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ANALYSIS OF THE PROPERTIES OF MILITARY VEHICLES

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Abstract. With the beginning of military aggression, the arsenal of military vehicles of the Armed Forces of Ukraine was replenished with modern and highly effective models from NATO countries. Current documents on the organization and operation of military vehicles need to determine some of the indicators for the use of vehicles. The indicators used do not allow us to assess the degree of combat effectiveness of vehicles during combat operations. The article analyzes various types (modifications) of the main properties of military vehicles and obtains dependencies to assess their combat capability when performing assigned tasks in the conduct of combat operations. The essence and content of the category of "combat capability of military automotive equipment" are defined and a common understanding of the properties included in this category has been developed. The paper proposes mathematical dependencies to determine the indicators of individual properties of the combat capability of military vehicles, which allows to create a mathematical apparatus for its assessment and forecasting, which makes it possible to build mathematical models of combat (operation) that will correspond to the real processes of armed struggle as much as possible. The objective of the study is to determine the indicators of the main properties of new models of military vehicles. The following theories were used as a research method for assessing the level of combat capability of military vehicles: the reliability of weapons and military vehicles, the effectiveness of the use of military vehicles, the survivability of military vehicles, the technical operation of military vehicles, probabilities and mathematical statistics.

Keywords: military automotive equipment, efficiency of application weapon systems, basic properties and combat capability of automotive equipment.

Introduction

Since the beginning of Russia’s full-scale invasion of Ukraine, the arsenal of the Armed Forces of Ukraine (AFU) has been replenished with modern high-performance models of military vehicles. These means are designed to dramatically increase the effectiveness of the use of weapons systems of military formations of the security and defense sector of Ukraine, reduce the aggressor's capabilities, and force the enemy to be defeated on the battlefield.

Military vehicles are the most popular means of equipment in the army and, thanks to their technical capabilities, ensure the fulfillment of assigned tasks at the tactical and operational levels. The need to provide military units of the Armed Forces of Ukraine with modern automotive equipment is associated with the increase in the tasks assigned to the troops.

With the help of military automotive equipment (MAE), various combat missions are solved:

– effective use of weapons placed on vehicles;

– ensuring fast transportation of personnel;
– delivery of ammunition, petroleum products and other material resources;
– evacuation, towing and repair of military equipment and weapons;
– placement of means of engineering support, communication, electronic warfare, protection and defense of areas;
– conducting reconnaissance;
– medical support and others.

To accomplish these tasks, there is a need to create various modifications of MAE. There is a need to adapt MAE samples to changes on the battlefield. At the same time, it is necessary to ensure the justification of the requirements for MAE in the changed conditions. Current documents on the organization and operation of automotive equipment need to determine some of the indicators of the use of MAE, namely:

– coefficient of technical readiness of machines;
– fleet utilization rate,
– load capacity utilization rate,
– mileage utilization rate, etc.

However, these indicators do not make it possible to assess the degree of combat capability of the automotive equipment of the military unit (subdivision).

Therefore, determining the indicators of the main properties of new MAE models for the Armed Forces of Ukraine (AFU) for further modernization of vehicles in order to meet the needs of military units is an urgent task.

Analysis of the latest research and publications. The scientific basis for research on the assessment of the level of combat capability of are the theories of reliability of weapons and military equipment, effectiveness of the use of MAE, survivability of military equipment, technical operation of combat vehicles, probabilities and mathematical statistics [1-5]. The basic terms and definitions of equipment reliability and reliability forecasting based on the results of testing and operation of equipment are given in the works [1; 2]. The papers [6-11] provide methodological bases for the development of models for assessing the expected effectiveness of performance of service and combat tasks by military units and subdivisions and features of assessing the effectiveness of systems in combat operations using probabilistic models.

The paper [12] analyzes the renewal of the fleet of wheeled vehicles of the armies of NATO member states from 2012 to 2022. The paper [13] substantiates the tactical and technical requirements for the development of promising models of "light" armored vehicles.

However, the results presented in the considered works do not make it possible to assess the combat capability of military vehicles during the performance of assigned tasks in the conduct of hostilities.

The aim of the article is to determine the main properties of MAE for their different types (modifications) and to obtain dependencies for assessing the combat capability of MAE during the performance of assigned tasks in the conduct of combat operations.

Statement of the main material. Multi-purpose wheeled vehicles are the most common type of MAE of the US Army (Table 1) and NATO member states. The main program in the field of improvement of multi-purpose wheeled vehicles of the US Army for the period up to 2025 is the "Army Tactical Wheeled Vehicles (TWV) Strategy" [13;15].

The purpose of this program is to:

– adapt existing MAE models to new changes on the battlefield, as well as reduce the risks of uncertainty that will be caused by new threats;
– to change the structure of the MAE fleet to perform new tasks.

Table 1. Type and number of tactical wheeled vehicles as of the beginning of 2022 in the US Armed Forces

Tactical vehicles of the US Armed Forces			Quantity, units	Total, units
1.	Light Tactical All-Terrain Vehicle LTATV (Light Tactical All-Terrain Vehicle)	Polaris MRZR X	20	2053
		MRZR-4 LTATV and MRZR-2	2033	
2.	Light tactical vehicles-LTV (Light Tactical Vehicle), carrying capacity up to 2 tons	HMMWV with reinforced armor protection (UAH)	50 thousand	119 thousand
		General purpose HMMWV (Utility)	35 thousand	
		HMMWV (obsolete)		
		Joint Light Tactical Vehicle (JLTV)	34 thousand	
3.	Medium tactical vehicles MTV (Medium Tactical Vehicles), carrying capacity 2.5-5 tons	Series: M35; M809; M939	76 thousand	
	Medium tactical vehicles FMTV (Family of Medium Tactical Vehicles), carrying capacity 2.5-5 tons	M1078A1 (4×4)		
		M1083A1 (6×6)		
	MTVR (Oshkosh Defense)	MTVR (6×6)		
4.	Heavy tactical vehicles - HTV (Heavy Tactical Vehicle), carrying capacity over 5 tons	Multifunctional high-mobility heavy tactical trucks NEMTT (Heavy Expanded Mobility Tactical Truck)	34 thousand	
		Transporter of heavy military equipment NET (Heavy Equipment Transporter), a family of cars with a packaged loading system PLS (Palletized Load System)		
		The family of cars of the M915 series		
5.	A family of vehicles with anti-mine protection from a hidden attack - MRAP (Mine-Resistant Ambush Protected)	Modernization of machines developed under the JMVP program (Joint MRAP Vehicle Program)	15 thousand	
The total number of			246053	

In addition to significant investments in the development and production of a new generation of MAE, it is also planned to finance the improvement of the existing JSC fleet in the following areas:

– modernization of the power drive (use of hybrid and electric drives);
– suspension reinforcement aimed at increasing the mobility of vehicles in off-road conditions;
– installation of improved ballistic and mine protection;
– ensuring counteraction to means of electronic warfare;
– development of new materials and technologies that reduce the weight of machines and fuel consumption [13].

Problems in equipping the Armed Forces of Ukraine are caused by the fact that a significant number of samples of the existing fleet of MAE have a long service life, are morally and physically obsolete and need to be modernized or replaced with new models. According to the order of the Cabinet

of Ministers of Ukraine dated 14.06. 2017 No. 398–p "On Approval of the Main Directions of Development of Weapons and Military Equipment for the Long Term" it is required: "To provide military units (subdivisions) with modern models of automotive equipment for various purposes, created on the basis of unified models with a wheel arrangement of 4×4, 6×6, 8×8 with increased mobility characteristics, cross-country ability, autonomy, economy and protection of personnel".

Units and military units are armed with the following types of armored vehicles:

– *the first type* – armored highly maneuverable passenger cars designed for:
– conducting reconnaissance and sabotage raids in areas where the enemy is concentrated;
– covert persecution;
– frontal observation of the battlefield and fire adjustment;
– patrolling sections of the state border and districts;
– withdrawal and evacuation of reconnaissance and sabotage units, as well as rescue operations;
– *the second type* – armored off-road vehicles, made on the chassis of trucks and designed to transport personnel in armored modules (container bodies);
– *the third type* – armored off-road vehicles, designed to place various special equipment (reconnaissance, communication systems and complexes, etc.) on their chassis;
– *the fourth type* is armored off-road vehicles designed to accommodate weapons (guns, mortars, missiles and air defense systems, etc.) on their chassis. The main purpose of the vehicle is fire support for the actions of troops in various combat conditions.
– *the fifth type* is armored and lightly armored heavy wheeled chassis of increased cross-country ability, designed for the installation of weapons systems, towing and transportation of bulky cargo and heavy armored vehicles.
– *the sixth type* – armored off-road vehicles designed for the evacuation of the wounded and sick, providing first aid in various combat conditions.

Military formations of the security and defense sector of Ukraine receive military assistance from the allies. Among the provided samples of foreign MAE, a significant place is occupied by American highly mobile multipurpose wheeled vehicles of the HMMWV type. HMMWVs are versatile vehicles that can perform a variety of tasks in combat conditions.

The military formations of the security and defense sector of Ukraine receive the following modifications of HMMWV vehicles (Table 2).

Table 2. Modifications of HMMWV machines that belong to different types of MAE

Types of armored vehicles	**General view of HMMWV machines**		
1	**2**		
1.			
2.			

followed

1	2		
3.			
4.			
5.			
6.			

These vehicles have different purposes, so they must have different properties that characterize their adaptability to conduct (support) combat operations.

One of the main properties of MAE is their combat capability.

The combat capability of military vehicles is its ability to function with the parameters established by the operational documentation [4; 5]. The combat capability of military equipment is ensured by its reliability and survivability.

Let us consider these properties for different types of MAE.

Reliability of MAE is its ability to maintain the values of all parameters that characterize the ability to perform the required functions in the specified modes and conditions of application, maintenance, repair, storage and transportation in time and established limits.

As one of the possible indicators of the reliability of the MAE, it is possible to use the complex indicators of the reliability of the MAE, i.e. the coefficient of operational readiness of machines. The coefficient of operational readiness of machines is the probability that the machines will be in working condition at any point in time, and, starting from this moment, will work flawlessly for a given period [4]:

$$K_{or(t)} = \frac{T_0}{T_0 + T_{ra}} e^{-\frac{t}{T_0}},$$

where,

T_0 – is the average uptime of machines, hours;

T_{ra} – random recovery time of machines, hours;

t – is the time of use of machines, hours.

The survivability of the bat is a complex property of the bat to maintain the values of combat capability indicators in terms of time (mileage, operating time) (even with a possible decrease in the value of these indicators below the established limits) in certain conditions of the enemy's combat impact (and emergency situations) and to restore them after the end (repair during) of the enemy's combat impact [5].

The survivability of the MAE is ensured by the strength of structures, resistance to the effects of shock waves, high temperatures and penetrating radiation, giving products streamlined, ricocheted shapes, reducing dimensions, applying camouflage painting, duplication of control devices and energy sources, creating a reliable system of biological protection of the crew (service) and facilitating the restoration of equipment.

The main components of the survivability of MAE: – secrecy of movement; – mobility; – maneuverability; – security; – cross-country ability, – autonomy.

Stealth is a property in which it is possible to keep secret from the enemy data the location, task, and combat capabilities of the MAE, etc. Indicators of secrecy characterize the adaptability of military equipment to conceal its deployment (probability of detection, average detection time, level of unmasking radiation, etc.).

The probability of detecting an object RB is calculated by the formula [11,13]:

$$R_i = R_{i.o.} + R_{i.s.} - R_{i.o.} \cdot R_{i.s.},$$

where,

$R_{i.o.}$ – is the probability of detecting the object without taking into account the shadow of the object;

$R_{i.s.}$ – is the probability of detecting the shadow of the object.

Mobility is a property that characterizes the ability of a MAE to move quickly, deploy in the area of combat use and move during combat operations. Quantitative indicators of MAE's mobility are:

– average speed of movement *Vser*.,
– the time of deployment of the MAE, t_{dep}.,
– the time of removal from the position and the readiness to move the $t_{tak.pos.}$.

The average speed of movement on the section of the path $V_{ser.}$ is the ratio of the length S of this section to the time interval t in which this section is traversed by the machine:

$$V_{ser.} = \frac{S}{t},$$

Autonomy is the property of MAE to function without the help of auxiliary external systems (energy sources, controls, support, etc.).

New vehicles under development for a long time during operation must be in the field at a considerable distance from the point of permanent deployment (being in areas of concentration, combat use). A quantitative indicator of autonomy is the term of autonomy – a certain time during which the MAE can perform a combat mission at the expense of its own resources without replenishing consumables (fuel and lubricants, coolant, water, etc.).

One of the quantitative indicators of MAE's mobility is the power reserve coefficient

$$C_{p.r.} = \frac{P_{ri}}{P_{rmax}},$$

where,

P_{ri} – is the current indicator of the power reserve of the i–th vehicle, km; P_{rmax} – is the maximum possible indicator of the vehicle's power reserve, km.

Maneuverability is the ability of the JSC to quickly change the speed and direction of movement on the ground, depending on the complexity of the situation. The manoeuvrability of wheeled vehicles depends on the turning radius and lane width, speed range, engine power, and controllability.

One of the quantitative indicators of the maneuverability of the MAE is the agility coefficient (the agility of the car is characterized by the turning radius, that is, the distance from the instantaneous center of turn to the longitudinal axis of the K_t car:

$$K_t = \frac{R_{ti}}{R_{tmax}},$$

where R_{ti} – is the turning radius of the i-th machine, m;

R_{tmax} – is the maximum possible turning radius of the machine, m.

Security is a property of resistance to external influences which characterizes the ability of JSC to maintain combat capability under natural and combat influences. A quantitative indicator of security is the probability of not hitting the vehicle.

The probability of not hitting the vehicle is determined by the expression:

$$P_{n.def.} = 1 - P_{def.}, \quad (1)$$

(a) When small arms are used, the following may be used:

– the probability of hitting the target with one Ruhr shot $P_{def.}$:

$$P_{def.} = p' \cdot G, \quad (2)$$

where,

p' – is the probability of hitting the target with one shot;

G – is the probability of hitting the target with one hit.

Given a known average number of hits required k:

$$P_{def.} = \frac{p'}{k}, \quad (3)$$

– probability of hitting the target with n independent Ruhr shots:

$$P_{def.} = 1 - \prod_{i=1}^{n}(1 - p_i), \quad (4)$$

where,

p_i – is the probability of hitting the target with the i-th shot.

– the probability of hitting the target with dependent Ruhr shots $P_{def.}$:

$$P_{def.} = p + (P_n - p)\sqrt{1 - r^2}, \quad (5)$$

where,

P, P_n – are the probabilities of defeat with one and n independent shots;

r – is the correlation coefficient of shots.

(b) For ground artillery, the probability of hitting an elemental target not observed by the $P_{def.}$:

$$P_{def.} = \hat{\Phi}\left(\frac{l_x}{E_{X_E}}\right) \cdot \hat{\Phi}\left(\frac{l_Y}{E_{Y_E}}\right), \quad (6)$$

where,

l_x, l_Y are the dimensions of the target in terms of range and direction;

E_{X_E}, E_{Y_E} – median errors of the shot in range and direction.

Dynamism is the property of a car to move at the highest possible average speed, which is characterized by the maximum speed, the intensity of acceleration to a given speed and the intensity of braking.

One of the quantitative indicators of the dynamism of the MAE is the coefficient of the dynamism of the movement K_d:

$$K_d = \frac{V_{p.i}}{V_{p.max}},$$

where,

$V_{p.i}$ – is the maximum speed of the first vehicle, km/h;

$V_{p.max}$ – is the maximum possible speed for cars of this type, km/h.

Cross-country ability of a car is the ability of a car to move on low-quality roads and outside the road network, as well as to overcome artificial and natural obstacles without the use of aids.

The cross-country ability of the car depends on many factors, the main of which are the traction properties and geometric parameters of the car.

One of the quantitative indicators of the cross-country ability of JSC is the coefficient of ground clearance of the car $K_{g.c.}$

$$K_{g.c.} = \frac{h_{g.c.i}}{h_{g.c.max}},$$

where,

$h_{g.c.i}$ – is the current ground clearance of the i-th car, cm;

$h_{g.c.max}$ – is the maximum possible ground clearance of the machine, cm.

Vehicle stability is the ability of a vehicle to maintain movement along a given trajectory, counteracting the forces that cause it to drift and overturn in various road conditions at high speeds and maintain combat capability under combat impacts.

One of the quantitative indicators of the stability of BAT is the stability coefficient $K_{dur.}$:

$$K_{dur.} = \frac{P_i}{P_{max}},$$

where,

P_i – is the overpressure of the shock wave of the explosion on the body of the i-th machine, Pa;

P_{max} – is the maximum possible overpressure of the shock wave of the explosion on the body of a machine of this type, Pa.

Vehicle handling is the ability of the car to move in the direction set by the driver. One of the characteristics is the property of the car to change direction when the steering wheel is stationary.

It is evaluated according to the following criteria: critical speed, ratio of steering angles, stabilization of steered wheels, angular oscillations.

One of the quantitative indicators of the controllability of the MAE is the controllability coefficient of the machine $K_{con.}$:

$$K_{con.} = \frac{V_{crit.i}}{V_{crit.max}},$$

where,

$V_{crit.i}$ – is the critical speed of the first vehicle, km/h;

$V_{crit.max}$ – is the maximum possible critical speed for vehicles of this type, km/h.

With the help of the method of expert analysis for armored wheeled vehicles (AWV) of different types, the weight coefficients of individual properties were determined. To substantiate the weighting coefficients of individual properties of different types of AWV, the provisions of the method of expert assessments were used. To determine the weighting coefficients of individual properties of different types AWV involved leading specialists of research centers, teachers, and practitioners on the problems

of assessing the level of technical perfection of MAE samples. The value of the concordance coefficient depending on the property was in the range of (0.8-0.9), which indicates a sufficient level of consistency of the results [13].

The value of the location of individual properties for AWV of different types is given in table 3.

Table 3. The importance of individual properties for different types of AWV

№	Properties	Machine Groups					
		Combat Vehicles	Reconnaissance vehicles	Angle grinder	Transport Vehicles	Machines with special equipment	Ambulances
1.	Reliability	1	1	1	1	1	1
2.	Security	2	4	3	4	2	3
3.	Dynamism	3	5	4	2	8	5
4.	Agility	4	6	5	6	6	6
5.	Cross-country ability	5	3	6	3	5	2
6.	Concealment	6	2	2	9	4	10
7.	Resistance	7	7	7	5	7	7
8.	Battery life	8	8	8	10	3	9
9.	Handling	9	9	9	7	9	8
10.	Fluency	10	10	10	8	10	4

Conclusions

1. The main properties of JSC for their different types are determined and dependencies for assessing the combat capability of JSC during the performance of assigned tasks in the conduct of combat operations are obtained.

2. The essence and content of the category "combat capability of MAE" are defined, a common understanding of the properties that are included in the category of "combat capability of MAE" is developed, which meets the interests of both the further development of military science and the solution of practical problems facing the troops.

3. Mathematical dependencies are proposed to determine the indicators of individual properties of the combat capability of MAE, which allows to create a mathematical apparatus for its assessment and forecasting. This, in turn, makes it possible to build mathematical models of combat (operations) that will correspond as much as possible to the real processes of armed struggle, which will be a promising direction for further research.

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Xülasə
Hərbi avtomobillərin xüsusiyyətlərinin təhlili
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Hərbi təcavüzün başlaması ilə Ukrayna Silahlı Qüvvələrinin hərbi avtomobil texnikasının (HAT) arsenalı NATO ölkələrinin müasir, yüksək effektiv modelləri ilə tamamlandı ki, bu da düşməni döyüş meydanında məğlubiyyətə uğratmaqla ordunun silah sistemlərindən istifadəsi effektivliyini kəskin şəkildə artırdı. Avtomobil texnikasının təşkili və istismarı üzrə mövcud sənədlər HAT-nin istifadəsi üçün bəzi göstəriciləri müəyyən etməlidir. Hazırda istifadə olunan göstəricilər döyüş əməliyyatları zamanı avtomobil texnikasının döyüş effektivliyinin dərəcəsini qiymətləndirməyə imkan vermir. Məqalədə hərbi nəqliyyat vasitələrinin əsas xassələrinin müxtəlif növləri təhlil edilir və onların döyüş effektivliyini qiymətləndirmək üçün riyazi asılılıqlar əldə olunur. “Hərbi nəqliyyat vasitələrinin döyüş qabiliyyəti” kateqoriyasının mahiyyəti və məzmunu müəyyənləşdirilir, bu kateqoriyaya daxil olan xassələrin vahid anlayışı hazırlanır. Məqalədə hərbi maşınların döyüş qabiliyyətinin fərdi xüsusiyyətlərinin göstəricilərini müəyyən etmək üçün riyazi asılılıqları təklif edilmişdir ki, bu da onun qiymətləndirilməsi və proqnozlaşdırılması üçün riyazi aparat yaratmağa, eləcə də döyüşün (əməliyyatların) riyazi modellərini qurmağa imkan verir. Tədqiqatın məqsədi hərbi hissələrin ehtiyaclarını ödəmək üçün Ukrayna Silahlı Qüvvələri üçün NATO ölkələrinin hərbi avtomobil texnikasının yeni modellərinin əsas xüsusiyyətlərinin göstəricilərini müəyyən etməkdir. Məqalənin məqsədi müxtəlif növlər

(modifikasiyalar) üçün hərbi texnikanın əsas xassələrini müəyyən etmək və döyüş şəraitində nəzərdə tutulmuş tapşırıqları yerinə yetirərkən hərbi texnikanın döyüş effektivliyinin qiymətləndirilməsi üçün riyazi asılılıqları əldə etməkdir. Hərbi maşınların döyüş qabiliyyətinin səviyyəsini qiymətləndirmək üçün tədqiqat metodu kimi aşağıdakı metod və nəzəriyyələrdən istifadə edilmişdir: silah və hərbi texnikanın etibarlılığı, hərbi texnikadan istifadənin effektivliyi, hərbi texnikanın dayanıqlılığı, hərbi maşınların texniki istismarı, ehtimallar və riyazi statistika.

Açar sözlər: hərbi avtomobil texnikası, silah sistemlərindən istifadənin effektivliyi; avtomobil texnikasının əsas xassələri və döyüş effektivliyi

Аннотация
Анализ свойств военной автомобильной техники
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С началом военной агрессии арсенал военной автомобильной техники (ВАТ) Вооруженных Сил Украины (ВСУ) пополнился современными высокоэффективными образцами стран НАТО, которые резко повысили эффективность применения систем вооружения военных формирований, заставив противника потерпеть поражение на поле боя. Действующие документы по организации и эксплуатации автомобильной техники нуждаются в определении некоторых из показателей применения ВАТ. Используемые показатели не позволяют оценить степень боеспособности автомобильной техники при ведении боевых действий. В статье проведен анализ различных типов (модификаций) основных свойств военной автомобильной техники и получены зависимости для оценки их боеспособности. Определены сущность и содержание категории «боевая способность военной автомобильной техники», разработано единое понимание свойств, входящих в эту категорию. В работе предложены математические зависимости для определения показателей отдельных свойств боевой способности военной автомобильной техники, позволяющей создать математический аппарат ее оценки и прогнозирования, позволяющий строить математические модели боя (операции), которые будут максимально соответствовать реальным процессам вооруженной борьбы, что является перспективным направлением дальнейших исследований. Задачей исследования является определение показателей основных свойств новых для ВСУ образцов ВАТ стран НАТО в целях обеспечения потребностей воинских подразделений. Целью статьи есть определение основных свойств ВАТ для различных типов (модификаций) и получение зависимости для оценки боеспособности ВАТ при выполнении задач по назначению в условиях ведения боевых действий. Методом исследований оценки уровня боеспособности военной автомобильной техники использованы теории: надежности вооружения и военной техники, эффективности применения ВАТ, живучести боевой техники, технической эксплуатации боевых машин, вероятностей и математическая статистика.

Ключевые слова: военная автомобильная техника, эффективность применения систем вооружения; основные свойства и боеспособность автомобильной техники

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