THE POSSIBILITY OF USING MULTIVALUED EVALUATION OF RESIDUALS IN THE DIAGNOSTICS OF MARINE DIESEL ENGINE

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Summary

This paper describes the possibility and the advisability of using multivalued evaluation of residuals in marine diesel engine diagnostics. All considerations relate to triple-valued evaluation (-1; 0; +1) based on two examples of FIS (Fault Isolation System). The first one refers to a diagnostic matrix of a turbocharging system, the second one refers to a matrix of on the injection system. FIS examples are based on the results of research conducted a real object – a Sulzer's four-stroke, medium speed marine diesel engine.

Keywords: diagnostics, marine diesel engine, diagnostic matrix, multivalued evaluation of residuals.

MOŻLIWOŚĆ WYKORZYSTANIA W DIAGNOSTYCE OKRĘTOWYCH SILNIKÓW WYSOKOPRĘŻNYCH WIELOWARTOŚCIOWEJ OCENY RESIDUÓW

Streszczenie

W referacie przedstawiono możliwość i celowość wykorzystywania w diagnostyce okrętowych silników wysokoprężnych wielowartościowej oceny residuów. Rozważania odniesiono do trójwartościowej ich oceny (-1, 0, +1) w oparciu o dwa przykłady FIS (Fault Isolation System). Pierwszy dotyczy macierzy diagnostycznej turbosprężarkowego układu doładowania, a drugi macierzy dla układu wtryskowego. Przykłady FIS powstały w oparciu o wyniki badań obiektu rzeczywistego – czterosuwowego, średnioobrotowego wysokoprężnego silnika okrętowego firmy Sulzer.

Słowa kluczowe: diagnostyka, silnik okrętowy, macierze diagnostyczne, wielowartościowa ocena residuów.

1. INTRODUCTION

Modern marine diesel engines are characterized by a complex and complicated construction and high levels of thermal and mechanical loads. Overlap is also specific working conditions, the impact of aggressive of combustion of heavy fuel oil 9residual) and a number of other factors, which together can load to a number of faults. Although the engine continues to perform its basic function working, that are serviceable, but no worse after the failure of technical-operational property. If the faults is not diagnosed in time, it can lead to failure to discontinue operation of the vessel, which together load to serious economic depreciation.

Implementation of the diagnosis to operation of marine engines give a chance for early detection of possible a and effectively avoid serious and costly consequences of failure.

The success and widespread use of diagnostics systems and devices for marine engines depends to a large extend on the perfection of diagnostic algorithms.

High efficiency is characterized primarily based on the diagnosis of parametric algorithms built on actual experimental research.

Creating algorithms and diagnostic programs should seek to obtain a good distinguishability of faults, witch ensures and clarity of diagnosis.

2. CREATE DIAGNOSTIC SYSTEM

The diagnostic system a very important stage of our work is to understand the relationship between respective faults and the values of diagnostic signals.

This information may be come from modeling studies. There are analytical models, neural and fuzzy [3]. They are also used to actual experimental research. They can carry out the passive or active experiment. Passive experiment is time consuming, because very often you use the active experiment. Individual faults are then simulated as faithfully as possible. The course of active experiment can be significantly reduced by selecting the diagnosis of major motor functional nodes, and they often resulting faults. For this purpose, use of statistical data and knowledge from experts, talking about the frequency of occurrence of faults and linking a particular fault disability with a potential threat to the correct operation of the engine.

So this is an action to decompose the object and diagnosis in decentralized structures. Correctness and effectiveness of such actions was confirmed in the work of many authors, including [1, 2].

On the significant advantages of a decentralized approach to solve the diagnostic complex technical object is the possibility of the occurrence of an assumption of single failure in particular systems object. The simplifies considerably the diagnosis algorithm, and the stage of collecting data obtained through active experiment, significantly shortens the course of the experiment and its costs.

Made actively experiment with simulated faults allows you to built a diagnostic matrix and then the algorithm and diagnostic program.

3. RESEARCHE

Test object was a ship's diesel engine SULZER AL25/30 (Fig.1) the following basic specification:

- power of a cylinder [kW] 136,
- number of cylinder [-] 3,
- rotational speed [r/min] 750,
- mean effective pressure [MPa] 1,575,
- compression ratio [-] 13,
- specific fuel consumption [g/kWh] 204,
- turbocharged – turbocharger BBC VTR160N,
- load an electrical generator.

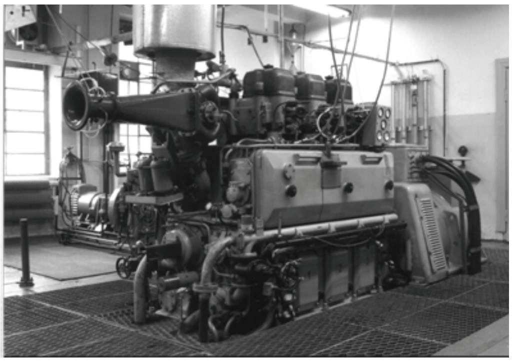

Fig. 1. Test object – diesel engine SULZER A25/30

The marine diesel engine is technically complex object. Therefore, in accordance with previous considerations must be made of its decomposition. To avoid an arbitrary division, adopted the following procedure. Collected statistics data on the frequency of specific faults and data on their potential negative impact on the process of working. This allowed the diagnosis to select appropriate motor functional nodes and in them the most common faults [4, 5].

Eventually selected for the diagnosis of components are: turbocharging system and engine fuel injection system.

To their diagnosis, select the appropriate set of diagnostic parameters according to the following basic criteria:

- information value, the amount of information about technical condition of the object, witch contains a parameter.
- accuracy of location of fault and therefore the closest possible relationship with one specific structure parameter,
- availability and ease of measurements of parameter.

The selection of suitable components and fir each of them the right set of diagnostic parameters allowed testing marine diesel engine, based on the active experiment.

Simulations were performed, with big accuracy obtain a faithful reproduction of the actual faults occurring during the life of the engine [6].

Our results indicated helped minimize the multiplicity of diagnostic parameters based on:

- calculated sensitivity of each of them to change the engine condition,
- statistical analysis of measurements results.

The concept of sensitivity defines the following relationship:

$$K = \frac{\Delta_D}{\Delta_C} \tag{1}$$

where:

K – sensitive diagnostic parameter,

Δ_D – relative deviation of the diagnostic parameter,

Δ_C – relative deviation of the stricture parameter,

- relative deviation of the diagnostic parameter Δ_D:

$$\Delta_D = \frac{\Delta D}{D} \tag{2}$$

where:

ΔD – deviation of the diagnostics parameter for the unserviceable engine,

D – diagnostic parameter value for technically serviceable engine,

- relative deviation of the stricture parameter Δ_C:

$$\Delta_C = \frac{\Delta C}{C} \tag{3}$$

where:

ΔC – deviation of the stricture parameter at a given fault,

C – structure parameter value for technically serviceable engine.

Ultimately to the turbocharger system diagnosis selected the following parameters:

- air pressure charging p_d,
- air mass flow trough the compressor $\dot{m}_S$,
- pressure drop over the filter Δp_f,
- rotational speed of the turbocharger n_{TS},
- exhaust gas temperature T_g,

and for the diagnosis of fuel injection system:

- maximum cylinder pressure p_{max},
- maximum injection pressure $p_{max\ inj.}$,
- mean indicated pressure p_i,
- air pressure charging p_d,
- exhaust gas temperature T_g.

Based on the obtained experimental data was possible to build a Fault Diagnostic System (FIS), examples of which are shown in figure 2 and 3.

S/F	f_1	f_2	f_3	f_4
s_1	0	+1	+1	+1
s_2	0	-1	+1	-1
s_3	-1	-1	+1	-1
s_4	-1	-1	+1	-1
s_5	0	-1	-1	+1

Fig.2. FIS injection system marine diesel engine
s_1 – air pressure charging,
s_2 – exhaust gas temperature of the cylinder,
s_3 – maximum cylinder pressure,
s_4 – mean indicated pressure,
s_5 – maximum injection pressure,
f_1 – drop injector opening pressure,
f_2 - non-leakproof injection pump (precise pair),
f_3 – wear the spray holes,
f_4 - carbonization the spray holes (plugging spray holes).

FIS describes the relationship between fault and diagnostic signals and an adaptation of the information system for fault location purposes. Adaption of trivalent residuals assessment of the facilitate distinguish all faults. But we ca n not authoritatively say that the diagnosis had to extend for a further faults (previously unrecognized), leaving the overall number of diagnostic signals (s), whether this fault could be identified.

Then would increase the set of diagnostic signals, by applying to them the right choice of criteria which were mentioned earlier.

4. SUMMARY

For the technically complex objects, objects decomposition and decentralized diagnosis, assuming a single fault, enables good location of fault.

Making the right choice of diagnostics parameters is one of the most important factors determining the proper operation of the diagnostic algorithm prepared.

For the technically complex objects, a possible large number of diagnostic parameters is also important to minimize the number of diagnostic parameters, as done for diagnostic algorithm was relatively simple but well-recognized faults.

The above-mentioned objectives can be achieved by introducing the concept of diagnostic sensitivity parameter. Greatly facilitates this, making the selection of diagnostic parameters appropriate decisions. Unfortunately, sometimes difficulty to access and measure the diagnostic parameter may be the reason for withdrawal from using in diagnostic algorithm of good, sensitive diagnostically parameter.

S/F	f_1	f_2	f_3
s_1	-1	-1	+1
s_2	+1	-1	-1
s_3	-1	-1	-1
s_4	-1	-1	-1
s_5	+1	0	0
s_6	+1	+1	+1

Fig.3. FIS turbocharger system marine diesel engine
s_1 – air pressure charging,
s_2 – rotational speed of the turbocharger,
s_3 – air mass flow through the compressor,
s_4 – air mass flow through the cylinder,
s_5 – pressure drop over the filter,
s_6 – exhaust gas temperature of the cylinder,
f_1 – pollution of the air filter,
f_2 - pollution of the air compressor,
f_3 – pollution of the air cooler.

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