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Motor Vehicles & Motors 2024

ECOLOGY - VEHICLE AND ROAD SAFETY - EFFICIENCY

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ANALYSIS OF PLACING ADDITIONAL SUPPORTS OF THE INTEGRATED ARTILLERY SYSTEM CALIBER 130 mm

ABSTRACT: As part of this work, the vehicle platform on which the 130 mm caliber artillery tool was integrated was analyzed. The analysis of the platform was performed in the numerical program FEMAP. As it is a fast variable impulsive process, a dynamic analysis was performed. The type of analysis, Direct Transient, allows the determination of various parameters of a structure that is loaded with a force that is variable over time. The platform was analyzed with 2D and 3D finite elements, which show different values of the final results. Analyzing the results leads to the most suitable final element for further analysis. The further course of analysis involves analyzing additional supports on the vehicle platform. Extra supports are placed at different angles about the vertical plane. The analyzed angles are 15°, 45°, and 60°, while the tool is placed at various angles of elevation and direction. Through this analysis, certain laws were observed in the behavior of the construction, and the best variant that could be realized in the future was observed. This is the variant that would be the most suitable in terms of the load on the supports during the action of the weapon. Since the process takes place in a short period, the optimal variant should handle rapid load changes.

KEYWORDS: artillery system, integration of artillery system, numerical analysis, FEMAP, Direct Transient

INTRODUCTION

The 130 mm caliber artillery system chosen for analysis in this paper is the 130 mm M46 gun, a towed artillery piece. It was developed in the 1940s by the Soviet Union after World War II [1]. While it was first used in the 50s of the last century. It has been developed in more than 40 countries and is still an important tool in most countries [1].

The selected artillery system of caliber 130 mm, gun 130 mm M46, as a towed artillery tool, consists of the following assemblies:

- barrel assembly,
- upper carriage assembly,
- assembly of the anti-roll device and
- lower carriage assembly [3, 4, 5].

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Figure 1. View of the 130 mm M46 gun [2]

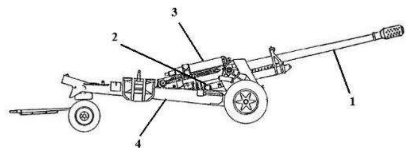

Figure 2. View of the 130 mm M46 gun with assembly positions: 1 – barrel assembly; 2 - upper carriage assembly; 3 - assembly of the anti-roll device; 4 - lower carriage assembly [6]

There are different variants of the 130 mm M46 gun, which are made identically to the original version, i.e. under license, made with the same caliber or another, whereby certain tactical-technical (TT) characteristics were reduced or increased. Also, there are variants when this tool is integrated into different vehicles.

VEHICLE INTEGRATION

To carry out the integration of the gun, first of all, a wheeled vehicle that is in use by the Serbian Armed Forces, the FAP 3240 vehicle, was chosen.

FAP 3240 (figure 3) is an off-road truck developed for the needs of the Serbian Army. According to the information so far, 4 such vehicles have been produced, while the 5th is a prototype [7]. Table 1 shows the characteristics of the FAP 3240.

Figure 3. FAP 3240 [7]

Table 1. Characteristics FAP 3240 [7]

FAP 3240	
Permissible total mass [kg]	24300
Payload [kg]	10000
Engine	OM 457 LA EU 3
Power [KW (KS)/min-1]	295 (401)
Maximum speed [km/h]	95
Maximum climbing ability [%]	60
Cargo Box [mm]	5500x2430x1700

Display of the forces acting on the tool

When the bullet is fired, the weapon recoils, that is, the recoil force P_{kn} occurs, which is caused by the accelerated movement of the projectile in the channel of the barrel and powder gases [3, 4, 5]. The recoil force depends on the resistance of the weapon and its firing stability. Total recoil force:

$$R = F_k + F_p + F_T - Q_t \sin\varphi \tag{1}$$

In which:

- F_k – hydraulic brake force,
- F_p – return force,
- F_T – total frictional force and
- $Q_t \sin\varphi$ – force component of the weight of the recoiling mass [3, 4, 5].

Due to the lack of data needed to calculate the force of the total recoil resistance based on the previous equation, the force R was calculated based on the recoil force P_{kn} and the recoil impulse I_t. The force R was caused by the total declaration by breaking the movement of the pipe. While the force It represents the internal recoil force. Figure 4 shows the forces acting on the tool. The mentioned forces can be calculated based on the conditions of the balance of forces, i.e. of the condition that the force of inertia of the twitching parts is by definition:

$$I_t = P_{kn} - R \tag{2}$$

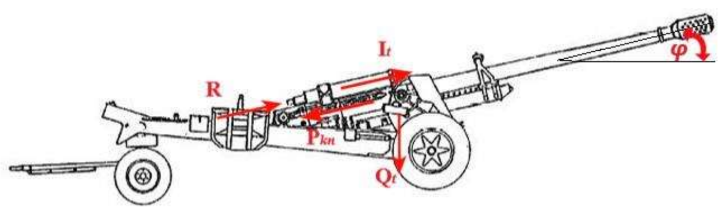

Figure 4. Force acting on the tool

The internal ballistic characteristics are shown in Table 2. To determine the internal ballistic characteristics, an internal ballistic calculation was performed using the Drozdov method [8].

Table 2. Internal ballistic characteristics

Internal ballistic characteristics	
v_o [m/s]	924.22
p_m [Pa]	331425536
t[s]	0.01308

Defining constraints and assumptions

Figure 5 shows the forces acting on the tool and the vehicle.

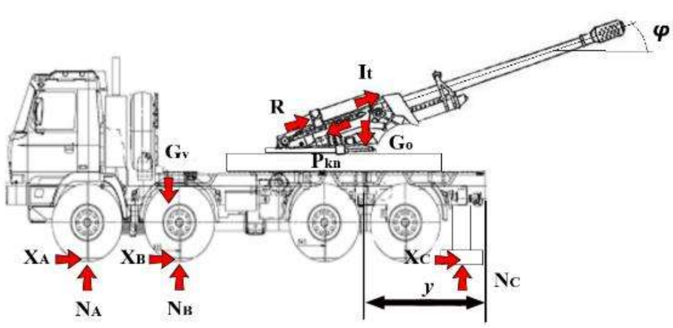

Figure 5. The forces acting on the tool and the vehicle

First, during the analysis of the reactions of the supports, certain assumptions were adopted to solve the problem more easily.

The adopted assumptions are:

- parts of the tool, the connection between the tool and the truck are rigid,
- the truck wheels are on a horizontal and solid surface,
- relying on the last four wheels is excluded,
- the effect of the weight of the tool (G_o) and the truck (G_v) is ignored and
- all forces act in the plane of symmetry.

The integration of the cannon on the vehicle was carried out on half the width of the vehicle, with the center of mass of the weapon located in the middle of the cargo box, marked with the symbol y (figure 5).

When integrating the cannon FAP 3240 needs to have additional supports at the end of its cargo area (figure 5). When the cannon is fired, the two end supports are lowered, disabling the other two pairs of truck wheels.

Defining the effect of force

To simplify the calculation, it is defined that the force acts at one point. The chosen point of action is localized at half the width and half of the cargo box. The magnitude of the force depends on the elevation angle ϕ and the direction angle ψ.

However, as the force P_{kn}-R (symbol F) acts in space and the plane of symmetry of the tool, it is necessary to determine its components in space. Figure 6 shows the force in space.

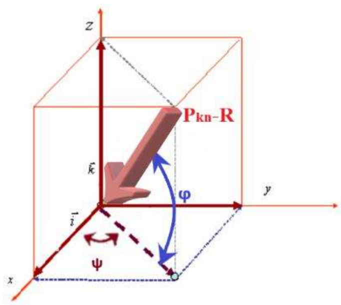

Figure 6. Force components in space

The equations for calculating the force components in space are as follows:

$$X = -F * cos\psi * sin\varphi; \tag{3}$$

$$Y = -F * sin\psi * cos\varphi; \tag{4}$$

$$Z = -F * sin\varphi. \tag{5}$$

How it is necessary to perform a dynamic analysis of the problem, i.e. to analyze a structure loaded over time, it is necessary to define a function in time. That is why a function is created to be analyzed. In this case, P_{kn}-R is analyzed over time (figure 7).

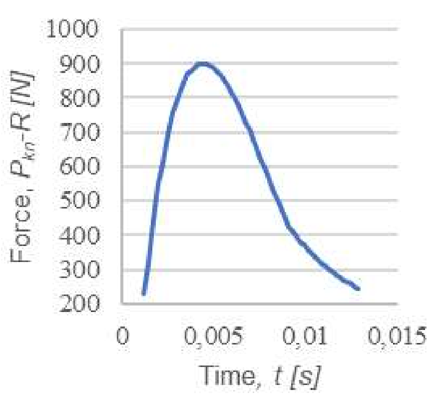

Figure 7. Force value over time

ANALYSIS WITH DIFFERENT FINITE ELEMENTS

To get the best results, an analysis of the problem with different finite elements was done first. Since the given force acts in space, the linear finite element is not considered. With a 1D finite element, it is necessary that the load acts along one axis ([9, 10]), which is impossible to establish here. So, the analysis comes down to comparing the results obtained with 2D and 3D finite elements.

Necessary data for the further course of analysis are geometric data of the structure and data on the material. Baseline data are given in Table 3.

Table 3. Initial data

Initial data	
Vehicle length [mm]	8500
Vehicle width [mm]	2800
Wheel height [mm]	1000
Wheelbase [mm]	2000
Width of supports [mm]	500
Modulus of elasticity, E [N/mm^2]	$2.1*10^{11}$
Poisson's coefficient, ν [/]	0.3
Material density, ρ [kg/mm^3]	$7.850*10^{-6}$

When creating a model using 2D finite elements, it is necessary to add the thickness of the shell in addition to the initial data. Wherein in the case of 2D finite element thickness is added symmetrically in half about the created surface [9, 10]. In this case, the default thickness of the 2D finite element is 100 mm. 3D finite elements are volume elements, by creating a shell in the required shape of a simplified construction, volume is added.

Figure 8 shows a comparative view of the reaction results of the supports of the analyzed structure with 2D and 3D finite elements. As the action was performed at a direction angle of 0°, the pairs of supports have identical values of the reactions of the supports. Therefore, diagrams are presented for pairs of supports.

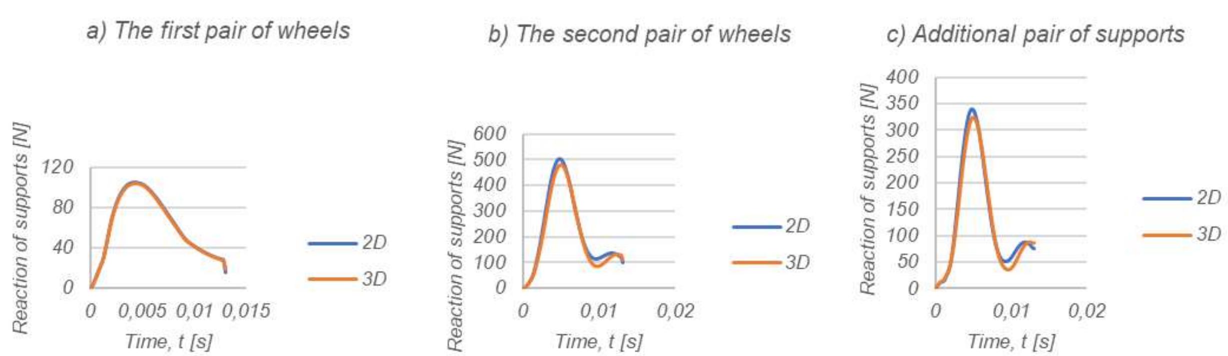

Figure 8. Comparative view of the results

The presented diagrams show that higher values of support reactions are obtained during the analysis of the structure made of 2D finite elements. Whereby the second pair of wheels bear the greatest load. Also, it is observed that the reactions of the supports when analyzing the structure with 2D finite elements have a faster response to the load. At the end of the firing process, they have a smaller increase in the reactions of supports, compared to analyzing the reactions of the supports with 3D finite elements.

Figures 9 and 10 show the displacement field for both types of finite elements shown at the moment of the highest load.

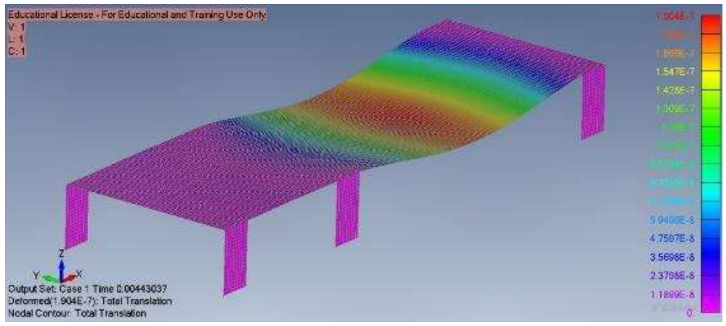

Figure 9. The displacement field of the analyzed structure made of 2D finite elements

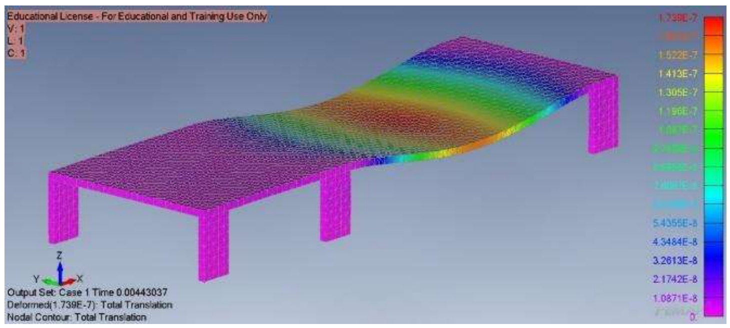

Figure 10. The displacement field of the analyzed structure made of 3D finite elements

With these images, it can be seen that the structure analyzed with 2D finite elements has a slight but larger field of displacement, compared to the structure analyzed with 3D finite elements. Based on the presented pictures of the comparative diagrams of the support reactions for pairs of supports, as well as based on the analyzed displacement field of the structure with different finite elements, certain conclusions can be made. First, the structure analyzed with 2D finite elements gave higher values of support reactions, which can be suitable for further calculations. For the reason that in real conditions it can be observed with a certain degree of certainty, because the real values can be smaller, and the analysis gives higher values, which represents a certain degree of certainty for constructors. Also, 2D finite element analysis shows a larger displacement field, which also represents a certain degree of certainty. The differences between the analyzed construction with different finite elements are not significantly greater, but there is still a certain difference. For this reason, the method where the structure is analyzed with 2D finite elements is used as a method for further calculations.

ANALYSIS OF DIFFERENT ANGLES OF ADDITIONAL SUPPORTS

Varying the angles at which the additional supports are placed about the vertical plane is the next step. The analyzed angles are 15°, 45° и 60°, shown with the symbol α. Figures 11 and 12 show the longitudinal and transverse views of the structure, respectively.

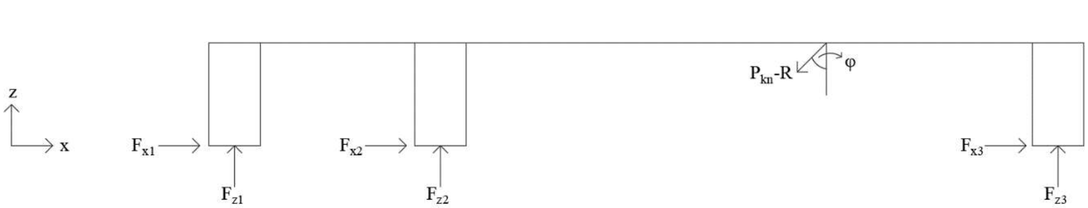

Figure 11. Longitudinal view of the structure

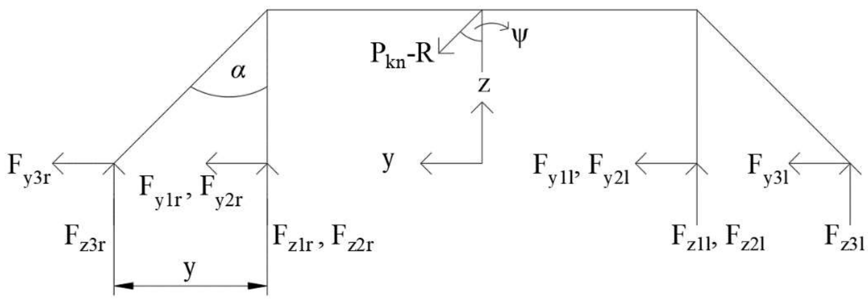

Figure 12. Cross-sectional view of the construction

Analyzing certain laws that have been established has been observed. Like that when acting with a positive angle of direction, the largest loads are borne by the left side of the structure. Conversely, by acting with a negative direction angle, the greatest load is borne by the right side of the structure. As well as that, when acting at any angle of elevation and direction, the biggest load is borne by the second pair of wheels. The exception that occurs is the effect of a negative elevation angle. In this case, the opposite situation occurs when acting at a positive or negative direction angle. For example, due to the negative elevation angle and the positive direction angle, the right side of the structure bears the greatest load, and vice versa.

Also, it was observed that the greatest load is borne by the supports when the action is performed at an elevation angle of 45°, at different angles of placement of additional supports.

Furthermore, a comparison of the angles of additional supports will be given when acting at an elevation angle of 45° and a direction angle of 0°. figure 13 shows a comparison of pairs of supports.

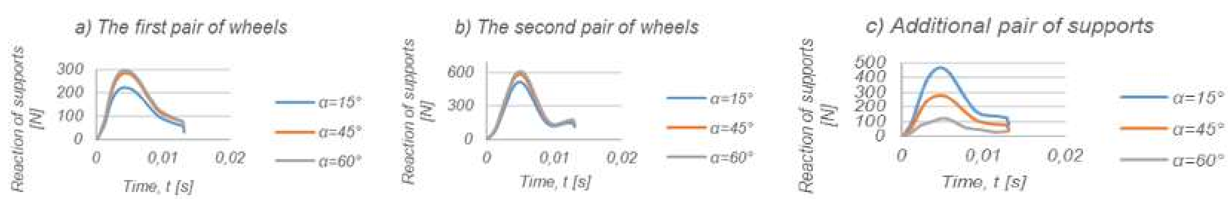

Figure 13. Comparative view of support reactions for pairs of supports

A comparative view shows that by placing additional supports at an angle of 15° about the vertical plane, the first and second pair of wheels bear the least load compared to placing additional supports at other angles. The exception is a pair of additional supports, which bear the higher load at an angle of 15°.

Also, it should be noted that when placing additional supports at a certain angle about the vertical plane, the reaction curves of the supports do not increase drastically at the end of the firing process, which was the case when the analysis of the structure with additional supports placed vertically was performed.

Analyzing the effect at an elevation angle of 45° and a positive or negative direction angle of ±25°, the following values are obtained for pairs of supports, shown in Figure 14.

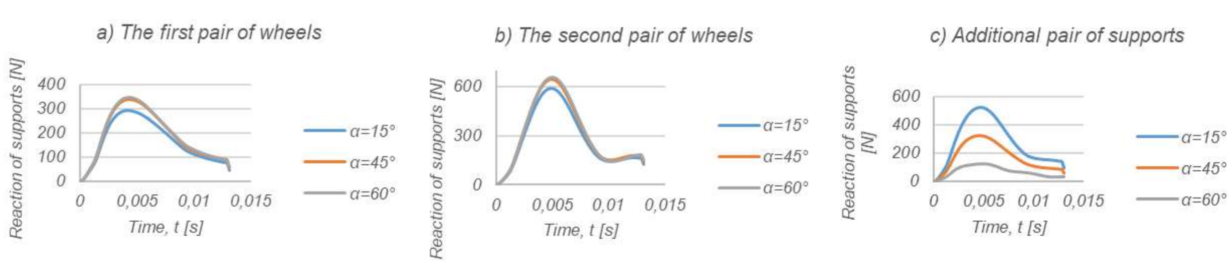

Figure 14. Comparative view of support reactions for pairs of supports

Based on the presented comparative analysis, the same pattern can be observed. Where a pair of additional supports bears the greatest load when placed at an angle of 15°, contrary to the first and second pair of supports which then bear the least load.

CONCLUSIONS

The selected 130 mm artillery system is integrated into the wheeled vehicle. In which a dynamic analysis was performed for the vehicle set up in this way, during the analysis, supports were added at the end of the cargo area so that the last two pairs of wheels were eliminated from the analysis. Additional supports, in that case, are vertical

The dynamic analysis was performed in the numerical program FEMAP. The type of analysis used is dynamic analysis, which enables problem-solving over time. Also, at the same time, it allows more realistic problem-solving. Making it possible to understand the magnitude of the problem, which happens in a fraction of a second, during which there is a huge effect of the load caused by the combustion of gunpowder gases at very high temperatures.

By comparing the results obtained from the analysis of these two elements, the analysis with a 2D finite element was taken as the optimal variant of the finite element. It is precisely with the help of this final element that higher values of support reactions and displacement of elements are obtained. Such values in real conditions may represent a certain degree of certainty.

The analysed additional supports are 15°, 45° and 60°. wherein the action was carried out at different angles of elevation and direction prescribed for the aforementioned artillery system.

By analysing the obtained values, certain regularities are observed. First, when operating with a positive angle of elevation and at a zero angle of direction the pairs of supports are identically loaded, with the second pair of wheels carrying the largest load. When the action is performed, also with a positive angle of elevation, and with a positive angle of direction, the left side of the structure bears the greatest load. Where the largest load is borne by the left second wheel. On the contrary, due to the negative direction angle, the greatest load is borne by the right side of the structure, i.e. right section wheel. The exception is the action with a negative angle of elevation, where when acting with a positive angle of direction, the greatest load is borne by the right side of the structure. Which is the opposite behaviour of the action with a positive elevation angle. Also, when the action is performed with a negative angle direction, the left side of the structure bears the greatest load.

By comparing the results obtained from the analysis of different angles of additional supports, it was observed that in the case of an action with an elevation angle of 45° and a direction angle of 0°, the highest load is borne by the first and second pair of supports when the structure is with additional supports that are at an angle of 60°, then with 45°, while at 15° they bear the least loads.

The exception is the behaviour of additional support. When the construction is with additional supports that are at an angle of 15°, then they are the most loaded. While at an angle of 45° they bear a slightly smaller load, and at an angle of 60° they bear the least load.

Such behaviour also occurs when the action is performed at the same elevation angle, i.e. 45°, and at a positive or negative direction angle.

For this reason, the variant where the additional supports are at an angle of 15° about the vertical plane was chosen as the optimal variant of constructions with additional supports. The reason for such a choice is that case the first and second pair of wheels bear the smallest loads. It was the second pair of wheels that was always the most loaded, in all analyses.

Based on the results shown, as well as the observation that the second pair of wheels bears the greatest load, it would be best to study the situation of installing additional supports just behind the second pair of wheels to secure the structure in that place, as well as to reduce the loads on the additional pair of supports.

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