Scientific Journal of Silesian University of Technology. Series Transport
Zeszyty Naukowe Politechniki Śląskiej. Seria Transport

Volume 118 **2023**

p-ISSN: 0209-3324

e-ISSN: 2450-1549

DOI: https://doi.org/10.20858/sjsutst.2023.118.11

Journal homepage: http://sjsutst.polsl.pl

Article citation information:
Lyashuk, O., Levkovych, M., Vovk, Y., Gevko, I., Stashkiv, M., Slobodian, L., Pyndus, Y. The study of stress-strain state elements of the truck semi-trailer body bottom. *Scientific Journal of Silesian University of Technology. Series Transport*. 2023, **118**, 161-172. ISSN: 0209-3324. DOI: https://doi.org/10.20858/sjsutst.2023.118.11.

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THE STUDY OF STRESS-STRAIN STATE ELEMENTS OF THE TRUCK SEMI-TRAILER BODY BOTTOM

Summary. Research on the influence of geometric parameters of body bottom elements on the stress-strain state (SSS) of the truck with the general application of computer simulation methods was conducted. The nature of the change in static stress and displacement depending on the change in the proportions of the cross-section of the channel at fixed geometric dimensions of the workpiece and the thickness of the workpiece and the bottom material of the body has been studied. Analytical, numerical and experimental methods were used in the study of the stress-strain state of the metal structure of car bodies. Its weight minimization is

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an important aspect of a truck body design. Because an excess weight leads to increased production costs, reduced payload and reduced fuel efficiency. According to the concept of weight reduction with the provision of a given strength, the body model with variable parameters of the bottom elements is modelled and analyzed. CAD - body models and analysis of the stress-strain state of the channels of the bottom of the bodies have been performed using the software package SolidWorks.

Keywords: semi-trailer body bottom, channel, scan, static stress, static displacement, cad model

1. INTRODUCTION

Lately, the volume of road transportation has significantly increased. Moreover, the share of road transport compared to other modes of transport is constantly growing. This has led to a sharp increase in the number of the freight vehicle fleet and an expanded range of design solutions used.

In recent years, Ukraine has witnessed a steady trend increase in the volume of transportation of goods by road [1]. Increasing the reliability, manufacturability, and load capacity while reducing metal consumption and increasing the service life of vehicles provides the necessary competitiveness in the freight market [2].

The body of a truck semi-trailer is the main part of a vehicle, which contains a series of channels made of mild steel or aluminium sheet metal. Most units of process equipment focus on the design of the truck body with various modifications required to minimize stress and increase the load factor. When designing the body, it is necessary to consider the operating stresses and material properties.

When designing a truck body, it is important to minimize its weight. Because excess weight leads to increased production costs, reduced payload and reduced fuel efficiency.

During the operation of trucks, their bodies (Figure 1a) fail rather quickly due to the accumulation of operational damage and extreme impacts. Often, the analysis of the truck’s condition reveals that the frame of the semi-trailer is in a satisfactory condition, and the body elements already contain cracks and have excessive deformation. [3-7].

Non-invasive diagnostic methods can be used to identify damage. Such methods include vibroacoustic methods. For example, they are successfully used in the diagnosis of damage to drive system components. [8-11].

Given the high intensity of the wear of the truck bodies, there is a constant need to restore their damaged elements or replace excessively damaged bodies with new ones [12-14].

Therefore, there is a need to optimize the design of the body, which allows for maximizing load capacity and improving strength, reducing weight, and extending service life.

In most designs of semi-trailers of trucks, the lower part of the bottom of the body is made in the form of a series of transverse channels covered with sheet material (Figure 1b). Hence, optimizing the design of the channel of the lower part of the bottom of the body by analysing models of elements with different design parameters is an urgent task [15-18].

(a) (b)

Fig. 1. The appearance of the truck body: (a) – general view; (b) – the bottom body view

2. METHODOLOGY OF RESEARCH

Analytical, numerical and experimental methods were used in the study of the stress-strain state (SSS) of load-bearing metal structures of truck bodies.

The analytical method is designed to determine the VAT of rod structures and is based on the principles of structural mechanics and resistance of materials. Usually, the hypothesis of flat sections is used. This method is used for preliminary and design calculations required for the selection of rational parameters of metal elements.

It is quite difficult to study spatial metal structures using analytical methods, and given the difficult configuration of the geometry of their elements, it is often simply impossible. This is due to the need to solve a large number of differential equations of the theory of elasticity. The ability to analyse the impact of individual elements on the result and the ability to find the optimal solution are the main advantages of this method.

The numerical method of SSS determination is based mainly on the finite element method (FEM). It allows the calculation of elements of complex configuration with any type of load. If necessary, it is possible to include various kinds of nonlinearities (geometric, physical).

When designing the bottom of the body of a semi-trailer truck, the dimensions of the channels, material, their location and quantity are important. According to the concept of weight reduction with the provision of a given strength, the body model with variable parameters of the bottom elements is modelled and analyzed using CAD-body models, and an analysis of SSS channels of the bottom of the body was performed using the software SolidWorks. Figure 2 shows a CAD model of a truck semi-trailer body.

The channels are made by bending blanks cut from steel sheets with dimensions of 2500 × 1250 mm and a thickness of 3 to 5 mm. Accordingly, the optimal cutting width of the workpiece from such a sheet will be 250 mm. The scan of the channel blank (t = 5 mm, b = 50 mm, h = 165.37 mm) is shown in Figure 3, and the channel obtained after bending the scan is shown in Figure 4.

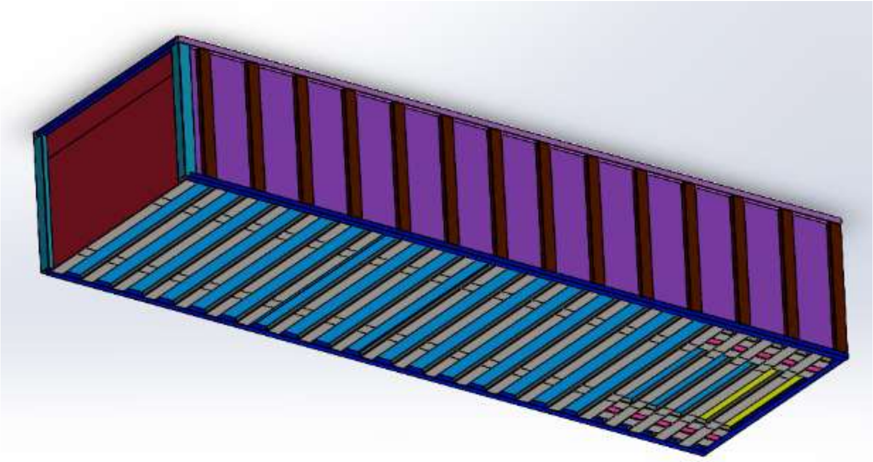


Fig. 2. The construction of the lower part of the body

Fig. 3. The channel scan ($t = 5$, $b = 50$, $h = 165.37$)

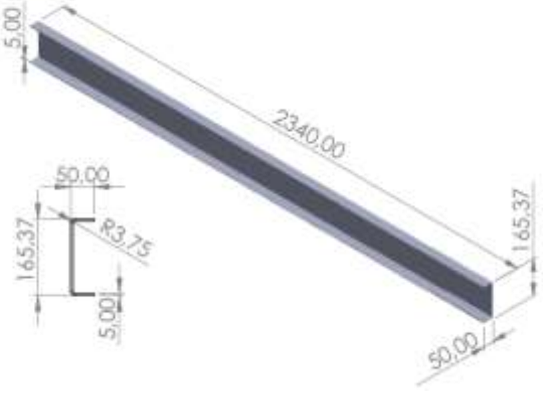


Fig. 4. The dimensions of the channel obtained from the scan (Fig. 3)

The study was performed for bent channels made of sheet material with a thickness of 3, 4 and 5 mm. The width of the shelf was 50, 55 and 60 mm. For different combinations of these parameters, the current value of the channel wall height was calculated under the condition of a fixed workpiece width of 250 mm. All combinations of channel sizes are given in Table 1.

Tab. 1

The dimensions of the channel depending on
the thickness and width of the shelf

Strip thickness *t*, mm	Shelf width *b*, mm	Channel height *h*, mm	Rounding radius *R*, mm
3	50	160.0	3.75
	55	151.0	3.75
	60	140.0	3.75
4	50	163.0	3.75
	55	153.0	3.75
	60	143.0	3.75
5	50	165.4	3.75
	55	155.4	3.75
	60	145.4	3.75

CAD - models of the channels for SSS research are created according to the sizes in Table 1. A grid of finite elements with a global size of 30 mm and a tolerance of 1.5 mm was constructed for all models (Figure 5).

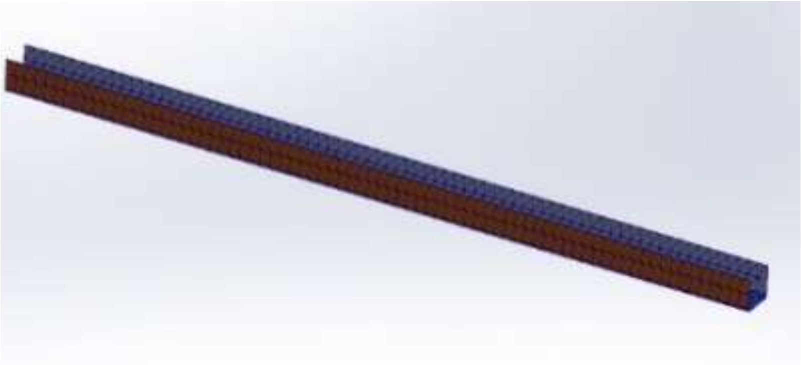


Fig. 5. The grid of finite elements on the channel model

The conditions of application of the load are shown in Figure 6. The applied transverse force P = 7700 N, material - steel St 3 according to GOST 380-88 (yield strength σ_T = 206.81 MPa, strength limit σ_B = 517.02 MPa).

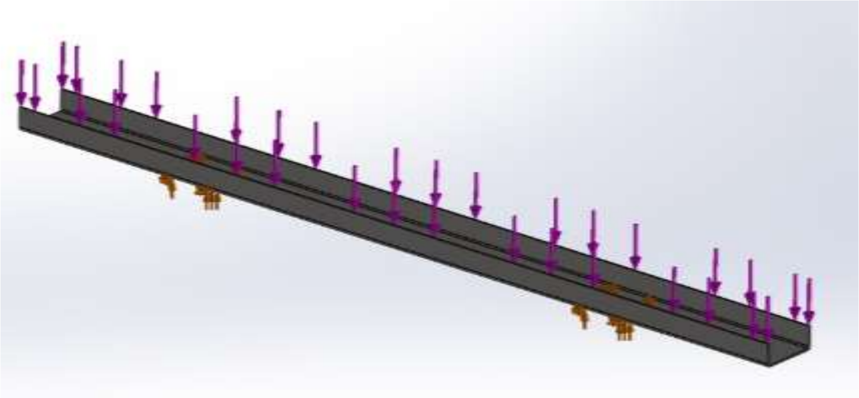


Fig. 6. Conditions for applying the load and fixing the element

3. RESULTS AND DISCUSSION

A CAD-body model was created to study the stress-strain state (SSS) of the body bottom, Figure 7. The applied force on the object was P = 200 kN and the material is a steel of ordinary quality, GOST 380-88.

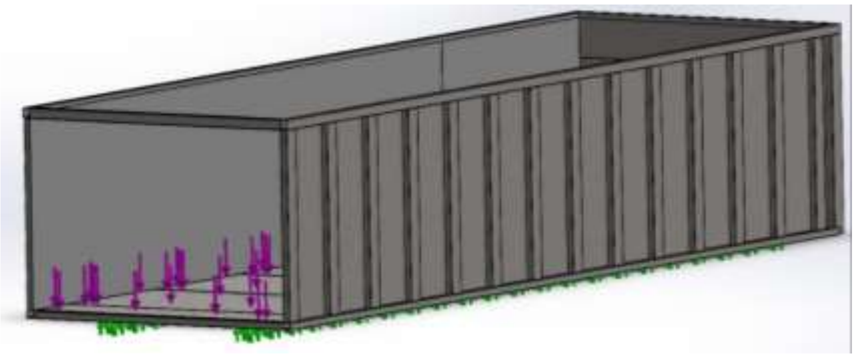


Fig. 7. CAD - body model

The change in the thickness of the sheets in the range from 3 to 5 mm was carried out during the study of the body bottom. Figure 8 shows the layout of the channels.

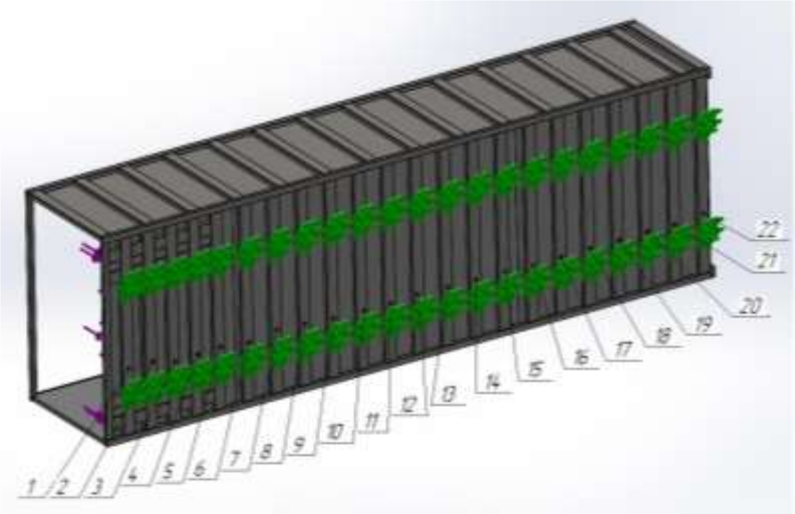


Fig. 8. Layout of channels

The obtained results are presented in Figures 9-11 and Table 2.

The analysis of the SSS channel models was performed using the Simulation module of the SolidWorks software package. General view of the study of the SSS channels with parameters 3 <*t* <5 (mm), 50 <*b* <60 (mm), 140 <*h* <160 (mm) is given in Figures 12-14. Summary results of the research are given in Table 3.

Based on the obtained results, the dependence of the static stress in the channels of the body bottom depending on the wall thickness of the channel and the thickness of the sheet of the body bottom was constructed (Figure 15).

Tab. 2

Estimated static stresses acting on the channel, MPa

Channel wall thickness, t = 3 mm	Bottom sheet thickness, mm	Channel position										
		1	2	3	4	5	6	7	8	9	10	11
	t=3	48.7	26.5	23.9	23.0	23.7	24.0	24.2	24.3	25.3	25.1	25.6
	t=4	47.3	25.3	22.9	22.2	22.8	23.5	23.8	24.2	24.6	24.7	25.1
	t=5	45.2	24.7	22.3	21.6	22.4	23.1	23.5	23.9	24.3	24.4	24.8
	Bottom sheet thickness, mm	Channel position										
		12	13	14	15	16	17	18	19	20	21	22
	t=3	26.1	26.3	26.8	27.5	28.1	28.5	29.4	30.7	31.1	31.3	27.7
	t=4	25.3	25.8	26.3	27.1	27.3	27.6	28.6	29.4	29.8	30.2	26.8
	t=5	24.9	25.4	25.8	26.5	26.7	27.1	27.9	28.7	28.9	29.4	25.8

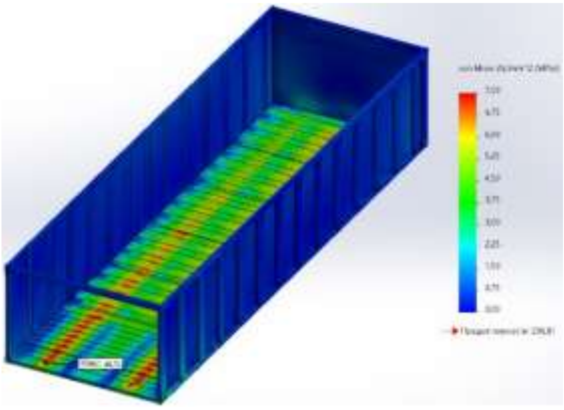


Fig. 9. Static stress acting on the channel No.1 (t_{ch} = 3 мм, $t_{s.bot}$ = 3, σ_T = 206.8 MPa)

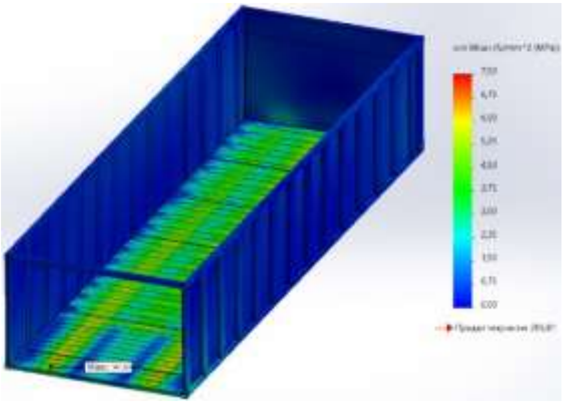


Fig. 10. Static stress acting on the channel No.1 (t_{ch} = 3 мм, $t_{s.bot}$ = 4, σ_T = 206.8 MPa)

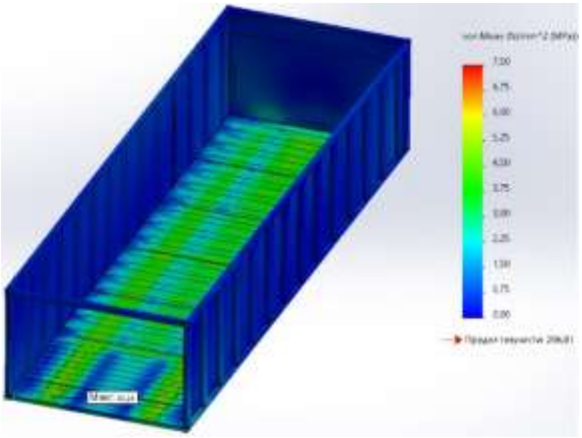


Fig. 11. Static stress acting on the channel No.1 (t_{ch} =3 мм, $t_{s.bot}$ =5, σ_T=206.8 MPa)

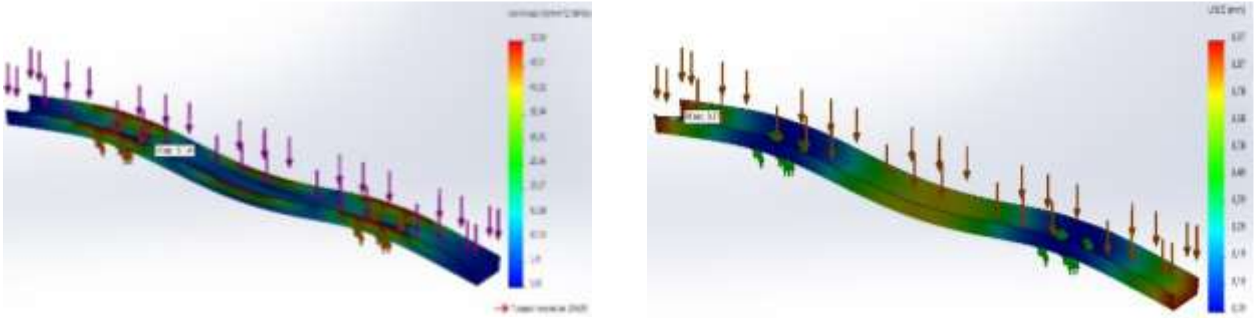

(a) (b)

Fig. 12. SSS channel at *b* = 50 mm, *t* = 5 mm; *a* - static stress; *b* - static displacement

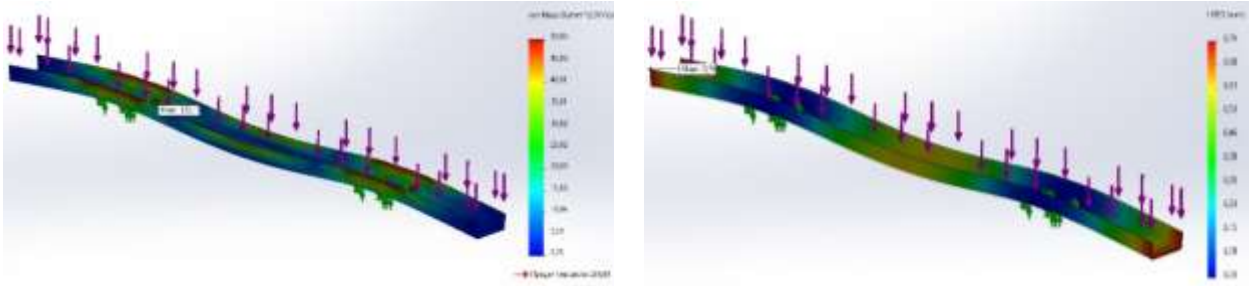

(a) (b)

Fig. 13. SSS channel at *b* = 55 mm, *t* = 5 mm; *a* - static stress; *b* - static displacement

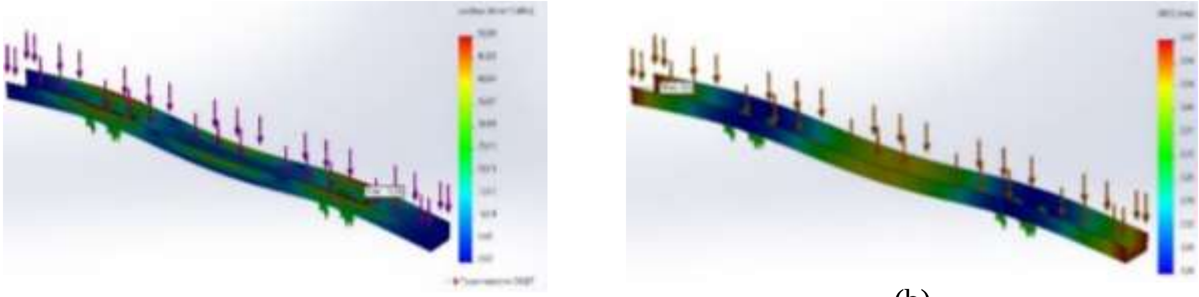

(a) (b)

Fig. 14. SSS channel at *b* = 60 mm, *t* = 5 mm; *a* - static stress; *b* - static displacement

Tab. 3

The results of the study of the SSS elements of the bottom of the body

Channel thickness t, mm	Channel shelf width b, mm	Static stress, MPa	Static displacement, mm	Strength margin coefficient
3	50	266.61	1.59	0.77
	55	241.0	1.27	0.83
	60	214.48	1.02	0.96
4	50	199.97	1.2	1.03
	55	176.51	0.96	1.17
	60	157.78	0.77	1.31

5	50	151.41	0.97	1.36
	55	133.17	0.76	1.55
	60	119.38	0.62	1.73

The nature of the stress change in the channels of the body bottom of the semi-trailer in general can be described by the equation:

$$\sigma_T(x) = 3\cdot10^{-5}x^6 - 0.0027x^5 + 0.0856x^4 - 1.329x^3 + 10.591x^2 - 39.905x + 77.394 \quad (1)$$

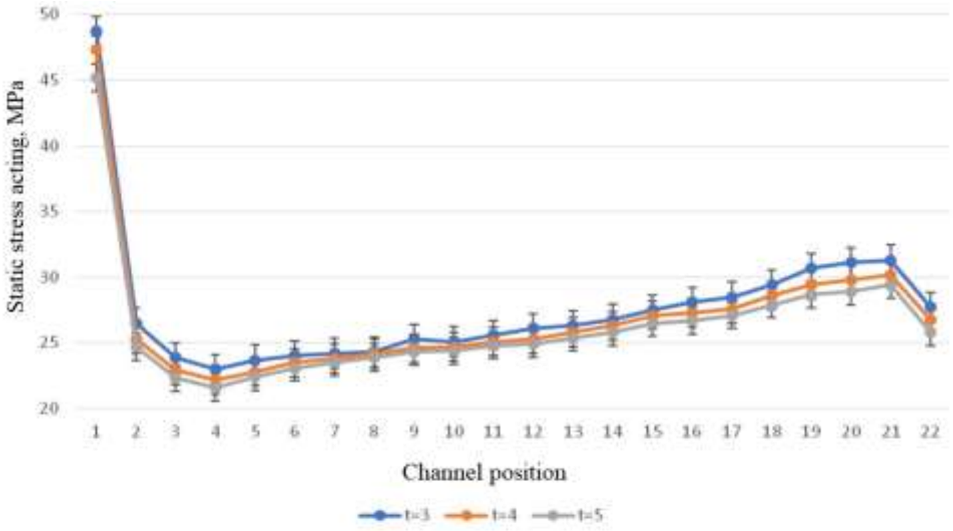
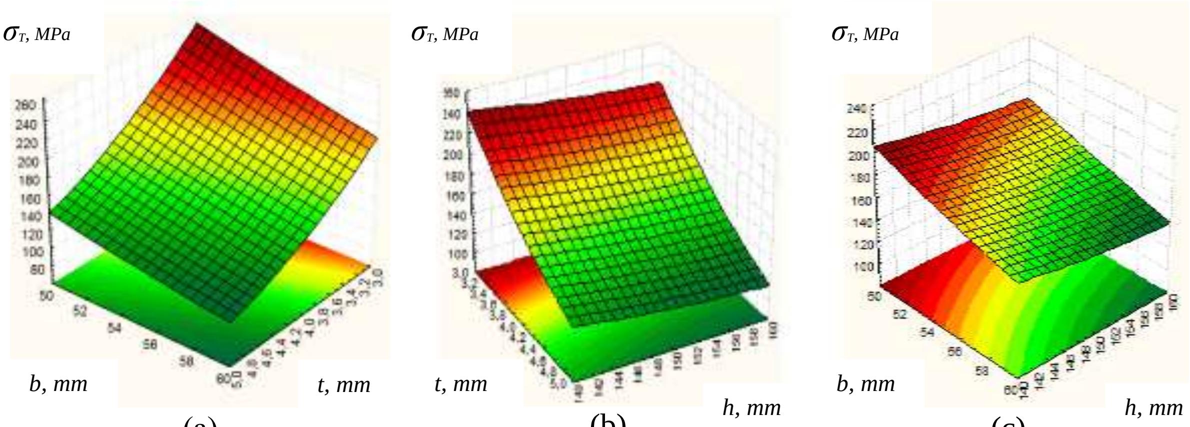


Fig. 15. Static stress in the channels of the body bottom depending on the wall thickness of the channel and the thickness of the sheet of the body bottom (t_{ch} =3 мм, $t_{s.bot}$ =3-5, σ_T=206.8 MPa)

Based on the obtained experimental data, statistical processing of the data set using well-known methods of correlation and regression analysis to obtain, ultimately, the empirical regression equation and response function (optimization parameter). Figure 16 shows the graph-analytical results of the change in static stress $\sigma = f(b, t, h)$ from changes in the thickness of the strip t, mm, shelf widths b, mm and channel height h, mm.



(a) (b) (c)

Fig. 16. The dependency response surfaces: (a) $\sigma = f(b, t)$; (b) $\sigma = f(t, h)$; (c) $\sigma = f(b, h)$

It was established that the predominant factors influencing the static stress σ are the thickness of the strip t and shelf widths b, but channel height h has less influence. The factor field has been determined by the range of parameter changes: $3< t <5$ (mm), $50< b <60$(mm), 140< h <160 (mm).

4. CONCLUSIONS

The analysis of the SSS of channels of a truck semi-trailer body bottom based on the developed CAD - model of channels allows:

- to investigate the character of stresses distribution in the elements of a bottom of a body;
- to establish dependences of level of stresses and deformations of elements of channels of a bottom of a body on their thickness and width of the shelf;
- identify the most dangerous bearing capacity of the truck semi-trailer body bottom.

It has been outlined that the predominant factors influencing the static stress σ are the thickness of the strip t and shelf widths b, but channel height h has less influence. The factor field was defined by the range of parameter changes: $3 < t <5$ mm, $50 < b < 60$ mm, 140 < h <160 mm. The obtained results are the basis for making engineering decisions to improve the design of the bottom of the truck semi-trailer body bottom.

The obtained results are the basis for making engineering decisions to improve the design of the body bottom of the semi-trailer truck, which allows maximisation of the load capacity, improved strength, reduced weight and extend service life.

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Received 20.10.2022; accepted in revised form 22.12.2022