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WANKEL ROTARY ENGINE IN 3D PRINTING

Abstract: In recent years, 3D printing (Additive Manufacturing) has evolved substantially and very rapidly, which has resulted in high affordability for the purchase of 3D printers and diversified printing by professionals, hobbyists, or the curious. Consequently, this type of technology is in a continuous evolution beneficial to mankind and offers development opportunities for almost every field existing in our lives such as: automotive engineering, space engineering, medicine, psychology, etc. The paper presents the solid modeling of the components of a Wankel engine, the method of printing the components with the help of the 3D printer, at a reduced scale compared to the real one, followed by the realization of the engine assembly, using Inventor Student 2023.

Key words: Additive Manufacturing, 3D printing, Wankel, modeling, simulation, Autodesk Inventor.

1. INTRODUCTION

Additive manufacturing is a process of manufacturing 3D solid objects by adding layer by layer, whereby physical objects are produced using data from a digital model, a 3D model, or other sources such as an Additive Manufacturing File [1], [2]. Such a process has already demonstrated high flexibility as well as innovative performance in multiple business sectors.

The most important 3D additive manufacturing technologies are [3], [4], [5]: FDM – Fused Deposition Modeling; SLA – Stereolithography; DLP – Digital Light Processing; SLS – Selective Laser Sintering; SLM – Selective Laser Melting / Direct Metal Laser Sintering; LOM – Laminated Object Manufacturing; PJP – PolyJet Printing etc., Figure 1.



Figure 1 Additive manufacturing technologies 3D: a – FDM; b – SLA; c – LOM; d – PJP.

As this technology changes and discovers new and new areas of application, especially in automotive engineering, space engineering, medicine, the toy industry, etc., its many advantages, from benefits for

production and quality control, to data flow analysis and predictive maintenance.

3D printing allows individuals and companies to quickly prototype ideas for new parts or products, and also significantly reduces costs related to product creation, minimizing supply chains, waste produced, and storage space required for the resulting products [1].

An extreme field to target where 3D printing is beginning to strengthen its effectiveness is the automotive field, where multiple companies design and build their products, from simple products to complex subassemblies, engine parts, etc. [10].

For example, one can demonstrate the feasibility of modeling, simulating and 3D printing a Wankel engine, obtaining a functional prototype [11], Figure 2. Basically, the Wankel engine is a type of internal combustion engine in which rotation is generated by a piston rotary with a triangular shape, thus replacing the traditional connecting rod-crank mechanism used in other engines.

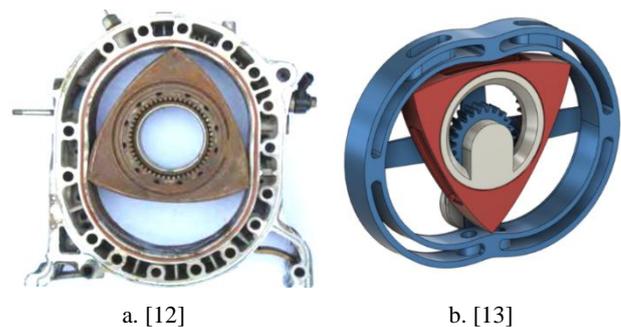


Figure 2 Triangular rotary piston Wankel engine: a – real model, Mazda RX-8 car; b – CAD model.

The CAD modeling process using Autodesk Inventor 2023 is an efficient and accurate process. The software provides powerful tools for partial recognition and modeling of the complex geometry of the Wankel engine, including the triangular rotor and ellipse-shaped casing, which can enable a detailed virtual representation of the engine prior to manufacturing [14], [15].

In any additive manufacturing process, the essential work stages are the following: design, pre-processing, 3D printing, post-processing and surface finishing [16], Figure 3.

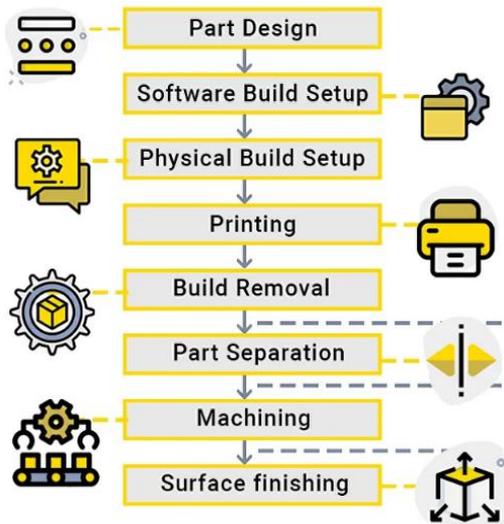


Figure 3 Additive Manufacturing workflow [16].

Once the CAD modeling is complete, the CAD file can be converted into sequences of instructions and tools that are used by a 3D printer to create each layer of the 3D printed part. For example, Creality Slicer 3D is one such free, open source program that allows visualization, processing, segmentation, registration and analysis of 3D images and networks from various domains, as well as planning and navigation of image-guided procedures [17].

FDM (Fused Deposition Modeling) rapid prototyping technology is the most widely used additive manufacturing technology due to its simplicity and affordability. The technique adopted in this technology consists in rigorous temperature control for melting the material and depositing it layer by layer [1], [3].

Additive manufacturing technology basically consists of passing a plastic filament, most often PLA (Polylactic Acid), through an extruder that heats it up to the melting point, then applying it evenly layer by layer. The extruder is heated to melt the plastic filament, moving both horizontally and vertically under the coordination of a numerical control mechanism controlled directly by the printer's CAM application. As it moves, the head deposits a thin string of extruded plastic which, upon cooling, hardens immediately, adhering to the previous layer to form the 3D model [1], [18].

PLA is a thermoplastic polyester made from renewable resources, being a very easy to use material. One of its major advantages is that it is naturally biodegradable, being able to decompose in the environment in about 6-24 months [18]. The behaviour of thermoplastic polymers is a function of the mutual relations between external factors (temperature, temperature action time, etc.) and the structure of the polymers, which is strictly determined by the molecular bonding mechanisms [19].

2. WANKEL ENGINE – CAD MODELING, SIMULATION, 3D PRINTING

Physically making a scaled-down Wankel engine by printing the components with the help of the 3D printer, followed by their assembly, starting from the solid modeling of the components and making the engine assembly, using Inventor Student 2023. The Wankel engine was printed on the components, with the help of the 3D printer - Creality Ender 3 Pro using PLA filament. Used the Slicer program to preview the parts to be printed and converted them to .gcode files to be recognized by the printer program.

2.1 Wankel Engine Modeling in Autodesk Inventor 2023

The CAD modeling of the Wankel engine elements was done in the Autodesk Inventor software program (Figures 4-11). Each component was modeled in Autodesk Inventor Part software (*.ipt), using 2D drawing commands such as Line, Arc, Rectangle, Circle and 3D drawing commands such as Extrude, Sweep, Loft, Mirror, Thread, Chamfer, Revolve etc.

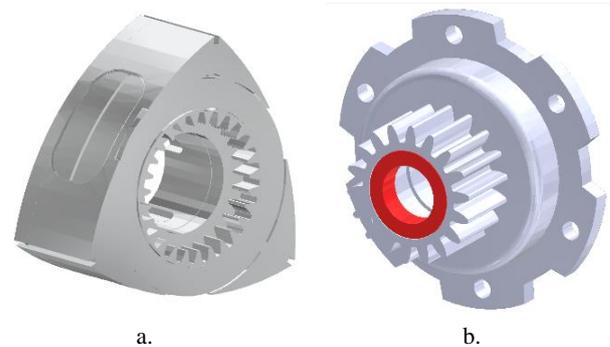


Figure 4 Wankel engine subset:
a – triangular rotor;
b – stationary gear.

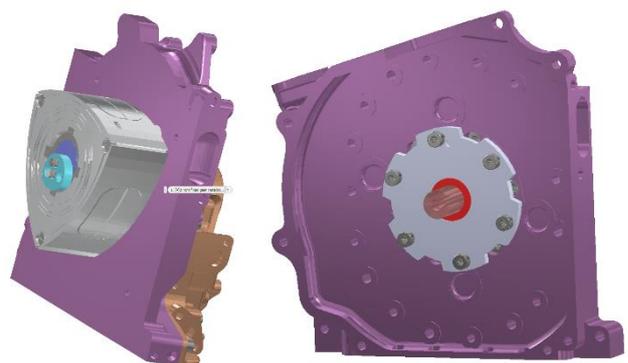


Figure 5 Wankel engine subset: rotor flank-ring gear-flange.

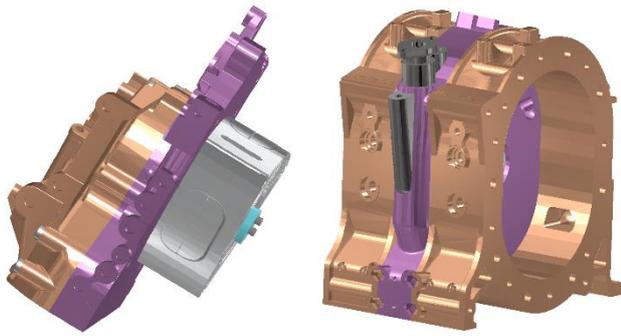


Figure 6 Wankel engine subset: rotor side housing-rotor housing.

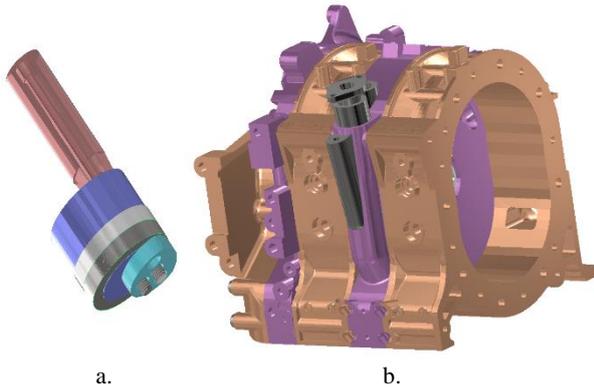


Figure 7 Wankel engine subset: a – eccentric shaft; b – side housing-rotor housing.

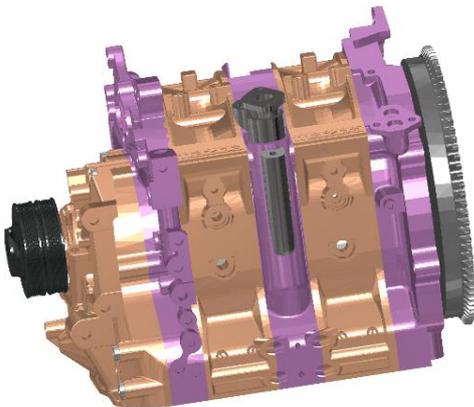


Figure 8 Wankel engine subset: rotor side housing-rotor housing-intermediate housing-rotor side housing.

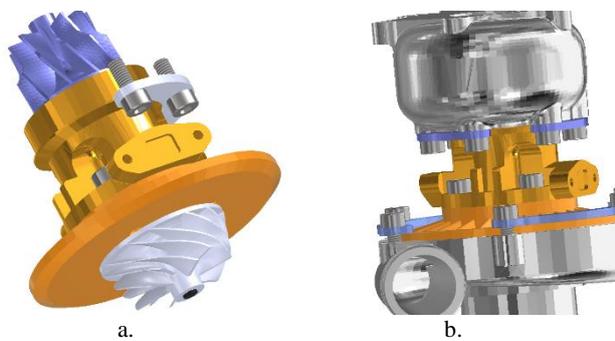


Figure 9 Wankel engine subset: a – compressor wheel-turbine wheel-turbo assembly;

b – turbo exhaust housing-turbo housing clamp-turbo assembly.

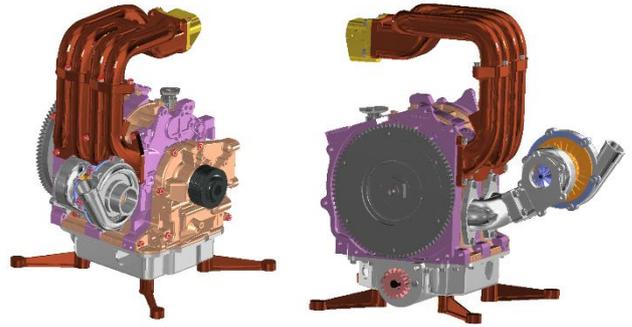


Figure 10 Assembled Wankel engine.

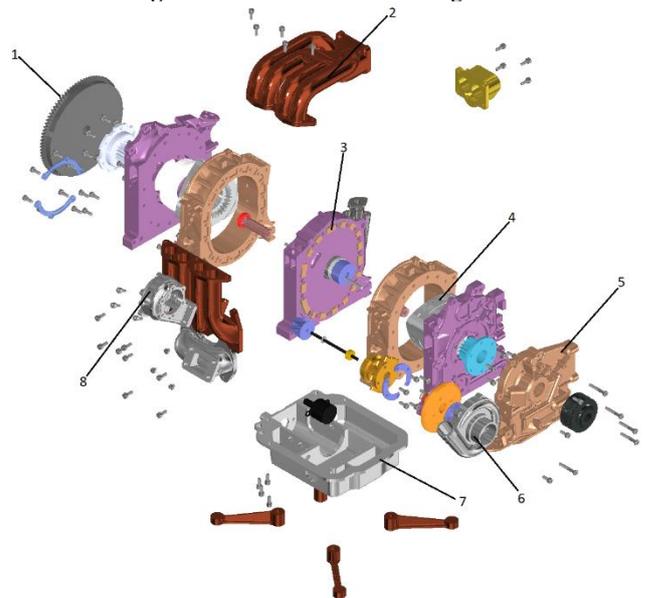


Figure 11 Wankel Engine – expanded view:
 1 - flywheel; 2 - upper intake manifold;
 3 - rear plate insert assembly; 4 - triangular rotor;
 5 - front plate assembly; 6 - compressor assembly;
 7 - oil pan; 8 - turbo assembly.

2.2 Creality Slicer 3D

Creality Slicer 3D software is used to convert the 3D models into a series of thin 2D horizontal layers and generate a set of instructions for the printer to follow. The cutting process is a very important step in preparing a 3D model for printing. This way various print settings such as layer height, fill density and print speed are customized. These settings can have a significant impact on the final quality of the printed object, as well as on its printing time.

Once the changes are made on the model, the printing profile must be chosen, but before using this profile, the nozzle (0.4 mm) and the filament (PLA) must be checked. If these conditions have been met, the model is chosen and the default configuration parameters of the model in the print area can be accepted.

Figures 12÷16 show the Wankel engine components in the Creality Slicer 3D software.

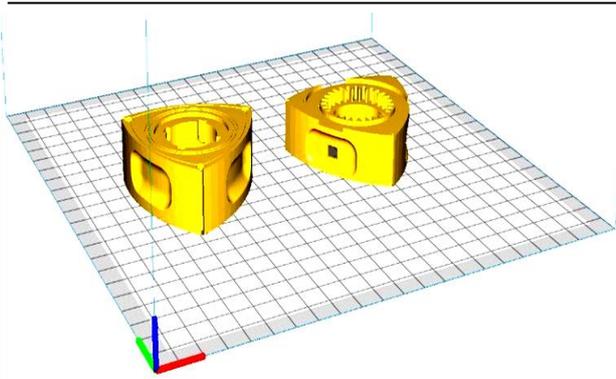


Figure 12 Creality Slicer 3D: triangular rotor.

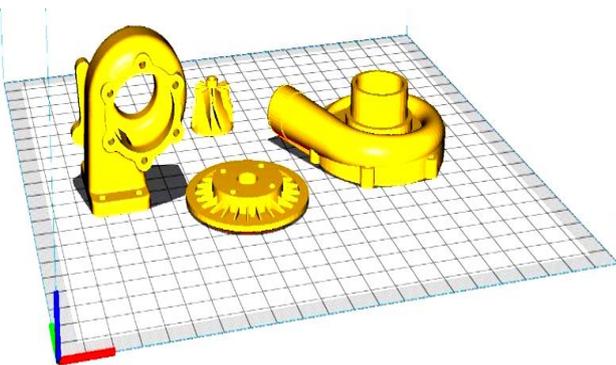


Figure 13 Creality Slicer 3D: turbo assembly.

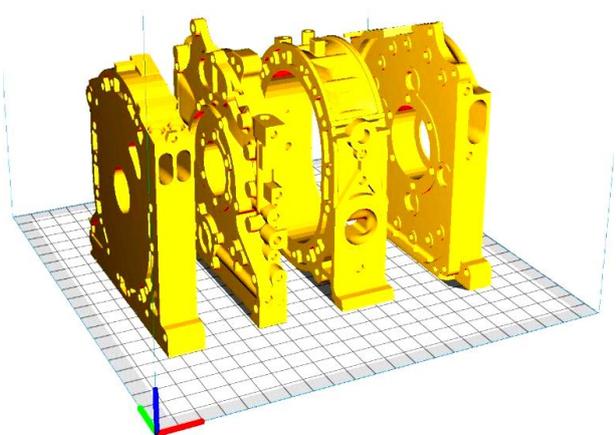


Figure 14 Creality Slicer 3D: rotor side housing-rotor housing-intermediate housing-rotor side housing.

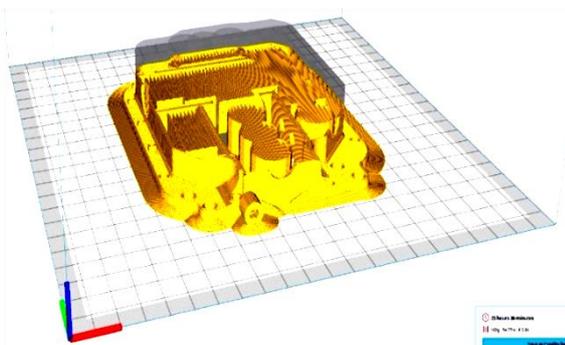


Figure 15 Creality Slicer 3D: front plate assembly.

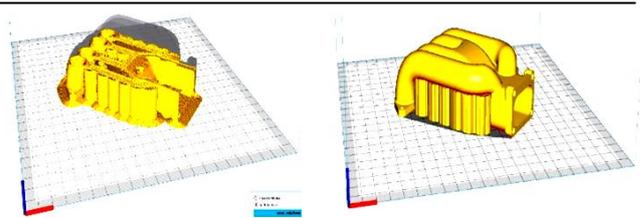


Figure 16 Creality Slicer 3D: upper intake manifold.

Once all the parameters are set up, it's just a matter of segmenting the parts to convert them into a Gcode file. At the end of the segmentation, you can define all the information related to the approximate time needed to print the laminated parts, the amount of filament that will be used and the Preview, Figure 17.



Figure 17 Creality Slicer 3D: parameter configuration.

In the preview area you can get information about the number of layers that will be used to print the part. By moving the scroll bar you can constantly check the printing process, all that remains is to save the Gcode file to take it to the printer and start printing.

2.3 Preparing for 3D printing

The Creality Ender 3 Pro Printer was used to make the Wankel engine components, Figure 18.

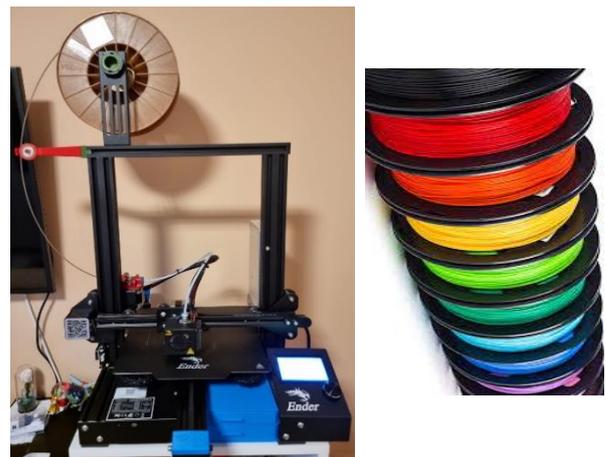


Figure 18 Equipment and printing accessories: a – Creality Ender 3 Pro printer; b – PLA filaments.

It presents a number of specific features, such as: easy use and handling; can use filaments of the following types: PLA, ABS and PET-G; can reach a resolution of 400 µm;

The pad is quite roomy (220x220 mm), it allows printing several objects at the same time, etc. Depending

on the infill adopted for the components and the types of materials used, final products with excellent hardness can be obtained. Also, the print time is quite fast, but it increases or decreases depending on multiple factors. For the actual printing, the .STL file is imported into the Creality Slicer program.

Place the part on the Pad in the application and position it for optimal printing. If the part requires supports or adhesive, these components are added from the program.

The in-fill of the piece and the quality at which the piece is to be printed are set. All changes in the program are saved in a Gcode file that is viewed by the 3D printer. The file is inserted onto a stick containing a memory card which is then inserted into the 3D printer.

The type of filament used is mounted, the Pad is adjusted and adjustments are made to it so that it is straight. To successfully load the filament, the end of the filament is cut at a 45° angle, then it is pressed until it passes through the filament detection hole and the handle of the extruder is held down to feed the filament into the Teflon tube to the nozzle. Next is the nozzle heating - if the filament comes out of the nozzle when the temperature reaches the target value, the filament is correctly loaded.

Set the temperature at the pad and at the extruder according to the recommendations on the filament spool. They contain a temperature range such as 200 C°÷240 C° for the extruder and 50C°÷60C° for the pad. After these settings the printing starts and the print is kept under observation for a print according to the requirements imposed on the parts. Some parts, after printing, require retouching, such as in the case of supports - they need to be cut from the part. Also, some parts require a finish with abrasive objects. It is recommended that when the printing process is interrupted for a longer time, the nozzle should be reheated to 185°C or more until the filament in the nozzle softens. Press and hold the extrusion handle to quickly eject the filament to prevent clogging.

2.4 3D printing of Wankel engine components

To make the components, thermoplastic polyester filament of PLA type, red and green, was used, with its important characteristic features shown in Figure 19.

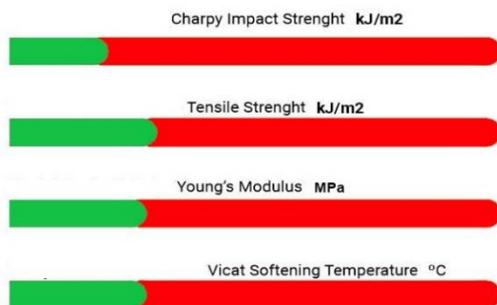


Figure 19 PLA features.

Figures 20÷23 show Wankel engine components printed with the Creality Ender 3 Pro printer.

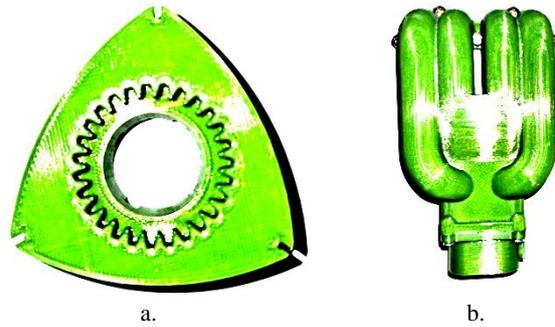


Figure 20 Wankel engine components – 3D Printing: a – triangular rotor; b – manifold.

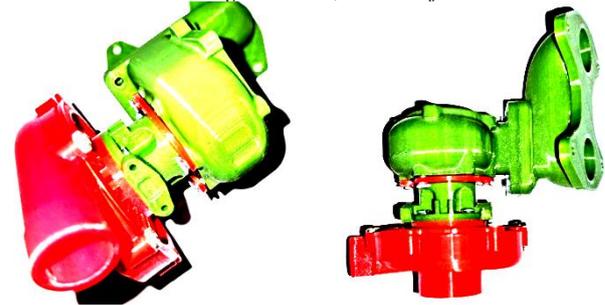


Figure 21 Wankel engine components – 3D Printing: turbo assembly.

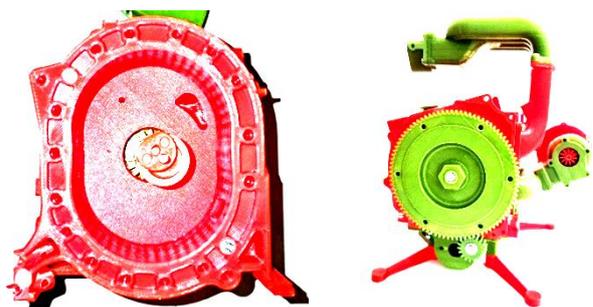


Figure 22 Wankel engine components – 3D Printing: rear plate insert assembly; flywheel and turbo assembly.



Figure 23 Wankel engine – 3D Printing.

In order to create the final assembly, sub-assemblies were made which, in the end, were joined by using assembly or bonding elements such as: screws, nuts, washers and other elements. By using Autodesk Inventor

2023 it was also possible to simulate the Wankel engine to evaluate its functionality.

3. CONCLUSIONS

The modeling process using Autodesk Inventor 2023 is efficient and accurate. The software provides powerful tools for recognizing and partially modeling the complex geometry of the Wankel engine, including the triangular rotor and elliptical casing. This allowed for a detailed virtual representation of the engine prior to manufacture.

The use of 3D printing technology allowed the manufacture of the Wankel engine in an efficient and precise way. This technology provided flexibility in the production of both simple landmarks and complex parts.

3D printing allows the realization of a functional prototype of the Wankel engine, which can be subjected to experimental tests and validation, which allow the evaluation of the performance of the engine in real conditions and the comparison of the results with the simulations made with the help of specialized software.

In conclusion, modeling, simulating with Autodesk Inventor 2023 and 3D printing a Wankel engine allowed for its efficient design and manufacture. Using these technologies, essential information about performance, strength and functionality is obtained, helping to optimize the design and develop a working prototype.

This work aims to contribute to the development and improvement of Wankel engine manufacturing technology by using advanced modeling methods and 3D printing technology.

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