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Redesign of a 3D low cost filament printer, adapting it to a pellet extruder for new material assays

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Summary: The present work arises from the need identified on the additive manufacturing field due to the lack of 3D low cost pellet printers and the little diversity of materials available for 3D FFF printing. Considering this problem, a 3D pellet printer design is proposed starting from a 3D FFF printer. To carry out this design work, at first it was selected a commercial pellet extruder which meets all the conditions to provide a proper printing quality. At second, a new mechanical propose is analyzed and tested by simulation programs considering the changes made. In the course of the mechanical analysis, the structure was reviewed, and also a temperature study was accomplished. Based on the results, it is possible to verify the correct performance of the machine. From the different simulations, the optimal conditions in terms of dimensioning, structure, internal temperatures and loads were obtained. This enables to determine an optimal and functional design which adapts into a commercial pellet extruder keeping low costs and simple implementation.

Keywords: 3D printer, extruder, low cost, pellet

1. Introduction

Nowadays, nanomaterials conform a fundamental part of scientific progress [1]. Most of the modern technological elements are made of or contains parts of materials with specific characteristics resulting from the combination of different material properties. However, in order to validate these materials and verify their safe operation, it is necessary to test them [2]. Additive manufacturing is one of the techniques used for testing materials as it allows the construction of small functional parts prototypes [3]. Some additive manufacturing methods have achieved high-precision printing at the nanoscale [4]. Fused Filament Fabrication (FFF) is a 3D printing technique that allows the usage of standard diameter filament polymeric materials. However, the development of new materials and composites with short fiber loads and nano-loads [5-6] had made it necessary to develop a technique for 3D FFF printing using pellets.

Considering raw material constraints and the higher cost of it, the complicated production process, and the few amounts of material that is obtained after the process in pellet form, it makes it easier to use 3D FFF printing technology based on a vertical pellet extrusion system without the need of producing filaments [7-8].

The high cost of pellet printers often makes it difficult for development centers to test their materials [9-10-11]. For this reason, the purpose of the present study is to develop a 3D FFF pellet printer starting from a filament printer. A mechanical design for the coupling of the hot end is suggested, and a structural analysis is proposed to evaluate the mechanical stress and the thermal diffusion ~~to which it is~~ subjected during the printing process.

2. Initial Conditions

The design is based on the "BCN3D +" commercial printer. Most of its components are reused to reduce costs. From the base printer, it is considered the dimensions, the printing area, the shape and the control of the device as well as the different mechanical, electronic and electrical components. The commercial pellet extruder "MAHOR PELLET EXTRUDER V4" is also selected and used because of its characteristics which are similar to the original extruder of the base printer.

3. Mechanical Design

Regarding on the initial conditions, a rectangular prismatic design is proposed with a series of characteristics that allows the usage of a commercial pellet extruder in order to perform 3D printing under suitable conditions. The main structure dimensions are 480 mm length x 480 mm width x 600 mm height. The final weight is 15 Kg approximately. The printing volume of the proposed design is 252 mm length x 185 mm width x 200 height. The model used a pellet extruder which reaches a temperature between 198-210 °C, and its dimensions are 190mm x 86mm x 42mm.

The proposed model is able to perform movements along the three main coordinate axes. Seen from the frontal view, Y axis corresponds to the movement of the hot bed which moves back and forward by the action of a pulley and a toothed belt mechanism. The same mechanism is used for X axis which moves the extruder from left to right. Supported by the presence of 4 bushings, the extruder support can slide over the two steel smoot bars. Finally, Z axis accomplishes vertical movements of the extruder using power screws. All movements are executed by the action of the stepper motors Nema 17.

The rest of the structure is built with aluminum profiles and PLA vertices, that are held together with bolts, nuts and washers.

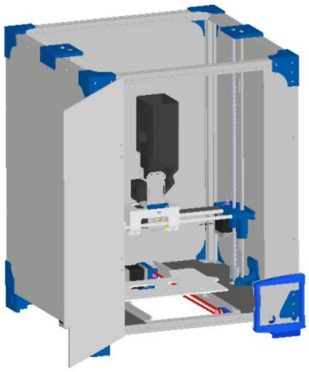

Figure 1. Proposed Model

The pellet extruder weight 2 kg approximately considering its larger dimensions and the presence of a material hopper. Once it is placed on the extruder support that rests on the smooth bars in the X axis, this will constitute a higher load than the filament extruder. Its temperature will be controlled using a thermistor, monitored by the Arduino microcontroller in which the Marlin V301 Firmware is loaded.

To verify that the new load hypothesis will not affect the performance of the system, the redesign was validated by series of calculus and simulations that allowed to know the stress and deformations in the bodies, mainly in the X and Z axes.

In the first place, it was necessary to calculate the torques needed to move the proposed loads. A torque of 0.02535 Nm is required on the X axis, and 0.03 Nm on the Z axis. This values demonstrate that the Nema 17 stepper motor will be able to fulfill the movements, since it has a torque of 0.35 Nm.

The main stresses and deformations of the critical elements were corroborated by a finite element simulation, and its results are detailed on the figures below. They were compared with the yield strength of the materials used, 190 GPa for steel and 3450 MPa for PLA verifying that the different elements of the body will resist the proposed load. Furthermore, the deformations of the bodies do not exceed 0.0015 mm when they are on the critical position in the middle of the structure, so it can be assumed that they will not affect the quality of the final part.

In figures 2 and 3, it is presented a simulation under the Von Misses criterion. It shows the stress to which the mechanical support elements in direct contact with the pellet extruder are subjected.

It can be seen that the stress of the body is between 20 Pa and 0.8 MPa. These results are similar to the ones presented by Suárez Luna´s research [9].

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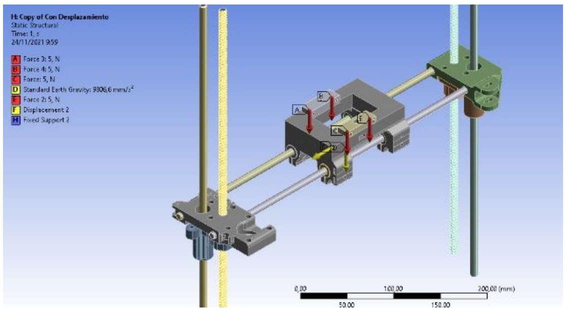

Figure 2. Force distribution of the printing system X-Z axis.

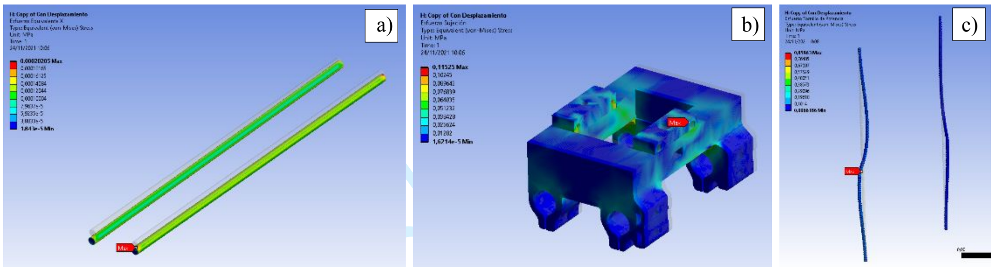

Figure 3. Stress on critical elements, a) X axis parallel bars, b) Pellet extruder support, c) Z axis power screw.

Figure 4.a shows the total deformation of the mechanical support system. Deformation presented on figure 4.b is caused by the displacement of the body and it is a natural movement that does not represent any inconvenient during operation. Figure 5 shows the deformation in which the elements that support the pellet extruder are subjected under load. The maximum deformation of the three elements do not exceed 0.0015 mm.

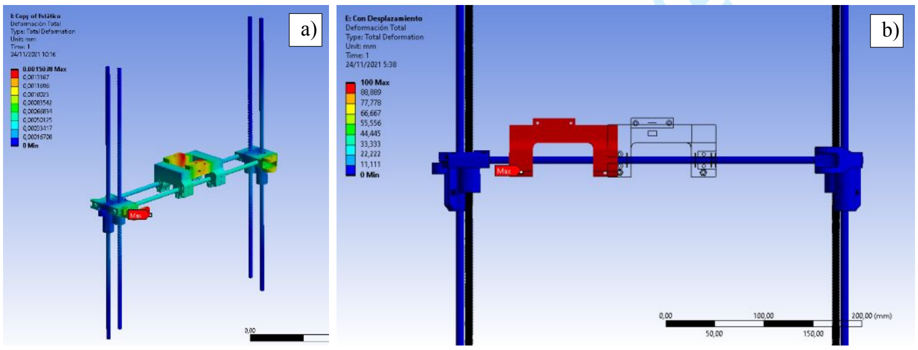

Figure 4. Total Deformation of the printing system X-Z axis: a) Static critical position, b) Deformation caused by displacement

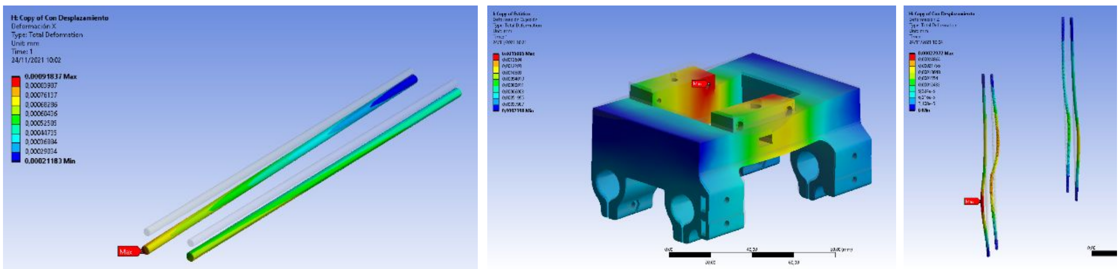

Figure 5. Deformation on Critical elements: a) X axis parallel bars, b) Pellet extruder support, c) Z axis power screw.

3.1 Thermal Analysis

Thermal analysis is performed to verify the internal temperature of the pellet printer. It seeks to keep the closed design of the device without exceeding 30° C, since a higher temperature gives poor results in the printed parts [10].

For the simulation, initial conditions are: hot bed 45°C, extrusion temperature 245°C.

On figure 6a, during the printing process the internal chamber reaches a maximum temperature of 27.03°C.

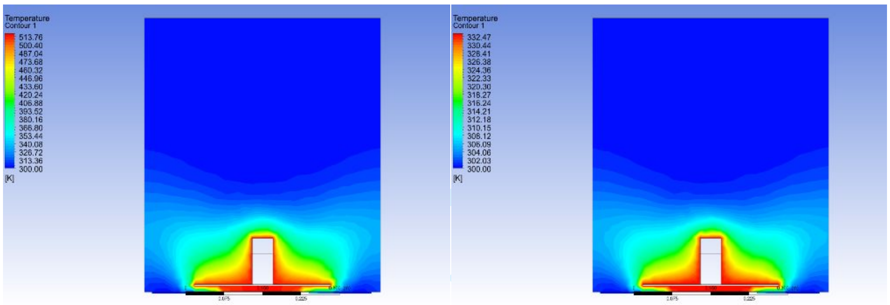

Figure 6. Thermal simulation open model.

6. Conclusions

It is possible to redesign a filament FFF 3D printer in order to use it for testing composite materials which main raw material are pellets. The general deformations of the elements considered as critical for their functionality are obtained by simulation in the software ANSYS. The simulation of the deformation in the X axis due to the load (extruder + material), is 0.0015 mm. Based on tolerance analysis studies [11], it is concluded that this deformation may not affect the dimensional tolerances of the printed part.

It can also be observed in the simulation that the calculated value of the torque required to move the X axis 0.02535 Nm is enough to move the proposed mass. The torque of the printer motors is 0.35 Nm which guarantees X axis normal operation.

Similarly, on the Z axis, the torque calculated value is 0.03 Nm applied to the power screws so they are able to lift the mechanism. As the force required to move the mass is less than the torque provided by the motor, it guarantees the correct performance of the Z axis.

These results show the functionality of the design as a robust mechanical system. In the same line, the results show that the maximum stress is less than 0.8 MPa, values below the ultimate strength of the used materials, steel and PLA, which strengths are 586 MPa and 59.2 MPa, respectively.

Regarding the thermal analysis, the best results are obtained with an open model printer, which allows air circulation maintaining an ideal internal printing temperature of 30°C or 300°K approximately.

The present study finally presents a standard shape model that is able to print with multiple pellet materials with several benefits, high quality and low cost. This was made possible by the usage of common and normalized materials.

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Author 1 and Author 2 contributed equally to this work, as principal writers.

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