DEVELOPMENT OF A MECHATRONIC MODULE FORA MOBILE ROBOT OUTDOOR-TYPE

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Introduction

The coal industry is one of the key sectors of the Russian economy, providing a significant portion of the country's energy needs [1]. However, working in a coal mine is one of the most dangerous professions in the world, associated with the risk of accidents, injuries, and illnesses related to the profession [2]. In this regard, improving occupational safety in the coal industry becomes particularly relevant.

One way to ensure occupational safety is through process automation. Some processes, such as evaluating the presence of coal, are solved using classical methods of process automation. However, tasks such as searching for people in case of collapses or creating maps of mines cannot be solved using traditional automation methods but can be addressed through robotics. For these tasks, a platform is required that can move in mine conditions.

The limited space and complex terrain are some of the problems in mines, making traditional chassis structures unsuitable due to the large turning radius, while track drives can significantly damage the underlying surface. Therefore, a chassis is needed that will provide a turning radius as small as possible and minimize damage to the ground surface during movement in the mine. Developing a robot with such a wheel rotation module will improve the efficiency and safety of work, which is an important step towards safe labor. For this reason, this work will consider the processes of designing and prototyping the wheel rotation module for such a chassis, as this module is fundamental.

Module Description

The design of the mechatronic module was based on the structure of the Perseverance Mars rover [3], which is distinguished by its construction that allows the robot to be in contact with the surface at all times with all of its wheels. Its front and rear wheel pairs can rotate around a vertical axis, allowing for steering control in accordance with Ackermann steering geometry. This increases efficiency, mobility, and the variability of movement.

The developed mechatronic module consists of a wheel and a steering mechanism. The three-dimensional model of the developed steering module is shown in Figure 1. The CAD software Inventor was used for modeling.

Parts 1 and 2 are the upper and lower washers for the thrust bearing. Plastic balls with a diameter of 6 mm were used as the bearing balls. Part 10 is a split bushing that holds the motor and is secured by the friction force after tightening two screws located at the bottom of the wheel. Part 1 also includes a channel for routing cables from the servo drive and later from the motor encoder.

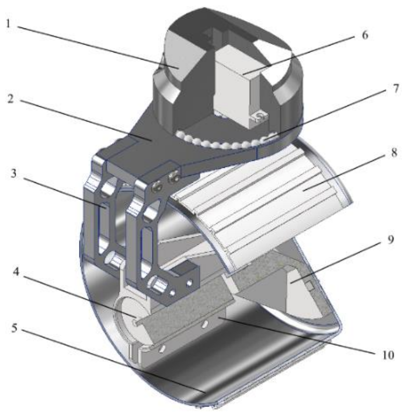

Fig. 1. Design of the turning module:
1 - bearing cover; 2 - bearing lower plate; 3 - supports; 4 - PCB; 5 - wheel; 6 - servo drive; 7 - bearing balls; 8 - tire; 9 - wheel attachment; 10 - motor holder

When designing new products and improving technological processes, it is necessary to consider the principles of efficient use of materials to achieve maximum efficiency and resource conservation. Therefore, artificial intelligence methods were applied to optimize the design of one of the parts.

Optimization of struts

The initial configuration of the supports was a solid aluminum bracket with a safety factor of over 15. This means that the structure can be lightened by removing excess material that does not affect the rigidity of the structure, thereby saving material and increasing the overall efficiency of the structure by reducing the moving mass, which positively affects the energy consumption of the actuators.

The optimization was performed using generative design technology and the topology optimization module in Inventor. Initial and boundary conditions were specified for modeling. As a result of this process, a new generated geometry was obtained, based on which a new solid model was simulated, taking into account the features of its further production. All optimization algorithm solutions require mandatory rechecking, as errors are not excluded. The repeated strength analysis allows for a quantitative assessment of the efficiency of the optimization. The models are shown in Figure 2.

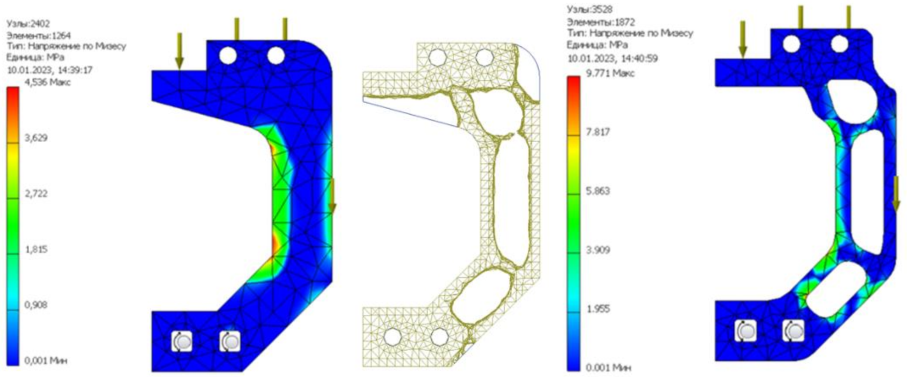

Fig. 2. Topological optimization process:
left (before), middle (generated geometry), right (after)

The application of this type of optimization allowed to reduce the weight of the structure by 30% without sacrificing the strength of the component. For a more detailed processing of the components, it is advisable to consider the structure as a whole and to carry out a greater number of iterations of topological optimization with different parameters.

Prototyping

For the prototype manufacturing, the 3D printing method was chosen as the main approach due to its relative speed and availability. The primary material used was PETG plastic, mainly due to its high interlayer adhesion, which increases the strength of the printed parts and the overall mechanical characteristics compared to popular plastics such as PLA and ABS [4]. All parts are joined by bolted connections using thread lockers or special nuts with plastic inserts to prevent self-loosening due to vibrations. An image of the prototype is shown in Figure 3.

Fig. 3. Manufactured Prototype

As a result of the tests, it was found that the engine mounting requires revision, since the fixation inside the bushing is insufficient, and increasing the compression force may cause damage to the geometry of the engine itself, leading to premature wear and breakage. The solution may be to add flange mounting of the engine using M3 screws, which will prevent the engine from slipping around its axis.

Conclusion

As a result, a design and three-dimensional models of a mechatronic module for steering the wheels of a high-mobility robot were developed. A prototype was manufactured, for which most of the parts were produced using FDM 3D printing additive technology. The manufactured prototype confirmed the operability of the design and revealed some shortcomings that will be taken into account in the final production of the first industrial sample.

Further plans include more detailed development of the module and the development of a control system for it. If funding is obtained for the development and implementation, the remaining parts of the high-mobility robot will be taken into consideration.

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