APPLICABILITY OF POLYMER COMPOSITE MATERIALS IN THE DEVELOPMENT OF TRACTORS FALLING-OBJECT PROTECTIVE STRUCTURES (FOPS)

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I. INTRODUCTION

Often tractors on the same basis are used for different types of work, e.g., agricultural and logging operations. However, power requirements for protective structure cabin in protecting from falling objects differ significantly, depending on the purpose of the tractor. Development and production of a universal cab for both agricultural and logging operations is very expensive and inappropriate.

Trends in the global tractor industry also dictate the increased demands to the design of tractors. The roof of the tractor, as part of the FOPS, is one of the main design elements. The use of PCM in the roof structure removes almost all constraints on its shape, which in turn has a positive effect on the design. Due to the mechanical properties of the composites, besides the aesthetic function, it becomes possible to significantly damp the impacts from falling objects.

II. GOALS AND OBJECTIVES

Within the framework of the project, funded by the Ministry of Education of the Russian Federation, the goal is to develop a methodology for designing tractor cabins, taking into account regulatory and design requirements. Approbation of the methodology is carried out on the articulated tractor of a new generation produced by OOO Zavod SPETSTEHNIKI (St. Petersburg) with improved design, visibility and ergonomics, vibro-acoustic and climatic comfort as well as safety.

At the first stage of the project, a digital model of the original design of the tractor was developed to define layout constraints for design. After that, the development of an updated stylized surface has been carried out, designed a frame structure of the cab and currently work is underway to refine the design and layout of the cabin (Fig. 1) [1].

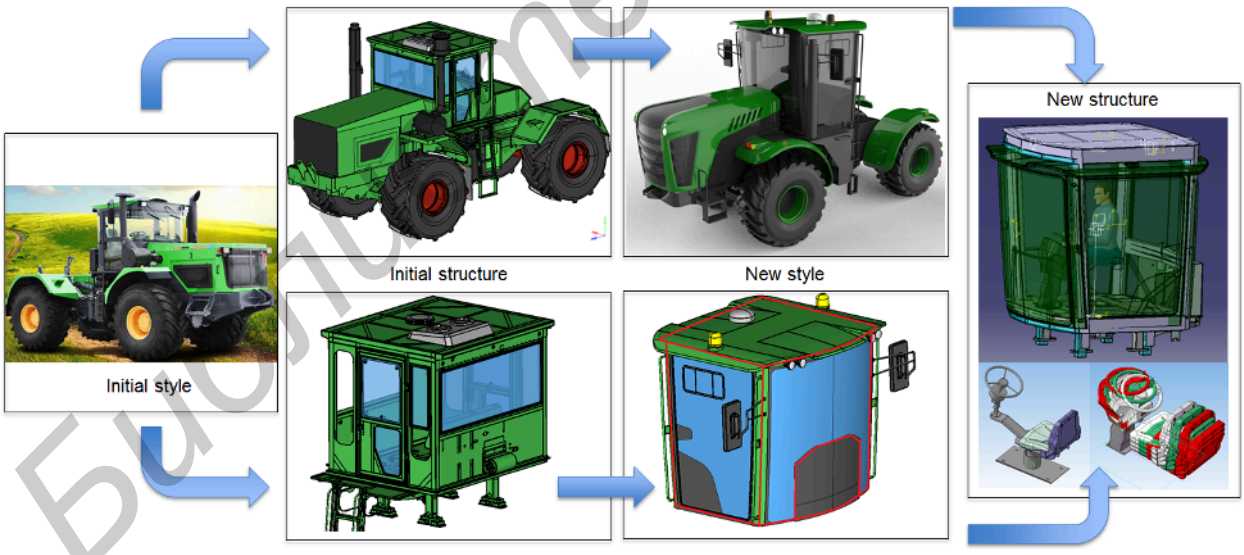

Figure 1 – The process of the development of the new cabin design.

The purpose of this work is to develop a methodology for designing a unified falling objects protective structure of the tractor cab using a PCM, capable to pass both the level I protection against penetration and level II [2].

In connection with the set goal, the following tasks are solved in the work:

- development of finite element model (FEM) of tractor's FOPS;
- development of a composite material model with damage;
- hold a series of virtual FOPS crash tests;
- development of a methodology for designing a FOPS tractor to reduce impact loads on the cab.

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III. FINITE ELEMENT MODEL OF FOPS DEVELOPMENT AND VIRTUAL TESTS

As the roof of the cab was more of an element of design and in structure of the FOPS was not included, in the first version of analysis it was not modeled. In the second variant, in the FEM included the roof with panel of the PCM. In this case, it performs two functions: a full FOPS element and a design element (exterior panel). A FEM of FOPS was developed in the software package ANSA [3] for the purpose of conducting virtual tests.

To simulate the composite panel material type 22 *mat_composite_damage was selected. It's model of composite material with damage. The model allows to define an orthotropic material with optional brittle fracture for composites [4,5]. As a material for making the roof of the tractor selected three-layer structure: glass Mat company Spheretex sphere.core "SP", covered both sides with fiberglass-type 120 and binder VSE-34. The material model *mat_composite_damage allows simulate the layered structure, which was done in the present work.

The main function of a roof panel of the cab during the crash tests is to maximize energy absorption from falling objects. It is necessary to increase the deflection of the composite roof panel of the cab. On the other hand, the maximum deflection is limited by metal beams of the FOPS structure. Thus, it is necessary to choose the thickness and material composition of the roof so that its maximum deflection until the beginning of the destruction corresponded to the distance from the plane of the roof to the FOPS beams. This parameter is constructive and can be modified, for the developed cabin it is equal to 70 mm. From static tests it is seen that the deflection of 70 mm is achieved when the thickness of the material of composite panel slightly less than 6 mm.

Tractors FOPS, according to [2], is divided into two categories: level I impact protection meets the impact from small falling objects (e.g., bricks, small concrete blocks, hand tools) for the landscape areas of clearing, such as highways and other maintenance; level II impact protection is consistent with a blow from the large falling objects (e.g., trees, pieces of rocks) for machines in the areas of clearing, timber cutting. In laboratory conditions, these tests are conducted by dropping a standard object (indenter) of a predetermined shape and mass from a certain height.

One of the objectives of the present work is the development of a unified tractor cab, according to the technical regulations of the Customs Union [6], able to withstand both the level I and level II impact protection. This cabin will significantly reduce the costs of development and production.

Both tractors cabs withstood the test of level I impact protection. Figure 2 shows the results of analysis the FOPS of the tractor cab after a series of virtual tests for level II impact protection. The places where the test impact was applied were selected according to [2] and [7].

From figure 2 it is evident that traditional tractors FOPS failed level II impact protection test, while the FOPS tractor with composite panel this test passed. Composite panel collapsed at all stages of testing, but the deflections of metal structures was reduced on average by 30%, thus providing greater protection of the operator. Analyzing the speed of the indenter, see it down at the time of contact with the metal FOPS structure at 36% for level I, 16% for level II protection against penetration. Accordingly, the use of PCM roof panel allows to reduce the energy of a falling object by 59% for level I and 30% for level II protection against penetration.

IV. CONCLUSIONS

On the basis of the analysis standardized cab that can pass both the level I and level II protection against penetration tests has been developed. This result is achieved by using the PCM in the roof panel of the tractor's cab. Thus, the composite panel, except an important design element included in the FOPS power structure. Also, developed a methodology for the design of the tractor's roof tailored to maximizing its deflection at impact. Further, through the use of more durable composite materials, increasing the thickness of the panel, or through reinforcement of metal panels, composite roof panel can fully replace the traditional metal roof that will lead to a significant reduction of material and mass of the tractor cab while also improving the ergonomics due to increase free space in cabin.

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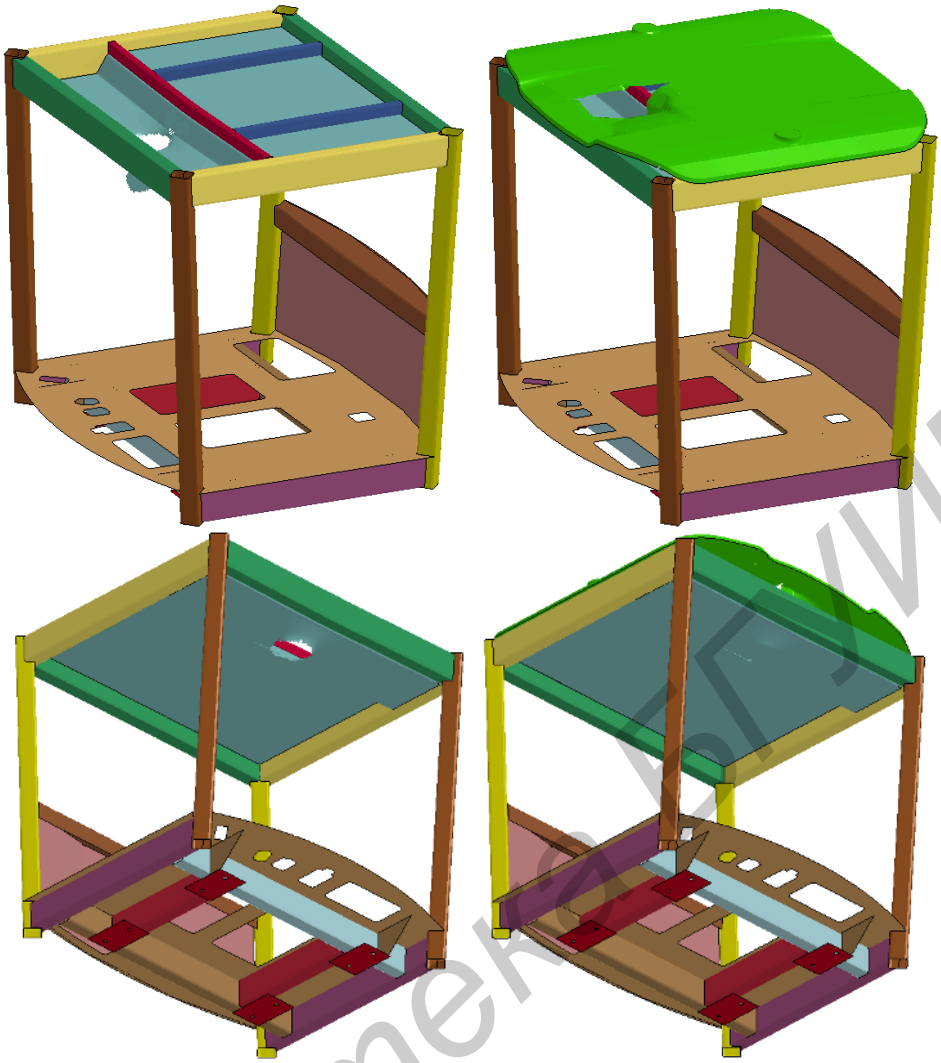

Figure 2 – Results of level II impact protection test, where
a – traditional tractors FOPS, b – tractors FOPS with composite panel.

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