Numerical modeling and optimization of geometric parameters of a composite bracket

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Abstract. The article presents the development and research results of the stress-strain state of a new composite bracket structural solution. The basic scheme of the invention and its application in hinged facade systems are described. The main feature of the developed design solution is the production of various shapes profiles made of aluminum alloys: a U-shaped profile with a wall thickness that varies along the length and an L-shaped uneven profile. Both parts of the bracket are made of aluminum alloys using extrusion method, which allows producing a profile of different shape on terms of area. The results of numerical modeling and selection of optimal geometric and physical-mechanical characteristics of the developed composite bracket in the software package are presented. The actual loads, impacts and operating conditions are taken into account. Based on the results of numerical studies, it is found out that the developed type of the bearing bracket meets the requirements of strength, rigidity and stability. The additional optimization allows reducing the weight of the bracket compared to the original model without significantly reducing the bearing capacity.

Keywords: facade bracket, numerical modeling, criterion of minimum mass, optimization.

1 Introduction

In recent years, the aluminum production market has been actively developing. In 2019, 69.148 tons were produced [1]. One of the main consumers of aluminum materials is the construction industry [2-5]. This is due to the following properties of the material: high strength and specific characteristics, high resistance to corrosion [6-9] and special properties [10-11], ease of transportation and installation of finished products due to their relatively small weight, as well as the possibility of "stress-free" processing (casting, extrusion) [12-13], which allows getting products of any shape and reduce the cost of their production [14-15]. The annual increase in prices for rolled metal can affect the reduction in demand for metal structures [17], since the estimated cost of construction projects can reach up to 60-70 \% of the price of metal [18]. At the same time, the cost of aluminum materials will decrease due to the development of the industry and technologies [19-21]. The purpose of the work is to develop and study a new design solution for a composite aluminum alloy bracket [22-24], with the most rational use of the material in terms of area and the possibility of mounting on two mutually perpendicular surfaces of the base [25-27].

2 Materials and methods

2.1 Object of research

The main feature of the developed new design solution is the production of various shapes in terms of area profiles from aluminum alloys (see Figures 1-2).
The developed bracket consists of two main parts:

Figure 1 General view of the new design solution.

Figure 2 General view of the new design solution.
Figure 3 The main parts of the developed bracket: a) U-shaped profile of the bracket. b) L-shaped bracket profile.

- U-shaped profile with variable wall thickness along the length, at the ends of which there are four holes for attaching the suspended elements with the possibility of changing their position in two mutually perpendicular directions. The support wall of the profile has two holes that allow adjusting the profile in a horizontal position relative to the anchor attachment or other attachment to the vertical surface of the base (see Figure 3.a);

- The L-shaped uneven profile, which is adjacent (by shorter edge) to the inner surface of the support walls of the U-shaped profile and is mounted together with the U-shaped profile by means of bolting or otherwise fastening to a vertical surface. Mounting on the horizontal surface of the base is carried out by the long end of the profile and is fixed to it by an anchor or other attachment through one adjustable hole. It must be located at a sufficient distance from the vertical surface of the base not to cross the axes perpendicular to the U-shaped profile bracing (see Figure 3.b);

The developed bracket design can also be used in the construction industry, namely for fixing the enclosing structures of buildings and structures in the form of hinged facade systems, including systems with a vent air gap or post-and-beam systems with translucent modules.

2.2 Numerical modeling and optimization
In order to determine the stress-strain state and the most rational geometric parameters, a parametric finite element model of the developed load-bearing composite bracket was created in the ANSYS PC. In the "Response Surface Optimization" an additional calculation of model parameters was performed for the main geometric dimensions of the bracket, physico-mechanical characteristics of the material, and the maximum values of deflections and stresses, with the condition not exceeding their maximum allowable values. The main optimization criterion is the minimum mass.

Based on the results of the model calculation in the PC "ANSYS", the values of deflections (deformations) and stresses from the design load are set to 92.65 MPa and 0.2 mm for the U-shaped profile, and 65.565 MPa and 0.05 mm for the L-shaped uneven profile, which does not exceed the maximum permissible values of the calculated resistance of aluminum \( [R] = 135 \text{ MPa} \) and deflection \( [f] = 3.33 \text{ mm} \). The optimal geometric dimensions of the bracket and its physical and mechanical characteristics for the specified conditions and loading values are obtained. The results of the numerical study are shown in Figures 4-7.
Figure 4. Equivalent stresses occurring in the U-shaped profile.

Figure 5. Total deformation of the U-shaped profile.
3 Results and discussion
The results of solving the optimization problem are shown in Figure 8 and Figure 9.
Both profiles of the bracket are made of aluminum alloys by extrusion, which allows performing a variable thickness of the walls of the U-shaped bracket and a non-standard shape of the L-shaped profile with further formation of holes, including adjusting ones, by any of the available methods.

4 Conclusions

Thus, a new type of composite bracket has been developed. Numerical studies of this bracket were performed, which resulted in determining the optimal geometric dimensions of the bracket and the physical and mechanical characteristics of its material for the specified conditions. A picture of the stress-strain state with optimal geometric and physical-mechanical parameters of the design model of the composite bracket is obtained. Based on the results of numerical studies, it was found that the developed type of load-bearing bracket meets the requirements of strength, rigidity and stability, and the additional optimization allows reducing the weight of the bracket compared to the original model by 14 % without significantly reducing the load-bearing capacity.

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