Constructive and Technological Considerations on the Realization of a Prototype of a Rotary Valve Made with 3D Printed Components with UV Resin

Prof. habil. dr.eng. ec. **Mircea Dorin VASILESCU**[1,*]

[1] Polytechnic University Timisoara, Mechanical Faculty, Department MMUT, Sq. Victoriei, no. 2

* mircea.vasilescu@upt.ro

Abstract: *This study is intended to be the first part of a series of technological studies to determine the possibility of realizing pneumatic and/or hydraulic components using 3D additive manufacturing processes with photopolymerizable resins. Since the problem of the environment protection is an important component, the author initiated a study on the structural and technical aspects of the efficient realization of a rotary valve prototype. Finally, considering the correlation and determination of dimensional repeatability of 3D printed parts using a polymerization process with a mask (MSLA) with light-emitting diodes, it is possible to transfer this study to industrial fabrication of this component. At this stage of the study, aspects of alignment in the printing of the analysed part assembly are also identified, as well as the way to determine its positioning and to subsequently correct it for surfaces with changes in flatness or cylindricity.*

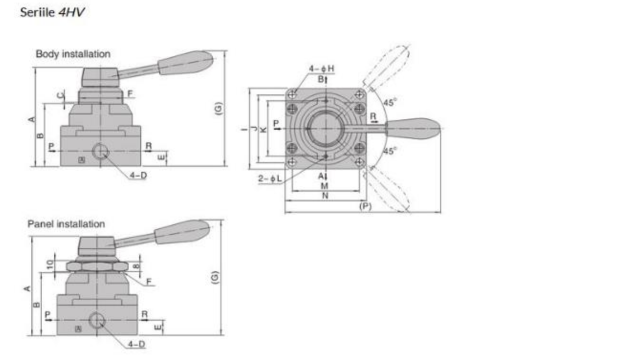
Keywords: *MSLA, 3D printing, resin, pneumatic/hydraulic valve*

1. Introduction

In the current economic conjuncture, determined both by the energy costs of manufacturing aluminium components, but also from other metallic and non-metallic materials, the approach of some technological manufacturing alternatives is becoming more and more important.
The present work addresses both the CAD design part of such components made of aluminium and steel respectively [1], but also the practical realization of these components taken into consideration the CAM and additive manufacturing.
For the present study, a valve with two paths and two positions was chosen. At the same time, it is important to note that the realization of this component will be integrated into more complex constructive solutions that use as an active environment air with pressures of up to 10 atmospheres and water with pressures of up to 50 atmospheres.
It should also be emphasized that the technology envisaged is that of additive manufacturing by optical photopolymerization with an LCD screen. This manufacturing technology was chosen for several reasons. The first is determined by the fact that compared to the other additive manufacturing methods, especially the one performed by the thermoplasty method, which has been encountered more frequently so far in the specialized literature [2, 3], the generated layer is much more compact both vertically and horizontally. Also, the dimensional accuracy of surface realization is in the range of 50 microns, and the quality of the surface generated is the best [4].

2. Constructive CAD-CAM consideration

From a constructive point of view, a rotary valve has a relatively parallelepiped or cubic construction depending on its functional role, one or more inputs, and one or more outputs, respectively. The overall constructive solution is presented in (Figure 1) where it can be observed that we have a lower prismatic body and a rotating cylindrical element, with the possibility of rotation at 360° degree [5].



Tip/Cota	A	B	C	D	E	F	G	H	I	J	K	L	M	N	P
4HV2□□-06	73	45	1.5	1/8"	11.5	M34×1.5	92.5	5.5	62	49	40	3	49	62	120
4HV2□□-08	73	45	1.5	1/4"	11.5	M34×1.5	92.5	5.5	62	49	40	3	49	62	120

Fig. 1. Constructive solution [5]

2.1 CAD consideration for constructive solution

To be able to use these elements in a constructive solution, we have the manufacturer generate them in a 3D CAD solution. The second solution is to generate them based on the size of these elements and an image of the constructive solution. It should be noted that usually the second solution is faster and, in some condition, safer as will be seen below given the aspects of mounting the components.

For a given case (rotary valve), the body of valve has two entry and two exit orifices, depending on the position of the central rod.

To understand its construction and how to assemble or use it, let us consider the individual components. This element is presented in the logical order of its position in the design where the construction valve is created.

The first of these is the body of the valve (Figure 2). For the constructive CAD design solution, the method used was based on scaling the view of the constructive element and inserting it into the side view. The advantage of the method is determined by the fact that it is no longer necessary to measure the dimensions of the element in the scaled picture, thus reducing the design time. The program used to design the component was the educational version of Inventor 2022 [6].

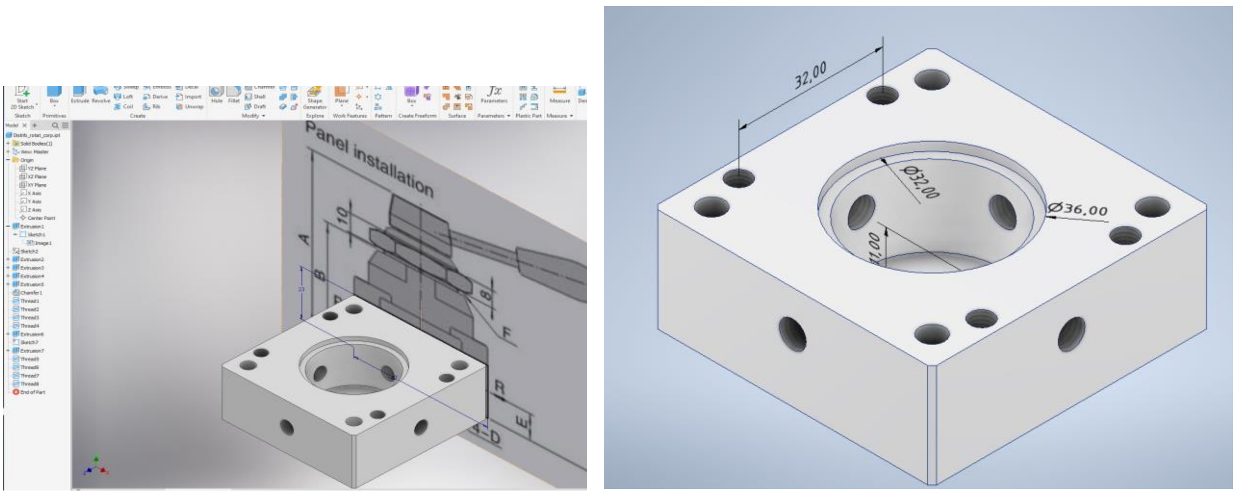
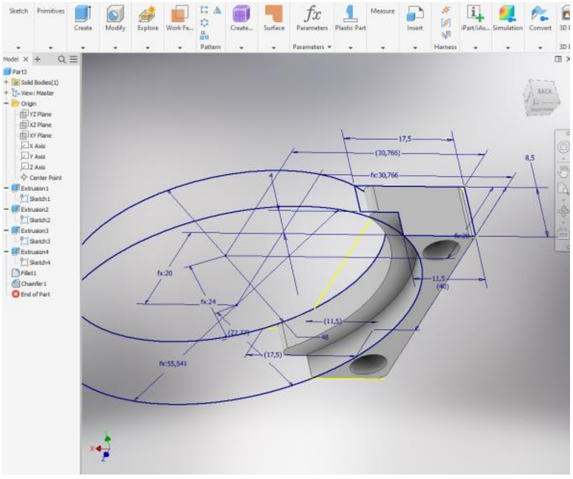


Fig. 2. Constructive body of the valve left picture and CAD construction, right important dimensional surface

The second element that comes into contact with the body is the clamps of the centring element (Figure 3). It can be seen from the picture on the left side of (Figure 3) that the realization of important surfaces is obtained by using the commands for cutting some circular areas. It is important to consider that the dimensions of the circular areas to be made with a play of at least 0.5 mm within the radius of the homologous dimensions on the body with which it comes into contact. The corresponding connecting dimensions are arranged on the body of the generated 3D part in order to correlate them with those of the parts with which it comes into contact, namely the body of the valve and the conic element for fixing and positioning the rotating central element.



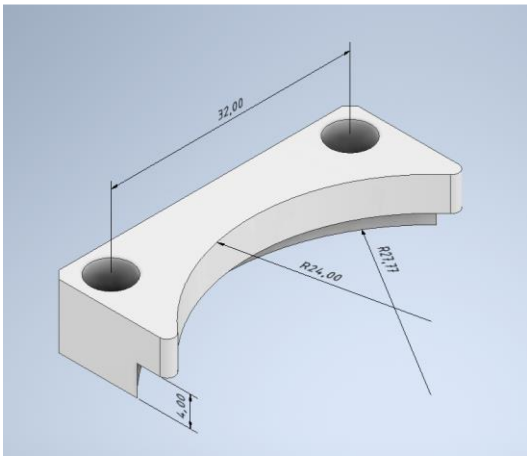
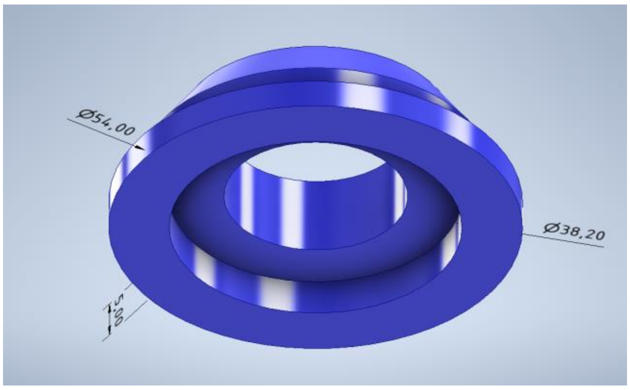


Fig. 3. Constructive clamp body of the valve left picture and CAD construction, right important dimensional surface

The truncated cone element is presented in (Figure 4 left), which is intermediate between the clamps and the rotating centre element which can be seen in (Figure 4 right). This element is positioned on the surface of the rotating valve body.



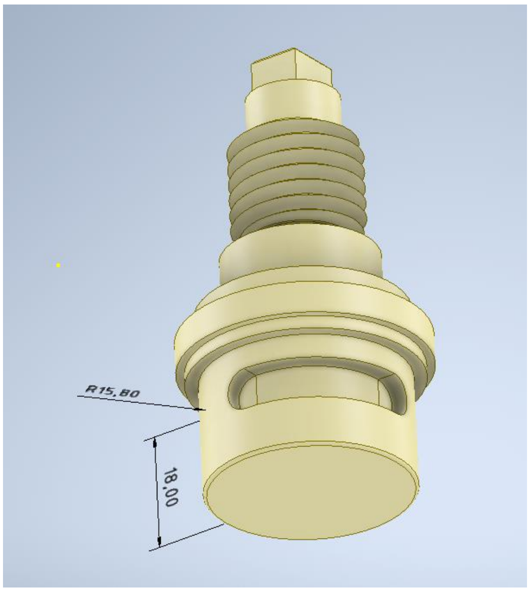


Fig. 4. Constructive body of the left truncated cone element and right the rotating center element

After generating these elements, we will proceed to position the 3D designed elements in order to start the construction of the rotary valve. The assembly order is that of inserting the rotating element into the body of the rotating valve, after which the ring-truncated cone element of fastening and pressing is inserted, respectively, into the fastening and positioning clamps on the side (Figure 5).

To be able to see whether the circuit is properly positioned in relation to the holes in the body, the transparency in the property command of the above-mentioned component will be assigned (Figure 6). It can be seen that the holes are below the median level of the canal, and the easiest way is to change the position of the four holes by changing the position of the centre of the holes. The final assembly with the control rod and the upper tightening nut can be seen mounted on (Figure 7).

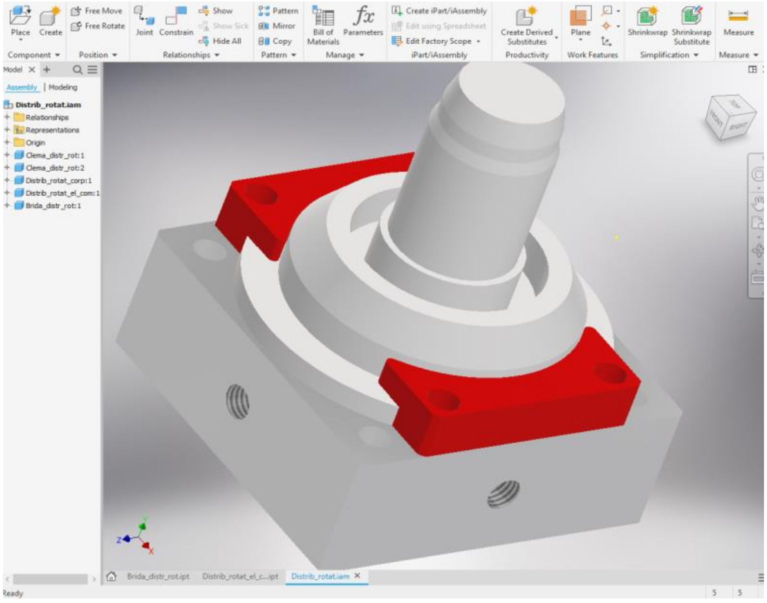


Fig. 5. Mounting of the CAD generated elements

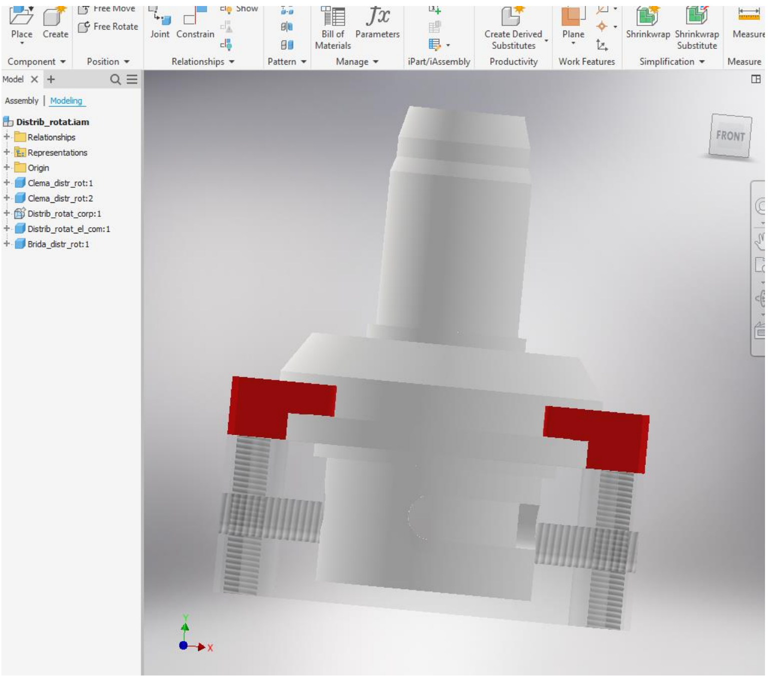


Fig. 6. Transparency of inferior mounting of the CAD generated elements

At this point the design part of the construction is completed and the previously presented parts are exported in solid format for preparation for printing.

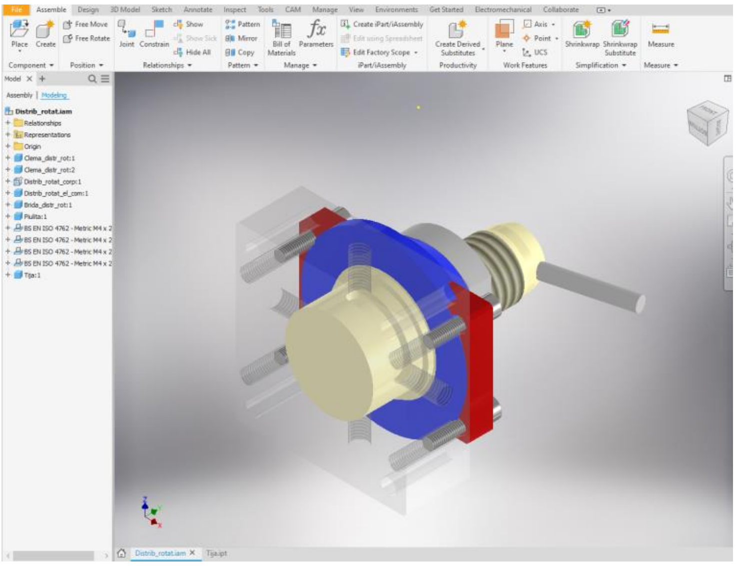


Fig. 7. Assembly mounting of the CAD generated elements

2.2 CAM consideration for elements of constructive solution

The first aspect that is taken into consideration is the roll of the generated components. If the role is for didactical mounting, the generation of the element can be made with a structure with a large dimension inside the body generated. If there is a functional role of this component them must have a smaller dimension, or the body must have a solid structure construction. At the same time, if the component has a static mounting function without mechanical or dynamical functionality, the dimension must be larger.

From the point of view of the mounting dimensions for the realization of the assembly, it is recommended the solution of modifying the dimensions by decreasing or increasing them from the program of generating the structure for printing for the parts that have a symmetry axis (Figure 8). In the other situations, it is recommended to make the correction from the CAD generation part because independent corrections can be made to increase or decrease the different functional dimensions on each area that will be manufactured additively.

The program used to design the layers of polymerized material is of open-source type [7] and is in agreement with both the type of resin used [8] and the printer used for generating the components [9].

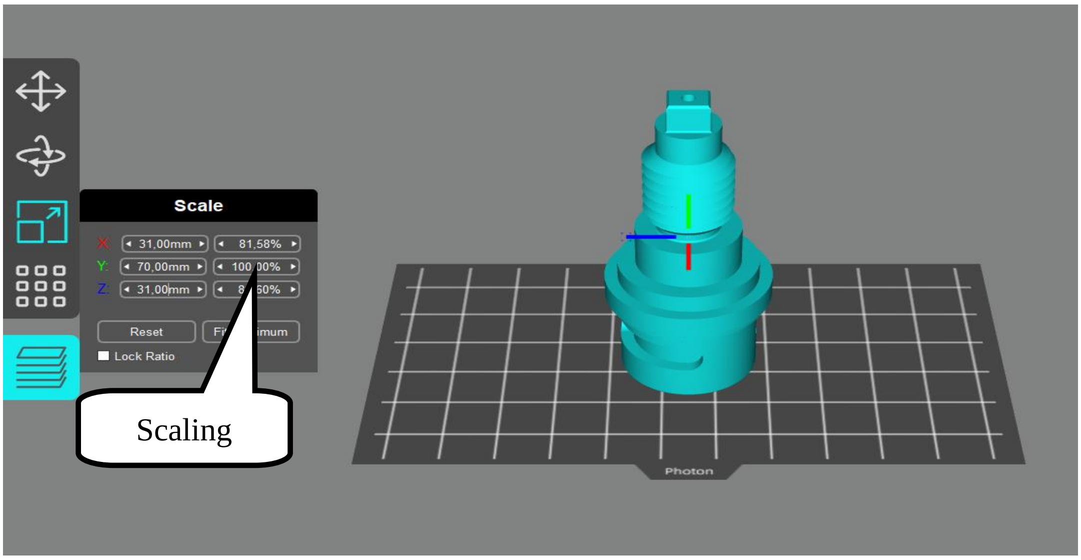


Fig. 8. Scaling of the STL rotating center generated

It is also very important to orient the parts according to the functional role of the printed surfaces because if the printed surface is oriented with supports after this the surface is damaged after the cut of the supporting elements of the part (Figure 9). In the left position of (Figure 9) it can be seen that the functional surface is not affected by the support structures normally used for resin printing (they are placed in the opposite position). The quality of the printed side is very good. After removing them put in the functional surface in right picture from (Figure 9), a different surface quality can be seen on the surface after removing the support’s structure.
An important aspect to consider when 3D printing is the actual value of the surface obtained by printing. It can be seen that the resulting dimensions are different from those designed CAD. For example, if we consider the diameter of the hole in the body of the part that is 32.00 mm, the actual value resulting from 3D printing is 31.96 mm. For the central part considered and which ensures by rotating it the stopping or transmission of air/oil, the value resulting from the design is 31.00mm and the one obtained from 3D printing is 31.34 mm.
A very important stage considering the previous observations of real 3D printed and designed dimensional differences is to ensure the functionality and installation of the valve components. Such a step can be seen in (Figure 10) where the possibilities of fixing the side fastening elements are checked, but also the provision of a clearance large enough to allow the rotating central element to position itself coaxially in the body of the valve and to allow the easy positioning of the axial locking element.

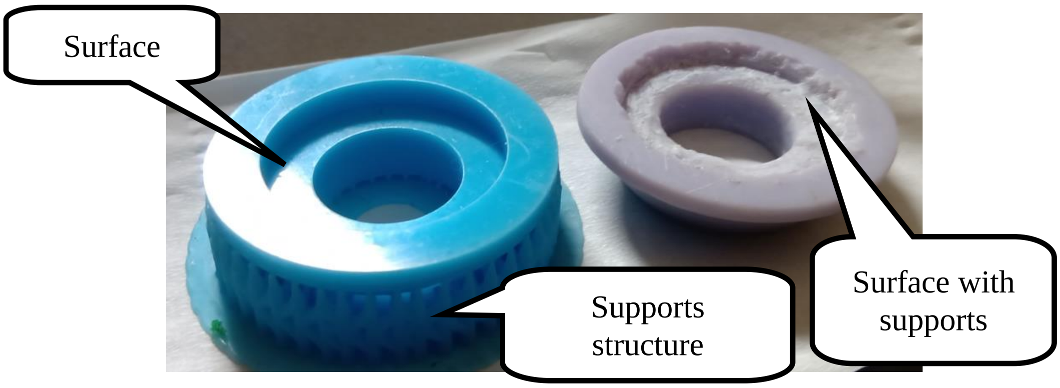


Fig. 9. Surface printed left without supports, right with supports after removing it

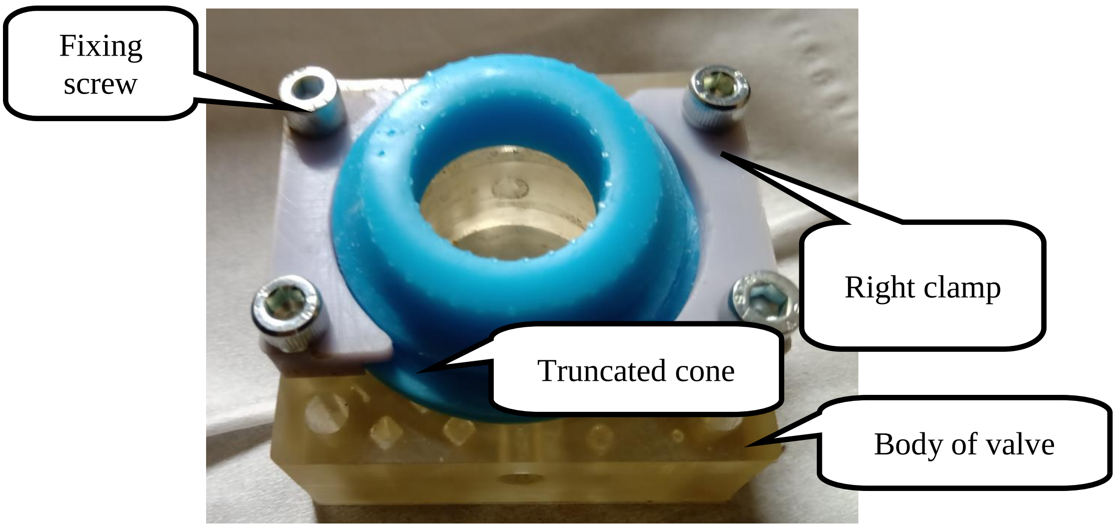


Fig. 10. Functionality and fixing of the valve components

One of the most important phases is the realization of the supporting structure of the part subjected to the printing process. As can be seen from (Figure 11) for the central command element automatic generation is often not with good accuracy. From the figure it can be seen that there are areas of red colour at the bottom that are not supported. This situation may cause surface or printed material deformations in the printing process. A second important aspect is the one related to the arrangement of the supporting structures. From the figure it can be seen that the conical part of such elements is arranged on the cylindrical edge area, and not on the flat surfaces of red colour. As presented in the quality of the surfaces generated at the truncated conic element, this aspect must be corrected by repositioning the supporting elements, or by deleting some of the automatically generated parts, or by moving the tip of the cone to the desired position (Figure 12).

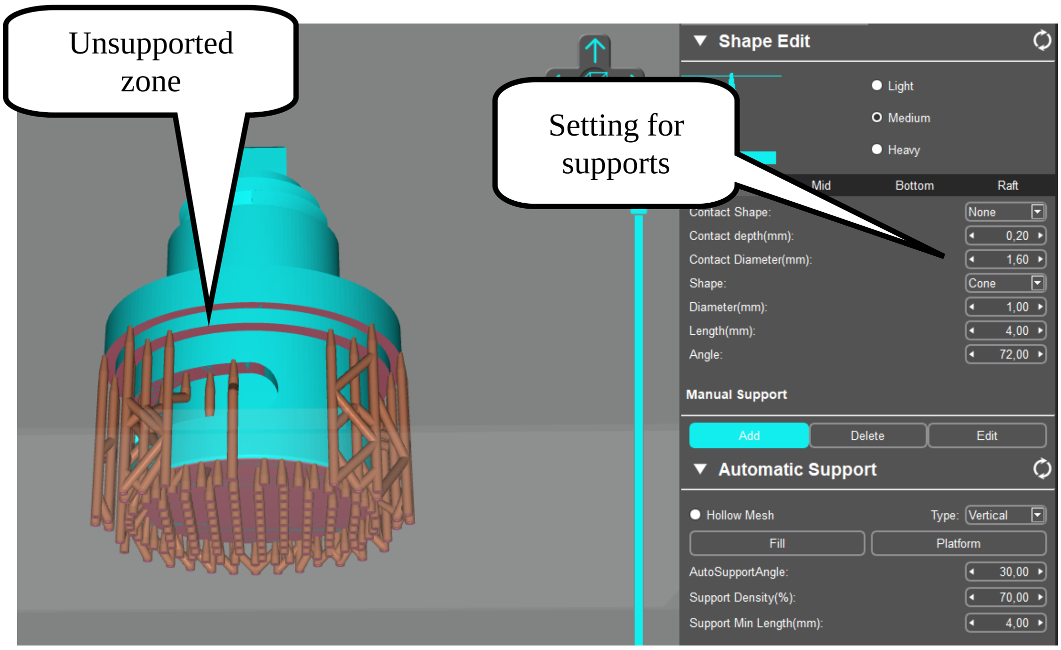


Fig. 11. Automatic generating supports for rotating center component

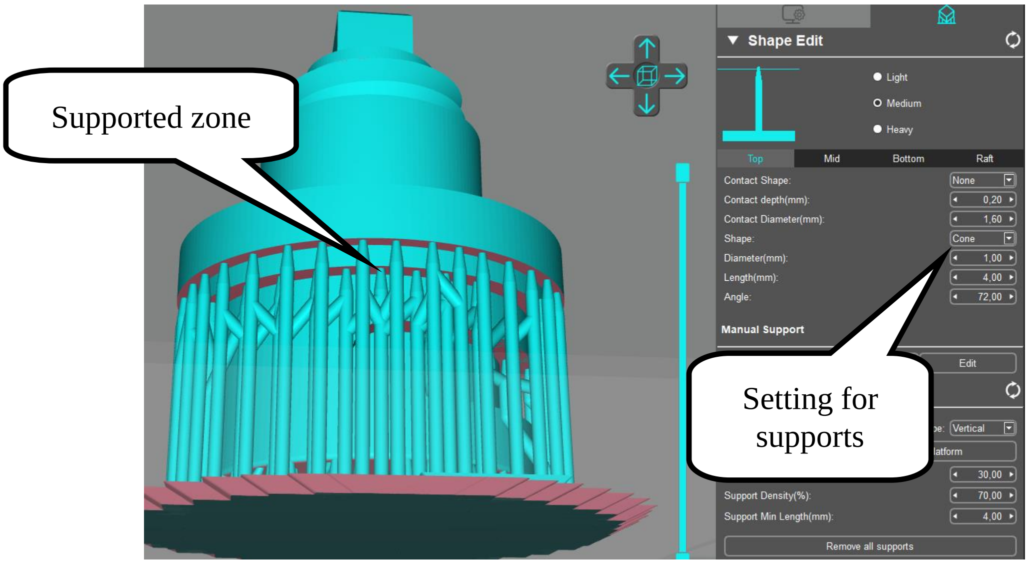


Fig. 12. Manual generating supports for rotating center component

3. Conclusions

Starting from the design part, but also the 3D generation of the part with the related support structure, it can be stated that through this work the bases of the possibilities of conception and technological realization with resin-based additive manufacturing technologies have been laid. The components under consideration are those in the command part specific to pneumatic drive systems, but also hydraulic.

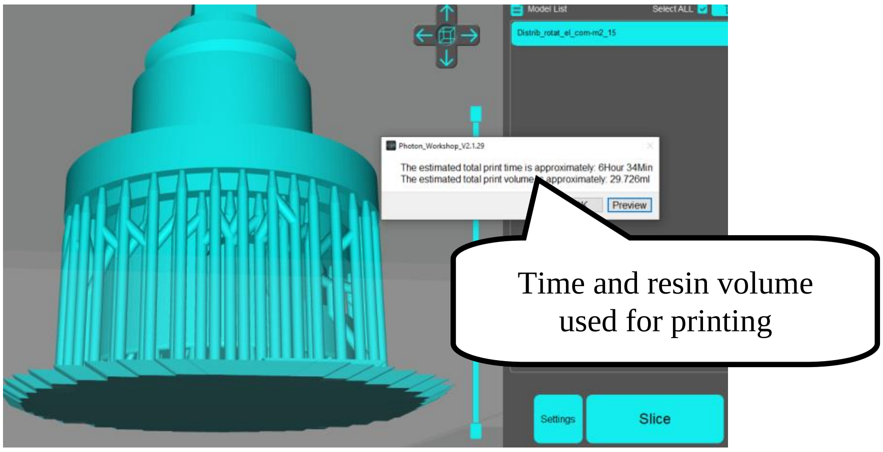


Fig. 13. Slice for generating structure for rotating center component

It should also be noted that the technology of 3D generation by photopolymerization is one of the most accurate both in terms of the surfaces obtained, but also in terms of characteristics of dimensional deviations and form. Based on these conclusions, the research process will be extended by following both the behaviour of the designed components at the flow and pressure demands of the gas or liquid medium used, but also in the comparative study in relation to other additive manufacturing technologies from the economic point and ecological efficiency of the industrial implementation of such a manufacturing solution.

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