Technical Sciences
Academy of Romania
www.jesi.astr.ro

Journal of Engineering Sciences and Innovation
Volume 11, Issue 2 / 2026, pp. 149 - 158

A. Mechanical Engineering

Received ***22 September 2025*** *Accepted* ***11 May 2026***
Received in revised form ***15 March 2026***

Molds manufacturing for UAV parts using innovative technologies

SERAFIM MUNTEAN[1], SEBASTIAN POP[2], GHEORGHE OANCEA[1*]

[1]*Department of Manufacturing Engineering, Transilvania University of Brasov, 500036, Brasov, Romania*
[2]*„Henri Coanda" Air Force Academy, 500183, Brasov, Romania*

Abstract. This article presents how the molds for UAV aircraft parts could be fabricated in an innovative and efficient way using the Fused Deposition Modeling technology. This innovative manufacturing process is oriented for unique products or small volume production. It presents a solution for the rapid manufacturing process of a prototype or final product for which it is not available a ready production line for a UAV aircraft manufacturing. The process consists in the fabrication of a mold shell using Fused Deposition Modeling processes not providing enough stiffness, being elastic in many situations. The stiffness is offered by the material filler which can be diverse, having the condition to expand or fill in the hollow volume inside the mold shell. The material will fill the void volume in the mold and provide rigidity. In the research, the material used for filling is epoxy resin mixed with glass granules. Subsequently the mold can be finished in order to obtain a better surface of the fiber part fabricated in this mold. The mold can be also used without finishing the surface, in this case final parts will not have a high quality and precision. Compared to a traditional wood or metal mold production, even to a production using entirely additive processes, this innovative process described in the current paper, has cost and time advantages.

Keywords: UAV, aerodynamic parts, mold, Fused Deposition Modeling

1. Introduction

Nowadays the unmanned aerial vehicles (UAV) are worldwide use in different of military and civilian applications such as: objects detection, traffic surveillance, military operations, public security, natural disaster, agriculture, logistic, emergency services, transportation industry etc. [1, 2]. The UAVs can be manufactured using production lines in series or mass production or in unique or small batch production when different technologies must be used.

*Correspondence address: gh.oancea@unitbv.ro

In many cases, the manufacturing of composite panels or parts from fiber consists of solidifying the part composed of layers of fiber and resin that polymerize, giving the part its strength [3, 4]. To manufacture of a glass or carbon fiber element requires a mold. The shape of the part is taken from the walls of the mold surfaces [5]. The longest and most expensive stage in the manufacture of a UAV element is the manufacture of the mold.
The mold can be made from a variety of materials. Traditionally, this is done as follows:
- by milling a metal or wooden block to create the cavities of the negative surfaces of the part;
- by making a prototype part, also called a master. Glass/carbon fiber is applied over this part to obtain the cavities of the negative surfaces of the part.

These traditional methods, especially the first option in the case of metal molds, are suitable for mass production.
However, if it is necessary to quickly prototype a UAV aircraft, these methods are not favorable in terms of time and cost. Still, there are technologies that allow for rapid manufacturing, such as the additive process for mold manufacturing or the method of making extruded polystyrene molds described in reference [5], with the disadvantage that they are not rigid and do not have durability over time.
This article proposes an innovative way for improving molds manufactured using a well-known in practice Fused Deposition Modeling (FDM) process [6], reducing production time and costs.

2. Materials and methods

The additive manufacturing process used for manufacturing the molds associated to UAV components, or any other field requiring the manufacture of fiber parts, is a fast process with low costs compared to traditional manufacturing processes. The mold can be manufactured even faster by using other materials in combination with the 3D printed material. This procedure also involves the use of an additive manufacturing process for molds, but only the shell, the mold body is left hollow which is then filled with a material that will subsequently solidify. Initially, the hollow mold shell is not resistant, being in majority of the situations only elastic, but filling the hollow with a material that subsequently solidifies gives the mold rigidity. This innovative method can be used to manufacture fiberglass parts such as aircraft wings, fuselage casings, including the fuselage itself, wing casings, NACA air intakes, and other small or large components for UAV drones, which can also be small unmanned VTOL aircraft.
In the next sentences, for an easier comparison and understanding, is defined *method 1* as a process for manufacturing the mold using only 3D printed material and *method 2* will be defined as an innovative manufacturing process that uses both 3D printed material and filler for mold rigidity.
The functionality of the mold made using both *method 1* and *method 2* is similar. To estimate the time and material required to manufacture the mold, a 3D printing simulation is needed, so manufacturing two molds are not necessary. Only the mold

made using *method 2* is needed to demonstrate this innovative manufacturing process.

The steps for manufacturing the mold are as follows:

1. *3D modeling of the fiberglass part;*
2. *3D modeling of the mold* – it will be performed for both, *method 1* and *method 2*;
3. *Simulation of 3D printing of the molds* – for both methods;
4. *3D printing of the mold* – just method 2;
5. *Filling the mold cavity* – just method 2.

3. Mold manufacturing

3.1. Mold designing

To illustrate the rapid mold manufacturing process a NACA intake was chosen. The purpose of a NACA intake is to provide the necessary airflow inside the aircraft to cool and supply with air the combustion engines (if they exist) [7]. The reason for choosing this element from a UAV aircraft is that the NACA intake is a small and common part for most aircraft, not just UAVs. For modeling the fiberglass element, first it needs the 3D model of the UAV aircraft. The 3D digital model of the UAV aircraft for which the NACA intake part is to be modeled is shown in Figure 1.

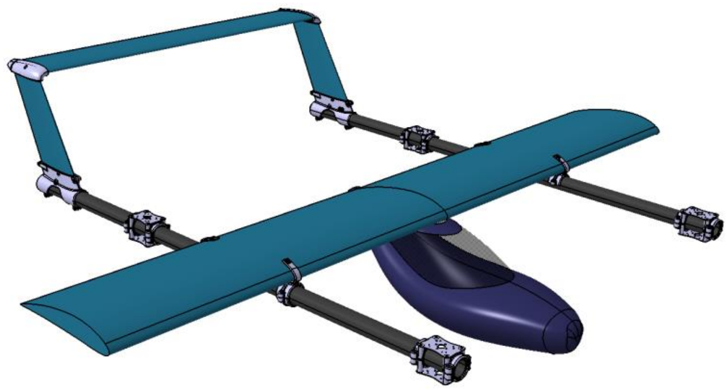
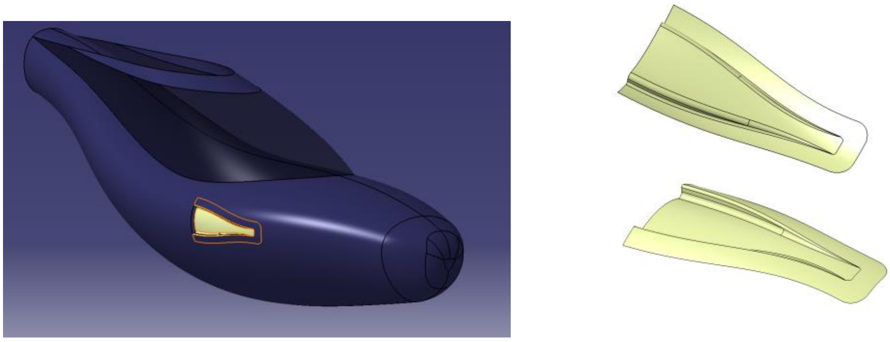


Fig.1. 3D model of the UAV aircraft. Dimensions: 2 m Wingspan and 1.7 m Length.

The NACA intake is modeled on fuselage and the 3D model is presented in Figure 2. To obtain the surface of NACA intake was used 3D software CATIA and module Surface Design

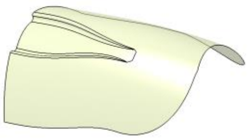
After modeling the considered part, the mold can be created. In Figure 3 is illustrated how a simply mold is made for a fiberglass part, and the result is illustrated in Figure 4.

Extend commands are applied to the surfaces of the fiber part to enlarge the ends of the part's surface (Fig. 1, a), which is also the closing surface of the mold. This surface then cuts out an extruded block (Fig. 3, b,c), thus obtaining a part of the mold (Fig. 3, d). Centering elements were also modeled to secure the mold when closed (Fig. 3, e).

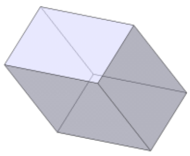


(a) (b)

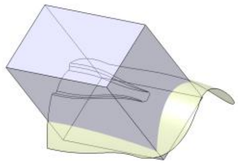
Fig. 2. NACA intake
a) position on fuselage; b) 3D model of NACA intake



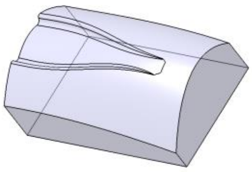
a)



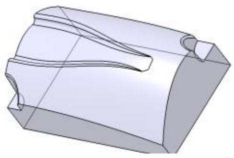
b)



c)



d)



e)

Fig.3. Modeling the mold *(method 1)*

a) extruded block; b) extended surface; c) merging of the block and surface;
d) result of the merge; e) bottom part of the mold.

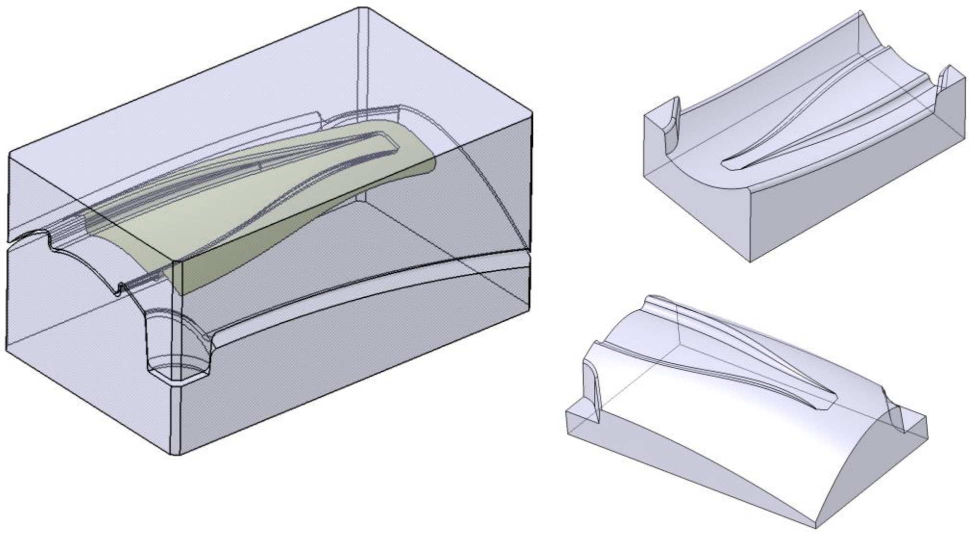
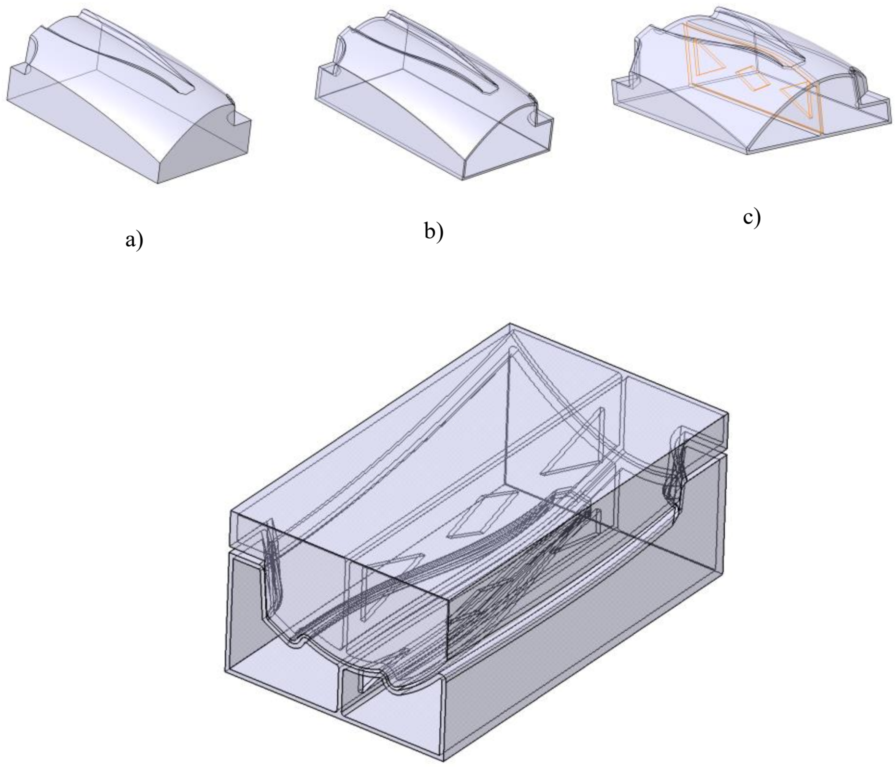


Fig.4. 3D model of the assembly of mold (*method 1*) and fiberglass part (NACA intake).



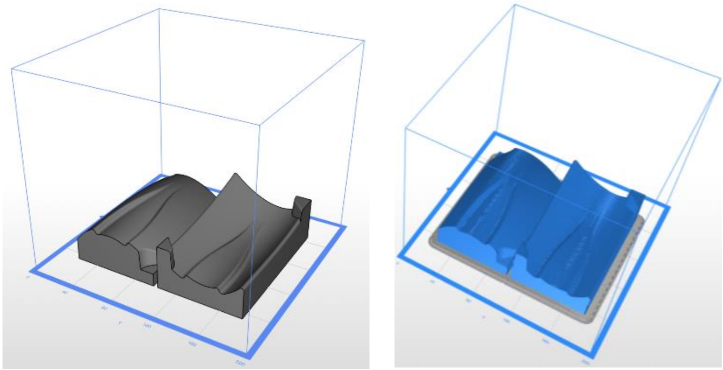
d)

Fig.5. 3D model of the assembly of mold for innovative fabrication (*method 2*)
a) 3D model of a side of the mold *method 1*, b) mold after shell,
c) mold with support rib, d) designed hollow mold

Figure 4 shows the mold obtained using only the additive process (*method 1*). To make the mold for *method 2* (Fig. 5), the 3D model from *method 1* is used. The shell command is utilized to obtain the mold skin (Fig. 5.b), then a rib is created (Fig.5.c). The rib is modeled to provide shape stability when filling the cavity. When filling the cavity with material, the active surface of the mold may have a large shape deviation that can significantly deform the part. The rib is perforated to allow the filling solution to communicate between the inner chambers of the mold (in this case, there are two chambers for each side of the mold). It is important that the opening of the mold is made in such a way that when printing, it is not support material to sustain inclined or horizontal surfaces. If all surfaces have an angle of inclination greater than 45 degrees to the horizontal, then no support material will be used.

3.2. Mold printing

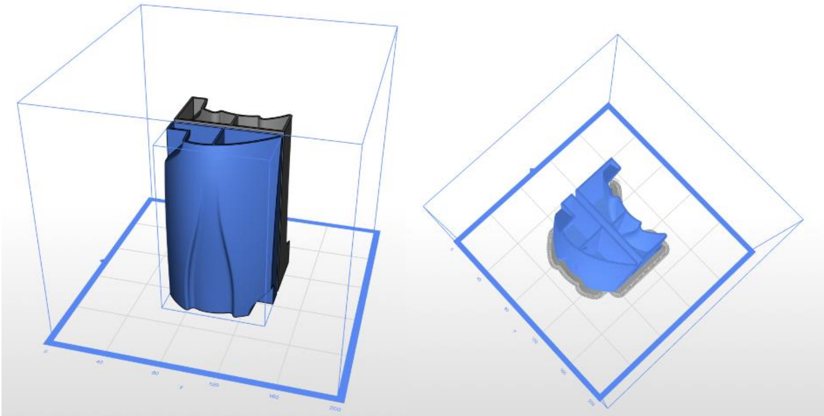
To manufacture the designed mold in an additive manner was selected the Fused Deposition Modeling (FDM) process available on Zortrax M200 Pro and Polyethylene terephthalate glycol (PETG) material as filament. Before to start the manufacturing process, using the dedicated 3D printing software called Z-suite are simulated the manufacturing process in several configurations for both methods. PETG material was chosen, a material that can withstand oven baking temperatures of up to 50ºC. According to the manufacturer's specifications, PETG material becomes malleable at 70ºC.
Method 1 - In the first phase of the simulation, the parts are placed in the print volume of the software (Fig.6.a). The 3D model of the mold *method 1* has a solid interior (Fig. 4.) The mold will be printed with 100% solid, it is not recommended to reduce material by applying infill if later is used vacuum coating. In this situation, the printing time is 3 days, 17 hours, and 54 minutes, and the quantity of material used is 661g.



a) b)

Fig.6. 3D printing simulation *method 1* (solid)
a) placement of parts to be printed in volum; b) 3D printing simulation.

Method 2 - manufacturing the designed mold in vertical position, the reason for placing the mold in a vertical position (Fig. 7) is to use a small quantity of material as possible, and this placement eliminates the needs of support material. The model has a missing front so that the mold cavity can be filled more easily and support material is no longer needed.
For this *method 2*, the printing time is 23 hours and 32 minutes, and the weight of material used is 141 g.
In Figure 8 is presented the used printer machine Zortrax M200 Pro and the obtained part in vertical position on the building chamber. In Figure 9 is shown the manufactured hollow mold.



a) b)

Fig.7. 3D printing simulation *method 2* (hollow mold)
a) Placement of parts to be printed in volum; b) 3D printing simulation,

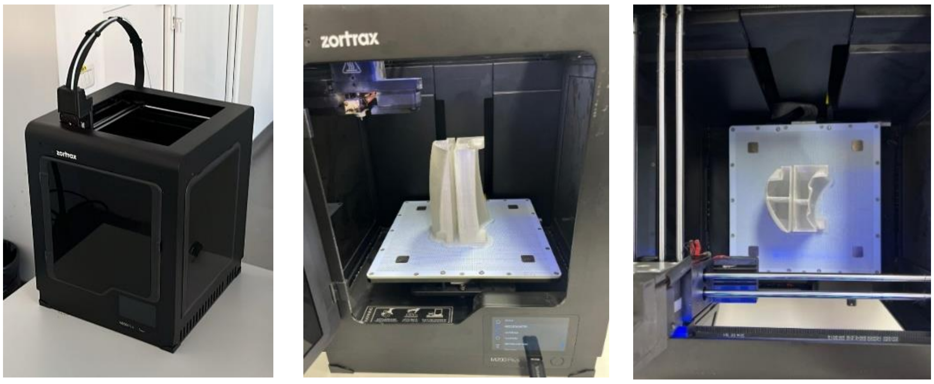


Fig.8. 3D printing of mold (*method 2*) on Zortrax M200 Pro

Fig.9. Manufactured hollow mold using *method 2*.

3.3. Filling the mold cavity

To make the filler, 1-2 mm paraver (Fig.10, a, special glass granules used to make fillers) and epoxy resin (Fig.10.b) are used. These materials are mixed together in an approximate ratio of 30% epoxy resin and 70% paraver (Fig.10, c.). Once the filling component has been obtained, it is poured into the mold to fill the hollow (Fig.10,d). The resin is then left to polymerize. The polymerization time can vary between 2 hours and one day, depending on the polymerization temperature. The mold was placed in a special baking oven at a temperature of 40ºC and the polymerization time is 5 hours (Fig.10, e). After polymerization, the excess of filling material is eliminated using a machining process (Fig.10, f).

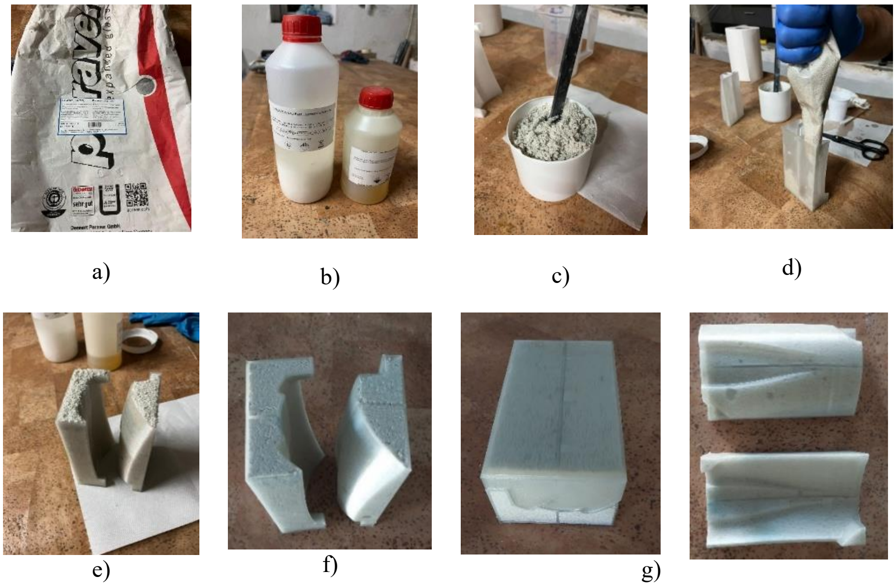


Fig.10. Filing the mold.
a) Paraver, b) epoxy resin, c) material mix, d) filling the mold, e) after coating, f) eliminating the extra material, g) final mold

4. Results and discussions

In table 1, specific data related to the two methods are presented. If *method 2* is used, there is a considerable reduction of time and material compared to *method* 1 for manufacturing the considered mold. Even compared to other traditional methods, the innovative manufacturing method (*method 2*) is considerably faster and more economical.

Table 1. Comparison of the two methods.

Method	Material	Weight of printed material	Printing time	Total fabrication time
1	PETG	661g	3d 17h 54 min	4 d
2	PETG + Paraver + Epoxy resin	141g	23h 32min	1d 6h

The total fabrication time includes the following activities: 3D printing, printer setup, material roll replacement, post-print finishing (for *method 1*). For *method 2* are added: filling material preparation, coating and final finishing.
The total fabrication time, for *method 1,* measured in laboratory conditions is four days, having in view that 3 rolls of 250g, PETG filament necessary for the 661g mold mass. The mold fabrication time for innovative manufacturing (*method 2*) was reduced at one day and six hours, it means of a reduction by approximately 69% compared to making the entire mold from printed material (*method 1*).
The quantity of the printed material was reduced by 79% (661g vs 141g), in this case it can be said that the cost of printed material has been reduced by approximately 79%. If it is compared with the price of the filling materials, paraver with resin mixed filler is at least twice as cheap as printed material. Therefore, the material costs for innovative manufacturing method (*method 2*) were reduced by approximately 40% compared to manufacturing the entire mold from printed material (*method 1*).
It should be also mentioned that even if the malleability temperature of the printed material (in this case PETG) is higher than the coating temperature, it can deform over time when it is reused. The resin with mixed paraven will provide plastic stability at temperatures over the time. Molds manufactured by using this innovative method have greater durability, rigidity and it can be used for o large number of times than molds made by using only 3D printing (*method 1*).

5. Conclusion

The innovative manufacturing of molds for producing fiberglass or carbon fiber parts for small UAV and VTOL aircraft consists of using additive manufacturing to create a 3D-printed shell and filling the void with an epoxy resin mixed with glass granules. Compared to traditional mold manufacturing methods and even the complete manufacture of the mold from printed material alone, the innovative method described in this article, offers the advantages of reducing the manufacturing time and cost. It is a method suitable for rapid prototyping of customized parts, even for

the production of a larger number of parts if the active surface of the mold is well processed.
Considering the fiberglass or carbon fiber parts, in the case of additive manufacturing of molds using FDM process offers cost and time advantages over traditional methods of manufacturing molds.
Comparing the time for entire mold manufacturing from printed material to the time for mold manufacturing in an innovative manner, it was reduced by approximately 69% and material costs were reduced by 40%. And if it is taken into account that the composite mold, made of both printed material and paraver resin filler, has plastic stability at coating temperatures over time and it has a better rigidity and longer life time.

References

[1] Estradaa M. A. R., Ndomab A., *The uses of unmanned aerial vehicles –UAV's- (or drones) in sociallogistic: Natural disasters response and humanitarian relief aid*, Procedia Computer Science, **49**, 2019, p. 375–383.
[2] Mohsan S. A. H., Khan M. A., Noor F., Ullah I., Alsharif M. H., *Towards the Unmanned Aerial Vehicles (UAVs): A Comprehensive Review*, Drones, **6***,* 6, 147. https://doi.org/10.3390/drones6060147
[3] Muntean S., Oancea G., *Current trends in designing and manufacturing of electrical VTOL Aircraft*, Acta Technica Napocensis - Series: Applied Mathematics, Mechanics, and Engineering., **67,** 2S, 2024.
[4] Croitoru E.I., Oancea G., Constantin N., *Impact Testing on Composite Panels of Fiberglass, Carbon and Kevlar-Carbon A comparison and validation study*, Materiale plastice, **4**, 2017, p. 700-707.
[5] Muntean, S., Pop S., Oancea, G., *Rapid prototyping process of aerodynamic components from an UAV,* Macromolecular Symposia, 414, **3**, 2025, 70041, Special Issue: 8th International Conference Polcom 2024, https://doi.org/10.1002/masy.70041
[6] Blaj M., Oancea G., *Fused deposition modelling process: a literature review*, IOP Conference Series: Materials Science and Engineering, **1009**, 2021, 012006, doi 10.1088/1757-899X/1009/1/012006
[7] Almeida O., Souza P.R.C., Cunha E. A., *Numerical Approach for Implementing Air Intakes in a Canard Type Aircraft for Engine Cooling Purposes*, Journal of Aerospace Technology and Management, **13**, 2021, https://doi.org/10.1590/jatm.v13.1192