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RELIABILITY EVALUATION OF THE OFF-ROAD VEHICLES

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Abstract

The research aim is to analyze the reliability of off-road vehicles, to determine the factors affecting it, and to provide recommendations for the increase of reliability. Factors allowing to improve their reliability were found by using the repair paper analysis, the questionnaire of the garage employees, and the empirical research of vehicles. The results revealed that the Central Tire Inflation System (CTIS) is the weakest system in off-road vehicles, which in turn requires a deeper investigation. Increasing the reliability of the CTIS makes the vehicle more reliable. Important conclusions were made about the CTIS: sealing elements are not affected by air pressure, but changing their sides may cause breakdown, the clearance of air directly affects reliability, the system can break down even when it is not used in the vehicle. Recommendations for the increase of reliability of pre-existing vehicles are as follows: not to change the side of the sealing element when repairing, the cleanliness and dryness of the air in the CTIS must be ensured by changing the air dehumidifier once a year and releasing water from the air drain valves; also, special training and instructions relating to the CTIS should be provided for garage employees.
Key words: reliability, off-road vehicle, limiting factors

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Introduction

Reliability is a feature of an object to perform its functions for a specified period of time while keeping up its maintenance characteristics under fixed conditions of mode, working hours, technical support, storage and transportation [7]. In other words, reliability can be defined as the likelihood that the product will not be affected by functional and environmental factors over a specified period of time [2].

The study deals with the off-road vehicles specially designed for use in extreme conditions. It is very important that these vehicles are reliable and that they can perform their functions with high credibility.

Reliability of the off-road vehicles is influenced by the following factors: structural solutions of separate parts and their combination, design accuracy of parts [4,8,9], reduction of cost of failure, complexity, functioning, higher responsibility, higher requirements for drivers, reduced development costs, shorter development time [2], and subjective and residual factors [5]. The frequency of malfunction depends on operational time [5]. It is believed that the malfunction rate is stable after major repairs [5].

Aim of the study

The aim of the study is to analyze operational reliability of the off-road vehicles, to determine the limiting factors and provide suggestions on the increase of reliability.

Tasks

1. To analyse the breakdown frequency in the off-road vehicles.
2. To identify system(s) and subsystem(s) that tend to break down.
3. To identify the reasons for breaking down.
4. To provide suggestions on the increase of reliability of the off-road vehicles.

Object and methodology

Object. The object of the study is the off-road vehicle. This kind of vehicles are usually used in the military. The main features of any kind of a military vehicle are traffic ability, buoyancy and reliability [1]. It must perform its functions precisely and timely during the military trainings and especially in a real battle [1].

Methods and reasons for their selection. In order to properly investigate the problem of reliability of the off-road vehicles and correctly justify the research methods, a preliminary research was conducted and scientific literature analyzed.

When the situation was clear, we carried out a descriptive quantitative research. It enabled us to evaluate the damage distribution in the off-road vehicles, identify the system and its subsystems that tend to break down, determine the reasons, and create the hypothesis of the study.

In this study we used two kinds of methods: evaluation of special documents (repair papers) and a survey.

106 repair papers with 22 vehicles described were analysed. Also, a survey of garage employees was performed in their working places. We provided a clear questionnaire convenient to fill. The depth of the survey was 7 statements/ questions. A simple (the same person is questioned once), direct (the purpose of the study is clear to the respondent) and factual (specific facts) surveys were performed. The Likert scale was used to evaluate the statements. This kind of a scale is a type of range scales. We used this scale to determine the level of agreement or disagreement with the statement. The width of the survey was 14 garage employees. We used non-random samples with the element of the sample chosen purposefully and we made an assumption that all the elements met the target audience.

A quantitative research, comprising a collection of information, its computing, and evaluation using quantitative methods was carried out. The results of the research were evaluated using statistical methods.

The collected data enabled us to formulate the hypothesis to continue the research. In this study we created three direct and one indirect hypothesis. All of them were checked using the empirical methods when the necessary information is collected by ensuring the direct contact between the researcher and its object. In this study we used empirical observation method. The information was collected using a pre-planned systematic registration order of the facts. We could control and check all the facts.

The logic and sequence of the study. The scheme of the logic and sequence of the study is provided in Figure 1. In the beginning, we made a quantitative research on the repair papers while trying to get a deeper understanding of the problem. The repair papers contain information about the model, mileage of the vehicle, and provide a short description of the problem/ damage. The papers do not provide information on the causes of the damage. That is the reason why we created a questionnaire for garage employees. According to the analysis results of the repair papers and survey, the hypothesis was formulated about the subsystem that tends to break down most often. We tried to approve or deny the hypothesis using an empirical observation method. The results obtained enabled us to provide recommendations for the increase of reliability of the off-road vehicles.

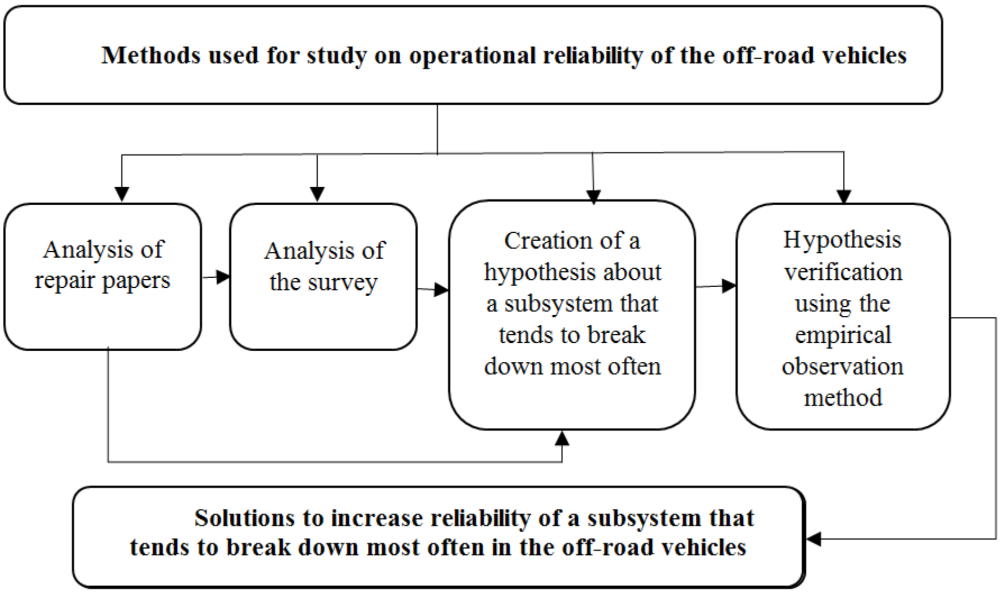


Figure 1. Logic and sequence scheme of the study on operational reliability of the off-road vehicles.

Results

In this study we analyzed the breakdown frequency and its reasons in the separate off-road vehicle systems. The results of repair papers show the breakdown frequency in separate systems (Figure 2). The most frequent malfunction was detected in the chassis (Ch.) – 40.97 %; the second most malfunctioning system was transmission (Trans.) - 21.53 %. The results indicate that engine (Eng.) and electrical (El.) systems break down rarely, and hydraulic (hyd.) system is the most reliable. We did not analyze the breakdown of other (Other) systems because it contained minor damages requiring the change of a bulb or strengthening of platforms.

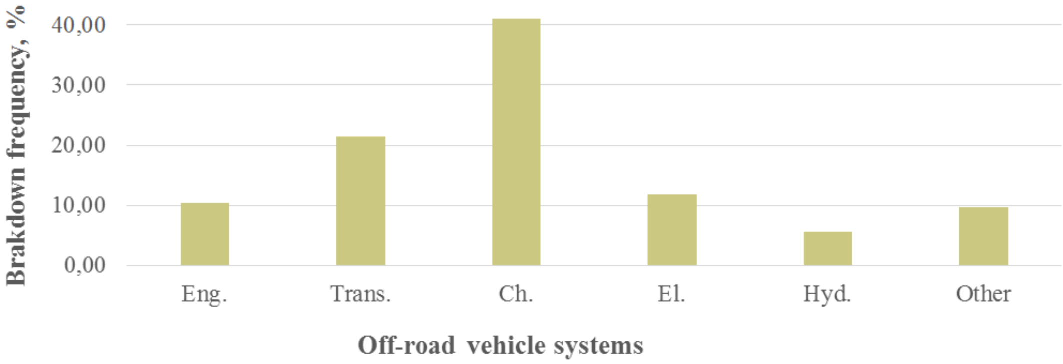


Figure 2. Breakdown frequency in the off-road vehicle systems.

When trying to specify the chassis subsystem that breaks down most frequently, we divided it into the following parts: Central Tire Inflation System (CTIS), tire, break, wheel, and suspension (Figure 3). The repair papers showed that the subsystem of the chassis that breaks down most frequently is the CTIS – 53.57 %. The break and suspension subsystems break down less often, respectively 19.05 % and 15.48 %. The tire and wheel subsystems break down rarely, respectively 8.33 % and 3.57 %.

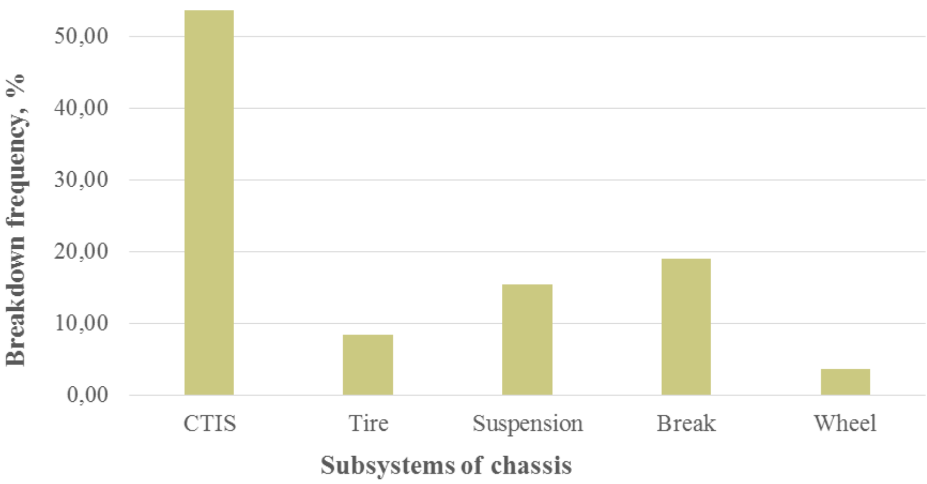


Figure 3. Breakdown frequency of the chassis subsystems in the off-road vehicles.

When trying to identify the causes for breakdown in the CTIS, we included the following statement in the questionnaire: which of the following causes have influence on breakdown, when 1 means that the cause does not influence breakdown, and 5 means that the cause has a huge influence on breakdown. In Figure 4, the main breakdown causes have been determined after calculating the average of the answers. The most frequent cause for the CTIS breakdown was indicated as the permanent use of the CTIS (3.79), the second cause – failure when assembling (3,21), the third cause was too high air pressure (3.07). According to the survey, the minor cause affecting breakdown of the CTIS was air pollution and humidity, respectively 2.79 and 1.7.

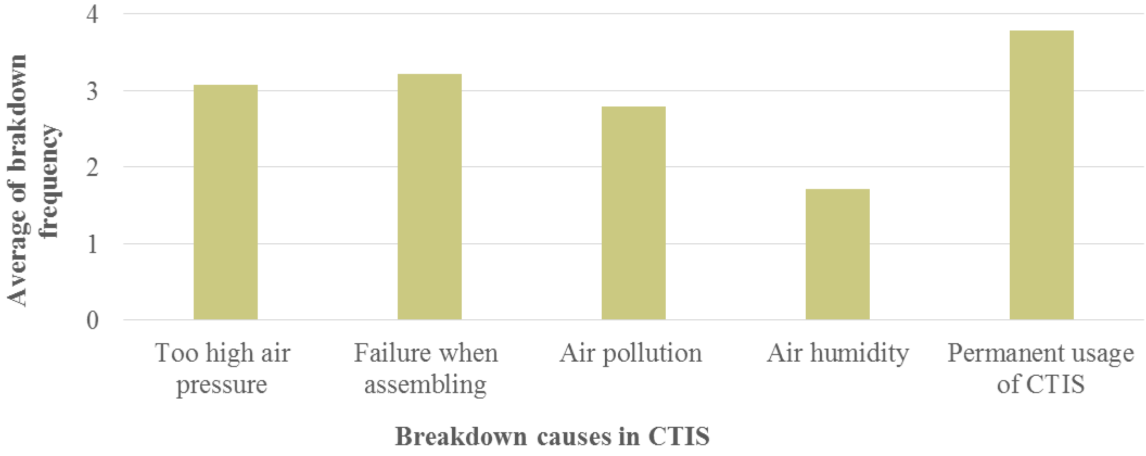
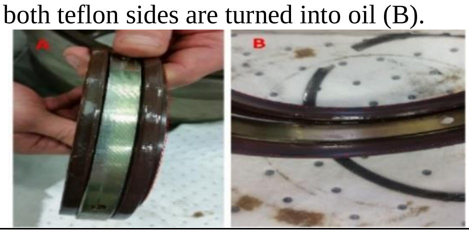


Figure 4. Breakdown causes in CTIS.

According to the results of repair papers and the survey, four hypotheses were created relating to the causes of breakdown in the CTIS. All the hypotheses, results, and their substantiation are shown in Table 1.

Table 1. Hypotheses, results, and their substantiation.

Hypothesis	Result	Substantiation
H1 – Too high air pressure in the CTIS negatively affects sealing elements.	Denied	• Air pressure was measured and the results showed that pressure in the CTIS does not exceed 8 bars. It means that such pressure does not affect sealing elements because such parameters are recommended in technical specifications of the CTIS. • It was determined that air pressure is not maintained constantly in the CTIS. It means that air pressure in the CTIS appears periodically. When the CTIS is turned off, air pressure in this system does not exist. When the CTIS is turned on, air pressure appears depending on selected function from manage panel of the vehicle. 
H2 – The change of sealing element side when repairing has a negative effect on the CTIS.	Approved	• Technical specification indicates that sealing elements cannot be assembled by turning on their teflon surface into oil [6]. • We determined that sealing elements have two different sides. That is the reason why it is very important to choose the correct side when assembling because that affects the reliability of the CTIS. • When repairing the CTIS, we identified that sealing elements are usually assembled incorrectly: the teflon side is turned into oil (A), and both teflon sides are turned into oil (B). 
H3 – Air pollution and humidity increase the breakdown likelihood in the CTIS.	Approved	• Air in the pneumatic system must match the ISO8573.1 standard, the second class of quality [3]. When pneumatic system is used in the CTIS, air dryer must be changed once a year. • The adsorption membrane dehumidifier is used in the CTIS. According to the requirements of the manufacturer, it must be changed periodically after 80,000 – 120,000 km (every autumn) during pre-planned check-up or once a year.

Continuation of table **Table 1.** Hypotheses, results, and their substantiation.

H3 – Air pollution and humidity increase the breakdown likelihood in the CTIS.	Approved	• The driver or operator must drain the water from the air pressure vessel, air drain valves every day during the winter season, and once a week during the rest of the seasons. • While repairing the CTIS, we determined that requirements mentioned above are ignored. We detected condensate in the CTIS that caused corrosion and damaged the sealing elements. 
H4 – The off-road vehicle breaks down less often after turning the CTIS off.	Denied	During the CTIS research, we found out that turning the CTIS off does not protect the system from breakdown. Moreover, when CTIS is not used, breakdown can be identified too late because it can be seen only when the CTIS is turned on or during its repair. 

Comparing the results of the questionnaire and the hypotheses about the cause for failure of the CPP subsystem, the opinion of the garage employees and the proven facts were different in certain situations. Garage employees chose the frequency of the CTIS usage as the main cause for the CTIS breakdown but that reason was denied when checking hypothesis H4. The same happened with hypothesis H1, when too high air pressure in the CTIS was denied as the cause for its breakdown. Garage employees and hypothesis H2 approved that one of the causes for the CTIS breakdown is failure when assembling during the repair process. Air pollution and humidity in the CTIS was also proved to be the cause for breakdown by garage employees and hypothesis H3.

According to the research results, we provide the following recommendations for the increase of the CTIS reliability:

- Do not change the sealing element sides when repairing the CTIS.
- Ensure air cleanliness and dryness in the CTIS using air dehumidifiers. They must be changed once a year; water must be drained from the air pressure vessel by opening air drain valves every day during the winter season, and once a week during other seasons.
- Knowledge of garage employees about the CTIS must be updated periodically by providing more accurate structure and assembly schemes, troubleshooting, fault diagnostics, specifications and instructions.

Conclusions

1. The chassis and its Central Tire Inflation System (CTIS) have been identified as systems that tend to break down most often in the off-road vehicles.
2. The main breakdown causes of the CTIS have been determined: failure when assembling during the repair; air pollution and humidity. When disassembling the CTIS, the sides of sealing elements are sometimes changed. Condensation and corrosion have also been detected.
3. Recommendations for the increase of reliability of the CTIS have been provided: not to change the sealing element sides when repairing the CTIS; to ensure air cleanliness and dryness in the CTIS using air dehumidifier; to update the knowledge of garage employees about the CTIS periodically.

Literature

[1] A.Amrazevičius, Lietuvos transporto sistema, Vilnius, 2008.

[2] B.Bertsche, Reliability in Automotive and Mechanical Engineering, 2008.

[3] J.Francis, Air Quality Standards ISO 8573.1 & ISO12500. The hyperlik: https://www.airbestpractices.com/system-assessments/air-treatmentn2/air-quality-standards-iso-85731-iso12500.

[4] H.Medekšas. Gaminių kokybė ir patikimumas – Kaunas, Technologija, 2003. – 279 p.

[5] V.Mickūnaitis. The qualiy of motor cars and is variation times // Transport. – 2004, Vol XIX, No 4, p. 177–179.

[6] SISU AXLES, Additional instructions for axles equipped with CTI-System, 2008, p.1, Picture 2. The hyperlink: https://www.sisuaxles.com/wp-content/uploads/sites/6/2015/08/15753-Installing-CTI-Seals-and-Hubs.pdf.

[7] I.Višniakas, K.Slivinskas. Patikimumo teorija, Vilnius, 2005. P.90.

[8] Zhang Y. M., Yang Z. (2009) Reliability-based sensitivity analysis of vehicle components with non-normal distribution parameters., International Journal of Automative Technology, Vol. 10, No. 2, pp. 181-194. DOI: 10.1007/s12239−009−0022−4

[9] Zhang Y. M. Reliability-based robust design optimization of vehicle components, Part I: Theory, Higher Education Press and Springer-Verlag Berlin Heidelberg, 2015, 10(2): 138-144. DOI:10.1007/s11465-015-0333-2

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