



## Optimization of Fire Truck’s Tanks on the Chassis MAZ-6317 by the Method of Computer Simulation

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### Abstract

Design calculations of the stress-strain state of a 12 m<sup>3</sup> fire truck tank based on the MAZ-6317 chassis are presented, taking into account the dynamic loads at the movement. As a result, the dimensional factors influence of the structural elements of a fire truck tank on its operational reliability has been established. In order to optimize the existing structure solutions have been developed. Some results of calculations are given.

**Keywords:** fire truck, tank, optimization, dynamics, design, deformation, acceleration, stress-strain state, computer simulation, stiffeners, movement.

## 1. Introduction

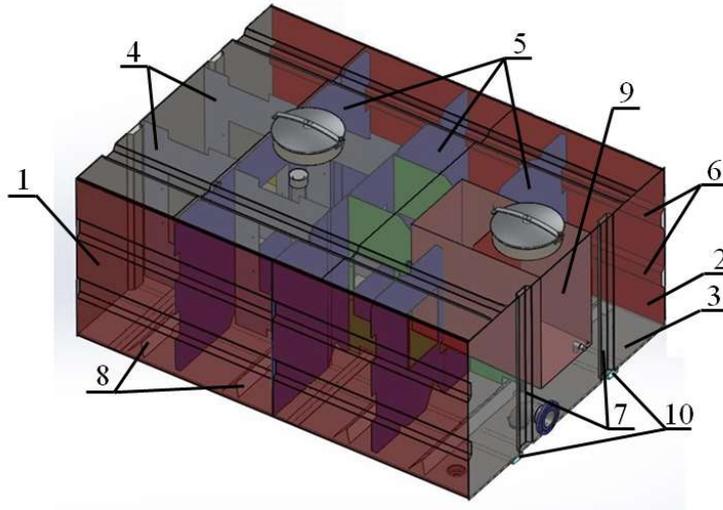
Every day, rescue units face various emergency situations of a natural and man-made nature in their work. Time has a decisive influence on the development of a fire and the degree of caused damage. Statistics show that 98% of the total death toll falls on the initial period of the development of fires and emergencies. For operational arrival of fire rescue units, it is necessary to have a new high-tech equipment or the existing one is to be constantly modernized. Therefore, the implementation of measures for updating and modernization of fire rescue equipment is one of the priorities of the Ministry of emergency situations of the Republic of Belarus.

A comparative analysis of the number of emergency trips for eliminating the consequences of emergency situations in the Republic of Belarus showed that the main unit involved is a fire truck in which the main element is the tank transporting fire extinguishing fluid [1]. The effectiveness of the use of fire trucks with large capacity tanks is due to the increased tactical capabilities in extinguishing fires in waterless areas and in the settlements poorly equipped with water communications, as well as while extinguishing forest and peat fires. Modern types of vehicles based on the MAZ-6317 chassis are capable of carrying 8-12 tons of water.

This is the construction of the tank which has to be in strict compliance with the increased requirements for the strength [2]. As the practice shows, one of the common causes of tank repair is the appearance of leaks [3]. When moving, the fluid oscillations and movement of the tank truck on uneven back roads have cyclical dynamic influence on the tank design, which leads to seal failure due to the cracks in the welds connections of breakwaters with the tank, as well as in the corner welds [4]. One of the ways to solve this problem is a scientifically proved design of the structure, optimization of the installed elements and stiffeners, which is a complex technical task [5].

## 2. Main part

In order to ensure the necessary operational reliability of fire truck tanks, a methodological approach has been developed, which allows investigating and evaluating the stress-strain state of tanks for the transport of liquids [6, 7, 8]. The task of dynamic modelling is solved by developing an estimated computer model and applying the experimentally obtained value of the maximum acceleration of oscillations of tested structural elements in the software settings. Using the capabilities of the ANSYS software package, 3D model of 12 m<sup>3</sup> fire truck tank based on the MAZ-6317 chassis (Fig. 1) has been developed.



**Figure 1. The design of 12 m<sup>3</sup> fire truck tank based on the chassis of the MAZ-6317**  
1 – rear wall of the tank, 2 – side wall of the tank, 3 – bottom of the tank,  
4, 5 – breakwaters (internal longitudinal and transverse breakwaters),  
6 – stiffeners on the side walls of the tank,  
7 – stiffeners on the front and rear walls of the tank,  
8 – transverse reinforcement in form of corners, 9 – foam box, 10 – lower longeron

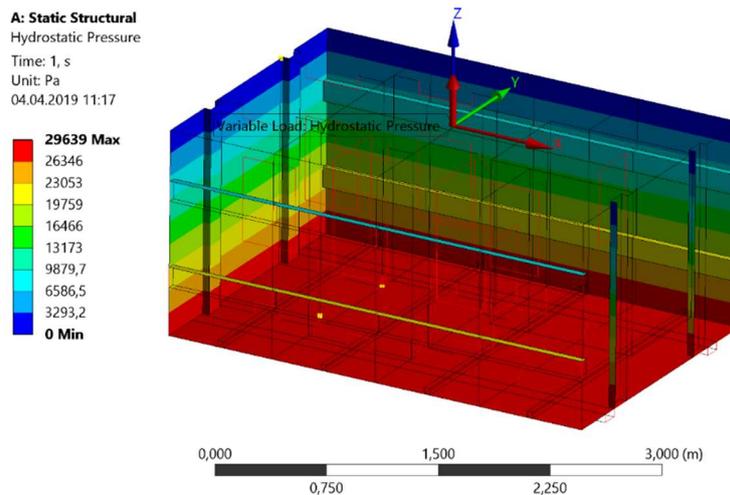
Computer modelling of the fire truck movement and calculations of mechanical tension were carried out with the use of the «Static Structural» module. By the way of initial parameters for calculations the following characteristics were used: geometric dimensions of tank's details, physicommechanical characteristics of materials and previously measured acceleration magnitude, which arise from the vibration of the structural elements during the vehicle movement. The next mechanical properties of corrosion resistant stainless steel AISI 430 2B were set to the program: module of elasticity  $E = 206 \text{ GPa}$ , Poisson ratio  $\nu = 0,3$ , density  $\rho = 7700 \text{ kg/m}^3$ , yield stress  $\sigma = 205 \text{ MPa}$ , limit of strength  $\sigma = 460 \text{ MPa}$  [9]. The mesh of computer model contains 58178 knots and 59277 elements.

The boundary conditions are arranged so that according to them the design of tank is fixed on the lower longerons. Schemes of hydrostatic loading include density of liquid and the operating force vector depending on different modes:

1 and 2 mode – car movement (vertical force =  $9.81 \times m$ , central force =  $0.4 \times 9.81 \times m$ , acting against the course of the movement). Hydrostatic loading of tank including the direction of vector of the operating force at this mode of the movement is shown in Fig. 2.

3 mode – turning right (vertical force =  $9.81 \times m$ , cross force =  $0.4 \times 9.81 \times m$ , the acting on the left, central force =  $0.4 \times 9.81 \times m$ , acting in the direction of movement);

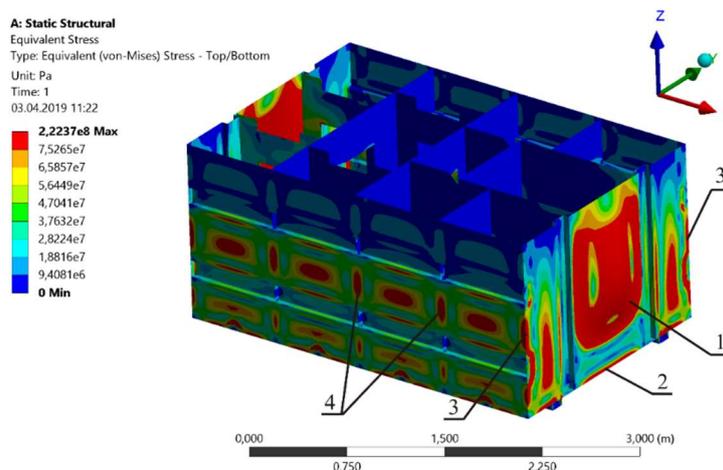
4 mode – emergency braking (vertical force =  $9.81 \times m$ , central force =  $0.7 \times 9.81 \times m$ , acting in the direction of movement) [10].



**Figure 2. Hydrostatic loading of car movement mode**

The testing procedure of vibration measurements are described in [6, 7]. Studies were conducted by the «Larson Davis 2900» noise and vibration analyser. In order to obtain the maximum values of the mechanical tension that the tank construction experiences during movement, the calculation was performed for the mode with the highest (in absolute value) fixed acceleration value ( $a = 25,2 \text{ m} / \text{s}^2$ ), which corresponds to the movement of the tank truck on uneven back roads with the speed of  $25 \pm 5 \text{ km} / \text{h}$ . Accounting for this value in the «Hydrostatic Acceleration» settings.

Taking into account all settings of computer model the calculation is carried out. Analysis of the distribution of equivalent voltage fields according to von Mises distribution allowed determining the areas experiencing the greatest stress-strain state (Fig. 3). These areas correspond to the corner welded joints of the foam box to the front wall of the tank, where  $\sigma_{\max} = 128 \pm 11 \text{ MPa}$ ; corner welded joints of the lower and front walls of the tank, where  $\sigma_{\max} = 148 \pm 10 \text{ MPa}$ ; corner welded joints of the front, rear and side walls of the tank, where  $\sigma_{\max} = 193 \pm 14 \text{ MPa}$ ; corner welds of transverse breakwaters to the side walls of the tank, where  $\sigma_{\max} = 181 \pm 12 \text{ MPa}$ . The obtained results correspond to the available information on problem areas in the construction of this tanks type.



**Figure 3. Von Mises distribution of equivalent stress fields in the tank design of a fire truck based on the MAZ-6317 chassis:**

**1 – corner weld of the foam box to the front wall, 2 – corner weld bottom and the front wall, 3 – corner weld of front and side walls, 4 – corner weld of transverse breakwaters to side walls**

### 3. Ways to modernize the design

As the practise shows, leakages in the tank design of a 12 m<sup>3</sup> fire truck based on the MAZ-6317 chassis most often appear in the corner welds of the front, rear and side walls of the tank and in the corner welds of the transverse breakwaters to the side walls of the tank. Based on the results obtained by computer simulation using ANSYS software package, the design calculations for reducing the stress level in these areas are presented (Fig. 4).

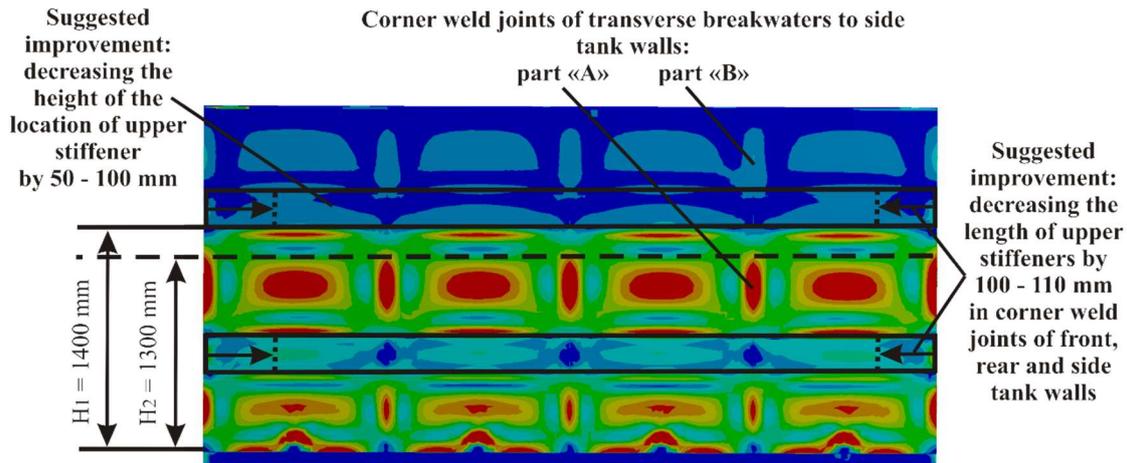


Figure 4. Von Mises distribution of equivalent stress fields on the side wall of fire truck tank based on the MAZ-6317 chassis

In order to reduce the estimated von Mises equivalent stress in the corner welds of the front, rear and side walls, it is proposed to reduce the length of the stiffeners on the side walls of the tank, making them without contact with the front and rear walls. A comparative analysis of von Mises equivalent stress calculations is shown in Fig. 5. It was found that the optimum distance from the corner welds of the front, rear and side walls of the tank before the beginning of the stiffeners on its side walls is about 100-110 mm, whereby the stress level will decrease by 36 % ( $69 \pm 7$  MPa).

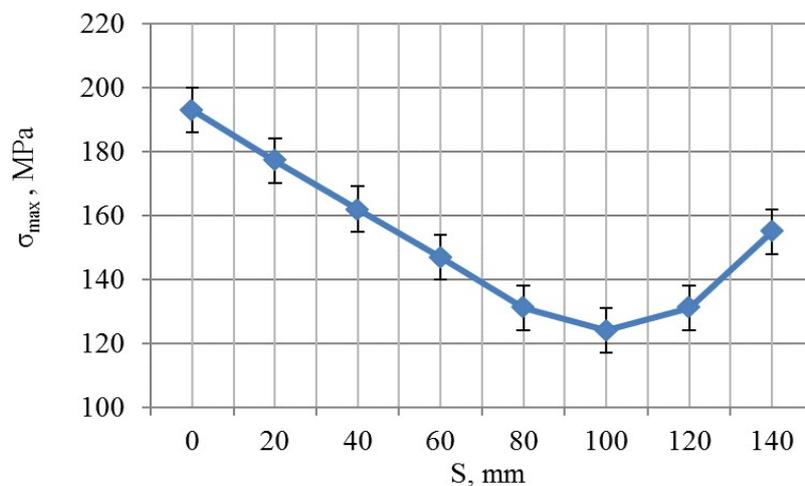
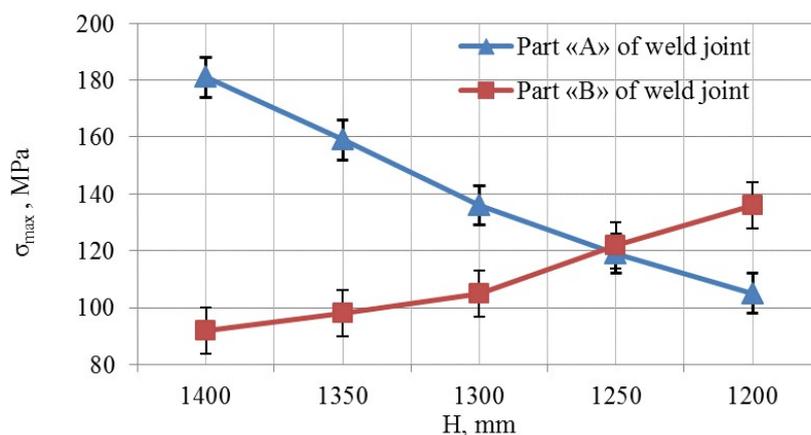


Figure 5. The dependence of the von Mises equivalent stress on the distance between the corner welded joints of the front, rear and side walls and the stiffeners on the side walls of the tank

In order to reduce the calculated von Mises equivalent stresses in the corner welds of transverse breakwaters to the side walls of the tank of a fire engine, the optimization of the location of stiffeners on its side walls was carried out. Thus, the optimization of the height of the upper stiffener from  $H_1 = 1400$  mm to  $H_2 = 1300$  mm helps reduce the resulting von Mises equivalent stresses by 25 % ( $45 \pm 6$  MPa) in part «A» of the corner weld of transverse breakwaters to the side walls. At the same time, in part «B» of this welded joint, the growth of stresses is by 12 % ( $13 \pm 3$  MPa). A further decrease of the height of the upper stiffener contributes to the critical increase in stresses in the area «B» of the welded joint (Fig. 6).



**Figure 6. Dependence of the height of the location of the upper stiffener on the side walls of the tank of a fire truck based on the chassis of the MAZ-6317 on the resulting equivalent von MISES stresses in corner welded joints of the transverse breakwaters to the side walls**

The research to optimize the components of structural elements has significantly reduced the stresses in the control points of the tank structure. The described methodological approach makes it possible to effectively evaluate and predict the operational reliability of the studied structure in a whole as well as its individual elements. Conducting a detailed analysis of the results of computer modelling at the design stage allows evaluating and predicting the state of the calculated structure depending on the different operating modes, and also makes it possible to develop the necessary structural changes [11].

#### 4. Conclusion

A new technique that allows designing elements and components of shell-type structures, in particular, fire-fighting vehicle tanks has been developed. The distinctive feature of the technique is in computer modeling of main operational modes of the target construction including the experimental data by the vibrodiagnostic complex. The results of the calculation make it possible to estimate with high accuracy the influence of dynamic force during the movement of a fire engine on the stress-strain state of the tank structure. There has been established a correlation of the dimensional factor of the structural elements of a 12 m<sup>3</sup> tank of a fire engine on the MAZ-6317 chassis on the stress-strain state. The design calculations were carried out in order to reduce mechanical stresses arising during operation. As a result, stiffeners on the wall's side of the fire engine tank were optimized. Comprehensive practical implementation of the development at the production plant of fire fighting equipment LLC «POZHSNAB», located on the territory of the Republic of Belarus, made it possible to increase the safety margin by 30-35% of tanks with a volume of 12 m<sup>3</sup> of fire-fighting vehicles.

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