NEW STORAGE SYSTEM FOR ENGINE DURING TRANSPORTATION

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Abstract

The existing system of protection of a machine group, engines in military vehicles TATRA 815, from corrosion effects is only applicable to vehicles parked indoors; in sea, air, railway and road transportation, individual machine components constituting functional parts of the engine cannot be protected adequately from relative air humidity possibly inducing degradation processes in a material leading to the occurrence of corrosion. In the paper, a scientific method of multicriteria evaluation of variants is employed, using Saaty's method to determine criteria weights and Metfessel's method of allocation of 100 points, to make a comparison of the existing method of storage of T3-930-50 type engine and a newly designed system of engine storage that is applicable indoors as well as outdoors, or possibly during transportation. The goal of the research was to provide a qualitative evaluation of the impact of degradation on the life cycle of a military vehicle, and an economic evaluation of a newly designed system of short-term military vehicle storage, applied to TATRA 815 military vehicle, as opposed to the existing storage method.

Key words: Corrosion inhibitor, degradation process, storage, life cycle relative air humidity

1. INTRODUCTION

Storage is defined as a set of technical and organizational measures inhibiting the influence of physical ageing and climatic conditions. From the military point of view, the primary reason why to store vehicles is to ensure proper state of military vehicles, and to make them ready for immediate use as required by the Army of the Czech Republic (ACR).

The term "life cycle" may be interpreted in accordance with the "NATO Life Cycle Working Group" definition for Life Cycle Management, when a comprehensive approach was applied to the description of all strategic, organizational, and technological tasks being of potential help in organizing flows in logistic systems (Standard NATO, 2013). In the Army of the Czech Republic, a definition named "Life Cycle Cost" is adhered to, which includes the following stages:

concept – identification of users' requirements, examination of the concept, proposal of feasible solutions;

development – specification of the product requirements, production of a structural design, manufacturing of prototypes, verifying and proving the correctness of the design;

production – production, inspection and testing of the product;

use – putting the product into operation, and its use by the user;

support – support of the product in operation;

putting out of operation – storage, archiving or disposing of the product (Binar et al. 2016), (Mykiska, 2000).

The definitions above may be applied to the life cycle of a wheeled military vehicle, i.e. the initial stage corresponds to collecting a vehicle from the factory, and the final stage corresponds to the removal of a useless vehicle, and its subsequent sale/disposal at an ACR facility (Guangbin, 2007). Military vehicle Tatra 815, require, in addition to common costs of operation and maintenance, considerable earmarked funds on spare parts and machine groups (e.g. transmissions, engines, …) for possible repairs (Binar et al., 2017). These spare parts reserves may be used in case of contingency (foreign peace missions, floods, humanitarian aid, etc.). In order to maintain the original useful properties of these reserves, they need to be stored indoors in military units and regular financial means have to be expended in connection with the storehouses (overhead costs of energy, lightning conductor inspections, repairs of buildings, personnel, security service) (Jeong et al., 2007). In case of corrosion occurrence in a material, corrosion products are produced gradually, and the dimensions of the original component change causing a decrease in the original weight (Dai et al., 2017). In consequence of these changes in a machine component, caused by the corrosion degradation effect, a change in the original material properties and irreversible damage to the component affecting the engine functionality can be assumed (Jordan, 2015). The occurrence of a limit state represents the initial stage of irreversible damage leading to a fault in the machine element material. Thus, the reliability and combat readiness of the military vehicles are compromised. Therefore, developed countries seek answers in various industries on how to reduce the occurrence, or at least decelerate the course, of corrosion degradation of materials (Eboli et al., 2008).

With regard to the reliability and combat readiness, long-term parking of military vehicles in a military vehicle depot may be considered to be a crucial stage. A military vehicle depot, i.e. a separate, delimited and guarded area at a cost centre (a military unit or facility), provides not only parking to military vehicles, but also repairs and prescribed maintenance at specified places. According to the internal regulations for the field of operation, it is stipulated that a technique that is not in operation for more than 30 days must be stored. The storage technologies themselves can be divided according to the time of use and the extent of work performed on short-term (1 to 2 years) and long-term (3 to 5 years) storage. The purpose of storing is to preserve the original properties of the technology while it is not being used (Kowalski, 2013).

Due to the large number of techniques and the economics of the present method of storage, the technique cannot be protected against the effects of the outside environment and the technique is built year-round on climatic changes of the climate, which reduce the life cycle of the vehicles. This fact is confirmed by the insufficient capacity of stalls in covered buildings for non-operational technology (Becker et al., 2016).

2. COMPARSION OF EXISTING AND NEW VEHICLE STORAGE SYSTEM

Existing storage procedure can only be performed by qualified shop personnel knowing the construction of the engine type under consideration. Also, the time intensity is rather big with a large amount of materials and tools required. The storage procedure requires two qualified shop specialists. The system does not guarantee 100% corrosion protection, even though the technological procedure is strictly adhered to (Binar et al., 2016).

The most serious drawbacks of this storage method can be summarized as follows:

- considerable amount of time required for the storage process;
- use of environment-unfriendly preservatives requiring depreservation when removing a vehicle from storage;
- the preservatives are no longer available in the commercial market;
- the depreservatives require environment-friendly disposal;
- qualified personnel with relevant know-how in the field of vehicle maintenance is required, as certain parts, e.g. of the engine, must be dismounted to be preserved and depreserved;
- the preservation and depreservation must be carried out in a roofed shop as a great amount of shop equipment is required;
- the complexity of the existing storage system does not allow performing the process under (Binar et al., 2016).

Newly designed storage system is based on releasing corrosion inhibitors from a special film, thus creating an ionic bond on machine elements in the crypto climate and protecting the material surface from corrosion. For the needs of the new storage system, a kit was designed allowing comprehensive performance of tasks related to the process of the vehicle storage and removal from storage. The kit is also convenient to be used in field conditions, e.g. in foreign peace missions (Binar et al. 2016).

The advantages of the new short-term storage system may be summarized as follows:

- the preservatives are environment-friendly, and do not require depreservation;
- the process of preparation and storage conducted by two workers shall take up to 3 hours in total;
- the removal of a vehicle from storage and replacement of the battery shall take up to 1 hour in total, and no depreservation is required; the vehicle is almost immediately capable of performing combat tasks;
- the short-term storage is performed outdoors, where vehicles are stored throughout the year;
- due to preservation materials and a film on the corrosion-inhibitor basis, the vehicle is protected from corrosion, and can be parked outdoors, exposed to climatic changes (temperature, relative air humidity, snow on the wrap surface), at a cost centre throughout the year (Binar et al., 2016).

In the decision-making process concerning the profitability of the new storage system, a method of multi-criteria evaluation of variants was employed. Criteria weights were determined by means of the Saaty's method, and then Metfessel's allocation of 100 points was applied (Boggia et al., 2010). Setting the preference of individual criteria for the storage systems – for the purpose of the evaluation of variants, individual criteria are identified to be compared within the existing storage system (referred to as "ES" in the text) and the new storage system (referred to as "NS" in the text).

Costs of administrative support – costs of the work process involving processing of documentation related to the short-term military vehicle storage.

Costs of storage preparation – costs of the work process involving the preservation of individual functional parts of a vehicle using prescribed means.

Costs of storage – costs of the storage proper.

Costs of removal from storage – costs of work related to the depreservation of a military vehicle.

Costs of depreservation – costs related to the environment-friendly disposal of the means of depreservation following the depreservation of a vehicle.

Price of materials and means of storage – costs of material support to the short-term military vehicle storage.

Price of reusable storage tools and kits – costs of tools and kits used repeatedly in the storage process.

Price of depreservation materials – costs of means of depreservation.

Price of reusable removal-from-storage kits – costs of kits used repeatedly in the process of removing a military vehicle from storage (Binar et al. 2016). When assigning weights to individual criteria, the rate of preference was expressed for the criteria using a numerical value:

- 1 – equal (in inverted form 1/1);
- 3 – slightly preferred (in inverted form 1/3);
- 5 – strongly preferred (in inverted form 1/5);
- 7 – very strongly preferred (in inverted form 1/7);

– 9 – absolutely preferred (in inverted form 1/9).

As soon as the criteria and respective preferences were determined, (Table 1 and Table 2) was designed containing input data and comparing pairs of individual criteria. Based on the comparison, geometric averages of the preferences were calculated. Column Π_i (geometric average) is reserved for a partial calculation helping to determine the resulting weight vector (v_i). The sum of the weight vectors shall equal 1. Thus, the correctness of the calculation is proved.

Table 1. Criteria

Coefficient	coefficient characteristics
c1	costs of administrative support
c2	costs of storage preparation
c3	costs of storage
c4	costs of removal from storage
c5	costs of depreservation
c6	price of materials and means of storage
c7	price of reusable storage tools and kits
c8	price of depreservation materials
c9	price of reusable removal-from-storage kits

Source: own

Table 2. Pair comparison of individual criteria

Criterion	c1	c2	c3	c4	c5	c6	c7	c8	c9	Π_i	v_i
c1	1	1/9	1/7	1/7	1/7	1/5	1/3	1/5	1/7	0.191	0.014
c2	9	1	5	5	5	7	7	5	7	4.757	0.343
c3	7	1/5	1	3	5	5	5	7	5	2.977	0.214
c4	7	1/5	1/3	1	3	1	7	7	5	1.913	0.138
c5	7	1/5	1/5	1/3	1	5	3	5	3	1.403	0.101
c6	5	1/7	1/5	1	1/5	1	5	5	7	1.196	0.086
c7	3	1/7	1/5	1/7	1/3	1/5	1	1/7	1	0.366	0.026
c8	5	1/5	1/7	1/7	1/5	1/5	7	1	3	0.636	0.046
c9	7	1/7	1/5	1/5	1/3	1/7	1	1/3	1	0.441	0.032
										13.88	1

Source: own

It follows from (Table 2) that the costs of storage preparation (0.343), costs of storage (0.214), costs of removal from storage (0.138), and costs of depreservation (0.101) have the highest weight vector.

2.1 Determining The Utility Function

At this stage of the decision-making process, the criteria values for the vehicle storage systems are supplied, and the Metfessel's allocation of 100 points is applied showing the profitability of the systems. In (Table 3), individual criteria values for the vehicle storage systems are stated. The table is based on the average net salary of a professional soldier, i.e. a rank-specific amount stipulated in the amended Act on Professional Soldiers (Act.no 137/2006), (Act. No 221/1999). Using the average net salary, the average hourly rate is calculated in the table with 160 working hours per month. The working hours also take certain insufficient qualification of the workers preparing the documentation into consideration. To a great extent, this drawback is a consequence of a regular rotation of specialists who often work in a particular post for only two or three years (Švarc et al., 2017).

It follows from (Table 3) that the minimum value (costs and price) is to be reached under all criteria; in consequence the lowest resulting value is searched when comparing the vehicle storage systems in (Table 4).

Table 3. Determined criteria values minimum costs in CZK unit

Criterion	ES	NS
Costs of administrative support	18.011	11.729
Costs of storage preparation	24.166	1.365
Costs of storage	8.738	2.730
Costs of removal from storage	5.461	1.365
Costs of depreservation	4.096	0
Price of materials and means of storage	11.852	13.798
Price of reusable storage tools and kits	45.430	34.000
Price of reusable removal-from-storage kits	3,000	0
Price of depreservation materials	2,386	0

Source: own

As soon as the values are determined, 100 points are distributed between both the vehicle storage systems depending on the values of individual criteria. The allocated share of the 100 points is then multiplied by the weight factor assigned to individual criteria by mans of the Saaty's scale. The distribution of the 100 points between the vehicle storage systems is based on the following formulae:

$$AP_1 = \frac{ES}{ES + NS} \cdot 100\ \% \qquad (1$$

where: AP_1 – share of points allocated to the existing system
ES – value of an existing system criterion
NS – value of a new system criterion

$$AP_2 = 100 - AP_1 \quad (2$$

where: AP_2 – share of points allocated to the new system

Table 4. Distribution of 100 points between the vehicle storage systems

Criterion	v_i	ES	NS	v_i * ES	v_i * NS
Costs of administrative support	0.014	61	39	0.85	0.55
Costs of storage preparation	0.344	95	5	32.68	1.72
Costs of storage	0.215	76	24	16.34	5.16
Costs of removal from storage	0.138	80	20	11.04	2.76
Costs of depreservation	0.097	100	0	9.70	0.00
Price of materials and means of storage	0.087	46	54	4.00	4.70
Price of reusable storage tools and kits	0.026	57	43	1.48	1.12
Price of reusable removal-from-storage kits	0.046	100	0	4.60	0
Price of depreservation materials	0.032	100	0	3.20	0
Total	1	715	185	84	16

Source: own

It follows from (Table 4), with regard to the selected criteria, their weights and values, that the newly designed system is a better alternative as the lower value is searched. The newly designed system allocated 16 points, and 84 points to the existing system. The newly designed system meets the requirement for lower costs of the work processes and lower prices of the materials and kits.

Possible minor inaccuracies in the tables are caused by the rounding of the values in Microsoft Excel application. As the inaccuracies are only presented in the tables, but unrounded values are used for the purpose of calculation, the results are not distorted. Final rounding of the values for the utility function calculation has a minimum impact on the result.

3. RESULTS AND DISCUSSION

A crucial factor in the selection of a suitable storage system is the period of time required for the vehicle storage or removal from storage so that the vehicle can immediately perform tasks of the ACR.
When comparing the storage system variants (Table 5), the costs of administrative support shall be excluded as the administrative support is secured by the chief specialist at a unit and does not enter the process of vehicle storage and removal from storage.

Table. 5 A comparison of the existing and the new system

Process	ES (hr)	NS (hr)	Difference between ES and NS (hr)
Time of storage preparation	17.7	1	16.7
Time of storage	6.4	2	4.4
Time of removal from storage	4	1	3
Total	28.1	4	24.1

Source: own

It follows from the comparison of the existing and the new system that a time saving of 24.1 hr per vehicle can be achieved with the new system. The newly designed storage system is 5 times better than the existing storage system. In consequence of the application of the new vehicle storage system in the ACR, considerable savings of financial means can be achieved.

4. CONCLUSION

The new variant of the storage system of T3-930-50 type engine are much more advantageous in terms of the time required if compared to the existing method of storage, i.e. 4 hr. As far as outdoor application is concerned, the new system can be used e.g. in sea transport, where very harsh conditions can be assumed. Also, the outdoor variants represent significant savings if compared to the indoor storage as roofed buildings require considerable financial means for their operation. Another great advantage of the newly designed system as opposed to the existing method is a rather small amount of tools, means, equipment and material required for storing.

The system of operation of military vehicles and materials, creating conditions to assure and retain maximum quality of the materials and vehicles, requires a considerable amount of financial means that could otherwise be used for other purposes. The allocated budget limits the expenditures on the operation and maintenance of military vehicles in a calendar year. Hence, perfect coordination of financial planning at all levels of command is essential in order to ensure purposeful, efficient and economical use of the financial resources available.

Considering that the vehicles are intended to be used immediately anywhere in the Czech Republic or abroad, the depreservation process is rather time and money consuming. The existing storage process proper requires qualified personnel sufficiently experienced in vehicle maintenance, capable of preserving particular vehicle parts. The total time of the current existing storage method application is rather long, and the process requires involvement of key specialists.

Compared with the existing storage method, rubber parts and tyres are protected from the effects of sunshine using a UV filter, which is part of the film. The application of the new storage method and the storage kit is simple, and no specialists are required. The application of the newly designed storage system can also be conducted under a public contract. Application of the new storage system at a cost centre eliminates losses, the state may incur, and subsequent unplanned expenditures on repairs due to damages caused by corrosion and premature ageing of rubber materials in consequence of sunshine. The new storage system retains useful properties of military vehicles making the expenditures during the military vehicle life cycle and management of the state's property at a cost centre more efficient.

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