Applied problems of information systems operation

UDC 623.942.2:623.592 **doi:** https://doi.org/10.20998/2522-9052.2021.2.21

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ANALYSIS OF THE POSSIBILITY OF USING BATTERIES OF THE LATEST TECHNOLOGIES ON SAMPLES OF ARMORED WEAPONS AND MILITARY EQUIPMENT

Abstract. The **subject matter** of the article is mass and dimensional characteristics of batteries, their design, electrical, operational parameters and energy capabilities. The **goal** of the study is the possibility of using maintenance-free batteries on samples of armored weapons and military equipment. **The tasks** to be solved are: to analyze the existing technologies for the batteries production, their advantages and disadvantages given the peculiarities of the operation of military equipment and the main technical characteristics of the batteries; by statistical data processing to investigate the dependences of "starter" discharge modes and energy capabilities of the batteries manufactured by technologies of different generations; to investigate the possibilities of constructive implementation of power supply formation taking into account possible design changes in the engine starting system, ensuring the necessary charge stability and compensation for exceeding the cost of gel and Absorbed in Glass Mat (AGM) batteries in comparison with the cost of the type 12ST85 ones. General scientific and special **methods** of scientific knowledge are used. The following **results** were obtained: The existing technologies of battery production, their advantages and disadvantages have been analyzed taking into account the peculiarities of the operation of military equipment and the main technical characteristics of batteries. The dependences of the "starter" discharge modes and the energy capabilities of batteries made by different technologies generations have been studied. Possibilities of constructive realization of power supply formation taking into account available constructive changes in the engine electric start system, providing the necessary charge stability and compensation for excess cost of gel and AGM batteries compared to the cost of batteries type 12ST85 have been investigated. **Conclusions.** Using at the samples of armored vehicles and military equipment batteries made by modern technology does not require fundamental structural changes in the electrical equipment of the machine. To meet the requirements of the standards for voltage parameters in the on-board armored weapons and military equipment networks, it is necessary to install an appropriate voltage relay regulator. The issue of exceeding the cost of gel and AGM batteries compared to the cost of type 12CT-85 ones can be compensated by the absence of costs for operating materials, maintenance personnel as well as the long service life of gel or AGM batteries compared to conventional lead-acid ones.

Keywords: lead-acid batteries; gel batteries; AGM batteries, electrical equipment for armored vehicles and military equipment.

Introduction

Formulation of the problem and research tasks. At present, the 12CT-85P and 6STEN-140M types lead-acid starter batteries of are mainly used as power sources in the native military wheeled and tracked vehicles. In the technology terms such batteries belong to the so-called maintenance-free class. The advent in modern industries the latest technologies can significantly improve the batteries resource and empower their applications. Lead-acid, gel and AGM batteries as the most suitable types of batteries for use as starters in military tracked and wheeled vehicles have their advantages and disadvantages. Of course, the change in the material resource costs ideology, approximation to world industry standards and NATO standards, in particular, require research into the possibility of using the latest production technologies. In order to justify recommendations for the inserting the batteries in the prospective and existing armored weapons and military equipment (AMWE) samples it is necessary not only to analyze the AMWE specific use but of operation features, mass and dimensions of the batteries, but also to study their design, electrical, operational parameters and energy capabilities.

In addition, it needs to be taken into account economic assessment of the prospects for replacing existing batteries with maintenance-free ones, the cost of operating materials, personnel maintenance of the batteries, etc.

The above indicates the **relevance** of the study of the prospects for the use of battery of the latest production technologies in military and wheeled vehicles.

Analysis of recent research and publications. The structure, the principle of operation of lead-acid battery are described by experts in a very meaningful way, because the first workable lead-acid batteries for use in engineering were invented in the XIX century [1, 2]. Recommendations for operation, maintenance and control of batteries are also, of course, very carefully worked out, as starter lead-acid batteries were used on AMWE samples in the Soviet Army [3, 4]. Given the unconditional thoroughness of the generalization of military experience, the provisions on the modes of bringing batteries into working condition, the volume and frequency of battery maintenance, the order of their storage outside the machine and in the machine today are obsolete and economically suboptimal.

The **goal** of the study is study the possibility of using maintenance-free batteries on samples of armored weapons and military equipment.

This goal defined the following research **tasks**:

– to analyze the existing technologies for the batteries production, their advantages and disadvantages given the peculiarities of the operation of military equipment and the main technical characteristics of the batteries;

– by statistical data processing to investigate the dependences of “starter” discharge modes and energy capabilities of the batteries manufactured by technologies of different generations;

– to investigate the possibilities of constructive implementation of power supply formation taking into account possible design changes in the engine starting system, ensuring the necessary charge stability and compensation for exceeding the cost of gel and Absorbed in Glass Mat (AGM) batteries in comparison with the cost of the type 12ST85 ones.

General scientific and special **methods** of scientific knowledge are used.

Main material

1. The existing technologies for the batteries production, their advantages and disadvantages given the peculiarities of the operation of military equipment and the main technical characteristics of the batteries. According to their functional purpose, lead-acid batteries is divided into four main groups; starter, stationary, traction and portable.

As a source of electrical energy in AMWE samples, it is the starter batteries that are used to start internal combustion engines and power supply of machine devices. In its development, lead-acid starter batteries have gone through the following stages.

The first generation of batteries can be classified as open or closed type batteries with liquid electrolyte, with a capacity of 36 to 5328 Ah and a service life of 10 to 20 years or more. Open-type batteries have no caps and the electrolyte is in direct contact with open air. Closed-type batteries have special plugs that ensure the retention of sulfuric acid aerosols. The plugs for filling electrolyte and adding water are unscrewed during operation. Closed type batteries can be maintained and maintenance-free. In the latter case, batteries from the manufacturer are supplied filled and charged, and during the service life there is no need to fill the system, since the design of the plugs of such batteries ensures that its vapors are contained in the form of condensate.

Maintained batteries are the cheapest energy storage. But at the same time, they not only require daily monitoring of operation, but also have a short service life caused by cracking, depressurization, and oxidation of battery cells. For batteries with filled electrolyte, in order to prolong the battery's performance, it is recommended to carry out a control-training cycle: first, discharge it with a current equal to 0,1 capacity, with an electrolyte density corresponding to the area of operation, and then charge it in the usual way, after which it can be operated.

Advantages of Lead Acid Starter Batteries:

– low cost and production simplicity (at the cost of 1 W•h of energy, these batteries are the cheapest);

– proven, reliable and well-understood service technology;

– permissible high discharge currents.

At the same time, lead-acid batteries have the following disadvantages:

– low energy density and, as a consequence, high weight of storage batteries;

– the smallest number of charge-discharge cycles in comparison with other types of batteries (on average 250 cycles);

– acidic electrolyte and lead have a harmful effect on the environment, hazardous to service personnel;

– overheating is possible with an incorrect charge;

– they cannot be stored in a discharged state, since a full discharge causes the formation of sulfates and such a loss of capacity after which are not restored;

– they are sensitive to deep discharges so a deep discharge causes an additional voltage similar to the voltage of a mechanical device. In fact, each discharge / charge cycle takes a small amount of capacity from the battery. This loss is very small in the good battery condition, but becomes more noticeable as soon as the capacity drops below 80% of the nominal;

– hydrogen is evolved;

– at temperatures above 30°C the formation of sulfate occurs in a geometric progression;

– at low temperatures, the batteries capacity decreases;

– limited shelf life of a battery with electrolyte is 1,5 years at a temperature not exceeding 0°C and 9 months at a temperature above 20°C to prevent irreversible processes;

– slow charge reception (normal time is from 8 to 16 hours) in comparison with other types of accumulators.

– high self-discharge is up to 1-2% per day, which leads to the formation of sulfate, during operation, this figure increases;

– energy losses for heat generation during charging are up to 15-20%;

– the need to conduct in-station control charge-discharge cycles at least once every six months;

– the need to check and replenish the electrolyte level in connection with its boiling during operation;

– battery life is limited to 5 years, subject to maximum compliance with the rules of operation.

Thus, lead-acid batteries are usually used when a large capacity is required, the weight requirements are not critical and the cost of the battery is low.

It should be noted that these characteristics of the batteries led to their widespread use on AMWE samples inherited from the Soviet Army.

Low-maintenance battery is the best choice in terms of cost and quality. It possesses rather high performance characteristics, has access for filling the electrolyte and from time to time requires monitoring the electrolyte level. A sealed serviced battery is the most expensive battery. It has no holes for filling the electrolyte and requires a relatively stable charging voltage [5].

The so-called sealed gel batteries, in which instead of a liquid electrolyte, a gel is used, which is a jelly obtained by mixing a solution of sulfuric acid with a thickener (usually it is silicon dioxide SiO_2 or silica gel). The gel electrolyte allows to achieve full tightness of the battery as all gas release occurs inside strongly developed system of pores in weight of gel. The technology for the production of gel batteries is called GEL.

During drying, microcracks are formed in the gel structure prevent the evaporation of the electrolyte: oxygen and hydrogen molecules are retained inside the gel, react with each other and turn into water, which is absorbed by the gel. Almost all evaporation is thus returned to the battery and this process is called gas recombination. However, all the molecules cannot be recombined and the excess gas is discharged through the safety valves. This usually occurs at high charge currents. Microporous dyuroplastic is used as a separator in gel batteries. Due to aluminum additives, it has high resistance in aggressive environments, reduces the internal resistance in the battery, has high temperature stability and mechanical strength, which also provides high vibration resistance and impact resistance of the structure.

The authors highlight the following as the advantages of gel batteries:

– small energy losses for heat generation during charging (10-16%);

– they do not require maintenance during the entire period of operation;

– sealed case allows you to install batteries in the most convenient place from the point of view of designers - near the center of gravity;

– there is no hydrogen evolution;

– small self-discharge (up to 1-3% per month);

– non-critical sensitivity to deep short-term discharge (gel electrolyte is in a “bound” state, battery discharge is not accompanied by its evaporation, lattice corrosion and shift of the active mass of the positive electrode);

– withstand about 1000 charge-discharge cycles and, accordingly, a long service batteries life is about 10-12 years;

– batteries can be in a discharged state for a long time.

Disadvantages of gel batteries are the following:

– to prevent abundant gas evolution during recharging, it is necessary to use chargers that provide instability of the charge voltage not worse than ± 1%;

– it is critical to ambient temperature: operating temperature from -40° to + 45°C (temperature over 45 ° C significantly reduces battery resource);

– the cost is 2-3 times higher than conventional lead-acid ones.

Further improvements in the design of gel lead-acid batteries are sealed batteries with electrolyte absorbed by separators - third generation batteries. They are often called batteries assembled by AGM technology (AGM – Absorbed in Glass Mat), i.e. a technology in which the electrolyte is absorbed in fiberglass separators placed between the electrodes. Such a separator is a porous system in which capillary forces hold the electrolyte. The amount of electrolyte is dosed so that the small pores are filled and the large ones remain free for the free circulation of the released gases. In terms of their properties, AGM batteries are similar to gel batteries, except that they have significantly less gas formation, and the ambient temperature has less impact on their operation. The most widespread were the following brands: Tudor, Marathon, Sprinter, Absolyte, Stark, Hawker, Deka, EXtreme. Monbat Gem (Fig. 1).

Fig. 1. AB Monbat Gem 670 901 105 (170 Ah)

As advantages of AB: AGM-technologies one can named the following:

– energy losses for heat generation during charging - about 4%;

– during all term of operation do not demand service, are not critical to temperature decrease;

– hermetic case;

– no hydrogen evolution;

– self-discharge 1-3% per month;

– low internal resistance, when charging the battery is almost not heated.

Since AGM battery is a kind of GEL, they have the same disadvantages. Comparison of the main technical characteristics of batteries 12CT-85, EXTREME 670901105 and EXTREME E89AF0_1 type are shown in table 1 [6, 7].

2. Investigation the dependences of “starter” discharge modes and energy capabilities of the batteries manufactured by technologies of different generations.

Justification of the use of the latest batteries on AMWE samples is proposed on the basis of a study of their design, electrical, operational parameters and energy capabilities.

By statistical data processing in the MATLAB environment, graphs of dependence of “starter” modes of discharge 12CT-85P batteries and AGM AB EXTREME 670901105 ones were obtained; and 6CT-140 AZ (3) EXTREME E89AF0_1 (low maintenance). The results of the study are presented in Fig. 2.

The measurement results correspond to the discharge mode of a 12CT-85P battery with a current of approximately 400 A at a temperature of 25°C. Batteries manufactured using the latest technologies were studied with a “starter” current of 500A at a temperature of 25°C (Fig. 3).

Table 1 – **The main technical characteristics of the batteries 12CT-85, EXTREME 670901105 and EXTREME E89AF0_1 types**

Parameter	Battery		
	12CT-85	EXTREME 670901105	EXTREME E89AF0_1
Rated voltage, V	24	12	12
Nominal capacity, Ah	85	170	140
Weight with electrolyte, kg no more	70	70	70
Length, mm, no more	586	513	513
Width, mm no more	243	223	189
Height, mm no more	240	223	220
Volume, m^3 no more	0,034	0,025	0,021
Cost, $ USD	590	720	140

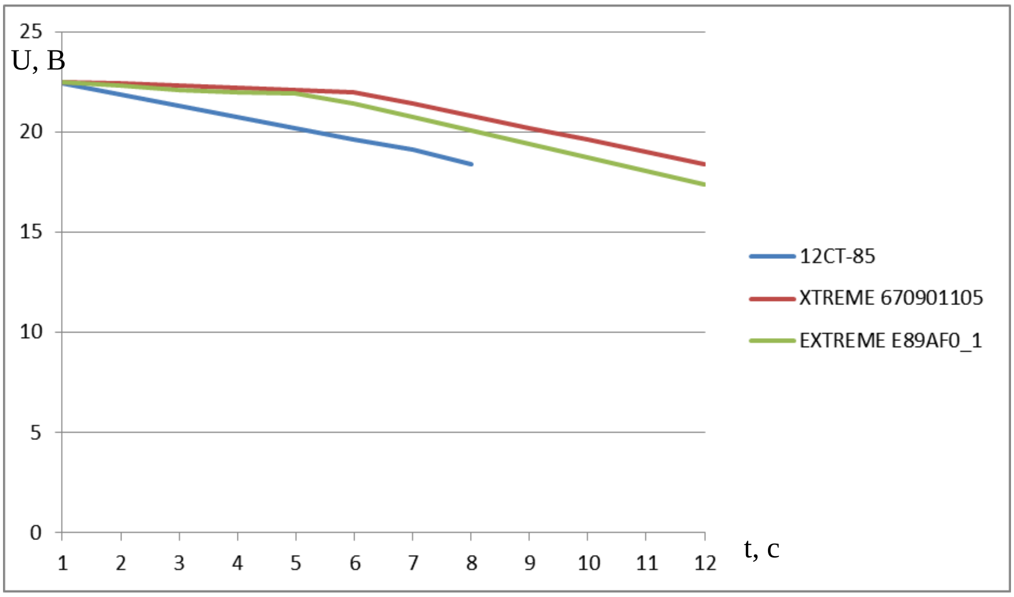

Fig. 2. Starter modes of battery discharge for 12CT-85P AGM EXTREME 670901105;
and 6CT-140 AZ (3) EXTREME E89AF0_1 types batteries

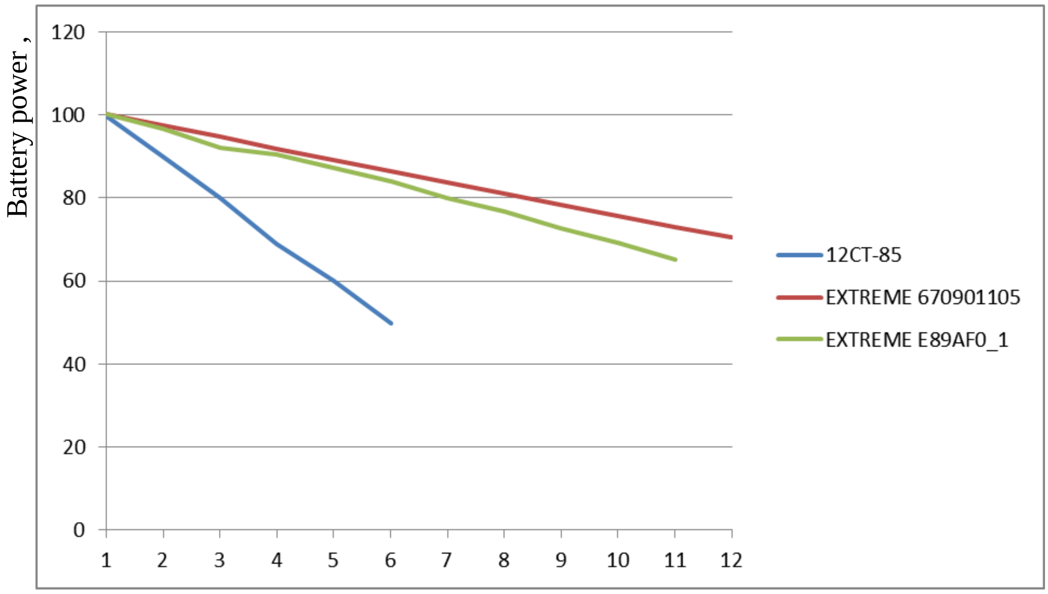

Fig. 3. Self-discharge 12CST-85P AGM EXTREME 670901105;
and 6CT-140 AZ (3) EXTREME E89AF0_ 1 types batteries at a temperature of 25 ° C

Thus, according to research, it can be concluded that AGM-batteries have a lower internal resistance compared to other types of batteries, capable of emitting higher currents in a short time.

Investigation of the various types batteries' energy capabilities of made it possible to draw a conclusion about the advantages of gel and AGM batteries over lead-acid batteries while maintaining the same level of mass and dimensional characteristics (Fig. 4).

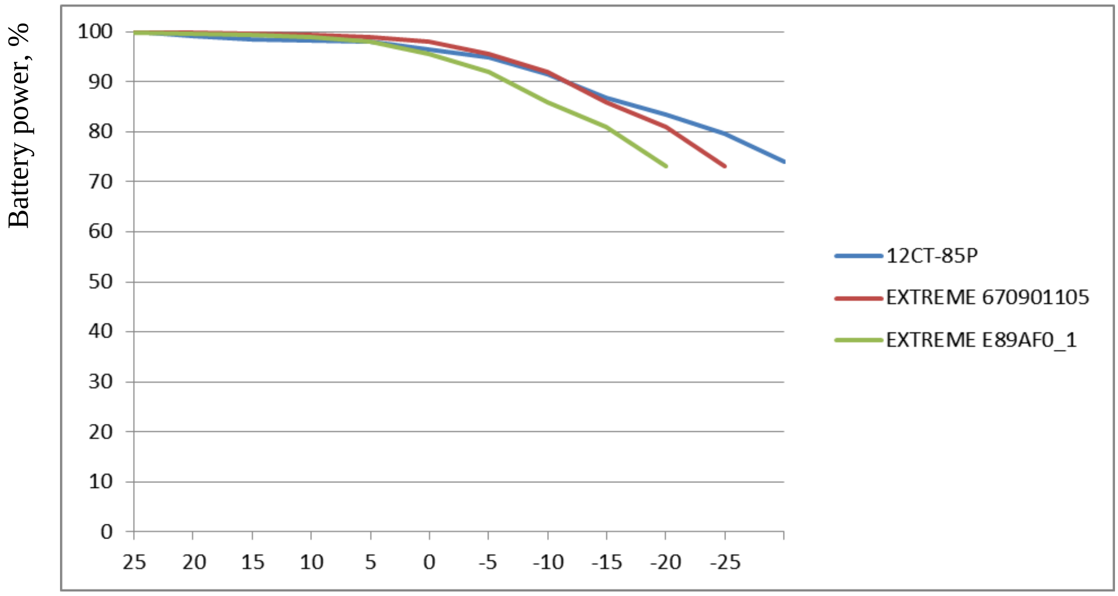

Fig. 4. The value of the power delivered by the batteries of different technologies depending on the temperature

As it is known, 4 batteries are installed in the tank. They are combined into 2 groups, which are connected in series-parallel. The battery groups are connected to the tank on-board network (BN) through the starter-generator relay (RSG) in parallel. To power the starter-generator (SG) when starting the engine, the RSG switches the batteries to a serial connection (48V) [8]. For a power source formed from 4 12CT-85 type batteries, the following ratios will be correct:

$$U_{gr}^{12CT} = U_1 = U_2 = 24V\ ; \qquad (1)$$

$$U_{SG}^{12CT} = U_{гр1}^{12CT} + U_{гgr2}^{12CT} = \\ = 24V + 24V = 48V; \qquad (2)$$

$$U_{BN}^{12CT} = U_{gr1}^{12CT} = U_{gr2}^{12CT} = 24V = 48V\ ; \qquad (3)$$

$$C_{gr}^{12CT} = C_1^{12CT} + C_2^{12CT} = \\ = 85A \cdot h + 85A \cdot h = 170A \cdot h; \qquad (4)$$

$$C^{12CT} = C_{gr1}^{12CT} + C_{gr2}^{12CT} = \\ = 170A \cdot h + 170A \cdot h = 340A \cdot h. \qquad (5)$$

That is, to form a power source in the tank, it is advisable to use 4 AGM batteries, so that a series connection of two AGM- batteries s in a group will provide 24 V. Such batteries connection will provide 24V and 48V supply to the BM when starting the SG, respectively.

$$U_{gr}^{AGM} = U_1^{AGM} + U_2^{AGM} = \\ = 12V + 12V = 24V; \qquad (6)$$

$$U_{SG}^{AGM} = U_{gr1}^{AGM} + U_{gr2}^{AGM} = \qquad (7)$$

$$= 24V + 24V = 48V\ ;$$

$$U_{BN}^{AGM} = U_{gr1}^{AGM} = U_{gr2}^{AGM} = 24V \text{............}(8)$$

In this case, the capacity issued by the AB group will be

$$C^{AGM} = C_1^{AGM} = C_2^{AGM} = 170A \cdot h\ ; \qquad (9)$$

$$C^{AGM} = C_{gr1}^{AGM} + C_{гgr2}^{AGM} = \\ = 170A \cdot h + 170A \cdot h = 340A \cdot h. \qquad (10)$$

It follows from relations (1) - (10) that the use of AGM-batteries to form a power source in a tank does not require structural changes in the engine electric starting system and provides the required values of electrical parameters while generally maintaining the same level of mass and dimensional characteristics (Fig. 5).

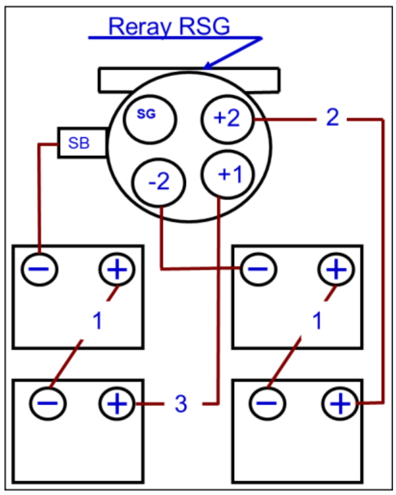

Fig. 5. Formation of the tank power supply using AGM-batteries

Note that when using AGM-AB type 6CT-140 AZ (3) EXTREME E89AF0_1 under similar conditions, the total capacity of the power supply will be

$$C^{AGM} = 280A \cdot h\ . \qquad (11)$$

Of course, this value is less than similar (10), but can also be taken into account in certain circumstances. Similar conclusions can be drawn for the formation of the power supply on other AMWE samples.

Thus, when using two AGM-batteries type EXTREME 670901105, the total capacity of the power supply for the BMP-2 will be:

$$C^{AGM} = C_1^{AGM} = C_2^{AGM} = 170 A \cdot h . \quad (12)$$

Similarly, the voltage that will be generated by the formed power supply in the BN is:

$$U^{AGM} = U_{gr1}^{AGM} + U_{gr2}^{AGM} = 12V + 12V = 24V . \quad (13)$$

Conclusions

1. Using at the samples of armored vehicles and military equipment batteries made by modern technology does not require fundamental structural changes in the electrical equipment of the machine.

At the same time, the fact that the latest technologies batteries occupy a smaller volume and have side terminals will require revision of the places of their installation in the car, namely, baskets and jumpers.

2. To meet the requirements of the standards for voltage parameters in the AMWE on-board network it is necessary to install an appropriate voltage relay regulator.

3. The issue of exceeding the cost of gel and AGM batteries compared to the cost of type 12CT-85 ones can be compensated by the absence of costs for operating materials, maintenance personnel as well as the long service life of gel or AGM batteries compared to conventional lead-acid ones.

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Received (Надійшла) 23.02.2021
Accepted for publication (Прийнята до друку) 21.04.2021

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Аналіз можливості використання акумуляторних батарей новітніх технологій на зразках бронетанкового озброєння та військової техніки

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Анотація. Предметом вивчення в статті є масо-габаритні характеристики акумуляторних батарей, їх конструктивні, електричні, експлуатаційних параметрів та енергетичні можливості. **Метою дослідження є** можливості використання акумуляторних батарей, що не обслуговуються, на зразках бронетанкового озброєння та військової техніки. **Завдання дослідження:** Проаналізувати існуючи технології виробництва акумуляторних батарей, їх переваги та недоліки з огляду на особливості експлуатації військової техніки та основні технічні характеристики акумуляторних батарей. Шляхом статистичної обробки даних дослідити залежності “стартерних” режимів розряду та енергетичних можливостей акумуляторних батарей, виготовлених за технологіями різних поколінь. Дослідити можливості конструктивної реалізації формування джерела живлення з урахуванням можливих конструктивних змін у системі електропуску двигуна, забезпечення необхідної стабільності заряду та компенсації перевищення вартості гелевих та AGM- акумуляторних батарей в порівнянні з вартістю акумуляторних батарей типу 12СТ85. Методологічною основою дослідження стали загальнонаукові та спеціальні **методи** наукового пізнання. **Отримані наступні результати:** Проаналізовані існуючи технології виробництва акумуляторних батарей, їх переваги та недоліки з огляду на особливості експлуатації військової техніки та основні технічні характеристики батарей. Досліджені залежності “стартерних” режимів розряду та енергетичних можливостей акумуляторних батарей, виготовлених за технологіями різних поколінь. Досліджені можливості конструктивної реалізації формування джерела живлення з урахуванням можливих конструктивних змін у системі електропуску двигуна, забезпечення необхідної стабільності заряду та компенсації перевищення вартості гелевих та AGM акумуляторних батарей в порівнянні з вартістю акумуляторних батарей типу 12СТ85. **Висновки.** Використання на зразках бронетанкового озброєння та військової техніки акумуляторних батарей, виконаних за новітніми технологіями, не потребує принципових конструктивних змін у електрообладнанні машини. Для забезпечення вимоги стандартів щодо параметрів напруги у бортових мережах об’єктів бронетанкового озброєння та військової техніки необхідне встановлення відповідного регулятора напруги. Перевищення вартості гелевих та AGM акумуляторних батарей в порівнянні з вартістю батарей типу 12СТ-85 може бути компенсовано відсутністю витрат на експлуатаційні матеріали, персонал, що забезпечує обслуговування АБ типу 12СТ85, а також тривалим терміном служби гелевих або AGM акумуляторних батарей в порівнянні з звичайними кислотно-свинцевими батареями.

Ключові слова: свинцево-кислотний акумулятор; гелеві акумуляторні батареї; AGM акумуляторні батареї; електрообладнання зразків бронетанкового озброєння та військової техніки.

Анализ возможности использования аккумуляторных батарей новейших технологий на образцах бронетанкового вооружения и военной техники

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Аннотация. Предметом изучения в статье является массогабаритные характеристики аккумуляторных батарей, их конструктивные, электрические, эксплуатационных параметров и энергетические возможности. **Целью исследования** является возможность использования аккумуляторных батарей, не обслуживаемых на образцах бронетанкового вооружения и военной техники. **Задачи исследования:** проанализировать существующие технологии производства аккумуляторных батарей, их преимущества и недостатки учитывая особенности эксплуатации военной техники и основные технические характеристики аккумуляторных батарей. Путем статистической обработки данных исследовать зависимости "стартерных" режимов разряда и энергетических возможностей аккумуляторных батарей, изготовленных по технологиям разных поколений. Исследовать возможности конструктивной реализации формирования источника питания с учетом возможных конструктивных изменений в системе электропуска двигателя, обеспечения необходимой стабильности заряда и компенсации превышения стоимости гелевых и AGM-аккумуляторных батарей по сравнению со стоимостью аккумуляторных батарей типа 12СТ85. Методологической основой исследования стали общенаучные и специальные **методы** научного познания. **Получены следующие результаты:** Проанализированы существующие технологии производства аккумуляторных батарей, их преимущества и недостатки учитывая особенности эксплуатации военной техники и основные технические характеристики батарей. Исследованы зависимости "стартерных" режимов разряда и энергетических возможностей аккумуляторных батарей, изготовленных по технологиям разных поколений. Исследованы возможности конструктивной реализации формирования источника питания с учетом возможных конструктивных изменений в системе электропуска двигателя, обеспечения необходимой стабильности заряда и компенсации превышения стоимости гелевых и AGM аккумуляторных батарей по сравнению со стоимостью аккумуляторных батарей типа 12СТ85. **Выводы**. Использование на образцах бронетанкового вооружения и военной техники аккумуляторных батарей, выполненных по новейшим технологиям, не требует принципиальных конструктивных изменений в электрооборудовании машины. Для обеспечения требования стандартов параметров напряжения в бортовых сетях объектов бронетанкового вооружения и военной техники необходима установка соответствующего регулятора напряжения. Превышение стоимости гелевых и AGM аккумуляторных батарей по сравнению со стоимостью батарей типа 12СТ85 может быть компенсировано отсутствием затрат на эксплуатационные материалы, персонал, обеспечивающий обслуживание АБ типа 12СТ85, а также длительным сроком службы гелевых или AGM аккумуляторных батарей по сравнению с обычными кислотно свинцовыми батареями.

Ключевые слова: свинцово-кислотный аккумулятор; гелевые аккумуляторные батареи; AGM аккумуляторные батареи; электрооборудование образцов бронетанкового вооружения и военной техники.