ISSN 2706-7386
UDC 623.4.018 DOI: 10.37701/dndivsovt.11.2022.01

Chupryna V.M., Dmytriiev V.A. *State Scientific Research Institute of Armament and Military Equipment Testing and Certification*

MODELING THE STRENGTH OF THE REAR SUSPENSION OF THE SPECIALIZED ARMORED VEHICLE “NOVATOR”

The problem of ensuring the strength of the rear suspension of a specialized armored vehicle during tests is considered. To solve it, a method of calculating the suspension for strength at maximum loads was developed and the modeling of the structure on the main modes of operation of the vehicle was performed. Mathematical modeling of the vehicle at maximum loads to determine the critical forces and maximum stresses in the structural element, as well as its analysis for the absence of residual deformations is made. The performed calculations, mathematical and simulation modeling proved that the necessary strength conditions are met for all elements of the suspension at its maximum load in the most severe modes of operation of the vehicle.

Keywords: *armored vehicle, rear suspension, tests, load, strength, calculation, modeling.*

Introduction. Tests play an important role in the lifecycle of modern armament and military equipment. They are an integral part of the technological process of manufacturing and modernization of technical facilities, including military equipment and special equipment.

The purpose of the tests is to determine and evaluate the combat, technical and operational characteristics of the samples of equipment submitted for testing.

The use of simulation in tests is a modern method that allows you to partially transfer real tests to a virtual environment. At the same time, you can significantly expand the number of modeling parameters and set different models of impact on the object. This can significantly reduce the time of testing and reduce the total cost of testing [1].

Tests of a specialized armored vehicle “NOVATOR” were carried out in the State Scientific Research Institute of Armament and Military Equipment Testing and Certification. The general view of the vehicle is shown in Figure 1.

During the factory tests when the vehicle climbed the sloping hill at an angle of 30°) there was an accident – damage (destruction) of the longitudinal levers of the rear-wheel drive. The investigation of the accident showed that the strength of the longitudinal rods of the rear axle is insufficient, and the material used does not meet the requirements of technical conditions.

Therefore, the task of increasing the strength of the rear suspension elements has arisen. To solve this problem, it is necessary to calculate the strength and make the necessary changes in the design of the vehicle’s rear suspension.

Presenting main material. Note the design features of the rear suspension “NOVATOR”. The specialized armored vehicle is assembled on the chassis of a FORD car. However, instead of the standard rear suspension spring suspension is used, without the installation of shock absorbers, which can reduce vehicle’s smoothness and reduce its life.

In the design of the rear suspension of the specialized armored vehicle “NOVATOR” a scheme with longitudinal side levers that absorb bending stress is used.

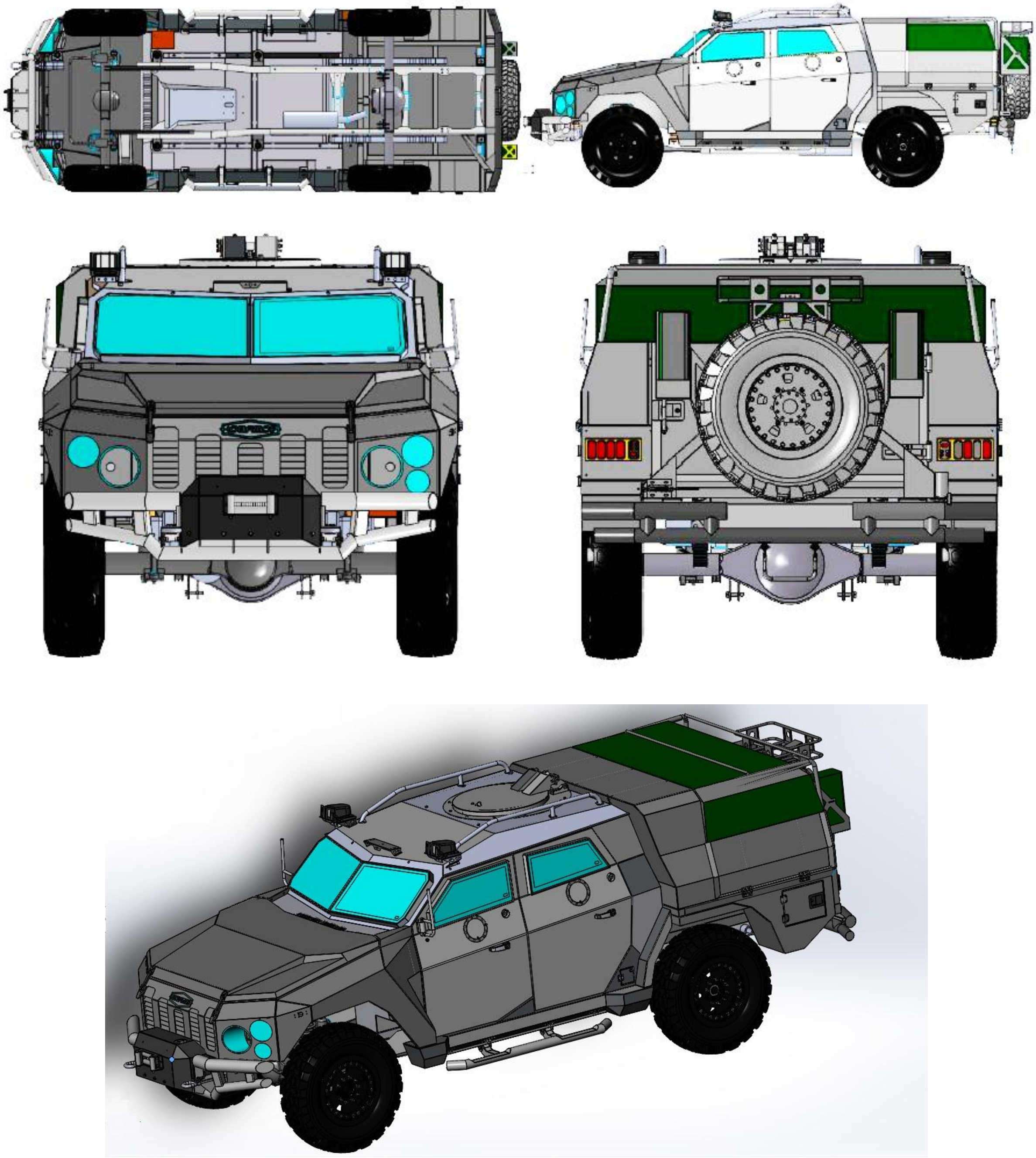

Fig.1. General view of the specialized armored vehicle “NOVATOR”

The amount of bending force for the above structure depends on the amount of traction during the movement of the vehicle and the amount of braking torque realized during braking.

A significant difference of the suspension is the effect of multidirectional vertical travel of the suspension on its guiding properties. This issue is constructively resolved by attaching the rear limb of the longitudinal suspension lever to the drive axle with two silent blocks.

The specialized armored vehicle “NOVATOR” uses a scheme with longitudinal on-board levers that receive different loads from forces and moments, which are due to the values of traction during movement and braking torque during braking.

The general design of the rear suspension is shown in Figure 2.

ISSN 2706-7386

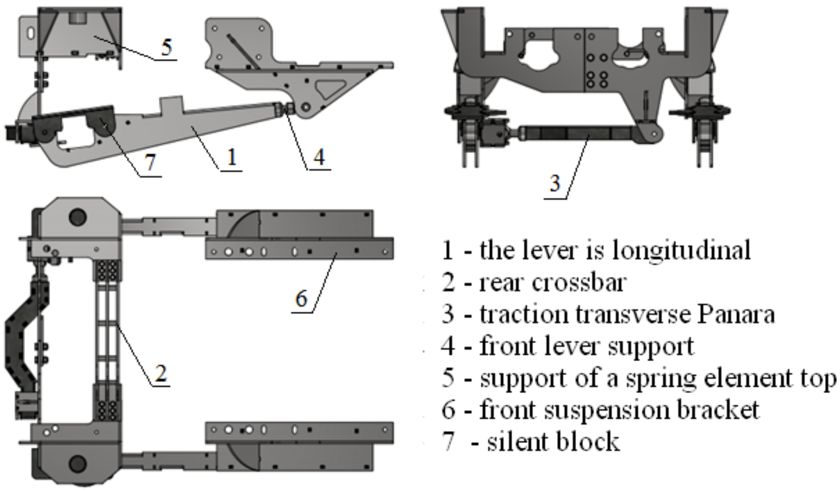

Fig.2. Design of the rear suspension of the specialized armored vehicle “NOVATOR”

The magnitude of the bending force for the above lever design depends on the magnitude of the traction force during the movement of the vehicle and the magnitude of the braking torque realized during braking or climbing up a sloping hill (Figure 3).

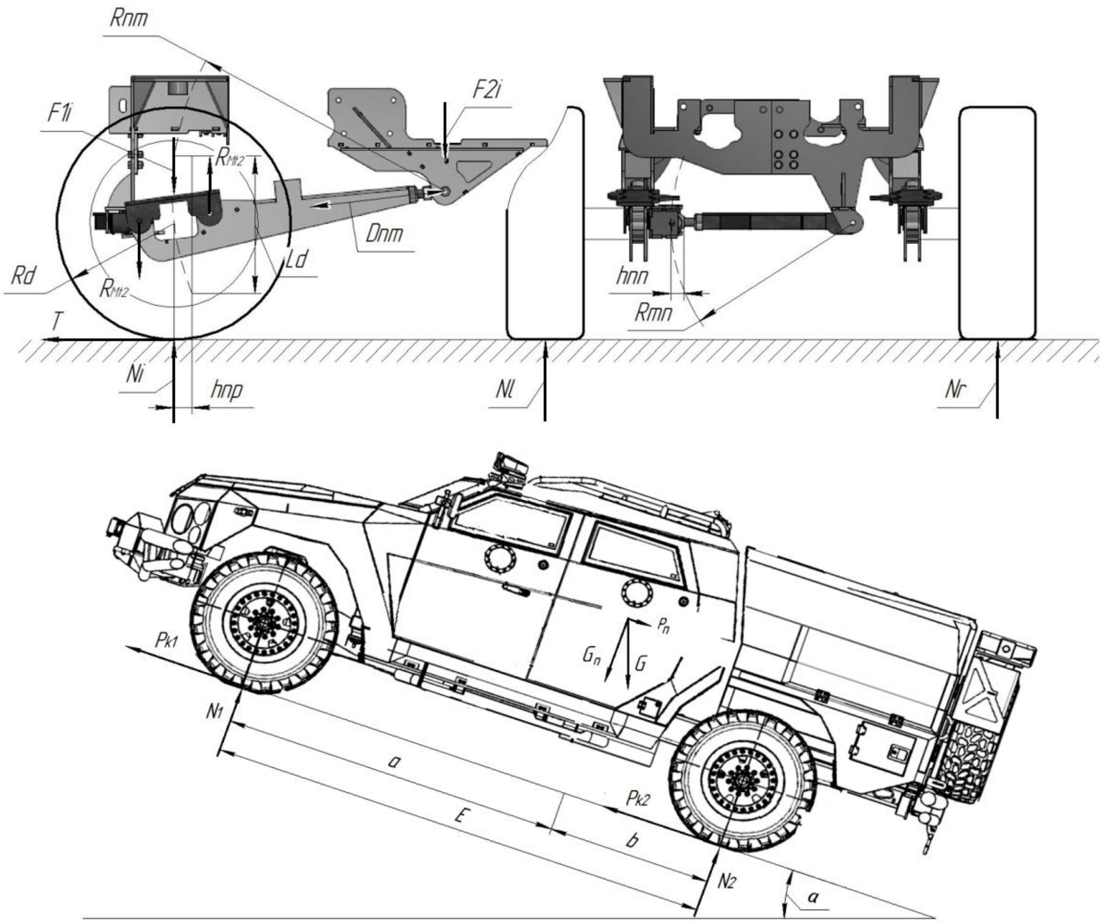

Fig.3. Scheme of forces impacting the specialized armored vehicle
during braking and on a sloping hill

The forces and moments impacting the rear suspension of the vehicle “NOVATOR” are calculated in [2]. Let's take them as a basis for calculating the model of the rear suspension for strength.

ISSN 2706-7386

The calculation of the main modes of suspension of the specialized armored vehicle "NOVATOR" showed that the maximum load is taken by the longitudinal levers of the suspension during braking and when climbing up (a sloping hill 30°). They represent the following values:

– during braking, the maximum torque M = 39715.5 Nm ≈ 40000 Nm;

– at the beginning of the movement on a sloping hill with a slope of 30 ° M = 60150.3 Nm ≈ 60000 Nm;

– force impacting the rear suspension (part of the load from the weight of the vehicle) P = 66700N.

Given that the maximum torque is distributed approximately equally on both wheels, it is advisable to accept the following options for applying the load:

– option 1 – P = 66700N (on the suspension);

– option 2 – M = 30,000 Nm (per wheel).

Based on the provided drawings, a detailed continuous 3D model of the rear suspension of the specialized armored vehicle "NOVATOR" in the SolidWorks system was developed [3, 4]. In accordance with the above load modes, the design scheme of the rear suspension of the specialized armored vehicle is made. The general view of the calculation scheme is shown in Figure 4.

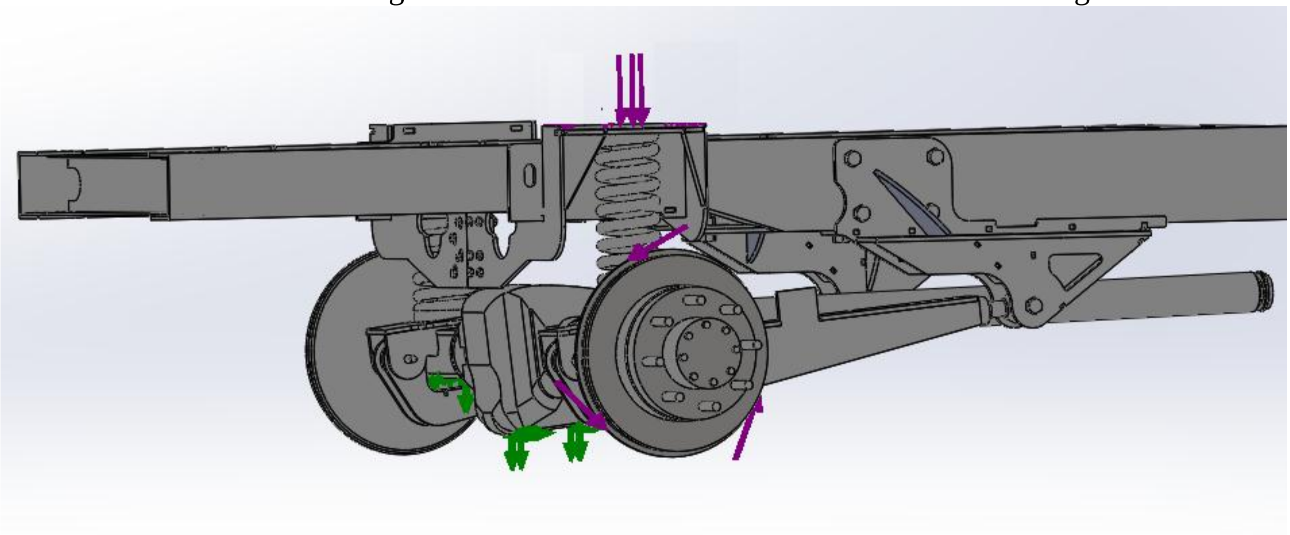

Fig.4. Calculation scheme of the specialized armored vehicle "NOVATOR"

In the 3D model, the rear suspension is mounted on a fragment of the vehicle frame according to the actual design. At the same time exact geometrical models of each detail received from the corresponding drawings are used.

The material and properties of the individual structural elements of the rear suspension were set from the drawings in accordance with the standards. Materials' mechanical properties which are necessary to test for the strength are summarized in Table 1.

Table 1

Mechanical properties of the materials used

№	Name	Permissible stresses, MPa	
		σ_m	$\sigma_в$
1	Steel 10ХСНД GOST 4543-71	410	540
2	Steel 40Х GOST 4543-71	1420	1580
3	Spring steel GOST 9398-75	1320	1320
4	Welding wire SW-307Si ISO 14343-A	350	500

ISSN 2706-7386

In the design of the rear suspension of the "NOVATOR" most welded parts are made of steel 10 ХСНД GOST 4543–71. Axles, bolts, nuts and screws are made of 40X steel. Springs are made of spring steel according to ISO 14343–A.

The design of the rear suspension contains both small elements (bolts, washers, nuts, etc.) and large elements (wheels, frames, rods, etc.). Also, many elements are used here with a large number of holes of different sizes, radii and roundings.

To build a finite element network of such a complex assembly model, it is advisable to use a combined network of tetraidal finite elements and sizes that are adapted to the size of the element. This allows you to more accurately describe the properties of structures with different sizes of elements, which include the design of the rear suspension of the specialized armored vehicle "NOVATOR".

At the preparatory stage of the calculation, a heterogeneous finite element network of the rear suspension structure was formed, which contained 6730923 degrees of freedom, 1390942 finite elements and 2249906 nodes (Figure 5).

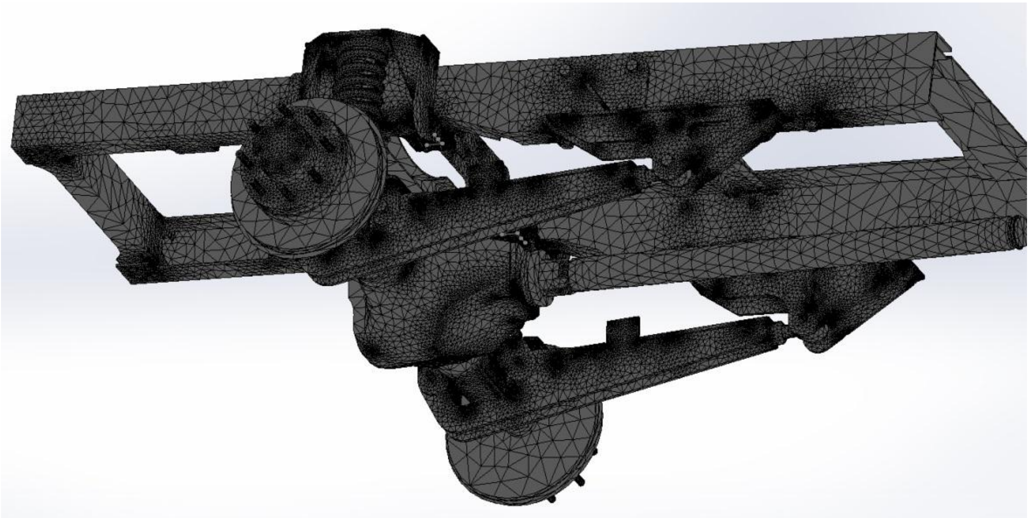

Fig.5. Finite element network of the rear suspension

After construction of finite element network of a rear suspension bracket static calculation of a design on durability was carried out. The protocol for calculating the system of equations of this model is shown in Figure 6.

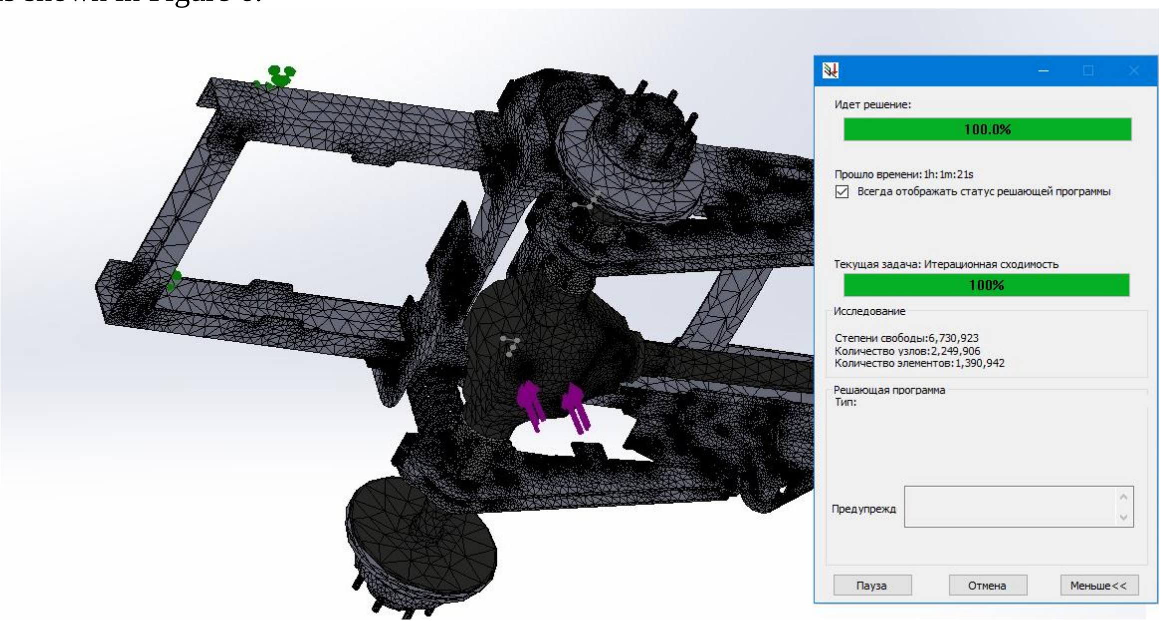

Fig.6. Protocol for calculating the rear suspension model

ISSN 2706-7386

Figure 7 shows the maps of the stress-strain state for different design options of loads.

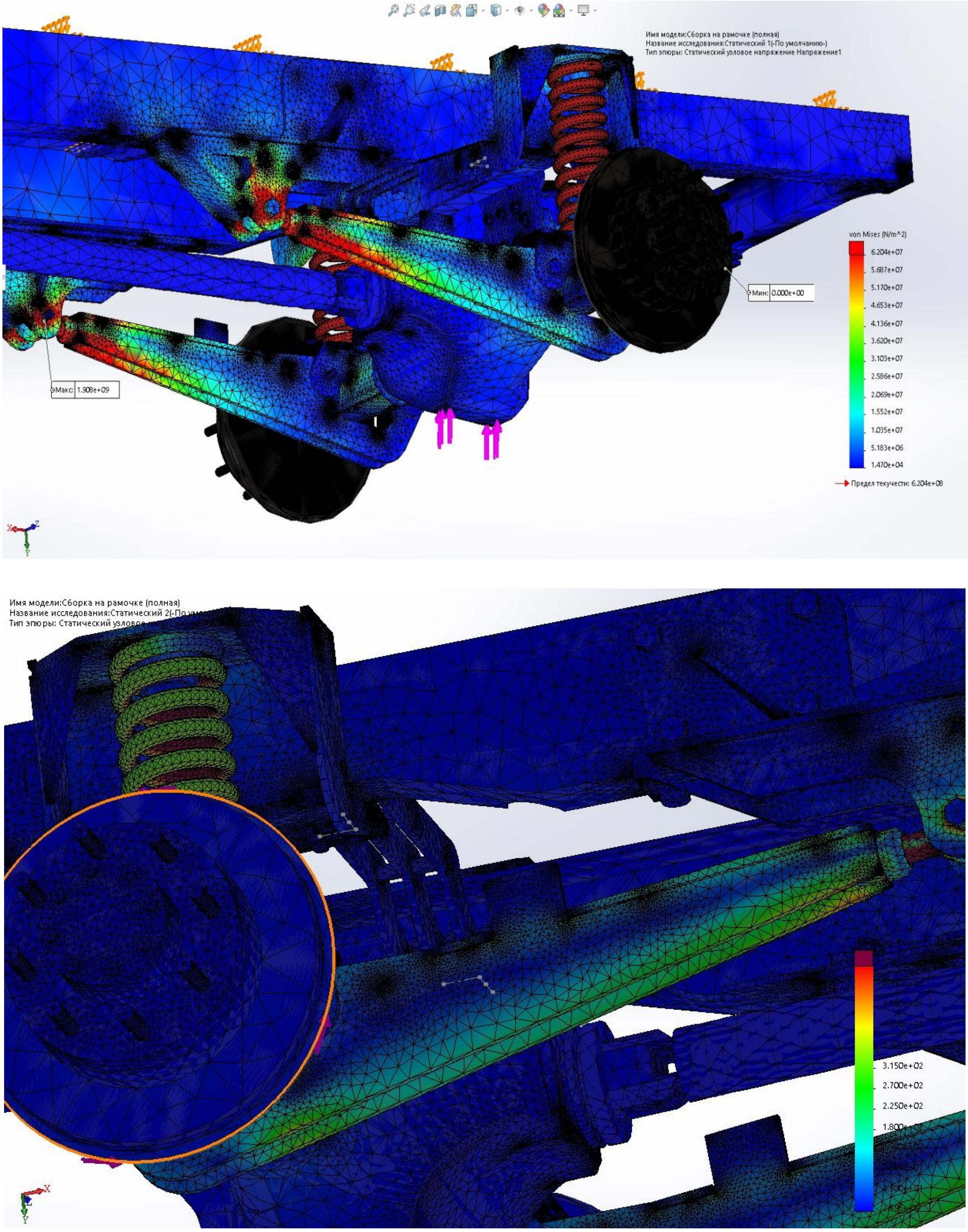

Fig.7. Simulation of the elastically deformed state of the rear suspension

To establish the maximum point stresses, the critical zones of the structure were probed, in which the stress values approach the allowable values. In Figure 8, these areas are marked with footnotes.

ISSN 2706-7386

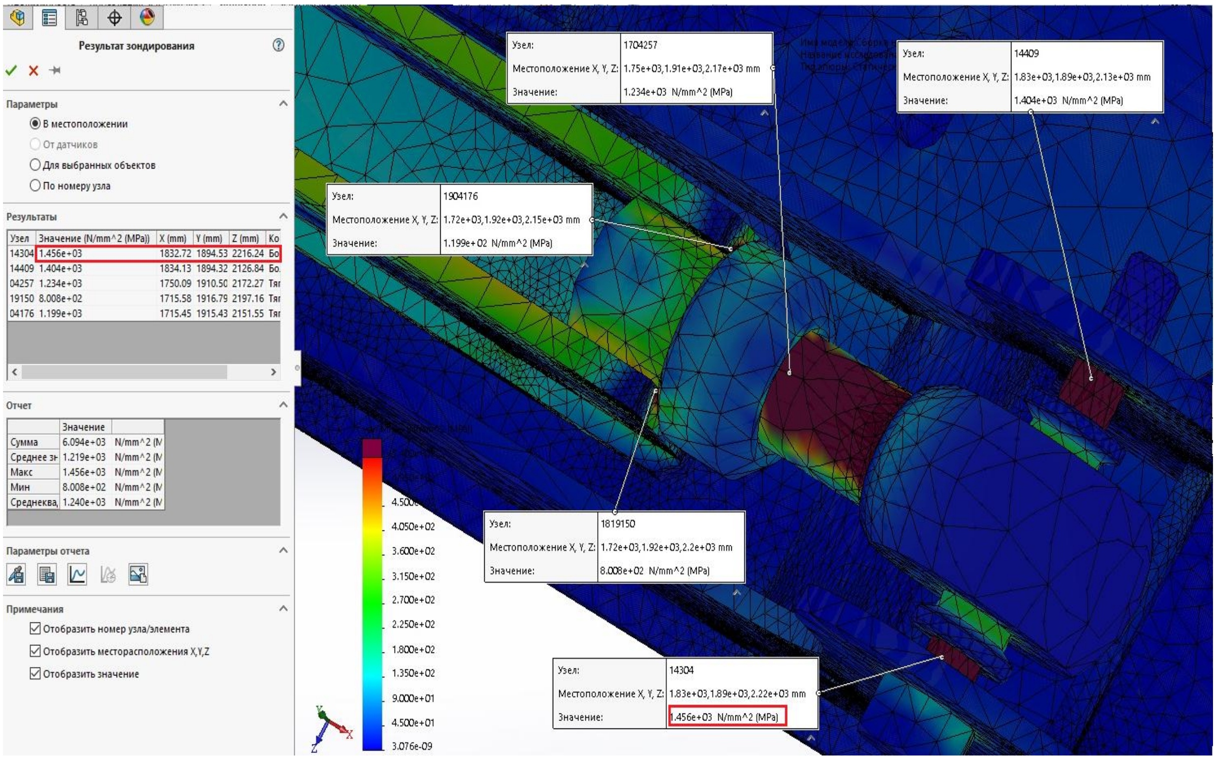

Fig.8. Probing of the rear suspension elements

Figure 9 shows an example of the pattern of deformations (movements) of the structural elements of the rear suspension under the impact of specified loads. The biggest movements here are due to the compression of the suspension springs.

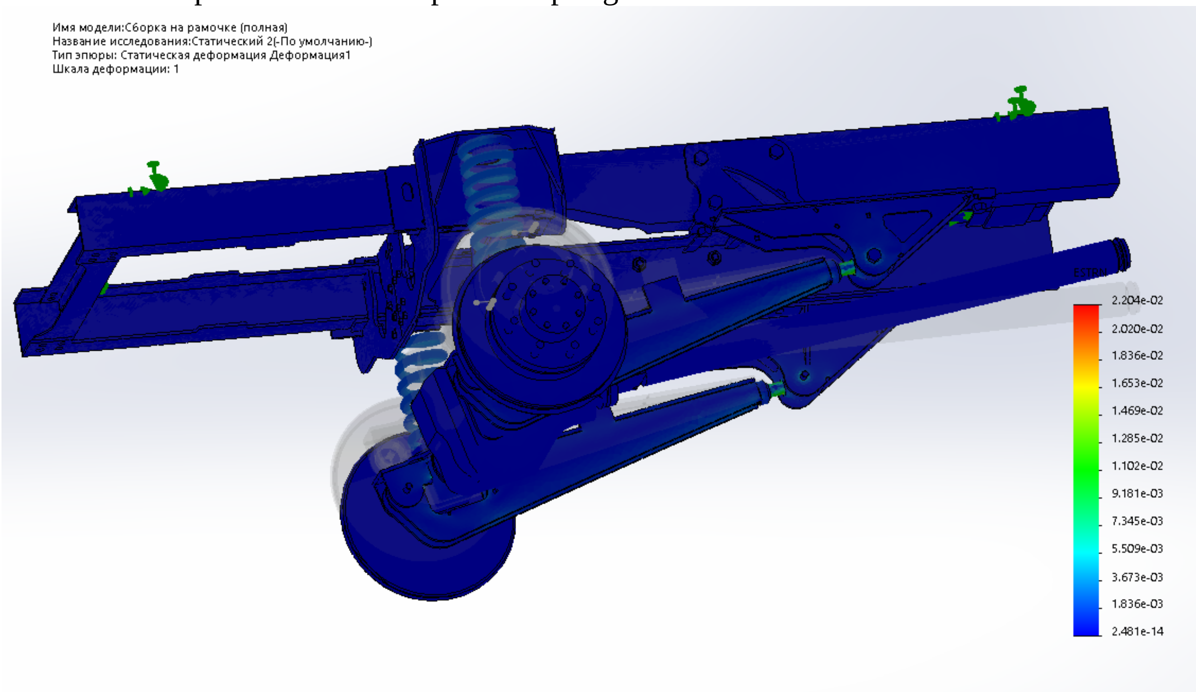

Fig. 9. Plot deformations (displacements) of the rear suspension elements

As a result of calculations of the stress-strain state of the rear suspension, the following is determined:

– in the first variant of loads (force P) stresses in the nodes are not significant, because all the loads are taken by the nodes of the springs;

– the highest stresses in the elements of the rear suspension correspond to the second variant of loads (moment M);

– the maximum stresses that are in the units of traction, working on the bend (the axis of attachment of the lever, screw, lever, axis of the silent blocks), do not exceed the allowable values;

– safety factors of these elements are (1,085–1.2) units.

For example, for the axis of attachment of the lever, the maximum stresses (Fig. 8) are 1456 MPa, which is less than the allowable value (1456 MPa < [1580] MPa). The safety margin is 1580: 1456 = 1,085 units (8.5%). That is, in general, the design of the rear suspension provides the necessary strength. However, the margins for individual elements are small.

To increase the strength and coefficients of safety (as well as the service life of these elements), it is advisable to take design and technological measures to strengthen the design of the rear suspension. For example, increasing the diameter of the lever mounting axis from 18 mm to 22 mm provides a margin of strength of 1.5 units (i.e. 50% instead of 8.5%).

Conclusions and recommendations.

As a result of the calculation of the strength of the rear axle subsystem, it is recommended to increase the wall thickness and replace the material of the longitudinal rods, which provided the necessary strength under the most difficult conditions of vehicle's operation.

Based on the results of simulation modeling of the "NOVATOR" rear suspension at certain maximum loads, it can be stated that the design of the rear suspension as a whole provides sufficient strength. However, the margins for the most loaded structural elements are small.

Recommendations for increasing the strength of the rear suspension are as follows:

– it is expedient to carry out constructive changes of some of the most loaded elements towards their strengthening;

– it is recommended to ensure the value of the coefficients of safety of the structure at the level of not less than 1.5-2 units.

The manufacturer is invited to take into account and implement the recommendations provided in the manufacture of a serial model of the vehicle.

REFERENCES

1. Dmytriyev V.A. Modern Methods of Modelling in Testing and Sertification of Special Technique / V.A. Dmytriyev, V.M. Chupryna, E.K. Chimbanga // Mathematical and simulation modeling of systems. Proceedings of the XII International Scientific and Practical Conference"MODS-2018", June 25-29, 2018, Ukraine, Kyiv – Zhukin. – C. 376–378.

2. Sosik A.Yu. Theoretical estimates of the strength of the elements of the rear spring suspension of a specialized armored vehicle for the transportation of personnel "NOVATOR" / Report on the research. – Zaporozhye, ZNTU, 2018. – 19 c. (in Ukrainian).

3. SolidWorks 2007/2008. Computer modeling in engineering practice / A A Alyamovsky, A A Sobachkin, E V Odintsov, A I Kharitonovich, N B Ponomarev. – St. Petersburg: BHV-Petersburg, 2008. – 1040 c. (in Russian).

4. Алямовский А.А. COSMOSWorks. Fundamentals of calculation of structures for strength in SolidWorks. – M.: DMK Press, 2010. – 784 c. (in Russian).

Чуприна Володимир Михайлович
доктор технічних наук, доцент, провідний науковий співробітник Державного науково-дослідного інституту випробувань і сертифікації озброєння та військової техніки, Чернігів, Україна
https://orcid.org/0000-0003-4886-090X
+38068-131-66-06

Volodymyr Chupryna
Doctor of Technical Sciences, Associate Professor, Lead Researcher of State Scientific Research Institute of Armament and Military Equipment Testing and Certification, Chernihiv, Ukraine
https://orcid.org/0000-0003-4886-090X
+38068-131-66-06

Дмитрієв Володимир Анатолійович
лауреат Державної премії України в галузі науки і техніки, член-кореспондент Академії технологічних наук України, доктор технічних наук, старший науковий співробітник Державного науково-дослідного інституту випробувань і сертифікації озброєння та військової техніки, Чернігів, Україна
https://orcid.org/0000-0002-0792-6397

Volodymyr Dmytriiev
The Laureate of State Prize of Ukraine in sphere of science and technique, Corresponding member of ATS Ukraine, Doctor of Technical Sciences, Senior Research of State Scientific Research Institute of Armament and Military Equipment Testing and Certification, Chernihiv, Ukraine
https://orcid.org/0000-0002-0792-6397

МОДЕЛЮВАННЯ МІЦНОСТІ ЗАДНЬОЇ ПІДВІСКИ СПЕЦІАЛІЗОВАНОГО БРОНЬОВАНОГО АВТОМОБІЛЯ “НОВАТОР”

В. Чуприна, В. Дмитрієв

Розглянута проблема забезпечення міцності задньої підвіски спеціалізованого броньованого автомобіля “НОВАТОР”.

При попередніх випробуваннях встановлено, що міцність повздовжніх тяг заднього моста є недостатньою. Для вирішення проблеми забезпечення міцності були внесені конструктивні зміни в конструкцію повздовжніх тяг, які необхідно перевірити при розрахунках міцності задньої підвіски.

Створена тривимірна модель задньої підвіски автомобіля та розроблена методика її розрахунку на міцність за методом скінчених елементів. Проведено імітаційне моделювання конструкції задньої підвіски на основних режимах експлуатації автомобіля. Для визначення максимальних напружень в елементах конструкції виконано математичне моделювання автомобіля при максимальних (критичних) навантаженнях на задню підвіску в режимах гальмування і руху (підйому) на косогорі. При цьому проведений аналіз конструкції, який засвідчив відсутність залишкових деформацій в найбільш навантажених деталях підвіски.

Виконаними розрахунками, математичним і імітаційним моделюванням доведено, що необхідні умови міцності виконуються для усіх елементів задньої підвіски при її максимальному навантаженні в найбільш важких режимах роботи автомобіля. Однак, запаси міцності для окремих елементів конструкції є незначними.

Для підвищення міцності і збільшення коефіцієнтів запасу міцності (а також і ресурсу роботи зазначених елементів) запропоновано виробникам здійснити конструктивно-технологічні заходи з підсилення конструкції задньої підвіски, які доцільно реалізувати при виготовленні серійного зразка автомобіля.

***Ключові слова**: бронеавтомобіль, задня підвіска, випробування, навантаження, міцність, розрахунок, моделювання.*