In this problem as in the previous for finding the added masses for vibrations of the plate we used two methods of integration: integration over the outer surface of the plate and volume integration of liquid. These methods are acceptable for solving the problem. We can use any of them. But finite element model for volume integration as was noted earlier requires a regular finite element mesh overall volume.

TOPOLOGY OPTIMIZATION AND CASTING PROCESS SIMULATION FOR LIGHTWEIGHT DESIGN AND MANUFACTURING FEASIBILITY OF AN AIRCRAFT BRACKET

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There is a large amount of cases, when it is required to reduce the mass of a casted part, while the structural performance shall remain unchanged. The most efficient way of doing this is based on the topology optimization procedure, which allows reaching the required goals, but makes the manufacturing much more difficult in case of using the traditional casting process design. The workaround is to use the optimization software in combination with the special tools for direct simulation of the casting processes. This approach allows designing such components, which fulfill both the structural and mass requirements and the technological requirements, while making the process of development of complex casts shorter. Current article shows the complementary effect of the topology optimization and casing simulation software on the design and manufacturing workflow for an aircraft bracket.

The methodology is based on the iterative process, which involves two software tools – Inspire and Click2Cast by solidThinking, Inc., the company owned by Altair Engineering, Inc. The tools are used for preparing the design of the bracket, which is lightweight, durable and technologically feasible.

Topology optimization is carried out in solidThinking Inspire, which allows designing lightweight parts without compromising their strength. The system analyzes the structural loads and constraints as well as the technological constraints and generates the distribution of the solid material inside the fixed volume – design space.

The part, which is considered in the article, is the bracket that is installed on the casing of a jet engine and carries the weight of the engine during service operations that are performed on the ground. Each of the engines is equipped with four brackets, which fly with the aircraft during the whole life of the machine. The mass of the original bracket is 1.046 kg.

The original geometry of the bracket and all the loads and supports are shown in Fig. 1.

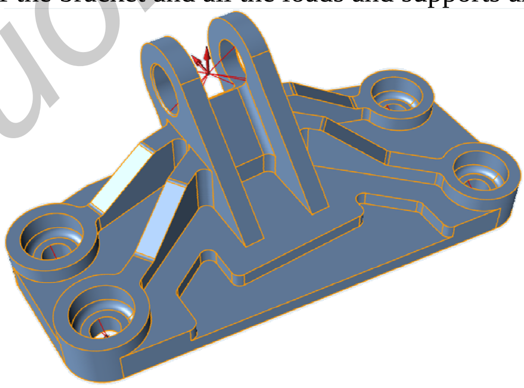


Figure 1 – Original geometry of the bracket

The design space with all the loads and supports for the considered bracket is shown in Fig. 2. The regions, where the solid material is distributed during the topology optimization run, are shown dark brown. Grey color represents the unchangeable regions.

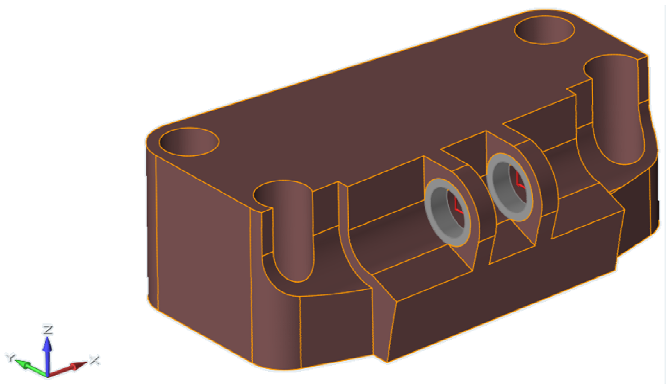


Figure 2 – Analysis model for topology optimization

As a result of the run, the optimized material distribution is defined. The resulting shape of the optimized bracket is shown in Fig. 3. The mass of the optimized bracket equals 0.238 kg.

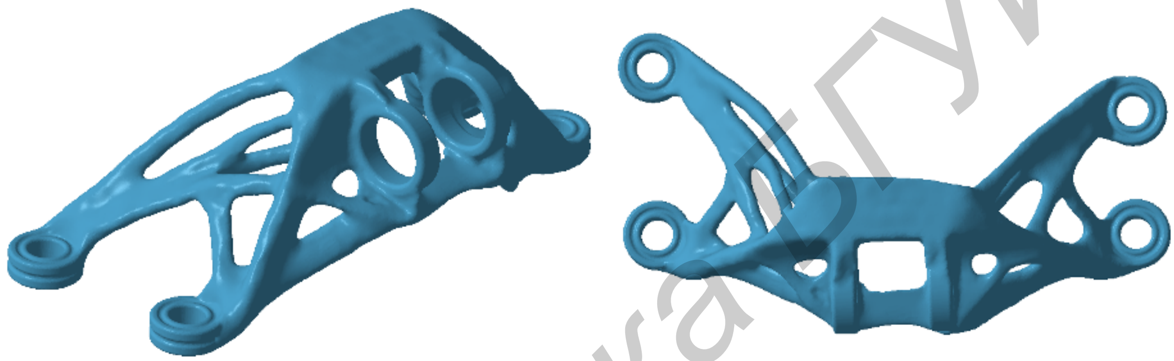
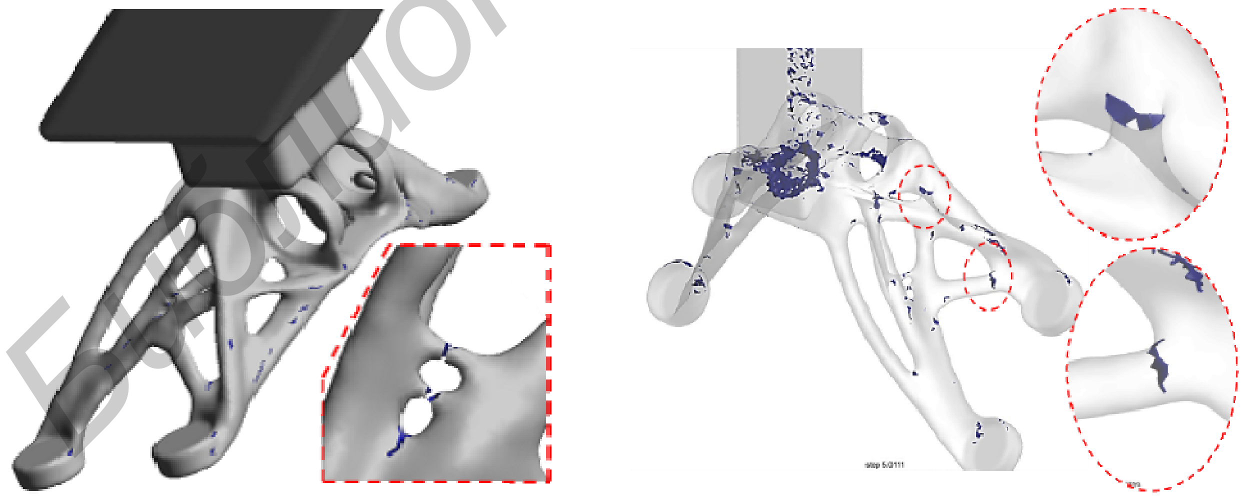


Figure 3 – Final shape of the optimized bracket after the interpretation and remodeling

Another tool – solidThinking Click2Cast – is used for improving the shape of the bracket with respect to manufacturing feasibility. It makes possible to run quick simulations of the casting process and predict the location and dimensions of the possible casting defects (Fig. 4) quite accurately.



a b

Figure 4 – Distribution of gas holes and cold shuts

The analysis model in Click2Cast is used to simulate 10 different configurations of the casting process in order to get the optimal parameter set from several options of the gating system configuration, pouring method and the mode of burning master-model off from the mold.

The goal of the analysis is to check the optimized shape of the bracket against such casting defects as misruns of the thin regions, shrinkage holes, shrinkage porosity and other types of defects for all the considered configurations of the casting process.

Several changes to the design of the model are implemented based on the results of the casting simulation and analysis. The updated model is forwarded to the next phase – additive manufacturing of the master-model.

Due to the complex shape of the topology optimized bracket, additive layer manufacturing is used for producing the master-model. The 3D-printing technology makes possible to shorten the process of preparing the consumable pattern and accelerate the manufacturing process without any additional expensive tools. The master-model is produced using the Russian photopolymer printer BRAVO-2, based on the stereolithography apparatus technology (SLA). To reduce the volume of the material that is burned off, the model is printed with an internal lattice structure.

Based on the simulation results, the gravity casting into gypsum mold with evacuation is chosen as the manufacturing method. The optimal configuration of the gating system is chosen according to the results of the simulation in Click2Cast, which considers two phases of the process – filling and solidification.

The results of the test casting performed during the described task are the five casts of the component. Three of them are considered as conforming parts due to no defects or some amount of defects, which are not critical.

The resulting cast of the bracket in $AlSi_7Mg$ that is produced using by gravity casting with evacuation – the optimal casting option for this component – is shown in Fig. 4a. The cast in $Cu_{60}Zn_{40}$ is shown in Fig. 4b.

a b

Figure 5 – Casted bracket made of $AlSi_7Mg$ (a) and $Cu_{60}Zn_{40}$ (b) using gravity casting in gypsum molds with evacuation

Thus, the topology optimization technology in solidThinking Inspire makes it possible to reduce the mass of the bracket in 4.39 times without compromising the structural strength and durability. The direct modeling of the casting processes using solidThinking Click2Cast makes it easier to improve the manufacturing feasibility of the model and to choose the optimal parameters for getting a high-quality cast. The results of the simulations are confirmed by the high-quality casts produced of $AlSi_7Mg$ and $Cu_{60}Zn_{40}$ through the gravity casting using the 3D-printed master-models.