CONSTRUCTIVE AND FUNCTIONAL CONSIDERATIONS CONSIDERING THE EVOLUTION OF TEMPERATURE IN THE DLP PRINTING PROCESS WITH ECOLOGICAL RESIN

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ABSTRACT: The purpose of this paper is to identify how the temperature of the print space changes in the DLP 3D printing process. To carry out the experimental program, a set of sensors was designed to be used. Them allow us to determine the temperature and humidity in several points considered in relation to the integrated 3D printing system. From the experimental tests performed at the level of the space in which the printing process is performed, the change in temperature and humidity is greater during the printing process than in the other two areas considered. It can also be seen that for better control of the temperature at the printing surface, it is recommended to carry out a process to improve the constructive solution of the printer with an additional ventilation system at the bottom of it.

KEYWORDS: 3D printing, MSLA/DLP printing, sensors, Arduino, resin,

1. INTRODUCTION

In the present study, the author intends to determine how the temperature and humidity changed in the 3D printing space. The role of this paper is exploratory and, at the same time, to be able to determine whether it is appropriate to introduce a temperature control and regulation system into the structure of a digital light processing (DLP) printer [1].

In the literature on the resin printing side, this aspect is less investigated, and many constructive solutions, some for economic reasons, do not have such control systems [2,3].

From a constructive point of view, the author proposes a system that ensures on the one hand the conservation of the thermal energy released and the reduction of the absorption or circulation of microparticles in the air [4].

This is ensured by a set of elements, thermal insulators, and air filtration, respectively, as well as its circulation systems with controlled circuit and speed in the space where the printer is positioned.

2. MATERIALS AND METHODS

2.1 Materials and sensors used in the study

In the experimental program, a resin with ecological properties of ANYCUBIC type and a printer from the same supplier as the resin were used [5,6].

The printed structure is of gear type. It has two distinct areas, the lower part of the wheel itself and the upper part, respectively. The last part is a cylindrical part to fix and position the wheel Figure 1. On the left side, you can see the structure of the ensemble that will be made. It consists of the basic flat part, the supporting part, and the wheel itself. On the right side of the figure, you can see the check box of the generated structure that does not have unsupported problems and, at the same time, provides information related to resin consumption and other aspects involved in the verification process [7].

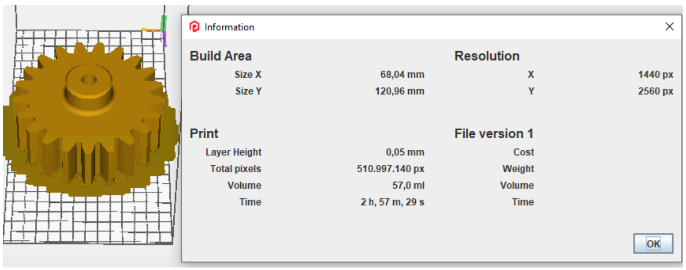


Figure 1. Structure of printed gear and data of printing

2.2 Sensor for temperature and humidity

Because temperature and humidity play an essential role in the 3D printing process with a resin medium, in which the printing temperature must be between 25°C and 30°C, the author designed a complex sensor system to determine and control the printing process. When considering the last aspect, measurement and control can be performed at multiple points in the space in which the printing process is generated.

First, a DHT22 [8] is used to determine the temperature and humidity in the superior position of the vat element. Him are connected to an ARDUINO MEGA 2560 [9,10] with an LCD2004 [11] and SD card [12] components. The second point at which the DHT22 sensor is placed is inside the enclosure for printing and the last is outside the enclosure. These loaded data for temperature and humidity are put into a spreadsheet data analysis software to study the modification of temperature and humidity.

2.3 Data processing system

From the point of view of the electronic data acquisition and processing architecture, it is structured on an ARDUINO Mega 2560 type assembly arranged in a 3D printed structure by thermoplastic construction Figure 2. The two components can be downloaded and printed in 3D from the bibliographic reference [13] for the LCD2004 screen and [14] for the box in which the ARDUINO Mega 2560 module is inserted.

From the point of view of the data processing mode, they can be viewed continuously on the LCD2004 Figure 3 screen but are also saved every 5 seconds on an SD card that ensures the retrieval of measured information line by line in text format.

Figure 2. Structure of ARDUINO Mega2560 and LCD2004

Figure 3. Data on LCD2004

The port allocation to the ARDUINO Mega 2560 module is on the digital side for the temperature and humidity sensors D9 for DHT22 placed in the printer chamber, D8 for DHT22 placed in the enclosure and D6 for DTH22 placed outside of the enclosure Figure 4. The SCL and SDA ports are used for the LCD2560 and the CS module on port is connected to D52.

From a constructive point of view, to ensure both the positioning of the temperature sensors inside the printing chamber, but also their protection from an electronic point of view, the author of the study designed and realized by 3D printing a set of structures that ensure the two conditions previously mentioned. A TRONXY 2PRO [15] printer was used to make the 3D printed structures presented above, and as a polylactic acid (PLA) [16]. The print speed was set at a speed of 40 mm / sec for all three specific elements of generating such a structure, and the recommended density was 30%, the type of thread was linear.

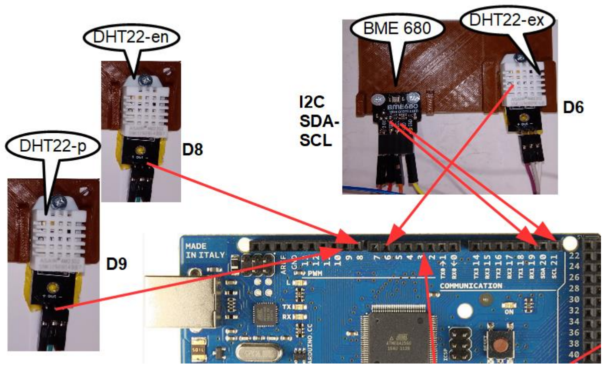


Figure 4. Structure of printed gear and data of printing

3. RESULTS

If the illuminated area increases during the printing process, the temperature should also increase at a certain rate and speed. Taking this into account, in the first zone of the printed structure, which has the largest illuminated area Figure 5a, the temperature increase is determined by the speed with which the evacuation of the heat system is made from the bottom part of the printer to the enclosure. Figure 5 presents the points and lines determined by measurements with the DHT sensors placed in the printing body (DHT-print), the enclosure (DHT-encl) and the exterior of the enclosure (DHT-out).

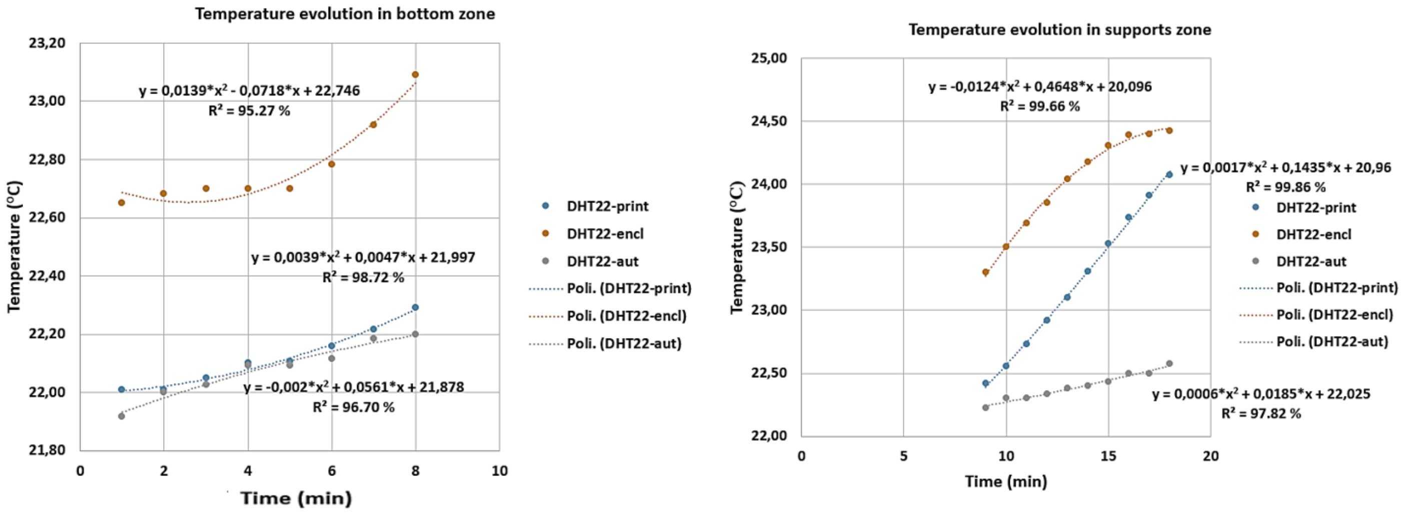
The analysis of the data presented in Figure 5a allows one to observe that these are positions in which the value of this physical parameter is less than 25 °C at the level of the printing body. It is important to note that the smaller value can determine a small contraction and tension in the printed structure. Therefore, it is important not to start the printing phase when the value is less than 20 °C from our printing testing.

In the second area between the eighth minute and the 18th minute, Figure 5b traces the increase which is much higher in the printing space than in the enclosure, as may have been expected.

The R square (R^2) value for each of the sensors in the area analysed approaches the maximum confidence value.

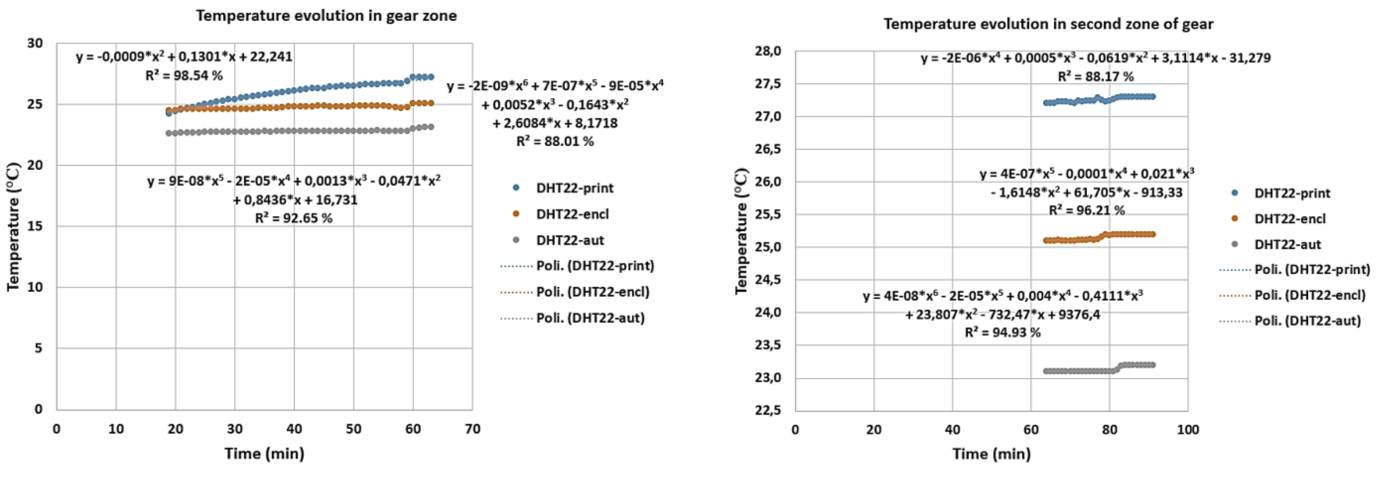
For the gear zone (body), the increase in the temperature in the printing space is less pronounced than in other areas Figure 6a. The regression equations with the higher value are found in the encloser structure, followed by the one in the outer space adjacent to it.

For the gear zone (body and cylindrical part), the tendency to increase tendency in the printing space is less pronounced than in other areas Figure 6b. The regression equations with the higher value are found in the encloser structure, followed by the one in the outer space adjacent to it.



(a) (b)

Figure 5. Evolution of the temperature for the DHT22 sensors in (**a**) the bottom zone and (**b**) the support zone



(a) (b)

Figure 6. Evolution of the temperature for the DHT22 sensors in (**a**) gear zone and (**b**) cylindrical zone

From the analysis of the evolution of humidity in each of the three zones, it can be deduced that with increasing temperature, there is a slight decrease in the humidity level. At the same time, the oscillatory evolution of humidity is similar for the area of generation of the base layer Figure 7a and on the area of the supports Figure 7b, this evolution is slightly different between that in the print space and the one in the structure. From a physical point of view, for the case of humidity, the evolution is slightly decreasing at the level of the two measuring spaces (printing and enclosed space, respectively). From the point of view of the evolution of humidity in the gear area in Figure 8, in the enclosure and the external parts, the evolution is like a small gap between them due to the influence of the environment in which the enclosure is placed.

4. DISCUSSIONS AND CONCLUSIONS

From the analysis of the data in Figure 9, it can be deduced that the greatest change in the temperature value occurs at the level of the internal space where the printing process has a value of 3,87 °C. The second value is in the enclosure space with a level of 2,09 °C, which leads to a temperature retention in the printing space of 1,78 °C. The slightest change in temperature, as expected, is at the level of the space in which the enclosure is placed with a value of 1,22 °C, determining a temperature reserve of 0,87 °C. It must be specified that the last temperature was measured on the outer wall of the encloser structure and not in the ambient space.

At the same time, from the analysis of percentage changes in temperatures in the three areas of its determination, the highest percentages are found to be in the supports at the level of the enclosure. The second values are in the same support generation zone for the printing process and, respectively, at the level of the generating gear in the ambient space.

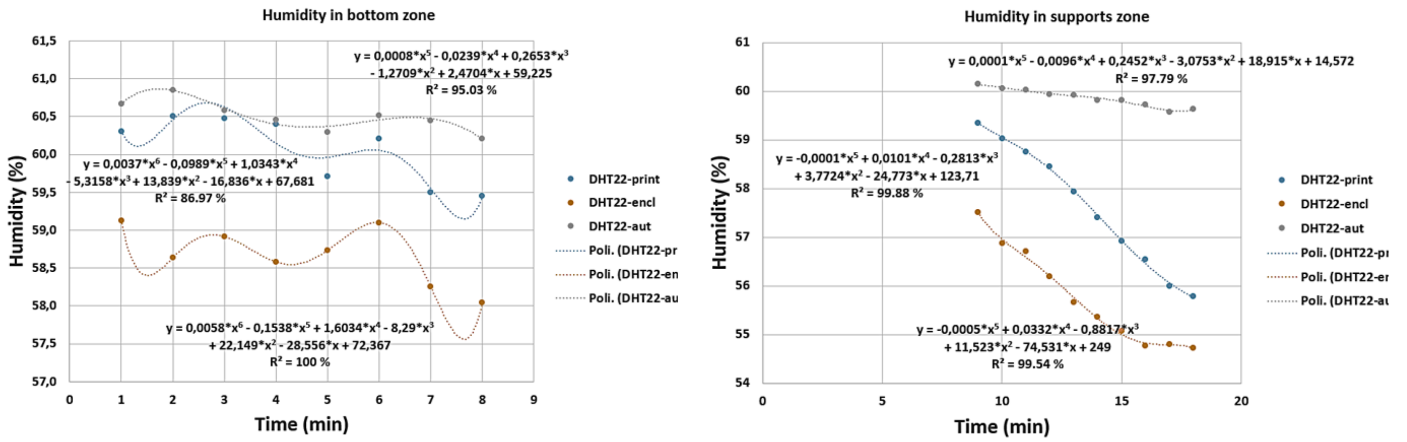


Figure 7. Evolution of the humidity for the DHT22 sensors in (**a**) bottom zone (**b**) support zone

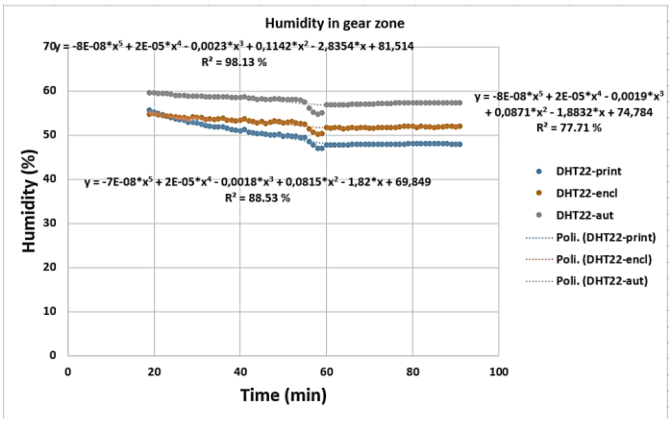


Figure 8. The evolution of humidity is determinate with the DHT22 sensor gear zone

According to the analysis of the data in Figure 10, the greatest change in the humidity value occurs at the level of the printing space where the printing process takes place, 9,23 %. The second value is in the enclosure space with a level of 8.33%, determining a humidity retention in the printing area of 0.9%. The slightest change in humidity, as expected, is at the level of the space in which the enclosure is placed with a value of 5,99 % and humidity reserve of 2,34 %.

Zone	DHT22 temperature print			
	Min	Max	ΔT	%
Bottom	22,01	22,92	0,91	23,49%
Suport	22,42	24,43	2,01	51,94%
Gear	24,25	25,20	0,95	24,57%
Total			**3,87**	

Zone	DHT22 temperature eclos			
	Min	Max	ΔT	%
Bottom	22,65	22,92	0,27	12,75%
Suport	23,30	24,43	1,13	53,78%
Gear	24,50	25,20	0,70	33,47%
Total			**2,09**	

Zone	DHT22 temperature aut			
	Min	Max	ΔT	%
Bottom	21,92	22,18	0,27	21,92%
Suport	22,23	22,58	0,35	28,77%
Gear	22,60	23,20	0,60	49,32%
Total			**1,22**	

Figure 9. Comparative evolution between DHT22 sensors for temperature

Zone	DHT22 humidity print			
	Min	Max	ΔU	%
Bottom	59,50	59,13	-0,38	-4,07%
Suport	55,78	57,52	1,73	18,79%
Gear	46,88	54,74	7,87	85,28%
Total			**9,23**	

Zone	DHT22 humidity eclos			
	Min	Max	ΔU	%
Bottom	58,25	59,13	0,88	10,50%
Suport	54,72	57,52	2,80	33,60%
Gear	50,08	54,74	4,66	55,90%
Total			**8,33**	

Zone	DHT22 humidity aut			
	Min	Max	ΔU	%
Bottom	60,29	60,85	0,56	9,32%
Suport	59,58	60,14	0,57	9,46%
Gear	54,66	59,53	4,87	81,22%
Total			**5,99**	

Figure 10. Comparative evolution between DHT22 sensors for humidity

An important aspect that emerges from the study is the development of a control system aimed at the preservation of the thermal energy generated by the printing process, which leads to a reduction of technological costs. The small temperature difference in which the printing process can be carried out efficiently also gives importance to this phenomenon.

From the analysis of the data in Figure 9 during the 3D printing process, the temperature rise in the print chamber is only 3.19 °C.

This increase, but also the existence of an area that ensures the maintenance of heat in the printing area, makes the process much more stable from a thermal point of view in the printing space. Consequently, an additional ventilation solution is required for the space below the printing surface with a controlled speed of evacuation of the hot air from the space. An important observation that emerges from the data analysis is that although printing can be done outside the recommended area, the characteristics of the component structures of the printed element and especially the area of the media can be affected.

5. REFERENCES

1. Lifsetb, R. - 3D Printing and Industrial Ecology, Journal of Industrial Ecology, Volume 21, Number S1, S6-S8, (2017).
2. Vasilescu, M.D. Influence of technological parameters on the emision on DLP 3D printing process. Rev.Chim., (Bucharest), 70, no. 12, 4387-4392, (2019).
3. Zguris, Z. FORMLABS WHITE PAPER How Mechanical Properties of Stereolithography 3D Prints are Affected by UV Curing. Available online: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=2ahUKEwiIjbSs06vrAhXqlIsKHeysCyk4FBAWMAl6BAgEEAE&url=https%3A%2F%2Fwww.dynamismpro.com%2Fdownloadfile%2Fwhite-papers%2Fwhite-papers_22.shtml&usg=AOvVaw0OFQOowyf_q3EJQ1Q63Tju, (15 December 2021).
4. Vasilescu, M.D. Study the influence of colour resin on the emission for DLP 3D printing process. Revista de Tehnologii Neconventionale, Sibiu Vol. 24, Iss. 2, 60-63, (Jun 2020).
5. {Get 3 for the price of 2} Anycubic Plant-based UV Resin 0.5KG. Available online: https://www.anycubic.com/collections/uv-resin/products/anycubic-plant-based-uv-resin?variant=40701789307042, (15 December 2021).
6. ANYCUBIC 3D Printing Photon. Available online: https://www.anycubic.com/collections/anycubic-photon-3d-printers/products/anycubic-photon-3d-printer, (15 December 2021).
7. Photon File Validator 2.1. Available online: https://github.com/Photonsters/PhotonFileValidator/releases, (15 December 2021).
8. DHT11, DHT22 and AM2302 Sensors. Available online: https://learn.adafruit.com/dht, (15 December 2021).
9. Getting Started with Arduino MEGA2560. Available online: https://www.arduino.cc/en/Guide/ArduinoMega2560, (15 December 2021).
10. Getting Started with Arduino MEGA2560. Available online: https://www.arduino.cc/en/Guide/ArduinoMega2560, (15 December 2021).
11. MyLCD20x4 Clock with Value-Added Information - BME680. Available online: https://www.hackster.io/ingo-lohs/mylcd20x4-clock-with-value-added-information-bme680-cd4cea, (15 December 2021).
12. Interfacing SD Card with Arduino using SD Card Module. Available online: https://www.galaxysofts.com/new/interfacing-sd-card-with-arduino-using-sd-card-module/, (15 December 2021).
13. Case LCD2004. Available online: https://www.thingiverse.com/thing:5244695, (13 February 2021).
14. Case Arduino Mega 2560. Available online: https://www.thingiverse.com/thing:5245192, (13 February 2021).
15. TRONXY XY-2 Pro I3 Structure 3d printer 255mm*255mm*260mm. Available online: https://www.tronxy3d.com/products/tronxy-xy-2-pro-3-structure-3d-printer-255mm-255mm-260mm, (15 February 2021).
16. PLA filament for 3D printing. Available online: https://devildesign.com/download/PLA_-_product_card.pdf. (15 February 2021).