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PRINCIPLES OF DEVELOPMENT AND PRACTICAL APPLICATION OF LOGICAL METHODS IN TASKS OF SEARCHING FOR THE FAILURE CAUSES IN INTERNAL COMBUSTION ENGINES

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Great efforts and funds invested for a long time in scientific research, design work and production of internal combustion engines have significantly increased their durability and reliability in operation. However, even with the technical perfection of new designs and production technologies, faults and failures may occur in modern engines. To effectively eliminate them, a correct identification of their causes is required [1].

One of the factors hindering the solution to this problem is the lack of methods with the help of which it would be possible to determine the failure causes of engines relatively simply, but at the same time with the necessary degree of reliability [2].

An analysis of published sources shows that currently known methods and techniques for determining the causes of faults and failures of internal combustion engines can be divided into three groups [3]. These are fault tables, fault reference books and technical condition diagnostics. Despite the large number of known materials, the use of tables and fault reference books in practice requires so much labor and specialist qualifications that it is actually ineffective. At the same time, the use of diagnostics is limited, since many types of damage and failures in the mechanical part of engines, as a rule, are poorly diagnosed, and in some cases are not detected at all by diagnostic methods (for example, when the engine has already failed and stripped).

The purpose of this work is to develop a logical methodology for determining the causes of internal combustion engine failures, which is applicable not only to expert-level specialists, but also to semi-qualified ones. To achieve the goal, the problems of choosing a general method and drawing up a logical algorithm (technique) were solved.

As a basis, the method of fault tree analysis, previously used in the study of faults of various technical systems, including internal combustion engines, was considered [4]. However, in order to determine the causes of internal combustion engine failures, this method has not previously been used, since the known techniques under its basis were developed for the task of calculating reliability parameters, and not searching for the causes of failures.

The fault tree determines the cause-and-effect relationships between the failure of the entire system and the failures of its subsystems and individual elements, as well as other events and impacts. Such a tree can be developed for any object. At the same time, sequential detailing of events that are associated with system failures is carried out. Such detailing is usually done in the direction of the effect on the cause of failure

(from top to bottom), but the analysis itself is performed in the opposite direction, from cause to effect (Fig. 1). If such an analysis is carried out at the product design stage, it allows one to calculate the probabilistic reliability characteristics.

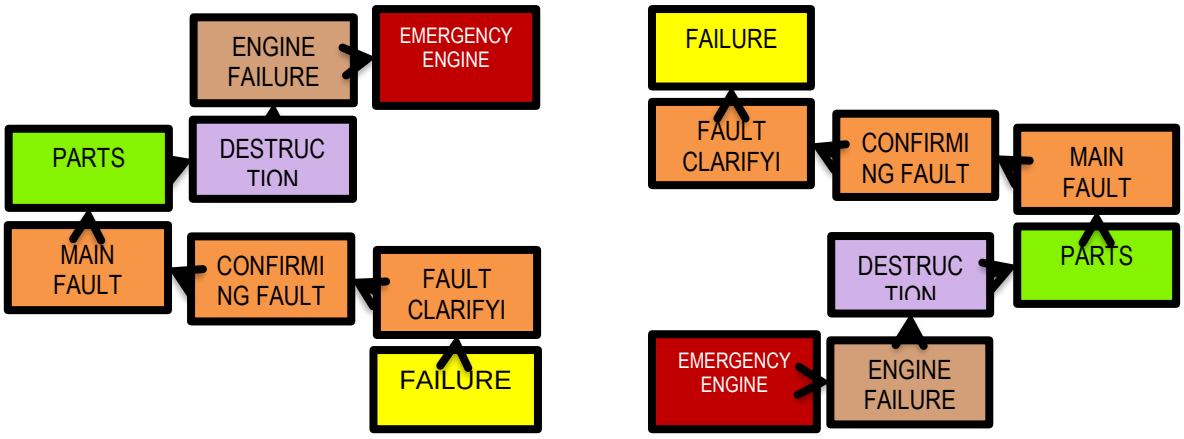

Figure 1. Forward logic tree (left) for calculating the probability of failure and reverse logic tree (right) proposed to find the cause of failure. The direction of analysis from bottom to top is the same for both schemes.

Drawing up a fault tree to find the failure cause of an internal combustion engine unit or system does not imply any calculations of the probability of failure, as is usually customary when assessing the reliability of designed objects. If we assume that a failure has already occurred in operation, the main task of the logical analysis of the fault tree will not be the derivation of formulas for calculating the probability of a failure occurring (this probability can be taken equal to one), but it will be the logical search for the cause of the failure that has already occurred [5].

To compile a fault tree of a complex object, a division (structuring) of signs into the following groups has been proposed [6]: main, confirming (main) and clarifying (type and location of damaging effects). In accordance with this, for each of the identified failures, it is possible to present the general logical scheme of direct analysis in the direction of the cause of the event of engine failure in the form of a simple structural graph.

Initially, such a graph is constructed as a modified one (each event can have several inputs, but only one output) and directed, i.e. in the direction of the cause of the failure event itself. After construction, the direct graph is turned over (reversed) in order to obtain a logical scheme for analysis in the opposite direction - from the failure event towards its cause, which corresponds to the task of finding the cause of an already occurring failure (as opposed to the direct task of determining the probability of failure).

As a result of this approach, it is possible to obtain a logical graph in which not only the intermediate states of nodes and elements are clearly identified, but also the signs by which the driver and/or service center usually identify the event (fact) of a fault or failure are described in detail (Fig. 2). If all the signs of failure are present, it is not difficult to determine its cause simply by following the logical chain of the graph.

Using this method, logical fault tree graphs can be developed for any individual cases [6], including destruction of the connecting rod after a hydrolock from liquid entering the cylinder, destruction of the bearing and connecting rod due to impaired bearing lubrication, destruction of the valve and piston pin, breakage of the pin axial fixation, etc. After drawing up individual graphs, they can be collected into one graph, combining the considered types of faults.

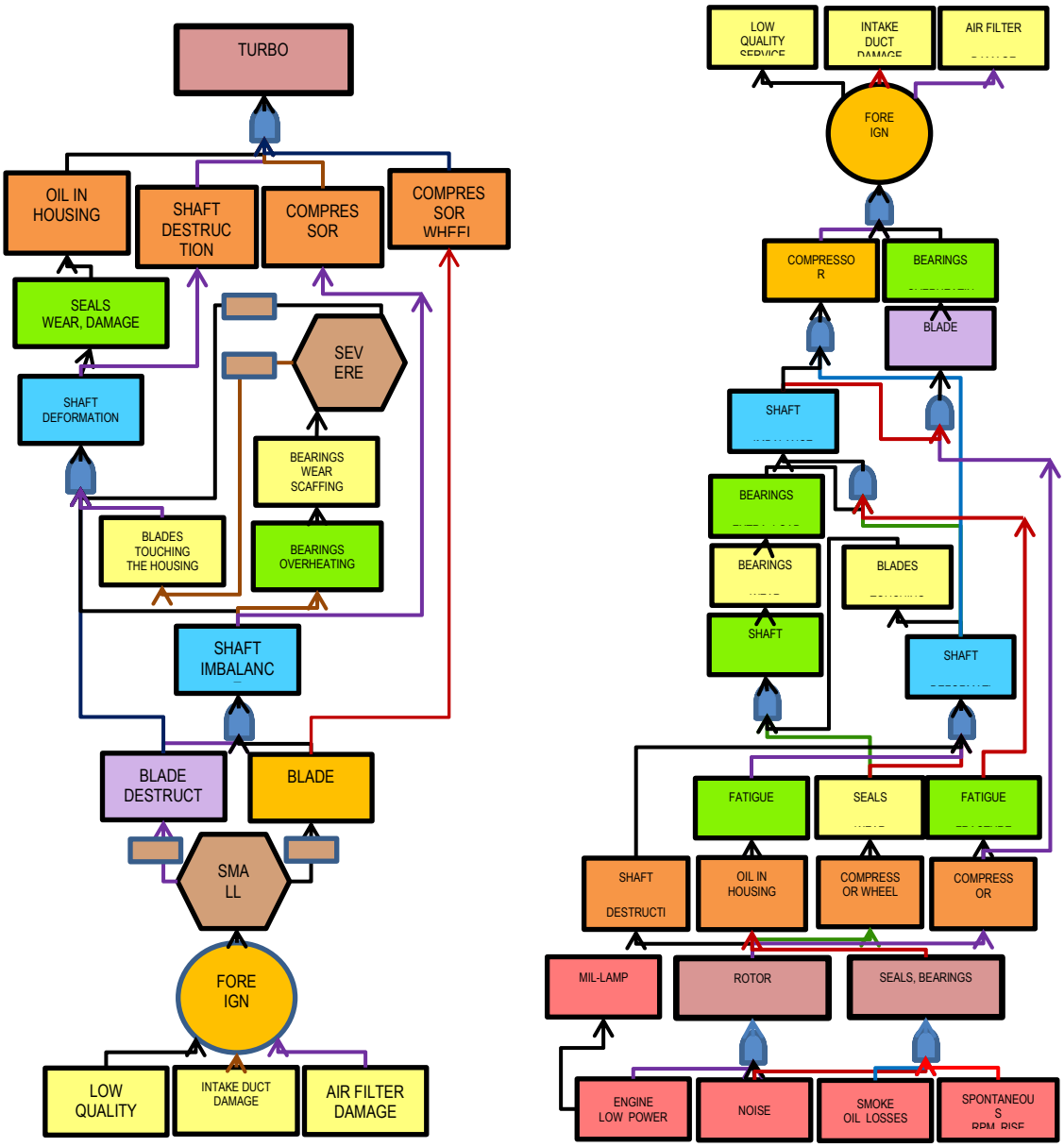

Figure 2. Example of a modified forward (left) and inversed (right) fault tree of an internal combustion engine turbocharger

To test the proposed method, a failure tree for the engine turbocharger was developed (Fig. 3). Testing on real failure cases showed [6] that the apparent complexity of the developed graph is not an obstacle to its practical use. Logics based on structuring the signs of a failure easily leads to the desired group of causes, after which it is only necessary to correctly identify the confirming and clarifying signs in order to accurately reach the actual cause of the failure.

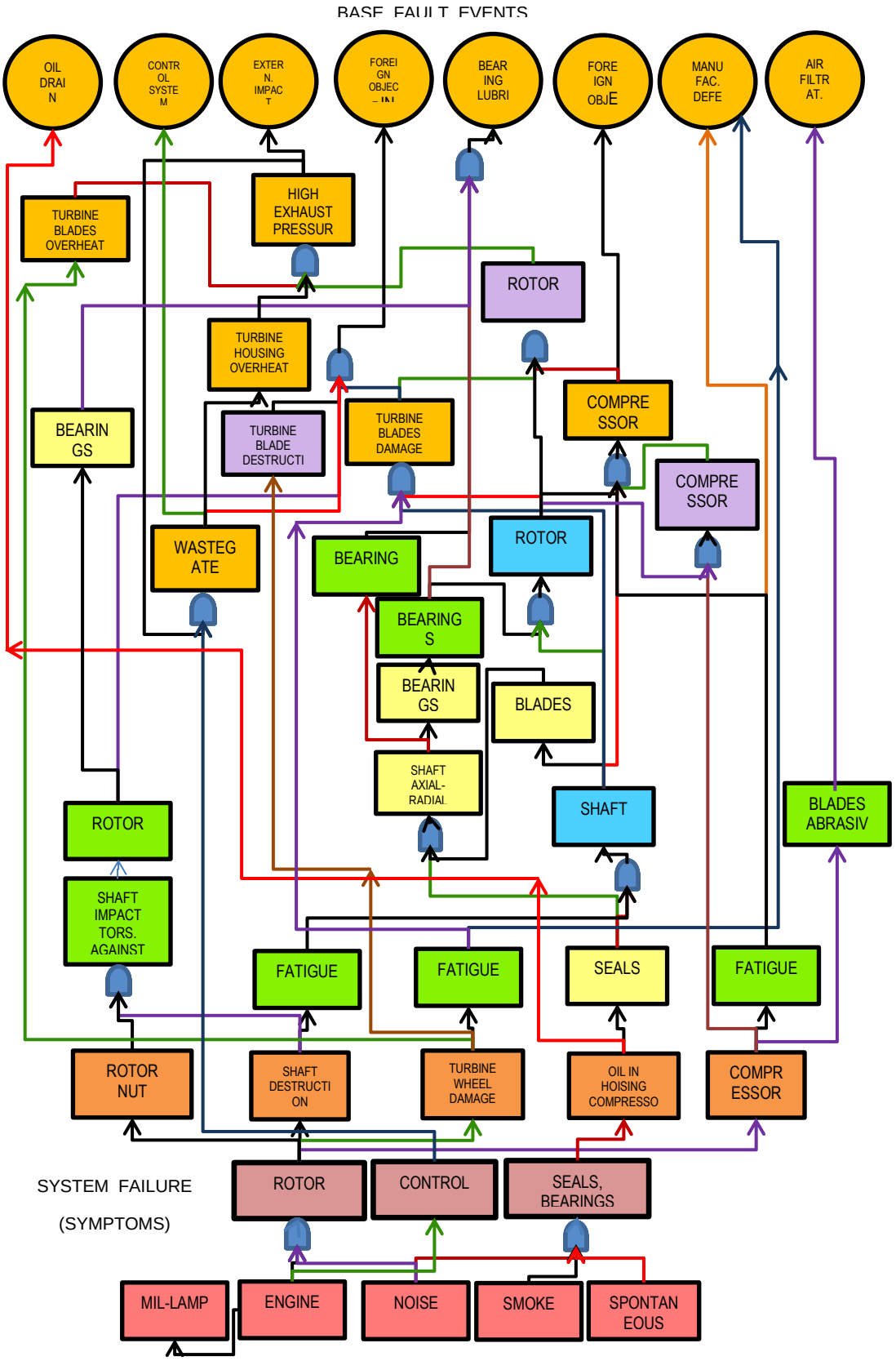

Figure 3. The turbocharger failure tree allows you to quickly identify the cause of the failure by analyzing the signs from bottom to top.

Conclusions. The completed study shows that determining the cause of internal combustion engine failures can be performed based on the analysis of a modified inversed fault tree. This method allows you to perform logical analysis in the opposite

direction to the generally accepted direction when compiling a fault tree, i.e. from the event of the entire system failure to the basic events that initiate failure in its individual elements. As a result, the determination of the cause of a failure can be made with sufficient reliability for practice with minimal time, which makes it possible to eliminate gross errors when investigating the failure causes.

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