Development of a low-cost extruder for the production of filaments for 3D printing of parts with monazite sand

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Abstract

The monazite sand present on the beaches of Guarapari-ES, due to its high natural gamma radiation, has sparked scientific interest in studying its potential biological impacts. Research into these effects on micro and macro organisms necessitates controlled environments. To create these environments through 3D printing, it is essential to manufacture composite material filaments (sand + polymer). The extruder plays a crucial role in this process, melting base materials such as plastics, metals, or composites and extruding them through a nozzle to produce homogeneous and uniform filaments. Therefore, this study aims to develop a low-cost extruder for producing composite material filaments, with the future goal of printing specific parts to investigate radiological effects on biological systems.

keywords: monazite sand, radiation, extruder, 3D printing, filaments.

Resumo

A areia monazítica presente nas praias de Guarapari-ES, devido à sua alta radiação gama natural, desperta interesse para estudos científicos sobre seus potenciais impactos biológicos. A pesquisa desses efeitos em micro e macro organismos requer ambientes controlados. Para criar esses ambientes através da impressão 3D, é essencial fabricar filamentos de materiais compósitos (areia + polímero). A extrusora desempenha um papel crucial nesse processo, fundindo materiais base como plásticos, metais ou compósitos e extrudando-os por um bocal para produzir filamentos homogêneos e uniformes. Assim, este estudo visa desenvolver uma extrusora de baixo custo para a produção de filamentos de materiais compósitos, com o objetivo futuro de imprimir peças específicas para investigar os efeitos radiológicos em sistemas biológicos.

Palavra-chave: areia monazítica, radiação, extrusora, impressão 3D, filamentos.

1. Introduction

The beaches of Guarapari are famous for the presence of natural gamma radiation in their sand. Monazite, most commonly found in the sands of Meaípe and Areia Preta beaches, is a mineral source of elements such as thorium, lanthanum, and cerium[1].

The monazite sands of Guarapari were discovered in 1898. Since then, the effects of this radiation have been discussed, but there is still more to study, especially regarding the impacts of this high natural radiation on biological systems[2].

For the study of these effects on micro and macro organisms, it is important to create controlled environments that contain monazite sand and polylactic acid (PLA), the most used biocompatible and biodegradable thermoplastic in the manufacture of fused filament fabrication (FFF)[3].

The creation of these environments is achieved through 3D printing, also known as additive manufacturing. Among the types of 3D printing technology is fused deposition modeling (FDM), where the thermoplastic filament is extruded through a heated nozzle and deposited layer by layer to print the final object[4].

The extruder is responsible for melting the base material, which can be a thermoplastic, metal, or composite, and pushing it through a small hole, producing a homogeneous and uniform filament.

The pursuit of a low-cost extruder aims to produce high-quality filament, reducing the costs associated with purchasing an extruder. Therefore, the article in question addresses the development of a low-cost extruder to produce composite material filaments, with the future goal of creating specific parts through 3D printing for the study of radiological effects on biological systems.

2. Methodology

For the production of the extruder, an initial CAD drawing was created, which allows for a detailed and precise visualization of the equipment to be designed, including all necessary measurements and specifications.

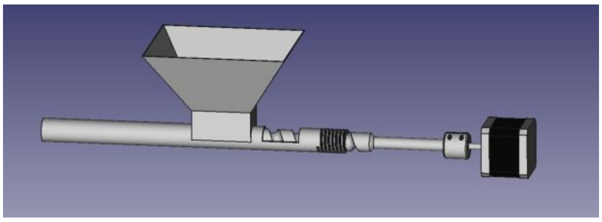

Figure 1: freeCAD.

The system was divided into three sectors: material handling, insertion and direction, and heating and temperature control.

For material handling control, a NEMA 17 stepper motor was used, allowing precise control of the traction speed, which is essential to ensure uniform filament. The NEMA 17 motor was coupled to a screw drill and integrated with an Arduino microcontroller.

Upon acquiring the parts, the initial assembly of the system was completed. The first modification was made to the material insertion part, where a stainless steel 'T' was used. This component ensures a good connection between the material inlet and the traction sector, as well as facilitating the assembly of the system in parts.

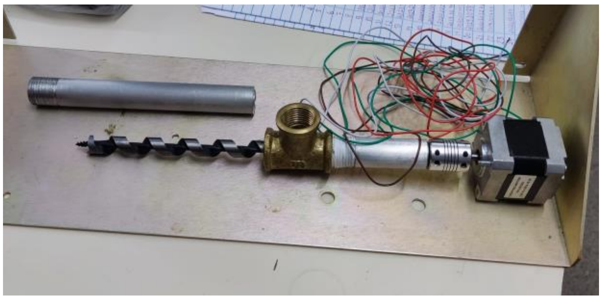

Figure 2: extruder drive system.

To automate the system and ensure precise control of the extrusion process, an Arduino Mega 2560 microcontroller was used. The use of Arduino in this project allows automation of all stages of extrusion, from adjusting the motor speed and direction of traction to precise control of heating temperature.

The heating system is a fundamental part of an extruder. By using a heating ring, coupled to the cylindrical tubing, it is possible to ensure the ideal temperature for the extrusion process.

To monitor and regulate the temperature of the heating system at three different points, three type K thermocouples were used. These sensors are highly sensitive to temperature variations, converting this information into electrical signals that allow precise control of the heating process, ensuring uniform heat distribution throughout the system. The choice of these sensors was motivated by their resistance to high temperatures.

Additionally, a potentiometer was integrated to allow manual temperature variation in the system, enabling precise adjustment to the ideal temperature for PLA, which is 220ºC.

2.1 Logic

O desenho do circuito eletrônico foi elaborado para compreender melhor as conexões e o funcionamento dos componentes.

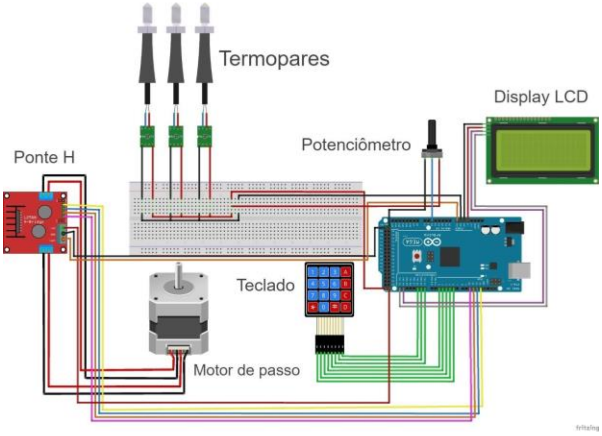

Figure 3: Simulation of the electronic circuit.

Quando o circuito é iniciado, o display apresenta quatro opções: "'A' para iniciar:", "'B' para alterar:", "'D' para cancelar:" e "'0' para medidas:". Ao pressionar a letra "A" no teclado, o sistema de extrusão é iniciado. Pressionando "B", é possível alterar a velocidade de rotação do motor de passo. Ao pressionar "D", o sistema de extrusão é cancelado. Por fim, ao pressionar "0", são exibidas as três medidas dos sensores e a média dessas medidas.

2.2 Modelo Lyman

As a basis for the project, the Lyman Filament Extruder model stands out as a better cost-benefit option. This model is designed for autonomous assembly, aiming to democratize the production of composite material filaments.


Figure 4: Lyman Filament Extruder V5, 2014.

Its design allows for possible adaptations, both in the composition and diameter of the filament to be manufactured, and it also includes a practical guide to support the entire assembly and operation process.

3. Discussions and Results

The first assembly of the extruder occurred without significant incidents, with all components integrated as planned.

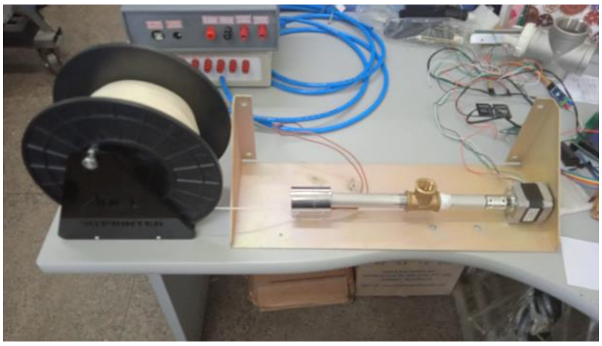
Figure 5: extruder system assembly.

However, a minor issue was identified regarding the stepper motor's rotation during assembly, experiencing jams when coupled with the drill. After a more detailed analysis, it was found that the 5V power supply used with the Arduino did not meet the system's requirements. The solution was to replace this supply with a more powerful 12V one, resulting in smooth and consistent operation of the stepper motor, thereby resolving the issue.

Subsequently, a C++ code was developed to control the system. This allowed for starting, altering the stepper motor's step speed, canceling extrusion, and viewing temperature measurements. This aims to enable temperature gradient control and, subsequently, adjust motor rotation speed to enhance filament quality.

The system assembly on the breadboard was conducted for bench testing purposes.

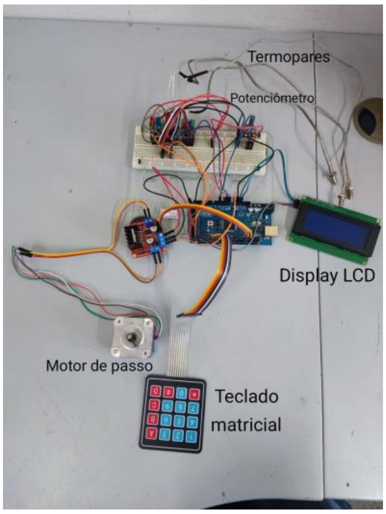

Figure 6: Assembly of the circuit on the bench.

During the initial test, the thermocouples recorded different temperatures, indicating incorrect readings. After reviewing the assembled circuit, it was found that the Max6675 modules were improperly configured, for connecting more than one thermocouple, the signal pins should be joined together on the Arduino. Upon correcting this configuration and properly connecting the cables, the system began to operate correctly, with all three sensors measuring temperatures very close to each other, indicating high precision.

4. Conclusion

The initial assembly of the extruder occurred without major incidents, although a problem related to the rotation of the stepper motor was identified due to the inadequacy of the initial 5V power supply on the Arduino. After replacement with a more powerful 12V supply, the system operated consistently and efficiently. Subsequently, the development of code in C++ allowed more precise control of the system, enabling adjustments to engine speed and temperature monitoring. During testing on the breadboard, divergent readings were initially found on the thermocouples, which were corrected by reviewing the configuration of the Max6675 modules and the correctly connected cable, resulting in accurate and close temperature measurements between the sensors.

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6. References

[1]ORLANDO, M. T. D. et al. Physicochemical characterization of monazite sand and its associated bacterial species from the beaches of southeastern Brazil. Environmental Science and Pollution Research, v. 29, n. 8, p. 11815–11830, 22 fev. 2022. Available in:https://doi.org/10.1007/s11356-021-16523-5(Acessed on 10/05/2024).

[2]COUTINHO, J. V. DA S. et al. Evaluation of induced biological effects in rats by continuous and natural gamma radiation using a physical simulator. International Journal of Radiation Biology, v. 96, n. 11, p. 1473–1485, 1 nov. 2020. Available in: https://doi.org/10.1080/09553002.2020.1812760(Acessed on 10/05/2024).

[3]COSTA, A. N. M. R. et al. Nanocompósitos de matriz polimérica para impressão 3D. 2016. Dissertação (Mestrado em Engenharia Mecânica) - Programa de Pós graduação em Engenharia Mecânica, Universidade de Aveiro, Portugal. Available in: http://hdl.handle.net/10773/16859(Acessed on 10/05/2024).

[4]SHAHRUBUDIN, N.; LEE, T. C.; RAMLAN, R. An Overview on 3D Printing Technology: Technological, Materials, and Applications. Procedia Manufacturing, v. 35, p. 1286–1296, 2019. Available in: https://doi.org/10.1016/j.promfg.2019.06.089(Acessed on 10/05/2024).

[5]LYMAN, H. LYMAN FILAMENT EXTRUDER V5 Construction and Operating Manual. Available in: https://www.thingiverse.com/thing:380987/files(Acessed on 18/04/2023).