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Application of ishikawa diagram for failure analysis of a car water pump

Zastosowanie diagramu ishikawy do analizy uszkodzeń pompy cieczy chłodzącej

Abstract

The paper presents an identification of potential causes and effects of failures of a coolant pump for internal combustion engines. Ishikawa's quality improvement tools have been used to analyze the defects. The main causes of pump failures and cause-effect relationships have been identified. The main causes were identified and classified in order to select those which have the greatest influence on pump damage during operation.

Keywords: Ishikawa diagram, coolant pump

Streszczenie

W artykule przedstawiono identyfikację potencjalnych przyczyn i skutków powstawania uszkodzeń dla pompy cieczy chłodzącej silnika spalinowego. Do analizy uszkodzeń wykorzystano jedno z narzędzi doskonalenia jakości jakim jest diagram Ishikawy. Dokonano określenia głównych przyczyn problemu, identyfikacji związków przyczynowo-skutkowych oraz sklasyfikowania i hierarchizacji przyczyn głównych w celu wskazania przyczyn, które mają największy wpływ na uszkodzenia analizowanej pompy w czasie jej eksploatacji.

Słowa kluczowe: diagram Ishikawy, pompa cieczy, uszkodzenie

1. Introduction

A cooling system is one of the most important systems of combustion engines which maintains the engine temperature at the appropriate level. The key component of a cooling system is a coolant pump, which is subjected to variable and extreme loads during the engine operation. Therefore, the identification of possible failures and their causes and effects is as well an important issue. More and more effort is put into the identification of possible failures at the design and manufacturing stages, which allows for eliminating the reasons of failure or introduce preventing actions. On the other hand, identification of failures is a half way of solving the problem. Identified failures have to be classified and organized in an appropriate way. Then, those that have the greatest influence on reliability have to be selected and cause-effect relationships has to be determined. Various methods and tools are used for quality improvement. One of them is the Ishikawa diagram. It allows for identification of the problem, determining the cause-effect relationship and classifying it in a correct way in order to undertake preventive and corrective actions. This tool may also be used in further qualitative analyses such as cause-effect, SWOT, PDCA or risk and decision management. The Ishikawa diagram allows for visualizing a problem clearly and easily along with possible areas of its causes. It also allows for solving problems during brainstorming sessions where various causes of failures may be presented within different groups.

2. The Ishikawa diagram principles

The Ishikawa diagram was used in Japan at Sumitomo Electric for the first time. It was developed by Kaoru Ishikawa, a professor at Tokyo University, who published the principles of the diagram in 1962. Initially, the diagram was used only during the manufacturing process, but in a short time it appeared to be useful also in other areas. It was successfully used in administration, project management and functionality analysis. The diagram is a graphical representation of the relationships between effects and possible causes [1]. It is an analysis of the top-down category, which means that the analysis is carried out from the general to the detail. A group of primary and secondary causes are determined in a hierarchical way. The procedure of solving problem (effect) in the Ishikawa diagram includes problem identification, determining the main categories of causes (selection of causes that have the greatest impact on problem which may occur) [2]. An example of the Ishikawa diagram is presented in Fig. 1.

The Ishikawa diagram is represented by a graph in which the main elements can be found:

- element 0 – indicates problem/effect,
- element 1,2,.. – indicates the main categories of the causes that have influence on problem/effect. The concept of 5M + E: Man, Machine, Material, Method, Management, Environment is usually used to prepare a group of causes,
- element A - indicates the causes identified within the main categories (for each cause a sub-cause (a) may be described, which allows for a detailed analysis of the problem/effect to be performed).

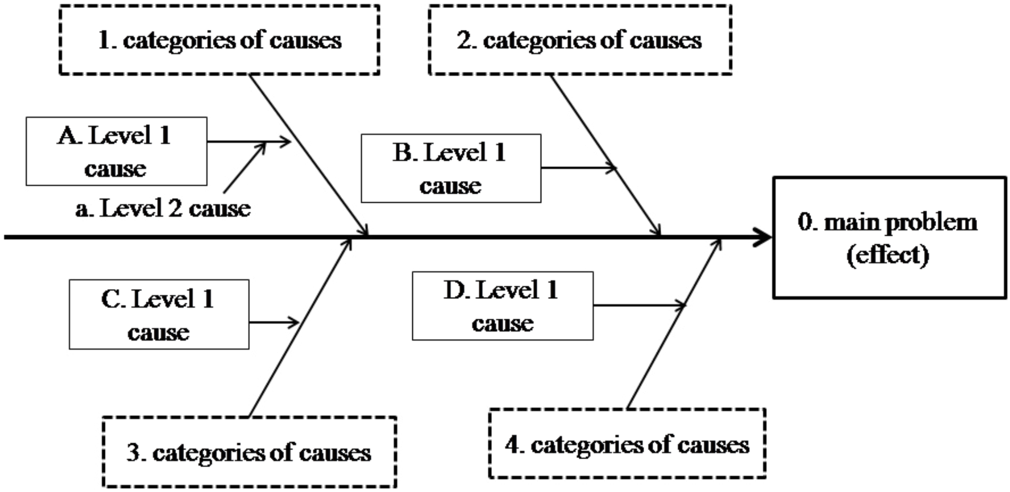

Fig. 1. The Ishikawa diagram

In the literature [3], three approaches may be found for causes of the considered problem:

- subject approach the causes are related to the components of the analyzed situation (categories are the components of the object, and the causes elements of these components),
- technological approach is considered as functional, because it depends on finding the causes within processes associated with the problem (technological processes and operations in these processes),
- approach of the factors involved the causes are presented in the form of so-called meta causes.

The created Ishikawa diagram allows for developing a numerical system of defect classification. The code characters can be specified depending on the level of details of identified causes. Accordingly, the code may consist of two or three characters. The code consisting of three characters 1Aa presented in Fig. 1, describes:

- the first character: 1 means a category of causes (100),
- the second character is the cause (1A0),
- the third character is a sub-cause (1Aa).

3. The Ishikawa diagram of coolant pump

A coolant pump which is a component of the engine cooling system is the object of the research. The main task of the pump is to circulate the coolant inside the engine, the cooler and the heater. The investigated coolant pump is a centrifugal pump with a belt drive which consists of housing (1), a rotor (2) mounted on a shaft (3), bearings (4) and a sealing ring (5).

The analyzed pump is shown in Fig. 2.

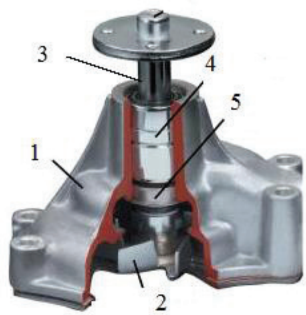

Fig. 2. Coolant pump [8]

The coolant is axially delivered to the pump where it is directed by the rotating rotor at the side to the outlet port [4]. The coolant pump is exposed to damages, whose symptoms can be noisy operation and leakage. Pump failure can be caused by many reasons, which may lead to overheating or even engine damage. Therefore, it is important to identify as many causes as possible and indicate those that are most likely to occur and have the greatest influence. The Ishikawa Cause and Effect Diagram was implemented for identification, classification, and ranking of potential causes of pump failures. Mechanical and operating damages as well as pump leaks were identified as the main problems for which a detailed identification of potential causes was made using both the technological and the subject approach. The use of the Ishikawa Diagram allows for linking the causes of a specific problem and assigning them to six main categories of causes:

- 100: assembly/disassembly,
- 200: medium,
- 300: exploitation,
- 400: maintenance,
- 500: sealing,
- 600: cooperating elements.

During the analysis, own categories have been developed, in which more than twenty reasons have been identified. On the basis of the Ishikawa Diagram, a numerical classification of causes has been proposed taking into account three levels of detail. Additionally, five main reasons have been identified from three categories with numbers: 100, 200 and 600. These causes are marked with the following code:

- 110: improper assembly/disassembly for category assembly/disassembly,
- 221: contaminated coolant for medium category,
- 240: low coolant level for medium category,
- 620: damaged impeller blades for category cooperating elements,
- 640: incorrect belt tension, worn belt,
- 650: sealing wear, seized bearing.

Those causes have significant influence on pump malfunction, noisy operation and leakages. Then, the causes were selected hierarchically depending on the probability of appearance. Therefore, the most important cause was considered to be code 221. The next order is: 110, 640, 650, 620 and 240. Table 1 shows four main causes of pump damage with description and associated damage type.

Table 1. Main reasons of pump damages

cause	failure	description
221	exploitation	Pump corrosion, rust, salt or lime deposits are in the cooling system, the coolant does not meet the manufacturer's requirements.
110 640	mechanical leak tightness	Deformation, gasket or casing breakage, impeller crack, no engine cooling; belt breaking, visible rubber tracks on the pulley, squeaking of the belt due to wear, damage and seizure of the pump bearings, impeller contact with the pump housing.
650	mechanical leak tightness	The use of improper or excessively contaminated coolant leads to deterioration of its lubricating properties; improper pump assembly with inappropriate tools, hitting the pump housing leads to distortion of the bearing seat and seizure, improper belt tension or settings.

A graphical presentation of the analysis and identified cause-effect relationships for pump failure [5, 6] is presented in Fig. 3.

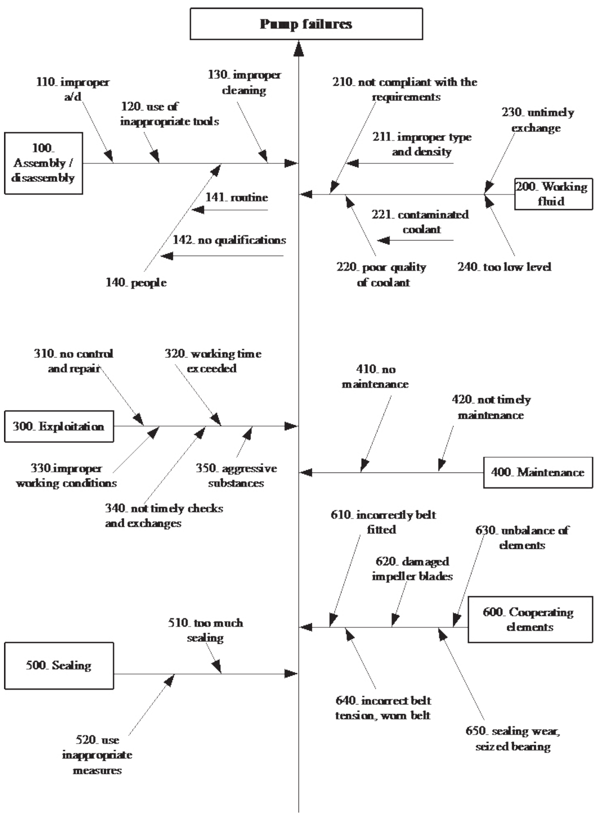

Fig. 3. The Ishikawa Diagram for the pump

4. Summary

The analysis of a pump by means of the Ishikawa Diagram proved that it can be a useful tool in identifying relationships between cause and effect for the during pump malfunction or its damage. The Ishikawa Diagram allowed for identifying the main problems and four most important causes that have influence on operational and mechanical damages and leaks as well. The selected main causes were categorized and sorted according to the considered problem. The clue of the cause-and-effect relationships was identification of problem location and reasons that have influence on efficiency of the engine cooling system.

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