# Research of Marine Diesel engine Maintenance Strategy

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## Abstract

Aiming at some existing problems in present maintenance management system of marine machine, we pose a set of maintenance management strategy (Selective Maintenance Strategy) suitable for complicated mechanical system as marine diesel engine. Main contents and key problems of this strategy are expounded here. Based on this strategy, we have developed a maintenance aided decision system. This system will guide equipment maintenance managers to make scientific action, and it is helpful to promote optimization for marine diesel engine maintenance management institution. Finally, some suggestions on how to carry out this maintenance system are also given.

## 1 Introduction

For long periods, scheduled maintenance(SM) is main maintenance way in our country marine machinery maintenance. The main shortage of this kind of maintenance way is to cause overdue maintenance and waste fund. How to decrease overdue maintenance and maintenance fund becomes a attention question in water transportation enterprise and china classification society. For resolving this question, we must research more suitable maintenance system, more effective maintenance strategy and develop more advanced maintenance technology. Here, we pose a set of maintenance management strategy (Selective Maintenance Strategy) suitable for complicated mechanical system .In accordance with concept of RCM ,this strategy carries out different maintenance ways based on reliability and different characters of equipment and its

circumstance   respectively. These ways include breakdown maintenance(BM), scheduled maintenance(SM), preventive diagnostic maintenance(PDM) .
Reliability theory shows that scheduled maintenance is only suitable for parts of wear-out failure, but not suitable for parts of accidental failure. In addition to few systems, failure rate curve of most complicated mechanical systems is not bathe pattern. Selective maintenance system is put based on this theory. Its main contents are: through analysis to equipment, dividing of maintenance ways will be carried on and it is built a modern maintenance management system(selective maintenance system) which includes breakdown maintenance ,scheduled maintenance ,preventive diagnostic maintenance based on daily maintenance, and scheduled maintenance. This system forces application of fault diagnostic and condition monitoring technique and carries on computer aided trends management.

## 2 Main contents

As introducing above, Selective Maintenance Strategy is a kind of complex maintenance system. It is different from maintenance management system based on condition monitor. Diagnostic maintenance is a sort of preventive maintenance based on equipment technology condition gotten by condition monitor. It is scientific and advanced, but this kind of technology is not the best ways to maintenance management of some equipment or parts.
Selective maintenance adequately considers advantages of diagnostic maintenance, scheduled maintenance and breakdown maintenance. Through optimization, three kinds of different maintenance ways will be selected according to particular situation of different equipment or different important parts. At the same time, diagnostic maintenance is still a kind of main popularized way. When some equipment or parts are decided to adopt diagnostic maintenance way, further maintenance type decision will be carried on. All of these form basic constitution of selective maintenance system. So, main contents of selective maintenance system are: (1)To divide equipment into different groups and carry on different maintenance ways; (2)To carry on three kinds of checking ways and two kinds of maintenance methods, that are daily checking, scheduled checking, precisely checking, item repair and overhaul repair; (3)To build a series of standards of maintenance and checking; (4)To strengthen application of fault diagnose and condition monitor technology; (5)To carry on computer aided dynamic management and aided decision and so on.

## 3 Basic steps

If you want to completely popularize selective maintenance system in marine diesel engine, following work have to be carried on in order.

## 3.1 Collection and analysis of history data

Because scientific and reasonable maintenance management carried on to any complicated equipment systems same as marine diesel engine is based on knowledge to their construction, function, specialty, main technology property parameters and so on, we will apply FMEA(failure mode and effect analysis)and FTA(failure tree analysis) technique to develop relative work and get all data which is required by this strategy.

According to various failure modes, reasons and effects, posing some precaution methods from qualitative aspect is a basic step to increase reliability of system. In maintenance management action of marine diesel engine, we should consider adopting following precaution methods: (1)To increase intrinsic property of marine diesel engine and improve its application circumstance; (2)To increase technology of maintenance management persons through education and training; (3)To reasonably store up spares; (4)To often check areas that fault happens easily; (5)To reasonably arrange and maintain apparatuses used in warning and monitoring; (6)To accurately make turn round parts balance; (7)To lubricate moving or turning parts as scheduled; (8)To carry on checking and accepting of assembly and operation.

## 3.2 Decision of maintenance ways of system

As equipment modern extent daily increases, equipment management way is taking place to changing from customary maintenance to selection synthetic maintenance based RCM. This maintenance unites together BM, SM, PDM into a integrated maintenance system. But, because performance, operation state and operation circumstance of complicated mechanical system are different, it is difficult to decide to use what maintenance way. For this reason, a type of method is posed which can conveniently and effectively resolve this question.

The first step carrying on maintenance way division is to decide factors to affect it, namely evaluation factor. The object carrying on maintenance way division is to make total life cycle cost of equipment the smallest. Five types of factors are considered. Every type includes a few items. The second is to make these factors quantized and resolve their value. The last is to apply fuzzy synthetic judgement method to get important degrees of equipment or parts and carry on maintenance way division.

## 3.3 Resolving of maintenance cycle

To scheduled maintenance system decided, their optimal maintenance cycle should be resolved. Commonly there are two types of methods.1)To use

preliminary gap after mounting, wear rate and limit gap to get optimal maintenance cycle. As following equation:

$$T = (G_l - G_p)/R_w \tag{1}$$

Where: T is Maintenance cycle. $G_l$ is limit gap. $G_p$ is preliminary gap. $R_w$ is average wear rate.

To same turning couple parts, because of existence of the difference in a lot of aspects, for example, spare manufacture, material, mounting, lubrication, working gap and wearing quantity are random variable. At the same time, limit gap commonly has certain range or obey some type of random distribution. So simply using above equation is not scientific and reasonable. 2)To use system availability or maintenance cost to get optimal maintenance cycle. This type of method is introduced in many books or research papers about reliability and maintenance. It is mainly based on probability statistic theory. Following two equations are the most basic.

$$C(T) = \frac{C_p \cdot R(T) + C_f \cdot F(T)}{MUT} = \frac{C_p \cdot R(T) + C_f \cdot F(T)}{\int_0^T R(t)dt} \tag{2}$$

Where: T is maintenance cycle, $C_p$ is average cost paid because of maintenance and replacing spares or parts as scheduled. $C_f$ is average cost paid because some failures are resolved during scheduled maintenance. R(t) is system reliability function. F(t) is failure distribution function. MUT is system's Mean Up-Time in one cycle. Optimal maintenance cycle $T_0$ is positive real number result when $\frac{dc_{(T_0)}}{dt} = 0$.

$$A(\infty) = UTR = \frac{MUT}{MDT + MUT} = \frac{\int_0^T R(t)dt}{R(T) \cdot t_P + F(T) \cdot t_f + \int_0^T R(t)dt} \tag{3}$$

Where: A is system availability. MUT is system's average operation time in one cycle. MDT is system's Mean Down-Time in one cycle. UTR is system's Up-Time Rate. $t_P$ is preventive maintenance time. $t_f$ is failure maintenance time. Optimal maintenance cycle $T_0$ is positive real number result when $\frac{d_{(UTR)}}{dt} = 0$.

## 3.4 Decision of maintenance type

In order to decide system divided into PDM to adopt what maintenance in reasonable overhaul, item maintenance and odd maintenance, it is important that deterioration extent of system is got. Equipment deterioration is that its technology state has deviated its good state and is developing forward to its bad state. So, when deterioration extent is considered, deviating extent of inspecting value and good value and their close extent should be considered meanwhile. for

this reason, Concept named equipment development reliability will be led which can show equipment present technology state.

In reliability theory, definition of reliability is probability of product finishing provided function in provided condition and time. equipment itself is also product. Its reliability in application is various. Its reliability will decrease with operation time if it is not repaired in this period. In order to show this various specialty, we call it development reliability. We have considered specialty of developing scheduled inspection in time t(t is broad sense time), so its definition is: probability of equipment finishing provided function in provided operation circumstance condition and in period of provided inspected time t to next time t+1. showed R(t), moreover:

$$R(t) = \sum_{h=1}^{H} \mu_{Nh} P_t (s_h) \qquad (4)$$

Where: $\mu_{Nh}$ is subordinate extent of state $s_h$ to fuzzy function sub-assembly, $P_t(s_h)$ is probability after experience obtained according to fuzzy Bayes rule. To observe external specialty value able to show equipment property ,we could gain development reliability of equipment (parts) if this formulation is used. Finally maintenance type of system will be decided.

## 4 Some suggestions to carry on selective maintenance system in marine diesel engine

At present, it is difficult to widely carry on Selective Maintenance Strategy in marine diesel engine. But because Selective Maintenance Strategy has a lot of advantages, it is possible to make ship owner and other departments overcome these difficulties. We pose following suggestions to resolve these difficulties.

1)To publicize peculiarity of Selective Maintenance Strategy actively and widely so as to make ship owner accept the idea of Selective Maintenance Strategy. Because carrying on what type of Selective Maintenance Strategy is not demanded forcedly in ship testing standards at present, ship owner has chance to select what type of Selective Maintenance Strategy. So, the key to carry on Selective Maintenance Strategy in maintenance and management of marine diesel engine is to make ship owner adequately know shortage of scheduled maintenance way and advantage of Selective Maintenance Strategy.

2)To build socialized monitoring and analyzing organization. According to present technology power of ship owner and classification society, it is difficult to finish all monitoring work and making work of monitoring standard only depending on themselves. Adequately to make society power join this work is a good way.

3)To deal with the relation between simply monitoring way and precisely monitoring way. In carrying on Selective Maintenance Strategy, condition monitoring is basic and key. Daily checking(adopting simple diagnosing

instruments), scheduled checking and precisely checking(adopting precise diagnosing instruments) all are very important. Making crews to take part in daily checking work is important guarantee to successfully carry on Selective Maintenance Strategy, because crews are user and manager of equipment. In fact, because a ship is commonly located to various sea areas, daily checking is finished only by crews. Daily checking work and few items of scheduled checking are able to be finished by crews through providing some simple monitoring instruments. At the same time, some faults will be eliminated during carrying on daily monitoring work. When combining simply checking carried by crews with precisely checking carried by engineering technicians or experts on land. A good condition monitoring effect will be got.

4)To build monitoring net. Some monitoring and analyzing organization should be built according to location of ports and their important degree so as to enjoy the use of monitoring resources together and decrease delivering work of samples through using modern information communication technology. If good cooperation is built among monitoring and analyzing organizations of all classification societies in the world, it is possible to build all over global monitoring net. At that time, some checking difficulties causing by ship widely moving will be overcome.

In a word, the object carrying on Selective Maintenance Strategy in marine diesel engine is to decrease maintenance cost and increase ship operation reliability and economic benefit. The key of this work is application of condition monitoring technology and failure diagnosed technology and maintenance decision based on condition monitoring. Water transportation enterprise should seize the opportunity and actively develop work to promote Selective Maintenance Strategy to be used widely in this area.

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