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NATURE AND PRINCIPLES OF MAINTENANCE SYSTEM DURING COMBAT OPERATIONS

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NATO armies still are looking for new solutions which let them improve the possibilities of the maintenance system during combat operations. The analysis of contemporary armed conflicts shows that maintenance activities are very often limited to basic actions like recovery, evacuation, expedient repair and cannibalization or destruction of broken weapon systems. The paper analyses the nature and the basic principles related to recovery, evacuation and expedient repair operations. It highlights the crucial role of the battle damage assessment process as the main factor which should determine further maintenance actions. The possibilities of performing expedient (temporary) repairs are analysed in the context of main weapon systems units or parts.

Keywords: *military logistics, combat service support, combat operations, maintenance, technical recovery, battle damage repair*

INTRODUCTION

Combat operations are very dynamic processes varying with time and space. A combat and tactical situation is changing on the battlespace instantly and randomly. Meanwhile, all combat service support processes are determined and they require precise management (planning, organisation and supervision). Given that, a combat service support system slows down the dynamics and pace of combat [1, 2]. Therefore, the combat service support system for maintenance should cross all the boundaries on the battlefield, and the common responsibilities of combat vehicle crews and maintenance teams should amplify the need for every member of the unit to do and understand his part. Failure at any level disrupts the continuity of support required to cross the line of departure with maximum combat power [3].

As a result, maintenance activities will often be limited to basic actions during combat operations, namely a quick assessment of the situation, recovery and evacuation to the unit collection point or an expedient (temporary) repair during a combat operation, or the cannibalization or destruction of equipment which cannot be evacuated or repaired [4].

It should be highlighted as well that weapon systems belong to a group of technical objects used in a random mode [5], and as agricultural, city or rescue service equipment, they require a special maintenance system which is determined to perform tasks just on time and place. Therefore, a modern weapon should be designed to be:

- ballistically survivable on the current battlefield by incorporating active and passive signature reduction and ballistic tolerance features [6];
- operationally susceptible to easily perform any maintenance actions like service, repair and recovery or evacuation [7].

1. BATTLE DAMAGE ASSESSMENT

A battle damage assessment plays a crucial role in the process of weapon system maintenance. It should be executed very quickly and carefully at the same time, since it determines further actions which will be taken by logistic elements. It includes evaluating the extent of damage sustained and determining whether deferment is feasible. Scheduled and unscheduled maintenance and minor battle damage, except for necessary lubrication, servicing, and preoperational checks, may be deferred. Unscheduled maintenance, such as the repair of systems and subsystems that have adequate redundancy or are not critical to mission accomplishment, can be deferred. Relaxed inspection criteria for repair and weapon systems performance should also be evaluated and defined [8]. Damage assessment is a procedure to rapidly determine what is damaged, whether it is repairable, what assets are required to make the repair, who can do the repair (e.g. crew, maintenance team or maintenance support team), and where the repair should be made.

The assessment procedure includes the following steps (Fig. 1) [6]:

- determine if the repair can be deferred, or if it must be done;
- isolate the damaged areas and components;
- determine which components must be fixed;
- prescribe fixes;
- determine if parts or components, materials, and tools are available;
- estimate the manpower and skill required;
- estimate the total time (clock hours) required to make the repair;
- establish the priority of the fixes;
- decide where the fix shall be performed;
- decide if recovery or evacuation is necessary and to what location.

2. RECOVERY AND EVACUATION

The recovery and evacuation of a weapon system should be executed very close to fighting units with the use of the latest technology, which allows for quick recovery of damaged equipment and accomplishing the task [9]. Recovery means the extrication of an equipment casualty and, if necessary, its removal to a place where it can be repaired. It is usually the first step in returning disabled or damaged equipment to the battle, although it is possible to repair a damaged object without recovery. In general, initial recovery is an owning unit responsibility. Based on a tactical situation, recovery operations may be limited to just moving equipment from the direct line of enemy fire. Evacuation means the movement of equipment casualties within the logistics system to

a place where repairs can be conducted. Evacuation should be executed only as far to the rear as it is necessary for repair. As far as weapon systems are concerned, most of the damaged parts can be recovered on the battlefield and reused. It is very often a basic source of supplying military units during combat operations [1, 10].

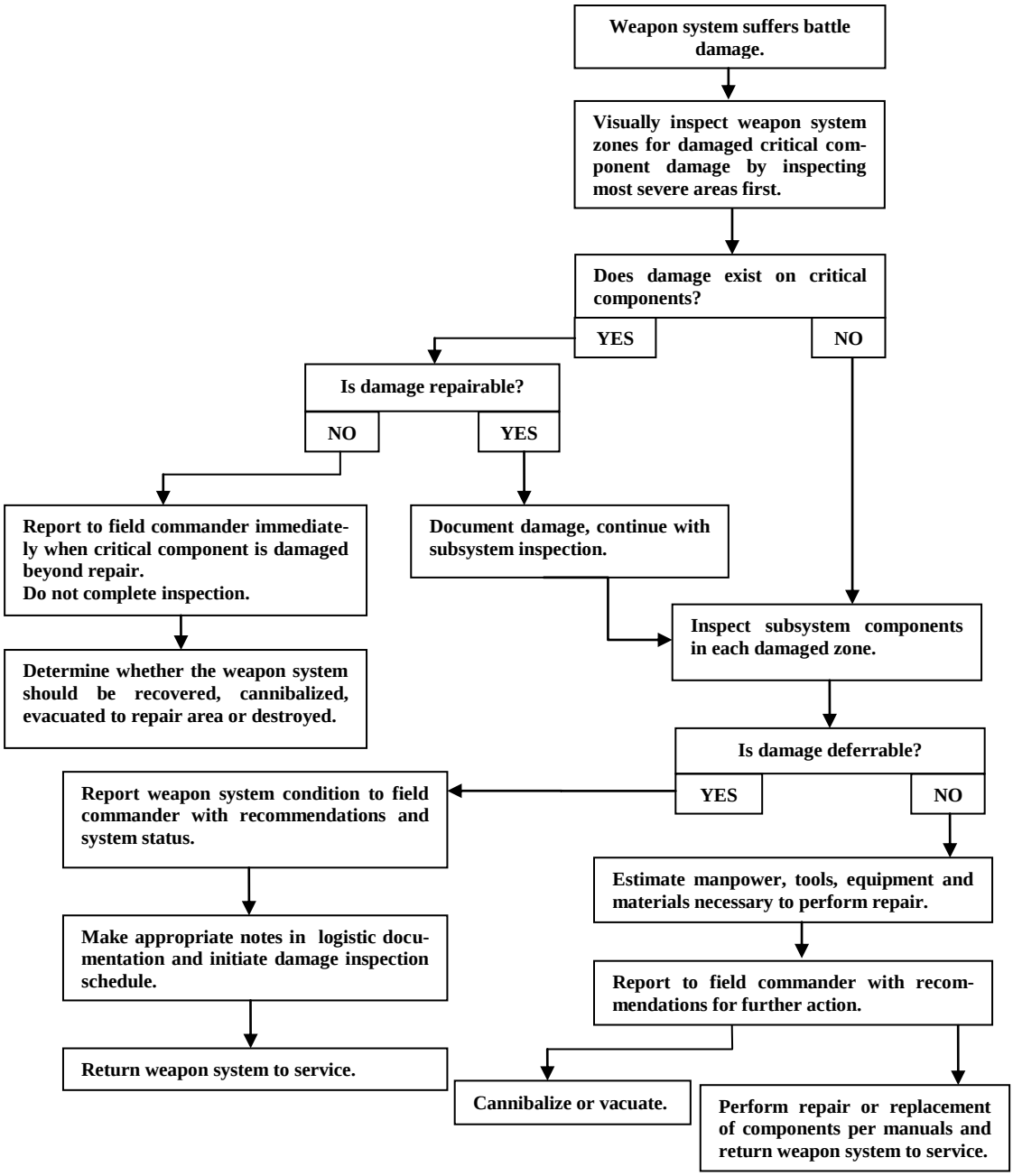

Fig. 1. The chart of battle damage assessment

Source: Own elaboration based on [6]

Recovery is performed to: retrieve damaged or mired equipment for repair and return to use, retrieve abandoned equipment for further use and prevent enemy capture of equipment. The type and quantity of supported equipment, as well as the tactical situation, may require tailoring of recovery assets. Only the minimum number of re-

quired recovery assets should be deployed for each operation. The following general principles should be applied to recovery management [8, 9]:

- units are responsible for their own equipment. The crew of units should first attempt self-recovery efforts, followed by unit-supported like-vehicle recovery. If necessary, limited backup support is available from the next higher level of maintenance;
- units are responsible for security during the entire recovery mission;
- recovery operations are coordinated with the maintenance effort;
- recovery vehicles of the correct weight class must be used to ensure safety. Recovery vehicle winches and/or towing capabilities must be greater than those of the disabled or mired vehicle;
- recovery vehicles should not return equipment farther than the unit collection point. This allows for keeping recovery assets forward.

Generally, the four methods of recovery are used during combat operations. These are as follows: winching (using winches on special purpose or cargo vehicles), lifting (using the lifting capabilities of special purpose vehicles), towing (using the towing capabilities of similar or special purpose vehicles) and expedients, used when other methods are not adaptable to the situation or when appropriate like vehicles or dedicated recovery vehicles are not available (Fig. 2).

Fig. 2. An example of recover action – lifting

Source: [11]

3. EXPEDIENT REPAIR

An effective expedient repair (including battle damage repair) system should provide an expeditious means of combat damage assessment for deferment or repair. The system should include special techniques, tools, equipment, and procedures to be used by military troops during combat conditions.

The expedient (temporary) repair system also includes procedures to perform rapid battle damage repairs where necessary within the constraints imposed by time, manpower, material, and operational requirements. The primary purpose of rapid battle

damage repair is to restore sufficient strength and serviceability to the weapon systems to permit them to conduct additional operational missions or to permit partial mission capability. Demonstrations of typical repairs should be made to determine whether the structural integrity, time constraints, tools, and maintenance personnel meet defined requirements [12].

The types of structure and the material forms should be considered. When combat damage reduces the strength, stiffness, or stability of the damaged elements, a decision on repair methods must be made. Typical materials used in modern weapon systems include steel, aluminium, titanium, magnesium, and composites. Consideration should also be given, in case of repairing aircrafts, to the use of installed instrumentation and monitoring devices to make reusability decisions in the field after a combat incident or resulting crash [13]. Knowledge of these damage or crash parameters helps expedite deferment or repair assessment. Measures used to quantify repair qualification may include time to repair at each maintenance level and effectiveness of the repair, which is expressed as the number of life units the repair lasts.

Any field repair actions of damaged weapon systems can be divided into two basic group: standard (regular) repairs or expedient (temporary) repairs. Standard repairs are conducted by exchanging the whole broken units or single spare parts, which are delivered by supply chains of logistic units or obtained from totally destroyed weapon systems (cannibalization). Sometimes spare parts can be obtained in the process of regeneration such as: welding, surfacing, applying galvanic coatings, metal spraying and even 3D printing [14, 15]. If possible, a standard repair is preferred, but it is very difficult to provide in the conditions of combat operations. An expedient (temporary) repair can be an alternative solution in many cases. Expedient repairs mean any improvised actions which may lead to making broken systems available temporarily. The primary function of a expedient repair system is to provide quick-fix material and techniques to increase a weapon system's availability under an intense combat environment. The system should be composed of required equipment and procedures to provide the capability to inspect, assess, and repair the military equipment. Support documentation should include inspection procedures, damage assessment criteria, serviceability criteria, expedient repair procedures, cannibalization techniques, and assessment and repair handbooks. Hardware should include damage assessment aids (such as die penetrant kits, micrometres, etc.), repair tools, ground support equipment, and repair material [6, 8, 16].

Any expedient (temporary) actions include [16, 17]:

- short cuts in parts removal or installation;
- installation of components from other equipment that can be modified to fit or interchange with components on the damaged equipment;
- repair using parts that serve a noncritical function elsewhere on the same equipment for the purpose of restoring a critical function;
- bypassing of noncritical components in order to restore basic functional capability;
- expeditious cannibalization procedures;
- fabrication of parts from kits or readily available materials;

- temporary substitute fix;
- use of substitute materials.

General procedures of expedient (temporary) repairs can be divided into systems or parts common for combat vehicles. The possibilities of performing expedient (temporary) repairs in the context of the mentioned systems are listed below [18, 19, 20]:

1. Tanks:
   - smaller ruptures and leaks which might be fixed by bandaging or cementing with the use of quick-setting adhesives;
   - disruptive breakdowns which might be repaired through a combination of bandages or fabric glass and adhesive or packings made of different material;
   - damaged tanks which might be replaced (by-pass) by connecting additional barrels, canisters or heat resistant cases capable of being closed with a specific medium.
2. Pipes and lines:
   - minor damage and the leak of a low-pressure pipe might be repaired by repair tape or using quick-setting adhesives;
   - more serious damage to a low-pressure pipe (not including exhaust pipes) can be solved by replacing a damaged part with a rubber hose fastened with sleeves or a band;
   - damage to a high-pressure pipe can be mended by pipe´s offset and cementing the ends with anaerobic or quick-setting adhesive, or by complete replacing the pipe using a high-pressure hose with endings.
3. Radiators (condensers):
   - leakage can be stopped using substances added to a cooling liquid which solidify during the leak from a cooling system, or quick-setting adhesives used in the place of the leakage;
   - disruptive breakdown can be fixed by squeezing a tube with pliers and then filling the hole with a sealant or hot lead;
   - damaged radiators can be isolated for a short time and a cooling system might be interconnected without the radiators, or radiator may be replaced by another part, e.g. a barrel or a demountable fuel tank.
4. Air and hydraulic systems: damaged part of a system might be disabled by blanking of a particular part, or providing a by-pass around a damaged part using hoses with endings.
5. Rods and shafts:
   - cracked rods can be joined by a thicker bond sheet metal, the ends of which will be drilled and screwed together, or there will be used a sleeve welded at the end;
   - cracked shafts will be joined by welding to a sleeve where applicable.

6. Windings:
   - minor damage can be solved by using a threaded coupling with an anaerobic adhesives;
   - damaged internal thread might be fixed by drilling off and using threaded insets which renew the original winding.
7. Electric cables:
   - visible local damage might be repaired using insulation with both ends twisted and insulated by an insulation tape or the joint is welded;
   - damage difficult to detect can be fixed by bridging a proper circuit using a new cable, or, in case of power supply, by connecting with a cable assembly with nominal voltage.

The justification of applying expedient (temporary) repairs depends on time, when this repair would be executed. It is obvious that during the first few days of combat maximum weapon system availability is essential. Military equipment will sustain varying degrees of damage during combat operations. The damage must be assessed and repaired as quickly as possible. Maximum availability must be maintained for further sorties. In addition to the combat damage, weapon systems will have higher component failure rates because of increased working hours and higher stress levels. The difference between the expedient repairs of military equipment performed in peacetime and in field conditions is that we should follow not only economic factors, which are the most important in peacetime, but also the provision of combat vehicle main functions, e.g. a fire system, vehicle mobility and communication. The simulations definitely indicate that during high intensity conflicts the availability of weapon systems becomes low within the first few days of the battle [21]. This is caused not only by numerous battle failures and system unreliability but mainly due to logistics delays such as spare parts, maintenance crew or equipment. Some of the mentioned problems could be at least partially solved by applying expedient repair procedures and methods.

Prediction of weapon systems damage losses based on daily rates which are assumed on the basis of lessons and conclusions from contemporary wars and military conflicts as well as fire power of an opponent's weapon system is considered [22, 23]. It is estimated in references that the daily losses of military equipment, depending on the type and pace of operation and many other factors, will vary from 10 to 40% [23, 24, 25, 26]. There can be some simulation models for the availability of weapon systems under battlefield conditions developed. The most often used functions are exponential, Weibull or log-normal distribution to perform simulation [21, 26]. In practice, a method based on taking account of the percentage disintegration rates is used for estimating the combat readiness[1] of fighting units. The percentage disintegration rates of the military equipment are often applicable historical data and prepared on the basis of the historical armed conflicts and experiences. What is more, they are taking account of the repair possibility by own maintenance elements.

[1] Combat readiness – the degree to which a unit or sub-unit is considered capable of fighting effectively. *Dictionary of military terms – third edition,* pp. 51.

If we consider a specific situation in which a mechanized brigade equipped with IFVs (BMPs) and tanks is conducting a defensive operation, it is possible to prepare more accurate calculations of repair needs, which results more from projected losses in the main groups of the military equipment, where the basic criteria of classification are the type of the damaged item, the repair equipment of the serviceman, and the predicted manpower intensity of damage repair [27]. Detailed assumptions and calculations are presented in paper [28]. The calculations described in the mentioned work prove that the synergy of action resulting from connecting a standard maintenance system with expedient repair actions should allow one to extend the brigade's combat readiness to three days of fight, which is described in the Figure 3.

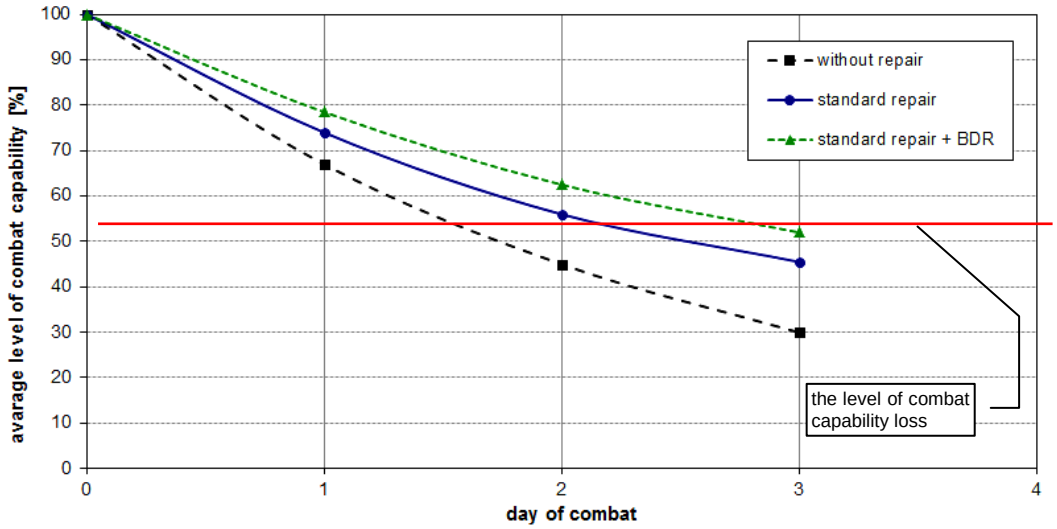

Fig. 3. Mission capable rates of main vehicles with reference to the assumed variants

Source: [28]

CONCLUSIONS

Taking into account the studies conducted, the following conclusions can be drawn:

1. Weapon systems belong to a group of technical objects used in task (random) mode and they require a special maintenance system, which should be aimed at executing tasks in a specific place and time regardless of circumstances.
2. Maintenance activities during combat operations will often be limited to basic actions, namely a quick assessment of the situation, recovery and evacuation to the unit collection point or an expedient (temporary) repair during a combat operation, or the cannibalization or destruction of equipment which cannot be evacuated or repaired.
3. A battle damage assessment plays a crucial role in the process of weapon system maintenance since it determines further actions which will be taken by logistic elements. It includes evaluating the extent of damage sustained and determining whether deferment is feasible.

4. The recovery and evacuation actions of a weapon system should be executed very close to fighting units with the use of the latest technology, which allows for quick recovery of damaged equipment and accomplishing the task.
5. An effective expedient repair system should provide an expeditious means of combat damage assessment for deferment or repair. The system should include special techniques, tools, equipment, and procedures to be used by military troops during combat conditions. Demonstrations of typical repairs should be made to determine whether the structural integrity, time constraints, tools, and maintenance personnel meet defined requirements.
6. The conducted analysis of numerous references and own calculations prove that the synergy of action resulting from connecting a standard maintenance system with expedient repair actions should allow one to extend combat readiness of fighting units.

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CHARAKTERYSTYKA I ISTOTA SYSTEMU EKSPLOATACJI PODCZAS DZIAŁAŃ BOJOWYCH

Streszczenie

Armie NATO stale poszukują nowych rozwiązań, które pozwolą poprawić możliwości systemu eksploatacji w warunkach działań bojowych. Analiza współczesnych konfliktów zbrojnych wskazuje, że zadania systemu eksploatacji podczas działań bojowych są bardzo często ograniczone do podstawowych działań, takich jak ratownictwo techniczne, ewakuacja, naprawy doraźne oraz ewentualna kanibalizacja lub celowe zniszczenie uszkodzonych systemów uzbrojenia. W artykule przeanalizowano charakter i istotę zadań związanych z ratownictwem technicznym, ewakuacją oraz naprawami tymczasowymi realizowanymi w trybie doraźnym. Podkreślono kluczowe znaczenie procesu oceny sytuacji technicznej (uszkodzenia) jako głównego czynnika determinującego dalsze działania. Omówiono również możliwości wykonywania napraw doraźnych podstawowych zespołów i części systemów uzbrojenia w warunkach polowych.

Słowa kluczowe: *logistyka wojskowa, zabezpieczenie logistyczne, działania bojowe, eksploatacja, ratownictwo techniczne, naprawy uszkodzeń bojowych*

BIOGRAPHICAL NOTE

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