Results of theoretical and experimental data of tractor cabin carcass

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Abstract. In the article results of the comparative analysis of the elastic-plastic calculation of a protective skeleton of a cabin of a tractor based on a method of final elements with the experimental research spent on the cabin of the tractor of class 1.4.are resulted. The carried out research has shown good adequacy of the received theoretical results (the maximum deviation does not exceed 12 %, and an average deviation of 8 %), and the offered technique of elastic-plastic calculation can be applied by working out new designs of a skeleton of cabins of tractors.

1 Introduction

For the competitiveness of their products, domestic manufacturers of agricultural machinery began to develop new equipment models.

When designing any new wheeled vehicle, requirements are imposed on the elements of passive safety and comfort in the design of this vehicle. The tractor's passive safety elements are contained in the tractor cabin. Therefore, one of the most important requirements for the cabin is to ensure passive safety, i.e., operator safety in the event of an accident and overturning. Cabin safety depends on many factors, among which its impact and strength properties take a special place. As an appropriate criterion, a certain volume inside the cabin is taken - a zone of free space into which no structural element should penetrate in an emergency[1].

The passive safety of new technology is usually assessed by experimental data obtained by testing full-scale samples when applying the corresponding normalized loads. However, this path is very time-consuming; therefore, there is a need for a calculation method with which it would be possible to evaluate the shock-strength properties of the cabin at the design stage, making the necessary changes to the design before creating prototypes.

2 Methods

We have developed a numerical method for the elastoplastic calculation of the protective frame of the tractor cab based on the finite element method [2, 3], which allows determining displacements in frame structures through the radius of curvature and bending

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moment, taking into account the variable load, and changing the rigidity of the structure [4-8].

To check the adequacy of the proposed calculation method, the calculations of the tractor cab frame were made and compared with the tests carried out on the 1.4 class tractor cabin.

The calculations were carried out according to the test method and program [9-11]:

- *Blow from behind to the right*.

When testing for rear impact, the tractor must be installed so that at the moment of impact on the corresponding zone of the protective structure of the suspension chain and the impacting plane of the pendulum load are at an angle of 20 ° to the vertical (Figure 1). If the angle exceeds 20 °, then the position of the impacting plane of the load is determined by the calculated maximum deformation.

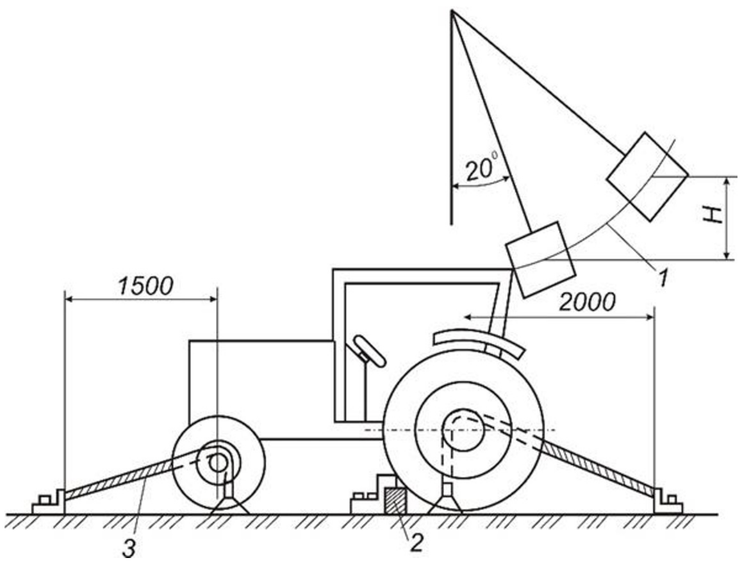

Fig. 1. Tractor fastening diagram during testing: 1 is trajectory of movement of the center of gravity of the pendulum load to the point of impact; 2 is a beam of coniferous wood with a cross-section of 150x150 mm installed in front of both wheels after tensioning the cables; 3 is position of the cable with a tensioner

- *Blow from the side to the left*.

For a side impact, the direction of impact must be horizontal. The tractor is installed so that at the moment of impact, the load's suspension chain and impacting plane must be vertical (Fig. 2).

If the structural elements are not vertical, then the adjustment of the position of the impacting plane of the load is determined by the calculated maximum deformation.

The impact shall be on the uppermost side member in a vertical plane perpendicular to the longitudinal plane of symmetry of the tractor and 60 mm forward and from the seat reference point (SRP).

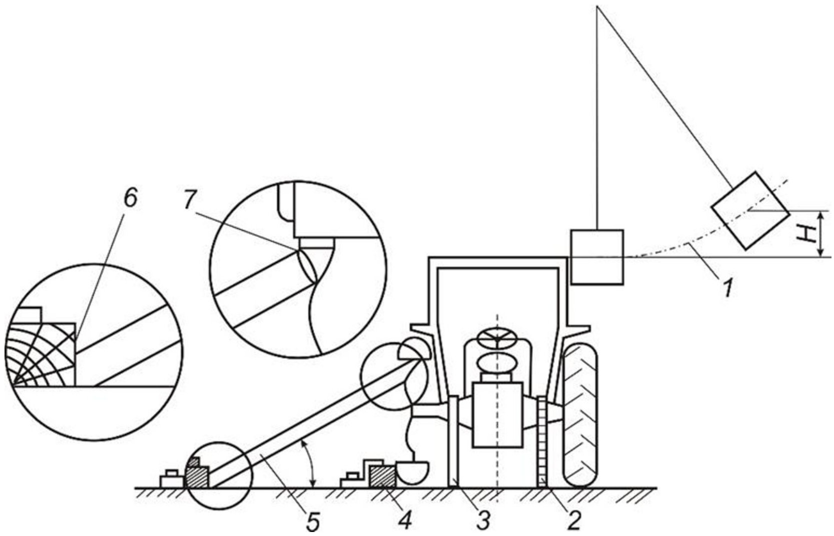

Fig. 2. Tractor fastening diagram for side impact tests: 1 is trajectory of movement of the center of gravity of the pendulum load to the point of impact; 2 is stretched cable; 3 is loose cable; 4 is coniferous timber with a cross-section of 150x150 mm; 5 is support; 6 is bevel; 7 is chamfer for secure installation of the support to the rim

- *Vertical static loading from the front.*

The loading beam should be positioned across the rear highest structural members, with the resultant force being applied in the vertical main plane (figure 3). Force applied $F = 20\,mt$.

This force must act within 5 s after the termination of any visually detectable movement of the elements of the protective structure.

- *Vertical static loading from behind.*

The loading beam should be across the front highest elements of the protective structure, while the equal force should be in the vertical main plane (figure 3). Force applied $F = 20\,mt$

This force must act within 5 s after the termination of any visually detectable movement of the elements of the protective structure.

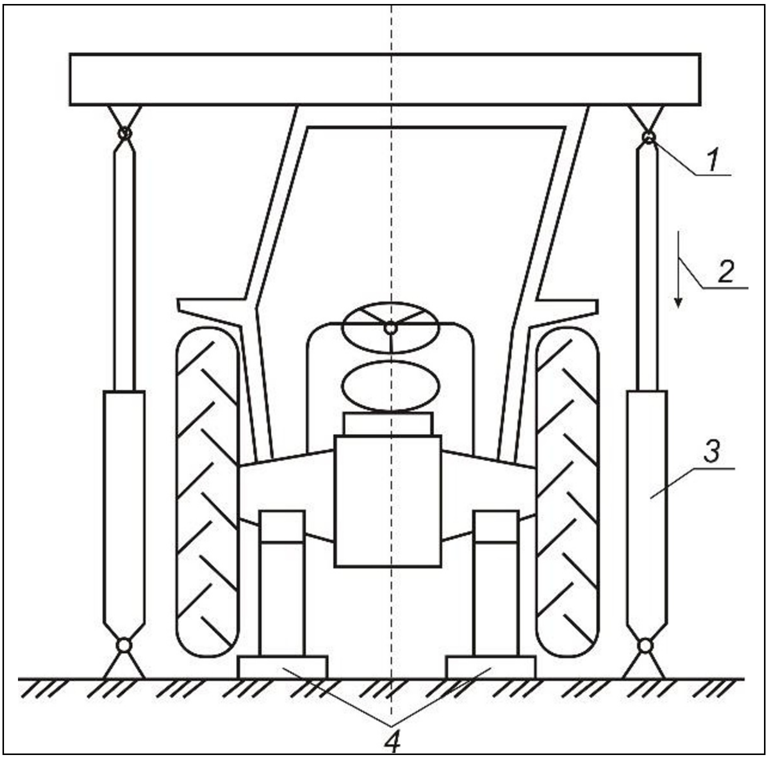

Fig. 3. Test setup for vertical loading: 1 is universal joint; 2 is direction of action of the load; 3 is double-acting hydraulic cylinder; 4 is supports under the front and rear axles

When calculating, the following initial data were taken[12-14]:

- design diagram of the frame of the tractor cabin of class 1.4;
- boundary conditions - rigid fastening on the base at four points;
- initial conditions: since the problem is solved in a quasi-static formulation, the load is applied in portions, then the initial load P_0 = 20.35 kg; temperature T = 20^0C; movement, speed, and acceleration, respectively $U = \dot{U} = \ddot{U}$=0;
- breakdown of the finite element model into finite elements in the form of a bar;
- the material of the rods has the following parameters: elastic modulus E = 20400.00 kg/mm^2, Poisson's ratio μ= 0.3, shear modulus G = 7692.31 kg/mm2, torque J_k = 151959 kg·mm, bending stiffness relative Y axis EJ_{uy} = 815776000.0 kg·mm2, bending stiffness about the Z axis EJ_{uz} = 815776000.0 kg·mm2, yield strength along the Y and Z axes M_{ty}= 91774.80 kg·mm and M_{tz}= 91774.80 kg·mm, tensile strength along the Y and Z axes M_{py} = 111132.0 kg·mm and M_{pz} = 111132.0 kg·mm, exponent n = 2.3;
- bar profile - rectangular with parameters: 40x40x3 mm.

3 Results and Discussion.

Figure 4 shows the dependences of the theoretical calculation and experimental data of deformation and force when the frame is struck from the rear on the right.

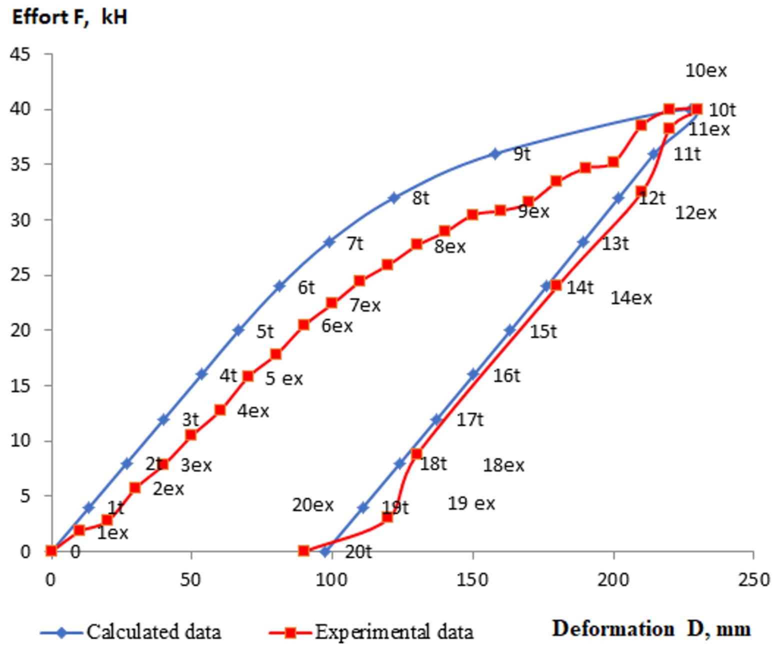

Fig. 4. Dependences of the deformation state of the tractor cabin carcass.

As can be seen from the graphs, the maximum deformation, according to the experimental data, is 230 mm, and the residual is 90 mm; according to theoretical studies, the maximum is 227 mm, and the residual is 97 mm.

The maximum discrepancy is 12% (at points 9t and 9ex).

The average discrepancy is 8% [14].

Figure 5 shows the graphs of the theoretical calculation and experimental data for the impact of the frame from the left side.

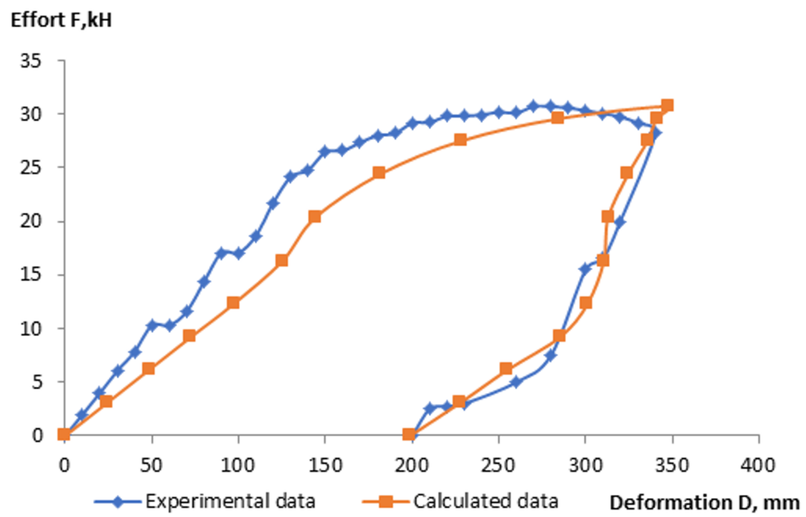

Fig. 5. Graphics of the deformation state of the tractor cab frame upon impact from the left side.

Analysis of the graphs shows that the maximum deformation, according to the experimental data, is 340 mm, the residual 200 mm; according to theoretical studies, the maximum is 347 mm, the residual is 198 mm.

The maximum discrepancy is 11% (at points 5t and 5ex).

The average discrepancy is 8% [15].

The results of theoretical calculation and experimental data for vertical static loading from the back and front are summarized in Table 1.

Table1. Deformation, maximum and residual under vertical static loading

	Vertical static loading			
	front		back	
	Calculated data	Experimental data	Calculated data	Experimental data
Deformation, maximum, mm	146	150	73	80
Deformation, residual, mm	73	70	41	40

4 Conclusions

The discrepancy between the theoretical calculation results and the experimental data of the deformation state of the cabin frame under vertical static loading at the front was 2.7% for the maximum deformation and 4.1% for the maximum deformation, and 8.75% and 2.44% at the rear, respectively.

Thus, the studies carried out have shown good adequacy of the theoretical results obtained (the maximum deviation does not exceed 12%, and the average deviation is 8%), and the proposed method of elastoplastic calculation can be used in the development of new structures for the frame of tractor cabs.

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