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REPAIR OF WEAPON SYSTEMS UNDER COMBAT OPERATIONS. PART 1 – NATURE, PRINCIPLES AND TECHNOLOGY

Abstract. The paper presents description of nature and principles of repair system under combat operations in context of using expedient (temporary, improvised) methods. Firstly, the crucial processes of battlefield maintenance were defined and principles and nature of expedient repairs were described. Additionally, basic allied documents were mentioned about battlefield maintenance and expedient repair. Furthermore, expedient repair systems in chosen allied armies were briefly described in order to identify basic elements of the expedient repair system which are common for all allies. The identified elements were shortly characterized.

Keywords: weapon systems, battlefield maintenance, expedient repair.

1. INTRODUCTION

Because of the allied commitments olish forces have to be mobile, inter-operational, well-equipped, trained and commanded, as well as, able to act in complicated conditions, and, last but not least – they need to have logistical autonomy [8], [9]. Additionally, polish troops conduct operations overseas fulfilling their tasks within the zones deprived of combat means, along with high exploitation of military equipment in harsh field and climate conditions [6]. Such situation causes damages, which do not take place in day-to-day peace-aimed usage at home. Along with intensive utilization effects and combat damages, also accident-related failures can grow sharply, usually as a result of the terrain obstacles, limited visibility and great dynamics of operation. Therefore, countries, which for decades have been taking part in various military conflicts or peacekeeping operations, are looking for new methods of expedient repair of weapon systems directly in the combat area.

Combat operations are very dynamic processes varying with time and space. The combat and tactics situation is changing on the battlespace instantly and randomly. Meanwhile, all combat service support processes are determined and they require precise planning, organization and supervising. Taking into account that point of view, combat service support system slows down dynamics and pace of combat. Therefore, maintenance actions will be often limited to recovering weapon systems, that is: quick assessment of situation, evacuation, quick expedient repair, cannibalization or destruction of equipment which cannot be evacuated or repaired (fig. 1).

Because resources are limited (personnel, tools, and parts), it is imperative that maintenance resources are not wasted. Crew members must do repairs within their capabilities immediately rather than requesting maintenance personnel to do simple mechanical tasks. On the battlefield, the objective is to return the system into battle with enough combat capability to get the mission accomplished. Cosmetic repairs are not necessary and are a waste of time and resources. If a broken item does not affect the ability to shoot, move or communicate, and does not pose a serious safety concern, it should not be repaired until the equipment is returned to maintenance where standard repair procedures can be performed [13].

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The crucial processes of battlefield maintenance are evacuation and repair of weapon systems used to perform combat operations. Efficiency of that process will determine success on the current battle space, which is connected with logistics forces and means supporting recovery tasks during operation [3], [23].

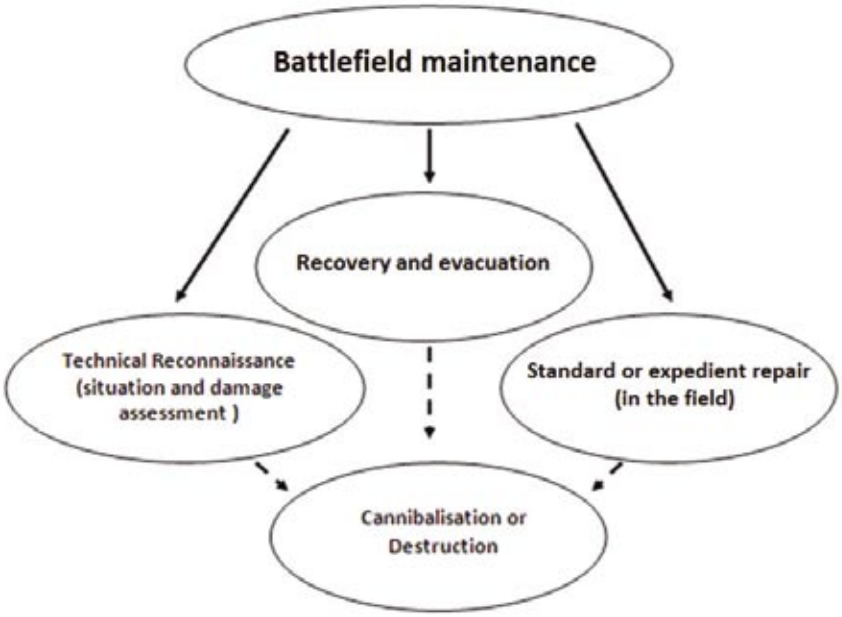

Fig. 1. Maintenance tasks of weapon systems under combat operation

2. EXPEDIENT REPAIR SYSTEM

According to the allied standardization agreement [14], there are the following types of expedient repair:

- Type 1: An improvised (non-conventional) repair which can be considered as permanent. This repair does not require subsequent replacement, but must meet any legal and safety requirements;
- Type 2: An improvised (non-conventional) repair which is considered only temporary by nature. This repair allows the equipment to complete the immediate mission or task, before being replaced by a standard repair. This repair should meet agreed legal and safety requirements;
- Type 3: An improvised (non-conventional) repair which rapidly returns the equipment for use under combat operations. This repair is unlikely to be permanent or may not meet legal and safety requirements but is essential in order to maintain military capability in periods of conflict or war. This type of expedient repair is considered to be Battle Damage Repair.

Taking the above into consideration, an expedient repair can be defined as a repair, which may be temporary, to restore equipment, both deployed and in-barracks, to a specified condition by non-conventional (improvised) methods, bounded by legal constraints. Whereas Battle Damage Repair can be defined as essential repairs, which may be improvised and/or temporary, carried out rapidly in a combat environment, in order to return damaged or disabled equipment to further contribute to operations. As a result, it can be claimed that the concept of expedient repair includes battle damage repair, improvised repair and non-conventional repair**.** Therefore, the name of expedient repair is used as the name for all kinds of the above mentioned activities.

In the Logistics Doctrine of the NATO Land Forces [20] it is also stated that expedient repairs, conducted in the fighting area, are crucial tasks of the battlefield maintenance system. It should be improvised and executed as close as possible to a broken equipment in order to quickly restore damaged weapon systems. The expedient repair is conducted if:

- there is not enough time or lack of spare parts to provide standard repairs;
- the operational situation forces to quickly restore damaged weapon systems;
- after an expedient repair and accomplishing task, a restored object must be repaired using standard methods.

According to the NATO Standard [10], evacuation and repair of weapon system should be executed very close to fighting units using the newest technology, which allows to quickly recover damaged equipment and accomplish a task. Recovery means the extrication of an equipment casualty and, if necessary, its removal to a place, where it can be repaired. Depending on a tactical situation, recovery operations may be limited to just moving equipment from the direct line of an enemy fire. It is usually the first step in returning disabled or damaged equipment to the battle. Still, it is also possible to repair a damaged object without recovery or to restore working order of an object only partially with a use of improvised and temporary methods and technologies.

The last NATO document which refers directly to battle damage repair of weapon systems is STANAG 2418, which introduces the idea of expedient repair. This kind of activity was defined as repair, which can be temporary and executed with use of nonconventional (improvised) methods in barracks or in field conditions. The expedient repair can be conducted only in accordance with the accepted procedures and instructions [14]. According to the quoted document, the expedient repair also includes a battle damage repair.

The analysis of battle damage repair systems in other armies of NATO [13], has proven that the system is an essential component of battlefield maintenance and it is being permanently improved and expanded taking its significance and complexity under consideration. The improvement of the system is provided by a lot of research, as well as, numerous analyses and tests of state-of-the-art technologies, lessons learned programs and trainings.

In order to briefly describe an exemplary expedient repair systems in allied armies, the systems in the USA and Norwegian Army are presented. Expedient repairs in the USA Army are conducted at four levels: crew/operator level, Combat Repair Team (CRT), Maintenance Support Team (MST) and Unit Maintenance Collection Point (UMCP). Each subsequent level is called for support only when the extent of damage is broader than possibilities of executing repair by a lower level [3]. Depending on the level of BDAR, different kinds of repair kits are available to support crew and maintainers in performing expedient repairs (fig. 2). BDAR kits allow repair in numerous areas, such as fuel, hydraulics, cooling, tires, electrical systems, and hull repair. Each unit is expected and encouraged to modify its kits to suit its special operational needs and geographic environment [4]. Crew members and drivers are expected to know the newest regulations and manuals of assessment procedures and BDAR kits' use. Commanders are obliged to perform BDAR training to make soldiers acquainted with the components of the BDAR kits that enable many repairs. Each crew member should know how to perform battle damage assessment and repairs.

The US experiences from operations the Allied Effort in Serbia and the Desert Storm in Iraq have proven that thanks to the implementation of executing improvised repairs in the centralized intermediate repair facilities, approximately 30-40% percent of all removed parts were found serviceable and returned to the original units [1], [2].

Fig. 2. FRS on a HEMTT-type vehicle during transportation (left), working post after removing from the transporting vehicle (middle) and during repair works (right) [5]

The Norwegian Army operates three-levels Battle Damage Repair system (fig. 3). At the first level there is BDR kit for operator/crew of military vehicle used; at the second level the recovery vehicle is used, which is equipped with BDR kit deployed in 3 aluminum boxes, and at the third level, a special mobile workshop with BDR stuff is used [7].

Fig. 3. The Norwegian Army three-level Battle Damage Repair system [7]

The above mentioned first level of BDR includes the following repair equipment: basic tools, regenerating taps, a repair kit for electrician and hydraulic installations, universal clamps, bands, pins and gaskets, epoxy adhesives and sealing agents for the installations. Every mechanic in the Norwegian Army, in addition to regular training, is trained during a 5-day -course in the BDR system and procedures of executing expedient repairs and using of BDR components. The BDR kit of the second level is located on the wheeled recovery vehicle 6x6 Scania. It consists of three aluminum boxes, which include 11 drawers with BDR materials and tools separated according to the purpose: epoxy adhesives, hydraulic installation, pneumatic installation, locksmith treatment, etc. [19]. According to Norwegian officers, the components selection for the BDR kits is based on two years of experiments and analysis. The equipment, which is used to execute expedient repairs, is automatically supplemented without additional record of the consumption. Placing the BDR kit in the recovery vehicle is a very interesting idea, because it enables to join evacuation with repair tasks. The crew of such vehicles can take action in the field of recovery concerning the circumstances, accessible time and extent of damage by conducting evacuation, repair or combination of the two tasks. An analysis of Norwegian experience from the ISAF operation has shown that recovery teams are able to carry out about 20% of expedient repairs in the site of damage with using the expedient repair kits [7].

The third level of BDR involves equipment of special designed mobile workshop in the standardized container 1C (20 ft.). Weight of the container is up to 20 tons and it includes all BDR components of the second level and; additionally, universal tools, such as a welder, soldiering irons, a wheel repair kit, a power supply, an air compressor, a lifting device, a set of

gas and plasma cutting, auxiliary equipment (e.g. vice) and air conditioning. The presented workshop is a prototype and its equipment and range of tasks are still being developed [7].

Regardless of the way and method of creating an expedient repair system, each of such systems should include (fig. 4):

- doctrines and procedures concerning rules and extent of expedient repairs and manuals (instructions) for a single weapon system;
- training system for maintenance personnel;
- expedient repair kits including cutting edge technologies and tools;
- repair actions recording and archiving systems, which allow to provide and support further recovery actions and use recorded data to conduct training and support maintenance personnel.

In addition to the general expedient repair doctrine at the level of land forces, which should be implemented primarily, specific instruction and procedures should be developed dedicated to specific weapon systems as well as instruction regarding the use of expedient repair kits on the various level of the system.

A training system should allow to train soldiers in the rules of expedient repairs and proper use of expedient repair tools and materials that will be used on their level. As a result, a manual should be provided for all drivers and crews (1st level), recovery teams and mobile recovery – repair sections (2nd level) and specialists of expedient repair squads of maintenance units (3rd level).

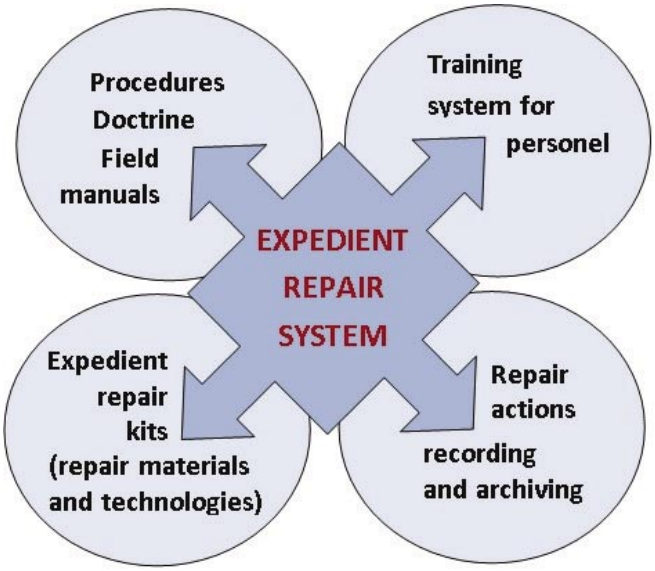

Fig. 4. Basic elements of the expedient repair system

There are many modern and efficient methods and technologies which can be successfully applied to expedient repairs of weapon systems in the field. They were already precisely described in many publications [9], [11], [12], [13], [17], so there is no reason to do it again. It is obvious that diversification of various solutions and adequate designing of equipment (reparability) will support maintenance units in recovering of weapon systems and can help to create advantage over an enemy.

Statistics is an invaluable tool for collecting, processing and using of all information referring to maintenance of weapon systems, in particular, special computer systems designed for supporting maintenance and supply management. The use of these systems in the future should allow to eliminate a large portion of faults and defects resulting from faulty design,

production technology or used materials and any other engineering solutions, as well as, take advantage of experiences and reports from already executed repairs. The implementation of a computer system would support not only current maintenance planning and execution but also permanent weapon systems improvement, design of new weapon systems considering expedient repair needs, prediction of battle and maintenance faults, planning recovery and repair operations, as well as, technical potential assessment, cost of repair calculation and stocks record to conducting repairs.

3. EXPEDIENT REPAIR PRINCIPLES AND PROCEDURES

As already has been mentioned, weapon systems belong to a group of technical objects used in a random mode and they require a specific maintenance system, which is determined to perform tasks at a given time and place. Therefore, modern weapons should be designed to be:

- ballistically survivable on the current battlefield by incorporating active and passive signature reduction and ballistic tolerance features;
- operationally susceptible to easily perform and maintain actions like service, repair and recovery or evacuation [18].

To be effective, an expedient repair should follow certain basic guiding principles [3]:

- ensure standard maintenance practice is always the first consideration;
- provide an accurate assessment;
- ensure economy of maintenance effort (use maintenance personnel only when necessary);
- train multifunctional skills;
- repair only what is necessary to regain combat capability;
- remain flexible about repair priorities.

Commanders should address problems using expedient repair in the logistics section of their operation order. This will provide the crews and maintainers with a clear understanding of when and at what risk level they can perform repair. In wartime, expedient repair may have to be liberally applied at the discretion of the commander. In military operations other than war, local command policy will direct the degree of expedient repair to apply and when to use standard maintenance. However, commanders at all levels must ensure that both crews and maintainers perform an annual expedient repair training.

Maintenance assets will be heavily taxed on the battlefield. Because resources are limited (personnel, tools, and parts), it is imperative that maintenance resources are not wasted. Crewmembers must do repairs within their capabilities immediately rather than requesting maintenance personnel to do simple mechanical tasks. Personnel shortages and battlefield casualties mandate that maintenance team members have some knowledge of other skills needed to achieve critical repairs. A lack of key repairmen must not deter a team from doing battle repairs. Whenever possible, on-the-job training or cross-training of personnel should be done. On the battlefield, the objective is to return the system into battle with enough combat capability to get the mission accomplished. Cosmetic repairs are not necessary and are a waste of time and resources. If a broken item does not affect the ability to shoot, move or communicate, and does not pose a serious safety concern, it should not be repaired until the equipment is returned to maintenance where standard repair procedures can be performed [13].

Recovery and evacuation of a weapon system should be executed very close to fighting units with use of the newest technology, which allows to quickly recover damaged equipment and accomplish a task. 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 is necessary for repair. As far as weapon systems are concerned, most of damaged parts can be recovered on the battlefield and reused. Very often it is the basic source of supplying military units during combat operations [3].

As it was mentioned earlier, 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 [3], [11]. 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 usually the following steps [11]:

- 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.

It is worth to add that any assessor must be equipped with some specialized tooling to conduct proper assessment. In addition to assessor tools, non-destructive inspection, when available, can aid damage assessment [21]. The exemplary tools which are useful to properly conduct battle damage assessment are as follows: flashlight, ruler or tape measure, inspection mirror, basic and weapon system specific assessment manuals. Apart from that it is useful to have recording equipment such as digital camera with abundant memory, a laptop computer with an internet connection or even without it, but with dedicated repair support and technical data about certain weapon systems.

It is obvious that non-standard repairs may lead to further damage of repaired equipment or even a threat to the crew, therefore prior to any expedient repair actions, the level of risk has to be assessed. According to [3] expedient repairs can be classified as:

- High-risk repair. Repair that may lead to further damage to equipment and/or injury to personnel. Example: emergency operation of an engine with inadequate lubrication may explode causing injury to personnel and further equipment damage;

- Low-risk repair. Repair that may lead to minor equipment failures but has no chance of injuring personnel. Example: placing a plug in the face of a tire - this is not likely to cause more damage to the equipment or injury to personnel;
- Medium-risk repair. Repair that may lead to further damage of equipment. Example: bypassing a starter relay will allow the equipment to start but may cause excessive heat.

To sum up, good assessment is the key to effective expedient repair. A properly trained and equipped damage assessor is the lead entity in defining a weapon system damage, determining repairs, and ensuring mission needs are met.

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 under combat conditions. An expedient repair system also includes procedures to perform rapid battle damage repair where necessary within the constraints imposed by time, manpower, material, and operational requirements. The primary purpose of an expedient repair is to restore sufficient strength and serviceability to the weapon systems to permit it 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 [22].

4. EXPEDIENT REPAIR TECHNOLOGY

Any field repair actions of damaged weapon systems can be divided into two basic groups: standard (regular) repairs or expedient (temporary) repairs. Standard repairs are conducted by exchange of 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. If possible, a standard repair is preferred, but it is very difficult to provide it in the conditions of combat operations. An expedient (temporary) repair can be an alternative solution in many cases. An expedient repair means improvised actions which may lead to breaking the temporarily available system. The primary function of expedient repair system is to provide quick-fix material and techniques to increase weapon system 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, micrometer, etc.), repair tools, ground support equipment, and repair material [3], [15], [17].

All expedient repair actions include [3], [16]:

- 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 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 repairs can be divided into systems or parts common for combat vehicles. The possibilities of performing expedient (temporary) repairs in context of the mentioned systems are listed below [3], [16]:

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 replacement of 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;

- a damaged internal thread might be fixed by drilling off and using threaded insets which renew the original winding.

7. Electric cables:
   - a visible local damage might be repaired using insulation with both ends twisted and insulated by an insulation tape or the joint is welded;
   - damages 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.

Most armies have an expedient repair program. Many of the allied tools, materials, and techniques are similar. Special repair kits are available to support crew and maintainers to perform a repair [15]. These kits allow repair in numerous areas such as fuel, hydraulics, cooling, tires, electrical systems, and a hull repair. When possible, BDAR should first be performed by the crew using its repair kit. Maintenance personnel will have access to the same items available to the crew/operator, as well as additional components.

It is critical to maintain hull integrity, especially during fording operations and when faced with a CBRN threat. Epoxies and polymers in the repair kit can be used to ensure hull integrity for small – to medium-sized holes (fig. 5). Other components in the repair kits, such as reinforcement tape and aluminum tape, can assist in patching armor tiles, vehicle fuel tanks, vehicle hulls, and any other metal surface or components on the vehicles. This capability allows military personnel to quickly reduce the effects of CBRN and other contaminants from entering their vehicle within minutes. It is worth mentioning that hull patches do not provide any additional ballistic protection; they are designed to maintain hull integrity only.

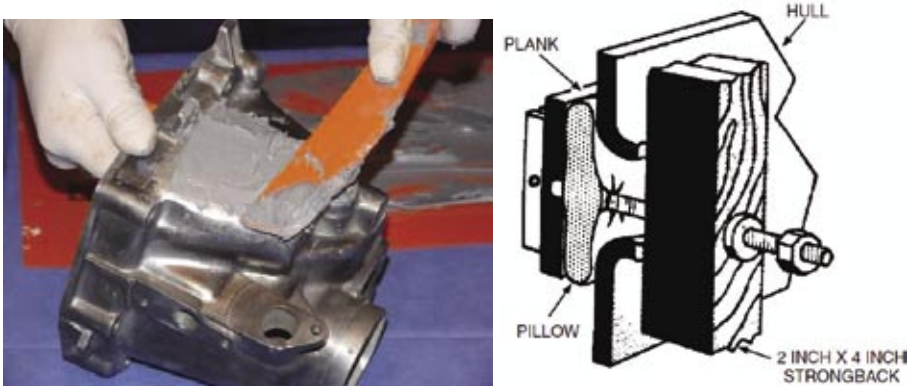

Fig. 5. Exemplary methods of repairing hulls by adhesive composites (left) and installing a folding T patch (right) [3]

Fluid line repairs can be carried out with the use of hose clamps, fast-joints, duct tape, aluminum tape and adhesive composites [17]. Elastomer can be used to repair low-pressure rubber hoses. Fittings needed for fluid line repair enable the maintainer to repair low- to high-pressure lines on most equipment (fig. 6).

Fig. 6. Sample methods of repairing lines by fast-joints (left), clamps (middle) and adhesive composites (right)

Simple electrical repairs can be done with electrical tape, wire-nut connectors, gauge wires, and wire ties (fig. 7). Pliers commonly found in most kits can act as cutters, crimpers, small bolt cutters, and wire strippers. Silicone sealant should be applied to the inside of wire-nut connectors before installing them to seal the connection from moisture and corrosion.

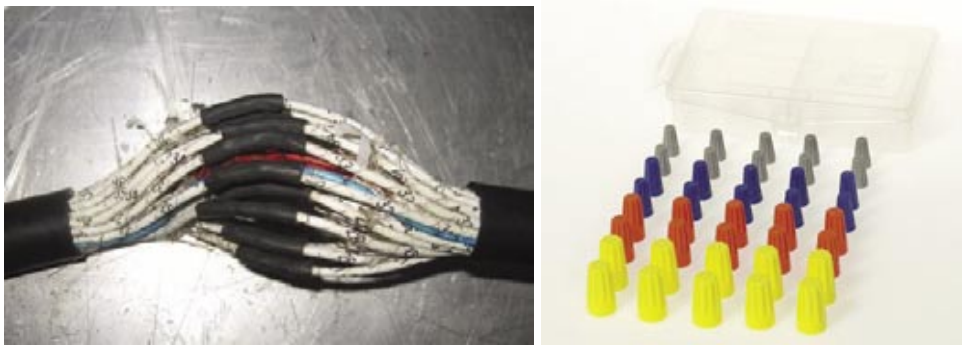

Fig. 7. A sample method of electrical repair with the use of wire-connectors

There are two methods of a tire repair. A fast and efficient tire repair is made with this kit if the hole is due to a nail or similar item causing small gashes. A tire plug kit is used in this case. If a tire damage is caused by a shrapnel, the adhesive composite and reinforcement tape can be used to patch a larger damage. A tire damage larger than 4 inches cannot be patched with this kit. Tire repairs can be made while mounted on the vehicle; however, the tire should not be under air pressure while patching (fig. 8).

Fig. 8. Methods of tire repairs with the use of the special kit (left) and adhesive composites (right)
Source: Own work

Small holes in radiators and cooling systems may be repaired with dedicated sealant to seal pinholes by pouring the sealant into the leaking radiatior. Large holes in radiators, fuel tanks, and oil reservoirs may be repaired using the environmental plugs which slow down leakage until a metal plug or other patching material are applied to the damaged area (fig. 9).

Fig. 9. Methods of small holes repair with a sealant (left) and large holes repair with plugs (middle) and adhesive composite (right)

Radiators are often punctured when vehicles are operating in wooded or combat areas. When this occurs the following procedures may be applied:

- cut the cooling fins and push them away from the leaking tubes;
- cut the leaking tube in half and fold the ends of the tube back;
- close the tube ends by pressing them flat with pliers.

The universal link belt (V-belt) may be used as a replacement for a fan, alternator, air compressor, and other belt-driven engine components (fig. 10).

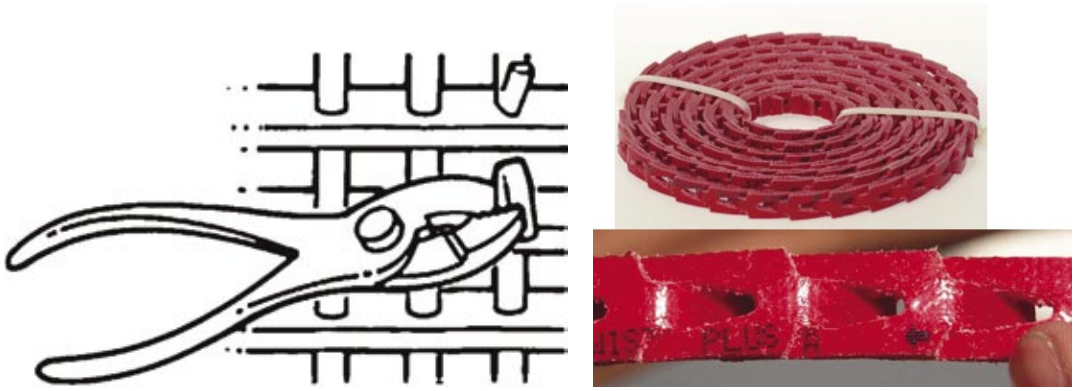

Fig. 10. An expedient repair of punctured radiator (left) and a universal link belt (right) [3]

In the above part of the paper there were presented only chosen technologies and materials that may be used to execute expedient repairs of the damaged weapon systems. Some examples were developed personally and some of them were taken from the U.S. Army and they are included in BDAR Maintainer and Crew Kit and presented in the Field Manual [3]. It is worth adding that repair kits developed by other armies include similar materials and equipment so it is not necessary to describe all of them. The presented materials and capabilities enable quick and efficient repair of common types of damage and random failures that occur under a military operations. It is very important that each soldier is encouraged to take part in permanent modification of maintaining expedient repair kit to fit specific operational needs and the unit's geographical environment.

5. CONCLUSIONS

According to conducted analysis concerning expedient sustaining of weapon systems' availability, following conclusions can be formulated:

1. Weapon systems belong to a group of technical objects used in task (random) mode and they require a specific maintenance system, which should be aimed at executing tasks in a specific place and time regardless of circumstances.
2. Maintenance activities under combat operations will be often limited to basic actions, that is: quick assessment of situation, recovery and evacuation to unit collection point or expedient (temporary) repair under combat operation or cannibalization or destruction of equipment which cannot be evacuated or repaired.
3. The allied armies, especially those numerous ones as the U.S. Army have got advanced expedient repair systems, while smaller armies and those which have recently joined NATO, such as the Norwegian Army are in the process of creating their systems. The individual armies organize expedient repair systems in a somewhat different way (they have various number of repair levels, repair time disposal, different equipment and expedient repair kits), which is caused by the size of Land Forces, specificity of tactics and weapon systems.
4. An effective expedient maintenance system should provide an expeditious means of combat damage assessment for deferment, repair or recovery. Regardless of the way and method of creating an expedient repair system, each of such systems should include: doctrines, procedures and manuals (instructions); training system for maintenance personnel; expedient repair kits, including cutting edge technologies and tools and repair actions recording and archiving systems.
5. The conducted analysis of expedient repair systems in other NATO armies indicates that it is a crucial element of Battlefield Maintenance. Considering its complexity and significance, the system is being permanently improved and developed by a lot of research, analyses and implementations of new concepts and solutions. As a result there is no confirmation for an opinion about higher importance of a standard repair in connection with an expedient repair executed in the area of operation.
6. The analysis of the literature as well as interviews with experts engaged in problems with execution of military equipment repairs directly in the battlefield, allow to draw the conclusion that the efficient functioning of expedient repair systems makes it possible to increase the recovery of damaged equipment by 20 to 40 % depending on a tactical level.

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