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Strength Characteristics of the Carcass of the Cabin the Tractor in Shock Loads

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Abstract: ***In The Article The Method Of Calculation Of The Bending Moment And Curvature In The Plastic Zone Of Elastoplastic Calculation Of The Carcass Of The Cabin Of Tractor And On The Basis Determined By The Strength Characteristics Of The Carcass For The New Cabin Cotton-Growing Tractors Of The Class 1.4.***

Key Words: Tractor, Cabin, Carcass, Strength, Passive Safety, Elastoplastic Calculation, Bending Moment, Effort, Deformation

I. INTRODUCTION

When designing a new wheeled vehicle, requirements are imposed on the elements of passive safety and comfort in the construction of this machine. The elements of passive safety in the tractor are contained in the tractor cabin. Therefore, one of the most important requirements for the cabin is to ensure passive safety, i.e. safety of the operator in the event of an accident and overturning.

The passive safety of the new technics is usually evaluated by the experimental data obtained by testing the real samples in the process of applying the corresponding normalized loads. However, this way is very laborious, so there is a need for a calculation methodic, with which one could evaluate the shock and strength properties of the cabin at the design stage, making the necessary changes in the design before creating prototypes.

When developing the calculation methodic, it is necessary to take into account the development of computerization and the achievement of fundamental sciences that make it possible to solve rather accurately the objectives of calculating the strength of complex designs of parts and components of tractors and other mobile machines that are subject at exploitation to accidental loading.

II. SYSTEM DESCRIPTION

In this paper, we propose a technique for calculating the bending moment and curvature in the plastic zone of the Elastoplastic calculation of the carcass of the tractor cab and on its basis the strength characteristics of the carcass of the cabin for new cotton-growing tractor of the class 1.4.

A spatial model of framework constrution is considered, in which the element of the spatial rod is considered as an element Fig. 1 (a) and (b). The element consists of two nodes in the figures, they are designated as *i* and *j*.

In the elastoplastic calculation of the spatial model of the rod, in solving the inverse objective, a bending moment is determined that has two limits- current and ultimate , respectively, M_{cur} and M_{ult}. By these limits, one can judge when the fluidity of the material of the construction and the limiting state begin.

For the elastic zone, the calculation is carried out according to known methods [1,2,3].

neutral axis is equal to χ_x [1].

$$\chi_x = \frac{EJ}{M_x} \tag{1}$$

In this case, the relative elongation is of the fiber at a distance y from the neutral layer is equal to

$$\varepsilon = \frac{y}{\chi} \tag{2}$$

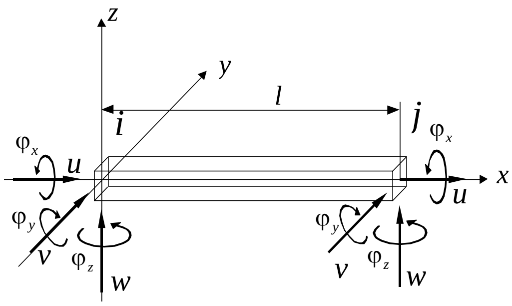
The magnitude of the bending moment at which the fluidity begins is calculated by formula

$$M_{cur} = \sigma_{cur} \frac{J_x}{c} \tag{3}$$

where J_x is the moment of inertia of the cross-sectional area of the joist relative to its neutral axis; *c* - is the distance from this axis to the farthest fiber of the joist; σ_{cur} – is the yield strength of the material, which is a reference value.

For a rectangular section of a hollow rod, the magnitude of the bending moment will be

$$M_{cur} = \sigma_{cur}\left(\frac{bh^3}{12} - \frac{b_1h_1^3}{12}\right)\frac{2}{h} \tag{4}$$



a)

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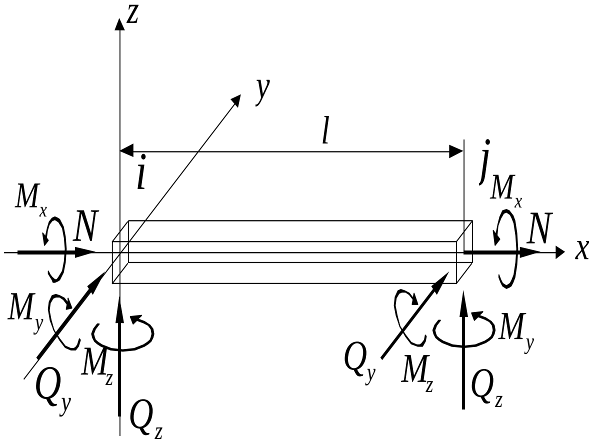

b)

Fig.1. Spatial finite element of the rod

a) - displacements and angles of rotation of the nodes of the rod; b) - the action of transverse forces and bending moments

Suppose that the radius of curvature of the neutral layer under the action of the bending moments M_x along the

As the bending moment is increased beyond the value of M_{cur}, the fibers near the upper and lower surface of the joist begin to experience a state of fluidity. Plastic deformations penetrate deeper into the joist at a depth of e with increasing bending moment. For each value e of the depth of this propagation, the corresponding bending moment

$$M = \sigma_{cur}\left(\frac{bh^2}{12} - \frac{b_1 h_1^2}{12}\right)\left[1 + \frac{2e}{h}\left(1 - \frac{e}{h}\right)\right]$$

(5)Using equations (1) and (4), the relationship between the bending moment M and the curvature $1/\chi$ can be represented graphically “Fig. 1”.

Up to the value $M = M_{cur}$, the deformation is elastic and the curvature increases proportionally to the bending moment. When M increases in M_{cur}, the relationship between M and $1/\chi$ becomes nonlinear. The curve becomes steeper as the depth e of propagation of plastic deformation approaches the value $h/2$. Substituting $e = h/2$ into expression (4) we obtain the highest value of the bending moment

$$M_{ult} = \sigma_{cur}\left(\frac{bh^2}{4} - \frac{b_1 h_1^2}{4}\right)$$

(6)

In Fig. 2 shows the bending diagram for different values of exponents n.

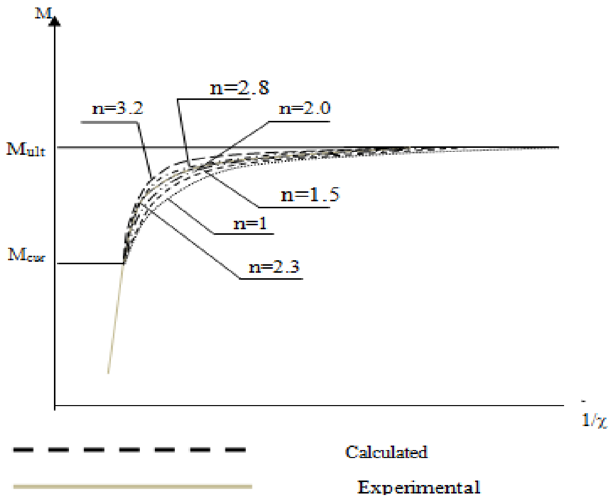

Fig. 2 . The diagram of the rod bending with various exponents of the degree *n*.

The M_{ult} value determines the position of the vertical asymptote to the curve. When M approaches M_{ult}, a small increase in M causes a large increase in the curvature, so that M_{ult} leads to complete destruction of the joist.

For $M > M_{cur}$, the bending moment is determined by the following formula:

$$M = M_{cur} + \left(M_{ult} - M_{cur}\right) \cdot e^{\left(\frac{1}{n}\right)} \qquad (7)$$

where n is the exponent in the approximate equation.

The radius of curvature χ can be determined depending on the bending moment $\chi = \chi(M)$..

In [3, 4], the radii of curvature χ are determined respectively in the form:

$$\frac{1}{\chi} = \frac{M_{cur}}{EJ_x\sqrt{3 - 2\frac{M}{M_{cur}}}} \quad \text{and}$$

$$\frac{1}{\chi} = \sqrt{\frac{b\sigma_{cur}^3}{12E^2\left(bh^2\sigma_{cur} - M\right)}}$$

(8)

In connection with the impossibility of adjusting these dependences with the experimental bending diagram, we propose the following dependence of the radius of curvature χ [5]:

$$\frac{1}{\chi} = \frac{M}{EJ \cdot \sqrt{1 - \left(\frac{M - M_{cur}}{M_{ult} - M_{cur}}\right)^n}}$$

The analysis of the graphs shows that the graph corresponding to the value of n = 2, 3 is quite well combined with the experimental graph.

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III. SIMULATION RESULTS

The proposed model became the basis of elastoplastic calculation of the carcass of the cabin of the new tractor increased comfort for new cotton tractors TTZ 811 [6]. A feature of the carcass of the cabin is the use of elements with a special profile, the cross section of which is shown in Fig. 3.

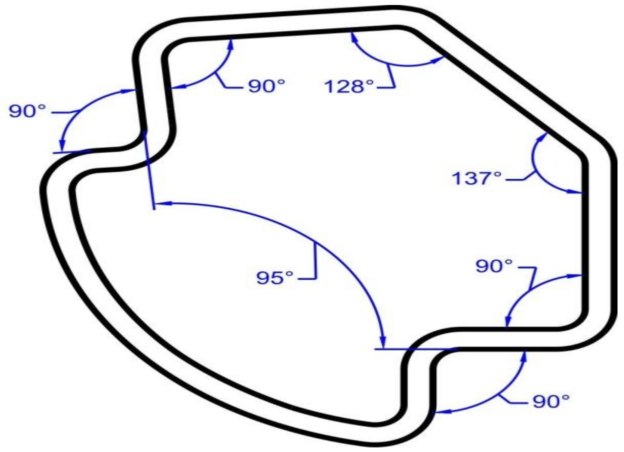

Fig. 3. Cross-section of the frame profile of the frame of the tractor cabin of class 1.4

To solve the model of elastic-plastic calculation, a package of applied computer programs was developed in the "QuickBASIC-4.0 (4.5)" environment, based on the finite element method [7,8].

The package provides for the creation of DXF-files for connecting CAD program files.

All modules have commented source programs. The individual modules of the system are connected by data files, i.e. the output files of one module are the input files of other modules.

In the first module, we indicate the address of the folder where the files will be saved during the calculation.

In the second module we will create the file « tablica » , displaying the coordinates of the nodal points of the tractor frame. After the tablica file has been created , it is necessary to run the epura file in the Visual Basic environment in the AutoCad application , the coordinates of the construction points are written .In the third module, we systematize coordinate data obtained from AutoCad .

In the fourth module, we create the file set _ ram , which serves to create a file with new source data. This file records how many nodes are contained in the structure , the physicomechanical properties of the sections of the beams that make up the structure , the orientation unit, the number of divisions, and the type of section are indicated .

In the fifth module, specify the nodes that will be fixed.

In the sixth module, you can view the design diagram .

The seventh module indicates the breakdown of the load into parts and the percentage of the applied force used to calculate

The eight modules manufactured linear and non-linear calculation s design depending on the task.

In the ninth, you can view the calculation results .

After completing all the work on the calculation, select the item “End of calculation”.

Using the developed package, the following issues were considered [9]:

- deformation of the carcass of the construction depending on the load for different values of the exponent *n*;
- deformation of the structure of the carcass of the cabin with the proposed profile and quadrangular profile of batch production;
- the effect of changing the rigidity of the carcass of the construction on its deformation.

In table-I shows the results of deformation of the carcass of the construction depending on the load for various values of the exponent *n*.

Analysis of the results shows the importance of the correct choice of the exponent *n*.

For example, for n = 1.0, the deviation from the experimental data was 9%; at n = 3.2, the deviation from the experimental data was 19%; at n = 2,3 deviation from the experimental data was 7%.

Analysis of the results of theoretical calculations and experimental data shows that the general deformation from the experimental data is 230 mm, the residual 90 mm; according to theoretical studies, when n = 2,3, respectively, 226 and 97 mm. The maximum discrepancy is 12%. The average difference is 8% [10].

Table - I: Propagation of deformation D in the construction of the carcass of the tractor cab for different exponents n of the degree.

Effort F, kH	Deformation D, mm							
	For n=1	For n=1.5	For n=2.0	For n=2.3	For n=2.5	For n=2.8	For n=3.2	For n=exper.
0	0	0	0	0	0	0	0	0
4	13.56191	13.56191	13.56191	13.56191	13.56191	13.56191	13.56191	10.12
8	27.08998	27.08998	27.08998	27.08998	27.08998	27.08998	27.08998	20
12	40.5798	40.5798	40.5798	40.5798	40.5798	40.5798	40.5798	40
16	54.02708	54.02708	54.02708	54.02708	54.02708	54.02708	54.02708	50
20	67.42754	67.42754	67.42754	67.42754	67.42754	67.42754	67.42754	60

24	82.50617	82.35628	82.2944	82.27357	82.26348	82.25224	82.24225	80
28	101.4104	100.6427	100.3577	100.2669	100.225	100.1819	100.1524	100
32	125.1212	123.9907	123.7435	123.8372	123.9639	124.2111	124.6004	120
36	158.0569	158.0437	159.0768	160.0428	160.7965	162.0298	163.7814	150
40	212.9908	218.1378	224.188	228.2805	231.1966	235.7569	242.0418	210
36	200.2134	205.3814	211.4549	215.563	218.4902	223.0678	229.3766	220
32	187.345	192.5328	198.6284	202.7513	205.689	210.2831	216.6145	230
28	174.3886	179.5951	185.7115	189.8485	192.7961	197.4057	203.7585	220
24	161.3475	166.5716	172.7076	176.8576	179.8146	184.4388	190.8116	210
20	148.225	153.4655	159.6197	163.782	166.7477	171.3855	177.777	180
16	135.0246	140.2804	146.4515	150.6251	153.5988	158.2492	164.6581	130
12	121.7499	127.0198	133.2063	137.3903	140.3714	145.0333	151.4581	120
8	108.4047	113.6874	119.888	124.0813	127.0691	131.7416	138.1808	130
4	94.99279	100.2869	106.5001	110.702	113.6958	118.3776	124.8299	120
0	81.51807	86.82244	93.04675	97.25603	100.2551	104.9453	111.409	90

In table II shows changes in deformations in the carcasses of the cabin the tractor with the proposed profile and a quadrilateral profile of batch production.

Table- II: Differences in deformations D of the new and serial carcass of the cabin the tractor

Effort F, kH	Deformation D, mm	
	Proposed frame	Existing frame
0	0	0
10	16.2948	13.40482
20	32.60843	26.77657
30	48.93625	40.11102
40	65.27364	53.40397
50	83.70586	66.65134
60	106.2578	81.22615
70	130.0402	98.63092
80	156.8714	121.,956
90	189.0133	158.092
100	227.653	227.051
90	211.6151	214.4775
80	195.5349	201.8123
70	179.4165	189.0582
60	163.2642	176.2184
50	147.0822	163.2959
40	130.8749	150.2941
30	114.6467	137.2164
20	98.40192	124.0662
10	82.14511	110.8472
0	65.88075	97.56319

Dependence analysis showed that the new carcass has a lower residual deformation (by 33.48%). Thanks to this, the new carcass construction absorbs more energy when overturning, thereby maintaining the safety zone.

The rigidity of the carcass construction of the cabin was considered in the following ways [11]:

- Change in the thickness of the wall of the profile of the rod element of the structure;
- Change of the modulus of elasticity of the material of the rod element of the structure;
- Change of the moment of inertia of the cross-section of the rod element of the structure.

The results showed that when the thickness of the profile wall is increased from 3 to 7 mm, the general deformation decreases from 226 mm to 98 mm, and the residual deformation from 74 to 8 mm. However, this leads to an increase in the weight of the joist from 23% to 52%, and because of the carcass of the cabin the tractor as a whole.

Under the rigidity was changed due to a change in the modulus of elasticity, the following values were taken: E = 2.0 GPa; 2.04 GPa; 2.07 GPa; 2.12 GPa; 2.16 GPa, corresponding to St.03, St.09G2, St.22K, St.35L and St.50.

The increase in the modulus of elasticity from 2.0 to 2.16 GPa, reduces deformation from 226 mm to 195 mm, residual deformation from 73.9 mm to 68.5 mm.

The change in the moment of inertia depends on the change in the area of the profile. For analysis, the profiles were taken from a quadrangular, pentagonal and hexagonal shape.

In table-III shows of the calculated dependence of the deformation state for various profiles of the rod elements of the carcass of the cabin the tractor.

Table- III: Dependence of the deformation state for various profiles of the rod elements

Effort F, kH	Deformation D, mm		
	4^{th} profile	5^{th} profile	6^{th} profile
0	0	0	0
4	9.50E-03	8.11E-03	4.02E-03
8	1.90E-02	1.62E-02	8.04E-03
12	2.85E-02	2.43E-02	1.21E-02
16	3.80E-02	0.0324498	1.61E-02
20	4.75E-02	4.06E-02	2.01E-02
24	5.70E-02	4.87E-02	2.41E-02
28	6.65E-02	5.68E-02	2.81E-02
32	7.60E-02	6.49E-02	3.22E-02
36	8.55E-02	7.30E-02	0.0361928
40	9.50E-02	8.11E-02	0.0402142
36	8.55E-02	0.0730116	0.0361928
32	7.60E-02	6.49E-02	0.0321714
28	6.65E-02	5.68E-02	0.02815
24	5.70E-02	0.0486748	2.41E-02
20	4.75E-02	4.06E-02	2.01E-02
16	3.80E-02	3.25E-02	1.61E-02
12	2.85E-02	2.43E-02	1.21E-02
8	1.90E-02	1.62E-02	8.04E-03
4	9.50E-03	8.11E-03	4.02E-03
0	4.82E-07	3.00E-07	3.65E-08

As can be seen from table-III, the profile with the hexagonal shape is stronger than the pentagonal shapes by 20% and the quadrangular shape by 45%.

Analysis of ways to increase the rigidity of the carcass construction showed that increasing the wall thickness of the profile and the modulus of elasticity increases the strength of the carcass, but at the same time the mass increases and the absorptivity of the impact energy deteriorates. A significant effect on the strength of the carcass is due to a change in the profile of the element. It is established that the deformation of the profile with the hexagonal shape is less than the deformation of the pentagonal shape by 20% and the quadrangular shape by 45%.

IV. CONCLUSIONS

Thus, studies have shown that the proposed methodic for calculating the bending moment and curvature in the plastic zone together with known methods for calculating the elastic zone allow the calculation of the deformation of the carcass construction of the cabin the tractor and justify its parameters. The methods are considered for increasing the rigidity of the carcass construction, in particular, increasing the wall thickness, the modulus of elasticity of the material and the section profile of the bar element of the carcass. The methods are considered for increasing the rigidity of the carcass construction, in particular, increasing the wall thickness, the modulus of elasticity of the material and the section profile of the bar element of the carcass. The analysis showed that a significant effect on the strength of the carcass is due to the change in the profile of the element. It is established that the deformation of the profile with the hexagonal shape is less than that of the pentagonal and quadrangular shape.

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