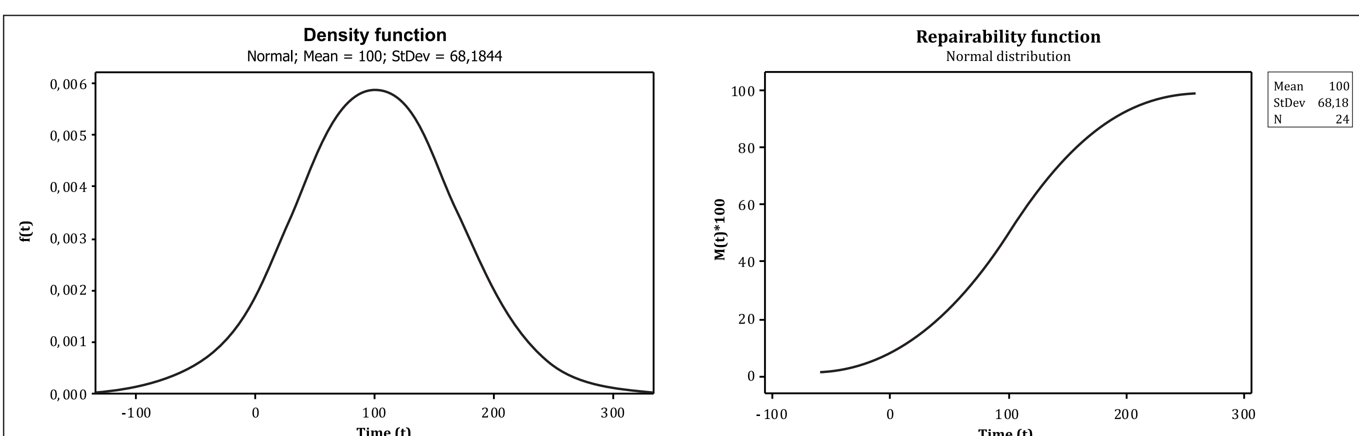

Figure 5 Density normal distribution function and reparability normal distribution function

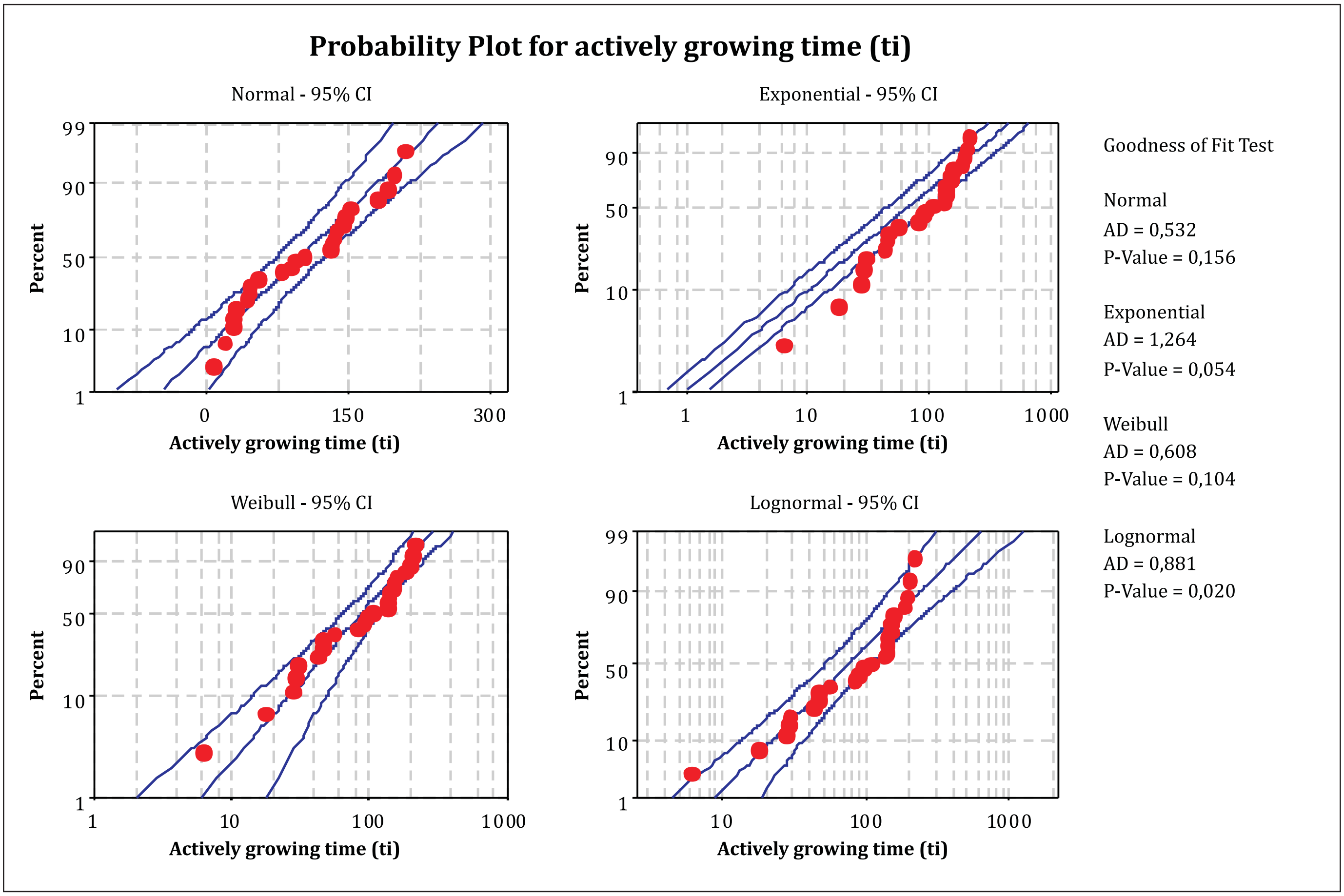

Figure 6 Comparative test of statistical distributions (normal, exponential, Weibull and logonormal)

B2 belong logonormalna distribution. Hence, Since D_{nmax} = 0.17552 is less than D_{max} = 0.1662, which is as well the default condition of the Kolmogorov-Smirnov test, the normal distribution is adopted as the best model of distribution data for active corrective maintenance of diesel engine M 504 B2.

Figure 5 shows the diagram density function of normal distribution functions and reparability normal distribution.

4 Analytical obtained results testing

Analytical obtained results testing on how the normal distribution function best approximates the empirical engine reparability function by subsystems, will be carried out with the help of the software package Minitab 16. The criteria based on which the previously mentioned hypothesis will be accepted or rejected, namely the minimum value of AD test and value *p* is a parameter greater than 0.05. Consequently specified on the figures 6 and 7 the results of testing are shown.

The test results shown in figure 6 indicate that normal distribution function best approximates the empirical reparability $M_R(t)$, because only then parameter AD and the smallest amounts 0,532, and the parameter p> 0.05, amounts 0,156. Figure 7 shows the main parameters of the normal distribution, and M = 100 hours and σ = 64.1844 hours.

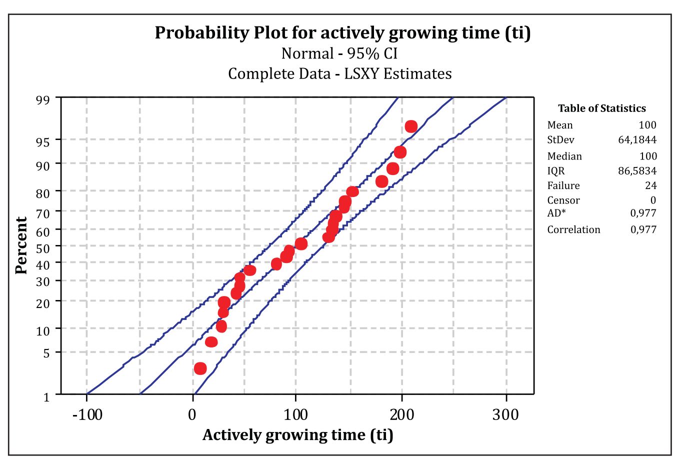

Figure 7 Normal distribution parameters

Following the foregoing the results are confirmed that the normal distribution function best approximates the empirical reparability, and the maintenance time medium value M corresponds to the medium time of engine repair by subsystems ($MTTR_{ps}$). Since the engine has 10 subsystems, then the medium time of engine repair amounts MTTR = 1000 hours. For the sake of the comparison, Figure 8 shows the empirical function and the approximated reparability function for high speed radial diesel engine M 504 B2.

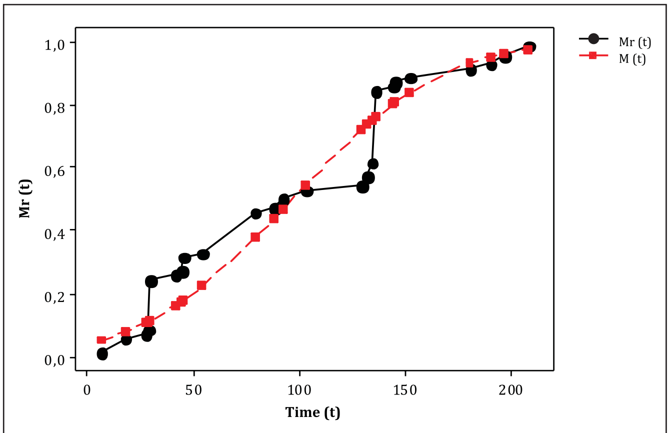

Figure 8 The empirical function and the approximated reparability function for high speed radial diesel engine M 504 B2.

5 Conclusion

Despite the new findings on exploitation reliability of marine diesel engines, there is still considerable scope for further research in durability increasing direction and availability of marine diesel engines, as in the case of faults caused by the material properties, as well the manner and conditions of use and in the case of selected technologies maintenance of diesel engines. This is especially referred on high speed radial marine diesel engines, which are the least represented in past researches, which are mostly represented in the fast ships of the Croatian War Navy. In this paper the problems that occurred in practice are investigated and analysed, with the aim to research applied maintenance methodology of complex technical systems, regarding into account the procedures defined by the manufacturer and by proposing new methods of maintenance that aim to increase the reliability of the Navy fleet in its entirety, which is very important for possible combats. One of the goals of the research was the spare parts stock reduction in the warehouse, which are not used and result in unnecessary cost of procurement and storage. As the main object of study the main engine is defined, which is a fundamental link in the reliability of the drive system RTOP's, and thus the overall RTOP's reliability. A large number of data is collected regarding occurrence and types of failures on six engines total RTOP-a. For main ship suitability maintenance model of a high speed radial diesel engine, an analysis has been made for suitability maintenance of the ship diesel engine type "Star" M 504 B2, to determine the empirical value reparability function of the same engine, a normal distribution approximation is carried out and also validated. The study concluded that Normal distribution best approximates the empirical function of maintainability and reparability for radial high speed marine diesel engine. The Normal distribution of failures appearance, indicates the dominant cause of the failure incidence and it is aging system during use, ie. there is an increased detrition of subsystem parts. Furthermore, it is demonstrated that the maintenance time medium value M corresponds exactly to medium time of engine repair by subsystems (MTTRps). The operational availability of 44% is insufficient as a direct consequence of the maintenance and repair chosen model, and the medium repair time from a minimum of 1,000 hours by engine is too high, as well as the medium time of engine repair by subsystems of 100 hours. The established ability to recurrence diesel engine in operating condition using corrective maintenance requires a high level of maintenance, ie. specialized personnel and repair capacity is to perform the most complex maintenance operations, and significantly it depends on the supply of spare parts and equipment.

Preventive maintenance recommended by the manufacturer as to prevent the occurrence of failure due to aging and wear and tear does not provide adequate results, therefore, the defects are caused mostly by human factor and unfavourable exploitation conditions of the rocket gunboat main engines, which are inconsistent with the manufacturer's recommendations. The general conclusion is that it is necessary to change the concept of use and maintenance of high speed radial marine diesel engines type "Star" M 504 B2. Results based on findings which occurred during the research will be useful to the management responsible for maintaining warships and system for stock spare parts management. Results would equally provide assistance in the training of the crew and staff directly involved in the exploitation and maintenance operations of war ships in the Croatian War Navy. It certainly should be noted that the research results are applicable not only to the Croatian War Navy fleet, but also on other high speed radial diesel marine engines and also to the same engines of other platforms.

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