quantitive analysis of repairs; specific repair actions;
subsystems of forklift trucks

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QUANTITATIVE ANALYSIS OF REPAIRS ACTIONS OCCURRING IN INDUSTRIAL TRUCKS IN SELECTED COMPANY

Summary. Knowledge about the failures occurring during life cycle of technical objects, enables to take appropriate action, in order to avoid costs in the enterprise. In the paper, the quantitative analysis of failures occurring in forklift truck in specific enterprise is presented. The percentage of various types of actions being taken is presented. Paper presents the number of action being taken per different systems of fork lift truck. Percentage of specific action in different subsystem, in relation to specific action in all subsystems is also analyzed. Furthermore number of subsystem replacements actions in relation to other action is illustrated on the chart.

ILOŚCIOWA ANALIZA DZIAŁAŃ NAPRAWCZYCH WYSTĘPUJĄCYCH W WÓZKACH JEZDNIOWYCH NA PRZYKŁADZIE WYBRANEGO PRZEDSIĘBIORSTWA

Streszczenie. Znajomość awarii zachodzących w trakcie użytkowania obiektów technicznych umożliwia podjęcie odpowiednich działań, które pozwolą na uniknięcie strat w przedsiębiorstwie. W artykule zawarto analizę ilościową uszkodzeń powstających w wózkach jezdniowych wybranego przedsiębiorstwa oraz analizę ilościową powstających uszkodzeń. Przedstawione zostały procentowe udziały rodzajów obsług podejmowanych w stosunku do wózków jezdniowych oraz procentowy udział obsług naprawczych przypadających na poszczególne układy. Przeanalizowany został również udział obsług w poszczególnych układach w stosunku do obsług danego rodzaju we wszystkich układach. Uwzględniono też stosunek wymian podsystemów do innych działań naprawczych w tych układach.

1. INTRODUCTION

Failure in technical object is a state in which the object moves from fitness to unfitness state [1]. Failure in technical objects causes loss to companies, resulting mainly from the inability to use broken machines and equipment and from the cost of the repair actions. In order to eliminate various types of losses, it is necessary to identify the types of possible failures and its frequency. Failure Analysis is one of the most important parts of reliability analysis and operational decision-making process in each company that utilizes various types of technical equipment. The main tasks of failure analysis are:

- identification of failures (classification),
- localization of failures,
- identification the causes of failures and their consequences.

It can be found in the scientific papers, that it is very important to identify those three points above In paper [5, 6], the main focus is on the identification of the reasons of failures and its effects, which includes FMEA (Failure Mode and Effects Analysis). Furthermore scientists combine the FMEA with Risk Analysis [7, 11]. In the paper [8] the Pareto Method was applied to evaluate number of parts failures in mining equipment.

There are a number of classifications that divides the failure due to various features such as [4]:

- source of development (construction, manufacturing, operational),
- interdependence of damage (dependent and independent),
- method of occurrence (sudden, gradual).

Determining the location of damage enables mainly to identify the bottleneck of analyzed object. Identification of the causes or failures allows replying to the question: why the specific part, subsystem, system is a bottleneck. Failure and effects analysis is important because not every failure brings the same effects. Some failure may, for instance, only cause damage to the utilized facility. While others, may be a potential hazard to human life. Failures in system are directly linked to customer dissatisfaction [9, 10], which implies that the identification of the potential failures and its prevention should be treated as the most important issue.

Failure Analysis conducted on the basis of data carried out in real operating conditions (and based on historical data), provide the reliable information about the types and consequences of failures [3].

The analysis of failures is carried out primarily on the basis of collected data and in relation to the actual object (objects). The analyzed object is presented as a collection of some systems, subsystems or components which are assigned to a certain number of failures (e.g within a specified period of time). In order to facilitate the work, the collected data is processed and presented in tables and various types of graphs. Presentation of data in charts simplifies bottlenecks location and assessment in which removal of failure is the most time-consuming or the most expensive.

2. CHARACTERISTICS OF ANALYZED ENTERPRISE AND OBJECT

The study was conducted in the manufacturing company (machines industry) that manufactures parts for mining equipment. The company has: raw materials, manufacturing and final products warehouse. Raw materials and manufacturing warehouse is a roofed storage facility with standard rack. Warehouse of final products is partly roofed and partly open-air storage facility.

The company operates 30 trucks that supports all three warehouses. 10 trucks is characterised by significant common features as to:

- year of production,
- mileage in hours of operations,
- the manufacturer and engine of forklift truck,
- the capacity and number of forks.

Included in the study, ten forklift trucks have a duplex mast. Year of production is: 2005 or 2006. Mean mileage expressed in hours of operation is about: 8000. Capacity of forklift trucks: 2 or 2.5 tons. Engine: Mazda powered by LPG. Manufacturer: Yale.

3. QUANTITATIVE ANALYSIS OF FAILURES

Quantitative analysis is a preliminary stage to test the reliability of technical objects. According to the philosophy of operational reliability tests - statistical data was collected. Process of quantitative analysis of failures includes [2]:

- data collection and its verification,
- analysis of data,
- interpretation of results.

Data collection was conducted in a manufacturing company based on filed data (the log book for records of inspection and maintenance), in cooperation with the service company. Data analysis was the statistical processing of collected data using MS Excel spreadsheet program. Interpretation of results was related to the presentation of the results in tables and graphs. Forklift truck has been divided into nine main subsystems. To these subsystems we can include:

- hydraulic subsystem,
- braking subsystem,
- steering subsystem,
- electric subsystem,
- lifting subsystem,
- transmission subsystem,
- fuel supply subsystem,
- wheels and suspension subsystem,
- cooling subsystem.

The collected data identified nine main types of failures occurring during the operation of industrial trucks. Also the percentage distribution of different types of action occurring in forklift trucks were determined (Figure 1).

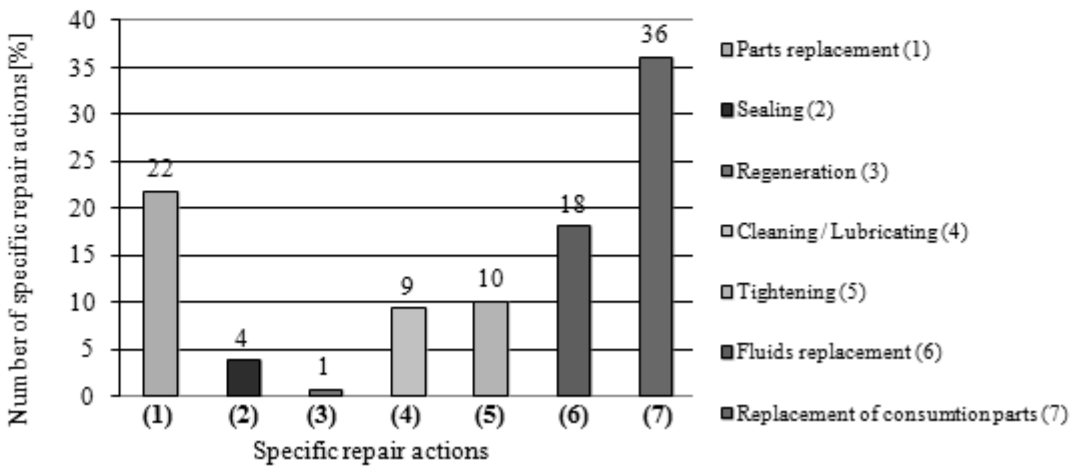


Fig. 1. The percentage of various types of actions being taken during operation
Rys. 1. Procentowy udział różnych rodzajów obsług w trakcie użytkowania

It may be noted that the largest share of actions has the operational elements such as: filters. A substantial share also has the action of parts replacement that represents - 22 percent of all failures. Whereas, the lowest share of the actions have the regeneration of subsystem or its sealing.

Taking into account the analyzed forklift truck subsystems, the percentage of action being taken during operation in each individual subsystem in relation to the total number of failures was identified in Figure 2.

Analyzing the contribution of individual systems in the amount of actions (Figure 2) it should be noted that the largest number of reported problems is identified in the lifting system.

A significant share is also found in subsystems: transmission, electric, fuel supply and braking.

Problems are the rarest in the cooling system, which has a share of only 2% in the total amount of actions.

In Table 1, whereas may be found the information of the percentage of each corrective action for specific subsystems.

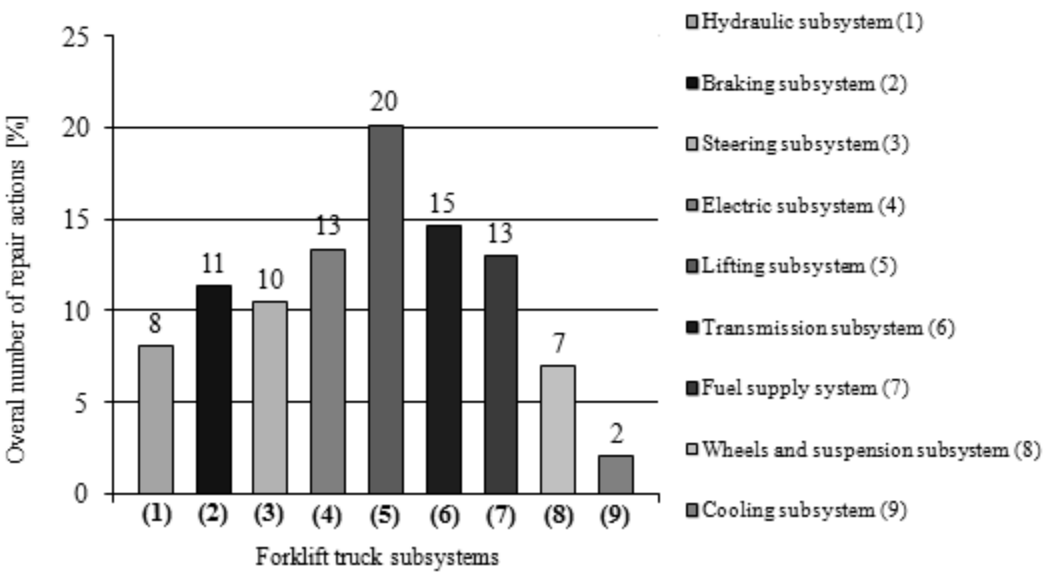


Fig. 2. Number of repairs action during operation in different subsystems of fork lift truck
Rys. 2. Liczba obsług naprawczych w trakcie użytkowania na poszczególne podsystemy wózka jezdniowego

Table 1
Percentage of specific action in different subsystems in relation to all actions in different subsystems

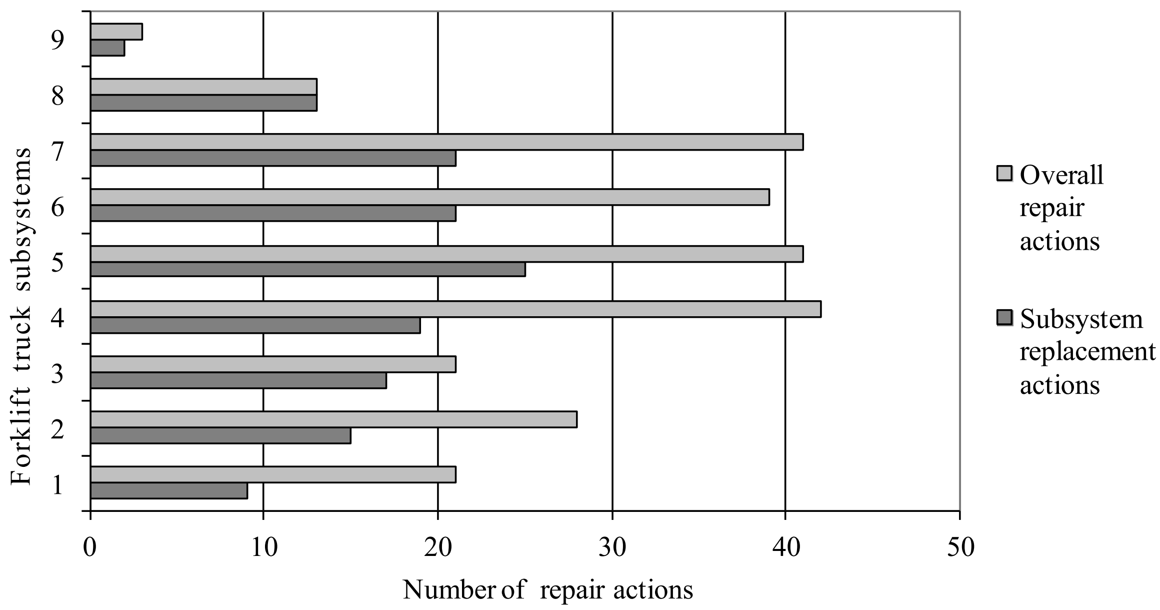
Forklift truck subsystems \ Repair actions	Parts replacement	Sealing	Regeneration	Cleaning / Lubricating	Tightening
Hydraulic subsystem	**28**	**18**	**0**	**26**	**28**
Braking subsystem	**42**	**2**	**0**	**29**	**27**
Steering subsystem	**63**	**10**	**0**	**18**	**10**
Electric subsystem	**75**	**2**	**2**	**9**	**12**
Lifting subsystem	**43**	**2**	**5**	**30**	**20**
Transmission subsystem	**39**	**11**	**3**	**20**	**27**
Fuel supply system	**41**	**16**	**0**	**13**	**30**
Wheels and suspension subsystem	**56**	**9**	**0**	**18**	**18**
Cooling subsystem	**20**	**30**	**0**	**10**	**40**

By analyzing the (table 1) participation of specific corrective actions needed to apply in the chosen subsystems, in relation to the total number of corrective actions in chosen subsystem, it can be noted that:

- In almost all subsystems parts replacement has the biggest share in comparison to other action in those subsystems.
- The smallest share in all subsystems has regeneration (in comparison to other action in all subsystems).

- Replacement of components is more likely to occur in electric, steering, wheels and suspension.
- Cleaning / lubrication and tightening have are likely to occur with nearly the same frequency

Figure 3 present the number of subsystem replacement to the total number of corrective actions undertaken with these subsystems.



Where: 1 – hydraulic subsystem, 2 – braking subsystem, 3 – steering subsystem, 4 – electric subsystem, 5 – lifting subsystem, 6 – transmission subsystem, 7 – fuel supply subsystem, 8 – wheels and suspension subsystem, 9 – cooling subsystem

Fig. 3. The ratio of all repairs taking place with the subsystems to the number of exchanges of these subsystems
Rys. 3. Stosunek wszystkich działań obsługowych podsystemów do liczby wymian tych podsystemów

Based on research results (shown in figure 3) it can be said that: the repairs action occurs (the most frequently) of following subsystems:

- fuel supply,
- electric,
- lifting.

On the other hand the cooling system has the lowest rate of failure.

Taking as a criterion the number of systems replacements it can be said that the bottlenecks are:

- lifting subsystem,
- transmission subsystem,
- fuel supply subsystem.

4. SUMMARY

Using the collected data set for 10 trucks used in manufacturing company, the analysis of the number types of failures has been developed. The aim of this study is to use the results to improve the decision making process. It may be noted that the largest share of repairs actions has the operational elements such as: filters. But it is absolutely normal that many filters must be exchange during its life time. A substantial share also has the action of parts replacement that represents - 22% of all replacement. Whereas, the lowest share of the actions have the regeneration of subsystem or its sealing. It should be noted that the largest number of reported problems is identified in the lifting system. A significant share is also found in subsystems: transmission, electric, fuel supply. Problems are the rarest in the cooling subsystem (only 2% in the total amount of actions). Taking into account all the presented analysis it can be stated that the lifting subsystem occurring the most frequently. This subsystem should be taken into consideration while preparing the preventive maintenance program or strategy or any decision.

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