Using computer simulation in designing new products

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Abstract. Design of new products and mechanisms is continuous and complicated process. The complexity of new products is explained by increased requirements for reliability and wide functionality of new products for its competitiveness. At the same time, design time is reduced by replacing natural tests with computational experiments and the widespread use of modern computer-aided design systems (CAD systems). This article presents the design of the bridge laying mechanism of tank bridge layer using modern CAD systems.

1. Introduction

In domestic and foreign combat manuals and regulations for engineering support of the battle, it is emphasized that, depending on the prevailing situation in the main types of combat operations, the subunits must carry out rapid attacks and marches [1]. In this case, the most important tasks are deployment of new bridge crossings and restoration of destroyed ones by the enemy. To solve these tasks, the tank bridges are used. Military application bridges were constructed several thousand years ago. Their primary function was to allow warriors, arms and equipment to cross barriers – rivers, ravines or other naturally and artificially made obstacles. After military operations these bridges performed the functions of military and civil communications. Time passed and development of military equipment and bridgebuilding created improved means of erecting bridge structures in the shortest time period [2]. In world practice, successful experience has been accumulated in the creation of tank bridgelayers for the deployment of bridges having length up to 25 m, with treadway not exceeding 4 m (Figure 1) [3]. When the convoy of vehicles enters such bridges, as a rule, its speed decreases in 2 - 4 times due to psychological and technical reasons. Such situation increases the possibility of formation of vehicles’ clusters in front of the bridge, which creates conditions for the destruction of all vehicles by the enemy.

![Figure 1. Bridge](image-url)
It is known that in the operational-tactical combat zone, the time of bridge crossing safe operation in one location with 80 ... 90 % probability of not being hit will be 25 ... 30 minutes. Foreign and domestic tactical manuals and regulations distinguish the bridge crossings as objects of priority defeat. This is exacerbated by the extremely rapid development of reconnaissance assets and new types of weapons in modern warfare. Increasing the efficiency of the use of tank bridgelayers through technical development should be aimed at increasing the reliability during operation, increasing the mean time between failures, minimizing the time for bridge deployment and retrieving, increasing the bridge crossing capacity by increasing the width of the bridge at least 4.6 m, ensuring the safe and non-stop vehicle passage on the bridge with a solid track-way [4].

2. Materials and research methods

One of the pressing problems in the bridge engineering is the development of rapidly deployable single span bridges capable of being placed on a single vehicular mounting means. Such bridge constructions may be used in instances where it is impossible to erect intermediate supports in a short time period. The reason is short time allotted for laying a bridge on the one hand, and, in case of availability of the intermediate supports on an obstacle, their big length, lack of information about physical and mechanical properties of soil, very fast flow of rivers, complicated outline of a profile and many more factors on the other hand [5]. According to modern requirements for tank bridgelayers, it is necessary to overcome obstacles having width up to 26 m (the length of the bridge must be at least 27 m), and the width of the bridge track-way must be at least 4.6 m. Development of such bridge will increase its weight, and the existing domestic tank bridge-laying vehicles are not able to install on obstacles and remove from the obstacle bridges of increased weight, therefore, the development of a new bridge-laying vehicle is required.

Under current conditions, the design of complex structures is impossible without the use of CAD, which can reduce the development time due to 3D modeling, provide demonstration and possibility to examine in detail the interaction of units and mechanisms while avoiding possible design errors.

The layout of the bridge on the obstacle is shown in Figure 2. In the transport position, the bridge is on the bridge-laying vehicle in the folded state, after reaching the obstacle, the sections of the bridge are opened, then the bridge is extended and lowered onto the ground.

![Figure 2. Bridge layout](image)
To lay the bridge with increased weight, one of the most important technical issues is to ensure longitudinal stability against rolling-over of the bridge-laying vehicle when the bridge is installed on the obstacle Figure 3.

The weight of bridge-laying vehicle with bridge is limited by the vehicle cross-country ability (specific ground pressure, loads on the support rollers of the vehicle running gear). When laying the bridge with increased weight on an obstacle, longitudinal stability is not ensured. To increase the longitudinal stability, the additional support is used (Figure 4). Creation of support with required length L, allows not only to ensure longitudinal stability, but also to level the ground for the bridge deployment or clear the road for the movement of a convey of vehicle.

Figure 3. Longitudinal stability without additional support

Figure 4. Longitudinal stability without additional support

When designing a new bridge-laying vehicle for laying the bridge with increased weight, it is necessary to develop bridge laying mechanism, which provides bridge extension and its laying on the ground, using retractable laying frame, so that the end of the bridge could be behind the additional support.

3. Design outputs

In workplaces, engineering design is supported by contemporary CAD tools capable of virtual prototyping—a full-cycle process to explore the structure, function, and cost of a complete product on the computer using modeling and simulation techniques before it is actually built [6]. For designing the bridge-laying vehicle it is required the CAD which provides the following:

- teamwork on the project;
- avoiding the fundamental mistakes at the earliest stages of design;
- demonstration of the future product and its assemblability checking;
- making the necessary calculations and optimization of the design without expensive field tests;
- change and modification of the project as soon as possible;
- preparation of effective marketing materials using of the 3D models;
- quick and qualitative execution of design documentation [7].

These requirements are met by the KOMPAS-3D system, which makes it possible to implement the above provisions by including in the specified software product a set of libraries of ready-made elements and circuits that meet the requirements of the machine-building industries, as well as provide engineers with application design tools (element libraries, applied CAD systems) based on Compass [8].
The 3D-modeling using in the design of the bridge-laying vehicle made it possible to organize the interaction of designers from various departments involved in the development of separate units of vehicle.

One of the main components of bridge-laying vehicle is the laying frame, on which heavy loads are applied when the bridge is installed on the obstacle and it is removed from the obstacle. The wide possibilities of the 3D-modeling made it possible to analyze possible options for a retractable laying frame and choose the most rational option (Figure 5) meeting the specified requirements. In the transport position, the bridge laying frame is within the dimensions of the bridgelayer, when the bridge is installed on the obstacle, the frame moves forward, due to this, the bridge together with the laying frame also moves forward and diverging from the bridgelayer support, lies on the original bank of the obstacle.

![Laying frame transport position](image)

![Laying frame extended position](image)

**Figure 5.** Retractable bridge laying frame

The laying frame consists of main frame and retractable frame.

The main frame (Figure 6) is installed on the vehicle hull and allows to install the retractable frame in it. The main frame consists of welded frame and rolling supports, mounted on it, and two geared motors for moving the retractable frame.

![Main frame](image)

**Figure 6.** Main frame
Retractable frame (Figure 7) is the assembly lever of bridge laying mechanism. It is a welded structure and consists of two longitudinal beams with rolling supports of bridge member mounted on them and two geared motors for moving the bridge, in addition, pins for engagement with the sprockets of the frame travelling mechanism are installed on the inner sheets of the beams.

Figure 7. Retractable frame

To ensure the strength of the laying frame of the bridge laying mechanism, a detailed analysis of the stress-strain state of structures is carried out to determine the most and least loaded points for optimal solution with the lowest weight.

The creation of modern equipment at the design stage is not limited to its geometric modeling. It is impossible to produce competitive products without a comprehensive engineering analysis of the designed object. Developers around the world are working to ensure that their design solutions could provide the static strength and rigidity, sufficient durability, stability and suitable dynamic characteristics, while having minimum weight, minimum cost, minimum power consumption, etc. [9].

In science and technology, one constantly has to deal with the problem of calculating the systems that have complex geometric configuration and irregular physical structure. Computers allow such calculations to be performed using approximate numerical methods. The finite element method (FEM) is one of them. The construction of a method using physical considerations and its name "finite element method" is contained in an article written by engineers [10]. In recent decades, it has taken a leading position and has been widely used [11]. To analyze the strength of the laying mechanism, the Creo Simulate system was used, the use of which provides design engineers with powerful and convenient tool that allows them to understand and analyze the real behavior of products under the action of loads during their design [12]. The analysis of the designed laying mechanism showed the possibility of providing strength using high-strength steel for some elements (Figure 8).

The creation of the 3-D model made it possible to develop in the shortest time the design documentation in the KOMPAS-3D system that fully meets the requirements of Unified System for Design Documentation.

Figure 8. Calculation of the stress-strain state of bridge laying mechanism
4. Conclusions

The use of CAD systems “KOMPAS-3D” and “Creo Simulate” made it possible in the shortest possible time to develop the bridge-laying vehicle laying mechanism for deployment of 27 m bridge with increased pass-through capacity with continuous roadway having 4.6 m width. The necessary calculations were carried out, the interaction between the mating units and mechanisms was checked, kinematic analysis of the bridge installation on the obstacle and taking from the obstacle was carried out, design documentation was created in accordance with the requirements of Unified System for Design Documentation.

Figure 9. Bridge installation on the obstacle

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