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THE USE OF TECHNOLOGY OF SPATIAL PRINTING IN DESIGNING THE PZL-10W ENGINE MODEL

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Abstract

The aim of this paper is to present the possibilities of using 3D spatial printing technology to create complex models, e.g. turbine helicopter engines, PZL-10W type, operated on the W-3 "Sokół" helicopter. We have presented the process of creating a spatial model using CAD software. It required a careful selection of the parts necessary for its manufacture as well as elimination of minor parts, which were insignificant from the functional and educational perspective of the model. We presented the type of printer which was used to prepare the model, and also its software. The verification of the correctness of designing the files for particular parts was made with Netfabb software. Proper verification affected the choice of files to be sent to the 3D printer software, where they underwent further slight changes concerning, among others, the thickness of the layers and the percentage of filling the interior of the individual parts of the engine. The printouts of the selected engine parts have been shown in the photographs. We also (briefly) described the processes of treatment of the parts, their labour intensity as well as the hardware used on a regular basis for this purpose. Finally, we discussed the assembly process of the entire engine. In conclusion, we stressed the importance of the model as a significant didactic aid which is to support the process of acquiring knowledge related to the construction, kinematics and operation of the turbine engine. We also specified the amount of used materials, labour consumption (in man-hours) with regard to the same printout of the parts as well as the finishing works.

Keywords: 3D printing technology, spatial modelling, PZL-10W engine model

1. Introduction

Ever since the introduction of the first prototype of the 3D printer in 1984, this technology has been rapidly developing. The demand for devices which are capable of producing a required element in a matter of hours has constantly been growing. Spatial printers are becoming standard company equipment in the automotive industry, aviation and other industries related to daily life. Depending upon the technology, these devices can generate objects of each shape. The only limitations are the skills of the user who projects their imagination onto a 3D model in CAD software and the price of the printout itself or a possible printer.

The exploitation of spatial printing to print aircraft components or their propulsions is becoming a more and more thoroughly examined and used method of manufacturing parts in aviation. In the Air Force Academy in Dęblin, the 3D printer working in FDM technology was used to print the PZL - 10W engine model. The engine solid consists of an internal combustion compressor as well as turbines with the exhaust outlet system. The model has got moving parts which present the engine kinematics. Spatial printing is a process of the formation of physical 3D elements, designed in CAD software. The model is created on the basis of a virtual division of the project into horizontal cross-sections of a suitable thickness, or as a constantly changing projection of horizontal cross-sections of the emerging model.

The design of the PZL-10W engine is a didactic-visual model, giving a possibility of a tangible contact with the elements of the engine used in the W-3 „Sokół" helicopter – 0.

Fig. 1. The W3 - Sokół helicopter and PZL-10W turbine engine 0

2. Preparation of the model of the engine

The initial stage of creating the engine model was its choice. We selected the PZL-10W engine since it is a popular propulsion unit in W3 "Sokół" helicopters, which has been successfully used in different versions in the Polish Armed Forces. The engine was produced by Wytwórnia Sprzętu Komunikacyjnego "PZL - Rzeszów " S.A. and is designed to operate in a twin-engine propulsion system of the PZL - "Sokół" helicopter (W3, W-3A and their versions).

The process of preparing the model for printing started with the selection of elements involved in the development of the engine. We rejected items containing minor, less important details such as labyrinth shaft seals, the inside of the starter, movable elements in the accessory gearbox (0), pumps and the like. We focused on the main parts, i.e. the compressor rotor, power turbine disks and also the entire engine body (0).

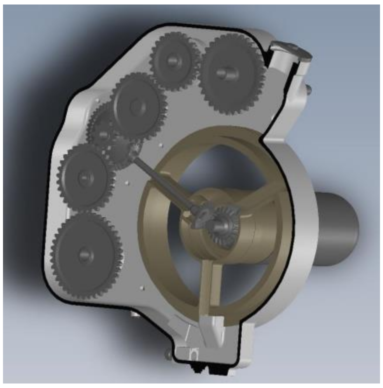

Fig. 2. Cross-section of the accessory gearbox

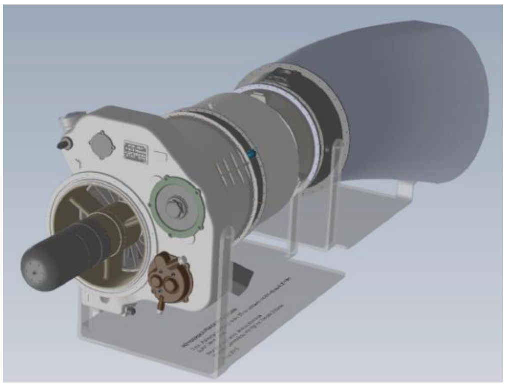

Fig. 3. Final CAD design of the engine

Inside the gearbox, gears and drive shafts which transmit drive from the compressor shaft onto individual units mounted on the gearbox are located. These were redundant elements which increased the weight of the building material, and thus the cost of the printing. On the other hand, gear transmissions are invisible in the model and do not serve any particular purpose.

The 3D printing technology of the MakerBot Replicator Z18 printer (0) required setting a specified thickness to the wall elements. Therefore all the parts composing the whole engine model were prepared in such a manner that the minimum wall thickness was no less than 2 mm. This condition was also met due to endurance reasons of the structure so that in exceptional circumstances when there is an interference of an external factor, there occurs no damage to the material structure.

Fig. 4. MakerBot Replicator Z18 Printer 0

Next, the particular components of the model were converted to the files format that was supported by all devices of this type, to the so-called STL format. At a later stage, they were all sent to the Netfabb programme, which was to check the correctness of the STL files, search for any possible irregularities, surface discontinuities in the parts, holes or other undesirable anomalies in the solid grids (0).

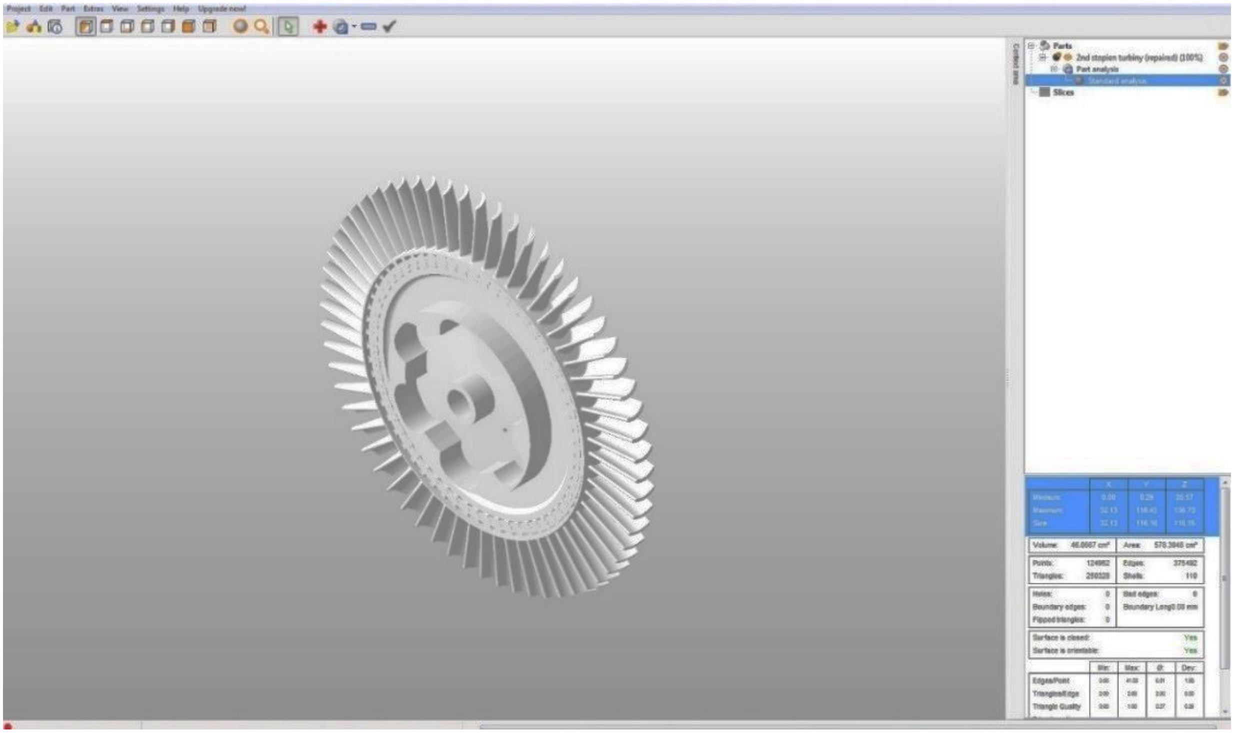

Fig. 5. A second stage compressor turbine disk in Netfabb programme

3. Printout of elements of PZL-10W engine model

The printing of the engine parts started with making all the rotating engine components on the Replicator18 printer. These were printed with the filament in the blue colour to make it stand out in the background of the light grey engine body. Printing in the FDM technology allows using materials in different colours, however, in the case of a given printer (single head), it is linked with replacing the filament every time. While using the software provided with the printer, it was possible to introduce changes to the thickness of the layers as well as the percentage filling of the solids of individual parts of the engine (0).

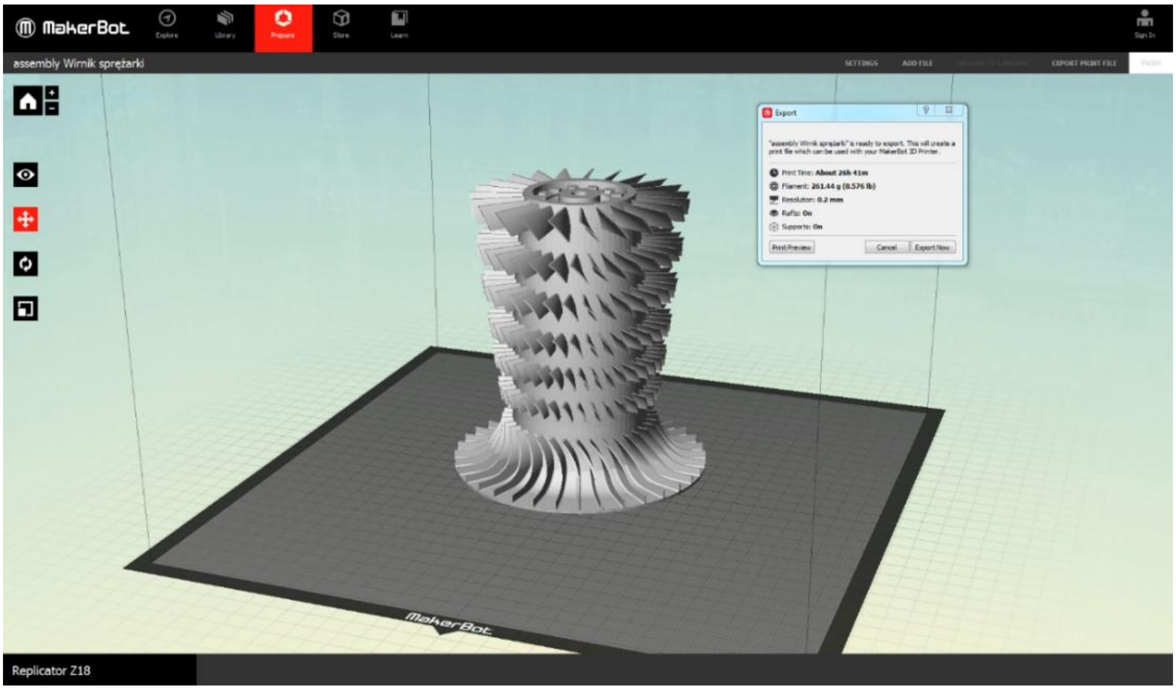

Fig. 6. View of the compressor barrel prepared for printing, placed on a table in the MakerWare software

The MakerWare software also allows adjusting the number of walls and the width of the raft and also interference in the use of support bearings during the printing of the parts. The printing accuracy ranges between 0.1 and 0.2 mm, allowing the user to print solids of a rather complex and challenging structure accuracy – see 0.

Fig. 7. Power turbine after its extraction from the inside of the Replicator 18

The resulting parts had 10- or 20-percent filling. The greatest challenge was to print the largest parts of the engine model, i.e. the accessory gearbox and part of the exhaust outlet system (0). The latter occupied approximately 90% of the working volume of the printer. The safety margin was equal to approximately 1.5 - 2 cm away from each side of the working table.

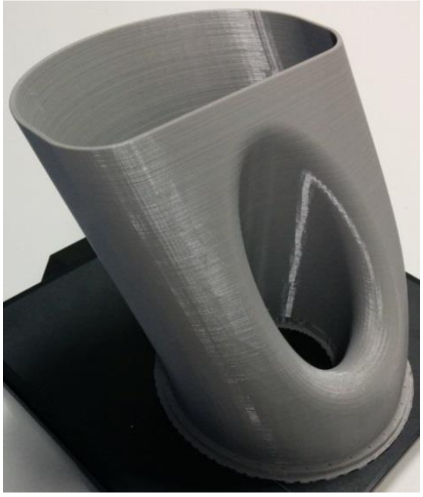

Fig. 8. The exhaust outlet system after printing

Another important element related to the printing was to perform elements of the compressor body along with the diffuser blades (0). An important aspect of the work was a removal of the bearing material, which in many components of the engine constituted a crucial part of the printout.

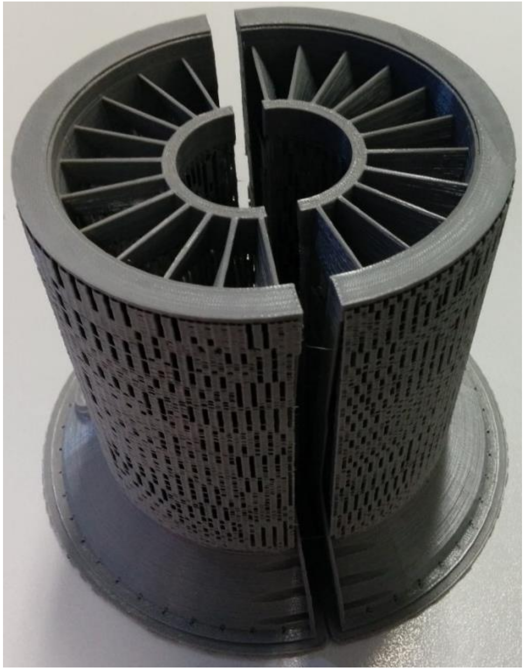

Fig. 9. Two halves of the compressor body

4. Treatment of components

All the parts that composed the whole of the PZL-10W engine model needed a removal of support bearings which emerged in the process of printing (0). These activities are time consuming, in this case taking up approximately 300 man-hours. Having removed the major mechanical elements such as support bearings, we went on to another, more thorough cleaning and matching the parts. The activities were carried out with the use of files, sandpaper of different grit sizes, blades, saws and multi-use tools with replaceable endings - 0 .

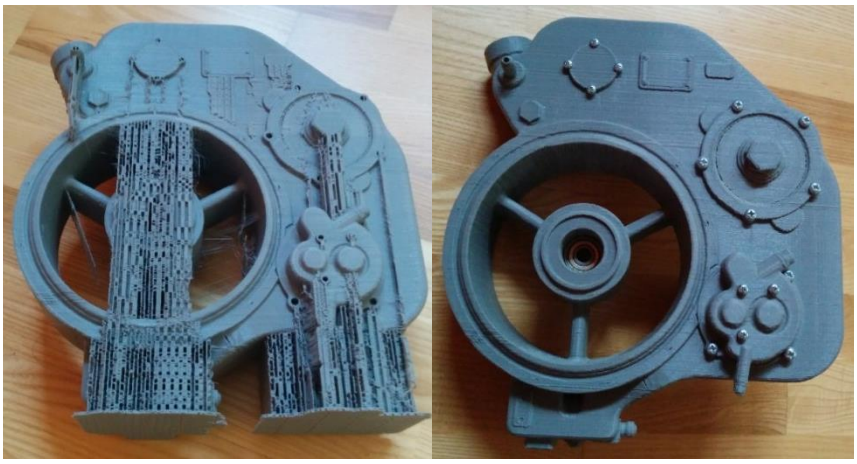

Fig. 10. The accessory gearbox before (on the left) and after (on the right) the process of removing support bearings and the finishing treatment

Fig. 11. A set of tools used for the treatment of the parts

5. Assembly of the PZL-10W engine model

The stage ending the works which is related to the construction of the PZL-10W engine model consisted in collecting and assembling the items, in good order, as well as combining them. The rotating sub-components were mounted on rods of carbon fiber, 8 mm in diameter. We did not use any adhesives or other connecting elements. They were merely matched by compression. The wheel shafts were mounted in ball bearings embedded in housings that had been prepared at the design stage and which ensure free rotation (0 . 0). The components that make up the body of the engine were connected by means of screws, 2 mm in diameter. It allowed, on the one hand, secure joining, taking into account the number of screw connections, without the fear of cracking of any adhesive bond; on the other hand, it was possible to achieve aesthetic finishing and to fully dismantle the model (0).

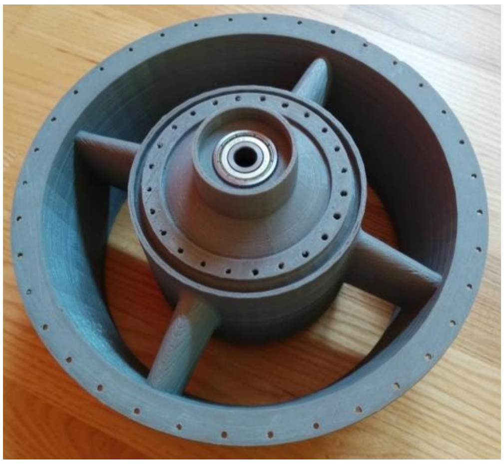

Fig. 12. Mounted ball bearing in engine unit

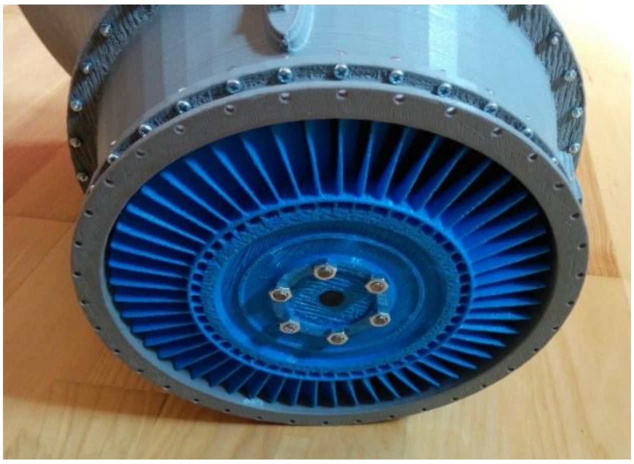

Fig. 13. View of assembled rear part of the PZL-10W engine model

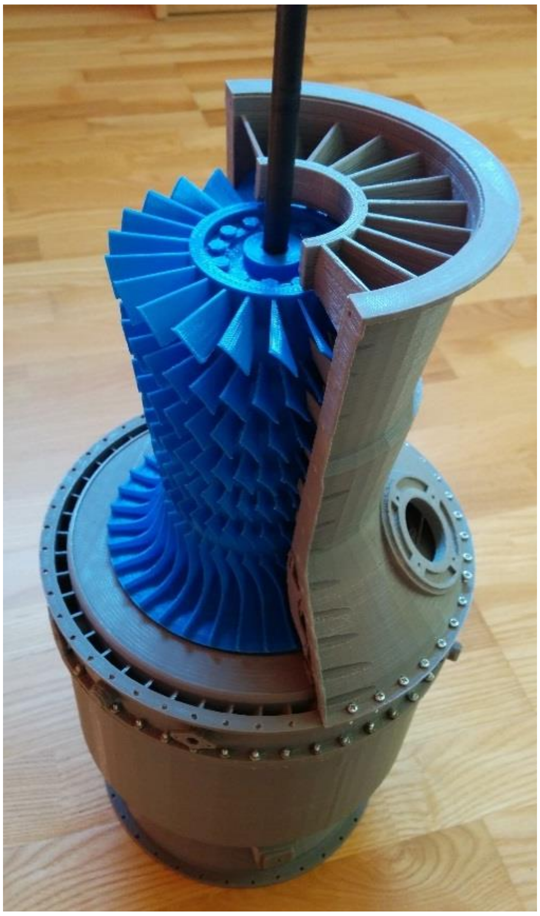

Fig. 14. Assembly of the model during the works

The design of the model ensures separation f the driving part, i.e. the turbine and the drive shaft together with the body and the exhaust fumes system, from the remainder of the engine, i.e. the combustion gas generator and the associated elements (0). Both parts of the model were placed on separate stands made of plexiglass. Moreover, the upper half of the compressor body can also be removed in order to check the functioning of the compressor's rotor.

Fig. 15. Complete PZL-10W engine model
Fig. Jarosław Ćwiek

Conclusions

When printing the individual components that make up the complete engine model, we consumed a total of 3,514.85 grams of filament, including 460.69 grams of blue and 3,054.16 grams of grey material. The time required to create all the eighteen parts inside the printer was equal to 291 hours and 18 minutes. The work performed during the processing, cleaning and assembly equalled approximately 400 man-hours. The problems encountered during the entire printing process of the model from its CAD form to the actual solid turned out to be minimal for such an advanced scale of the task, and using the Markerbot Replicator Z18 printer, for the first time in the creation of parts of such a size.

The rotating elements which are mounted on the bearings move without any hindrances, there is no contact between them and the adjacent fragments of other engine parts. The screwed connections are solid and secure. The whole PZL-10W engine model can be carried easily, with no fear of any faults, however it is necessary to maintain proper care due to the type of the material it was made of.

The engine model is an interesting example of using new innovative 3D printing technologies in the design of engine parts and engine components exploited in industry as well as aviation. The created model may easily serve as a significant didactic aid which is to support the process of acquiring knowledge related to the construction, kinematics and operations of the turbine engine.

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