Design and 3D Printing of a Mini Vacuum Table with FDM Technology

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Abstract. The paper presents a fastening system of parts of small size and thickness of a vacuum table type. The proposed solution is intended to be used in the clamping and machining of this type of part mainly on the vertical machining center Young Tech YMC 1050, but also on other production systems. The virtual model is made using CATIA V5 software. Modeling with the help of this software will give us the possibility to obtain a part with important interior details. To obtain a one-piece product with all interior details, which can be very hard to machine in traditional ways, we used an FDM (Fused Deposition Model) rapid prototyping technique. Based on the virtual model, with the help of Dimension SST 1200 es 3D printer, a prototype is obtained.

Keywords: vacuum table · 3D printing · FDM printing technology · CNC manufacturing

1 Introduction

The processing of thin-walled parts or sheet metal products has been and represents a delicate problem, especially when catching on the table or in a device is not possible. Also, ensuring a condition of parallelism between the upper and lower surfaces is difficult to satisfy when processing these types of blanks (parts).

The classical fastening systems (vice, specially designed systems, chuck) do not offer the possibility of processing under the imposed technical conditions, especially for the small parts. Therefore the clamping-fastening system with a vacuum table was developed. Vacuum tables are defined as systems used for holding workpieces during a machining process [1]. They consist of a flat top surface with small holes related to a chamber through which the air between the desired workpiece and table maintains a clamping force which must be greater than that needed to machine a part. The part is placed on the top of the vacuum chamber and "fixed down" by the pressure difference between the vacuum chamber and atmospheric pressure created by a vacuum pump [2].

For determining the clamping force is used the formula [3]:

$$F = P \times A \tag{1}$$

where:

– F represent the clamping force [N];
– P represent the pressure difference [N / cm^2];
– A represent the vacuum plate area [cm^2].

The variety of shapes and sizes of the processed parts requires the vacuum fixtures to adapt as well. The clamping force depends on the contact surface, the diameter, and the distribution of the holes in the grid, but also on the type of sealing material used. For that, we have to cover the exposed areas with some waste material or tape [4], to maintain a high suction force.

When it is necessary to machine parts that are much smaller than the active surface of the vacuum table, some manufacturers [5] propose the use of vacuum cards or even adhesives. In this way, it is ensured uniform holding force, through the uniform distribution of vacuum, even when machining into the card layer. In this way, a minimization of vacuum losses is achieved.

The main purpose of the vacuum table is to ensure the access of the tools to all surfaces of the workpiece except that which is in direct contact with the table.

Vacuum clamping systems are widely used for quick and simple machining of wood, plastics and non-ferrous metals. These systems have the great advantages like:

• Time reduction of clamping up to 70%;
• Clamping of thin and flexible materials without vibration or deformation;
• Time-saving for thin materials up to 90%;
• The clamping of non-magnetic material is possible as well;
• Comfortable assembling and handling;
• Compatibility with CNC machine tools;
• In the machining process, there is nothing in the way of the tool;
• No consumables involved;
• No need for an industry-standard vacuum pump.

All these benefits lead to increased productivity and cost-effectiveness because the clamping does not cause any damage to the part and is no need for a laborious time-consuming aligning process.

These paper objectives are:

1. 3D model design of a vacuum table in CATIA V5 software environment
2. Making the physical model by 3D printing technology using the Dimension 1200 SST printer;

The paper consists of 4 sections, the first section presents some introductory details about vacuum tables, in the second section is presented the design mode of a mini vacuum table with the help of the CATIA V5 software. The third section presents the 3D FDM printing technology used for obtaining the psychical model and in the fourth section, some conclusions are presented.

2   Design of Mini Vacuum Table

To design the vacuum table we used the CATIA V5 software. In Fig. 1 we presented the component elements of the vacuum table and Fig. 2 highlights the overall dimensions.

As it can be seen, the vacuum table is made up of a base plate that uses for fixing on the working table of the vertical machining center Young Tech YMC 1050, but, by the dimensions (120 × 140 mm) that we chose, it can be used on any type of working table. Also, the base plate has 2 elongated holes only on the sides of 140 mm for fastening with screws on the table, and the other sides offer the possibility of fastening by any other clamping system.

The body of the vacuum table, with the dimensions of 100 × 100 × 35 mm, offers sufficient rigidity so that the machining takes place correctly.

The vacuum chamber is formed between the lower surface of the work piece and the upper surface of the vacuum table. Sealing is done with the gasket positioned in its channel. The vacuum table is connected to the vacuum pump through a fixture connection.

As we can see in Fig. 3, the air from the vacuum chamber is "sucked out" through the 3 mm diameter holes into the internal chamber, which has the dimensions of 80 × 80 × 6 mm. This chamber positioned at 10 mm below the upper surface of the vacuum table is connected to the vacuum installation through a connecting hole of 6 mm diameter.
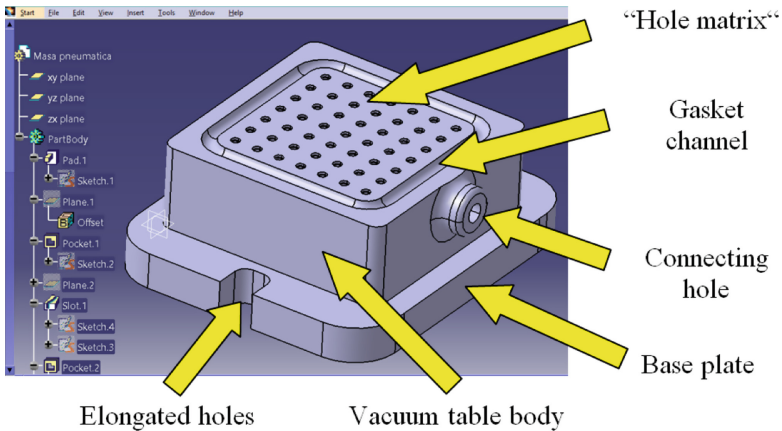

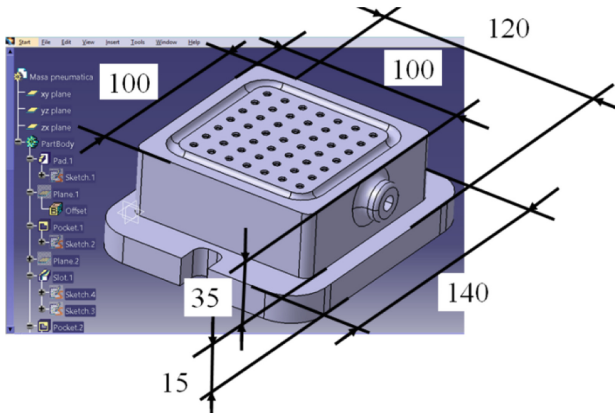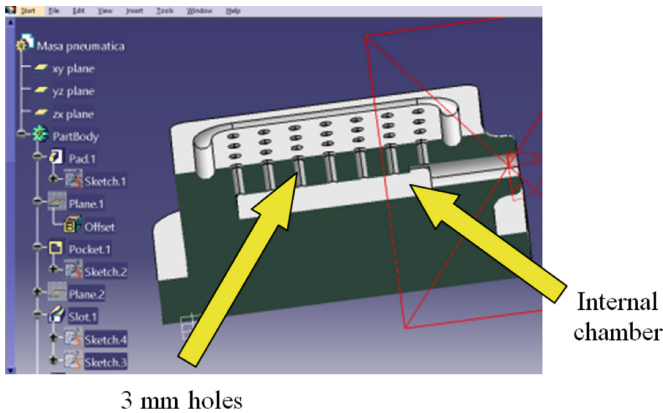
Fig.1. Vacuum table components

Fig. 2. Vacuum table dimensions

3 mm holes

Fig. 3. Main section trough the table

3   3D Printing

For the printing process, we used the 3D printer Dimension sst 1200es (1) from STRATA-SYS manufacturer, Fig. 4, which also has an auxiliary tank (2) with a saturated solution of NaOH. This printer uses FDM (Fused Deposition Model) technology, in which the material used for printing is an ABS terpolymer stored in the cartridge (3) and a soluble polymer for the support material, the cartridge (4).

The 3D model is saved with extension.stl and then imported into a special application named CatalystEX, Fig. 5. After the introduction of initial printing conditions (layer resolution, scale, number of copies, support fill, model interior) an important step is correct orientation on the printing table. This step can sever influence material consumption or the printing time and quality.

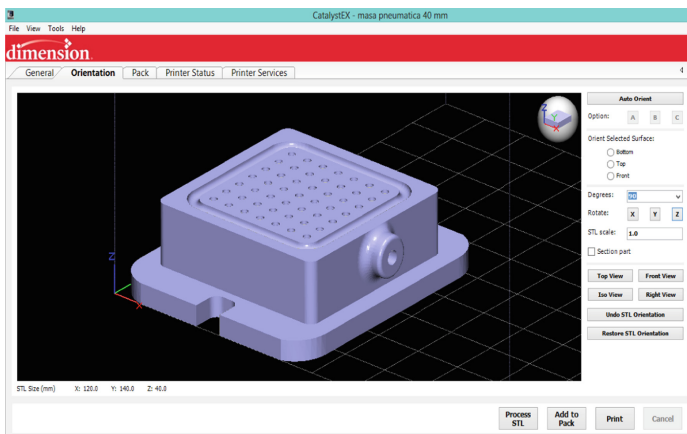**Fig. 4.** Dimension sst 1200es 3D printer

Fig. 5. Imported model and the orientation plan

Once the first step is finished and the stl file is processed the tool paths of the tips (both the ABS and the support) are calculated, as we can see in Fig. 6.

If everything is in order, clicking the "Add to Pack" button the CatalystEX application offers some information about execution time and the material consumption, both the ABS and the support, Fig. 7.

The printing process begins after the button "Print" is pushed.

Figure 8 a) present the final product on the printing table, after the printing process is finished. The part is detached from the printing table and inserted into the tank. After the support material has dissolved, the final piece results, Fig. 8 b).
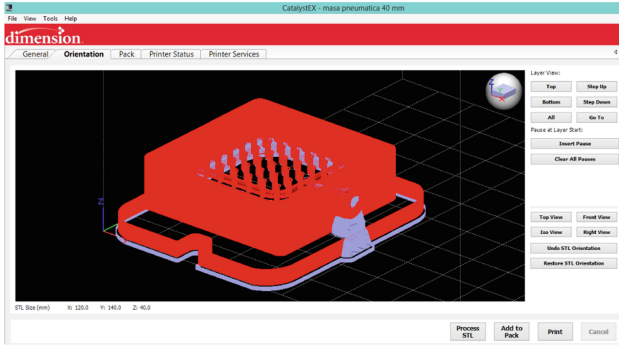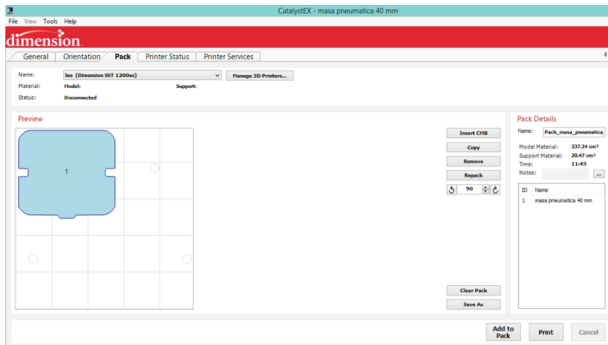
Fig. 6. Tool paths calculation

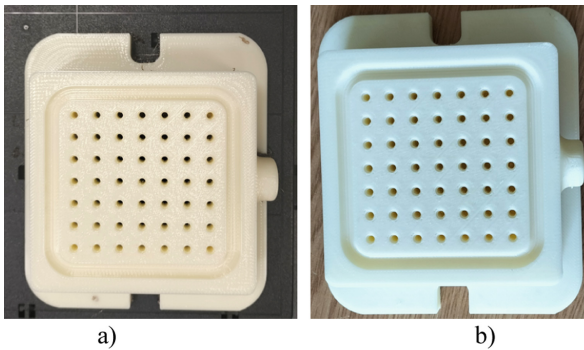**Fig. 7.** Information about the printing process

|a)|b)|

Fig. 8. Final product: a) on the printing table b) after dissolving the support material

4 Conclusion

We designed a mini vacuum table model. We wanted to design this device that would meet the needs of the manufacturing laboratory for machining small parts.

The CATIA V5 software has a friendly and intuitive interface that makes the design easy and fast.

The vacuum table obtained by printing is correctly made both from the dimensional point of view but also from the point of view of the accuracy of the shape and position of its surfaces.

The printing method offers the possibility of obtaining parts that have surfaces that cannot be processed traditionally. In most cases, these pieces are obtained from two halves that are later merged. In our case, we wanted to get the vacuum table in one piece which eliminates a series of inconveniences.

We are going to attach the vacuum table to the vacuum pump [6] and validate the choices made both at the design stage and from the material point of view (ABS) if the obtained product is an honest solution for processing.

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