

CONSIDERATIONS FOR EVOLUTION OF INDOOR AND OUTDOOR EMISSION IN RELATION WITH THE PRINTING SPACE USING ECOLOGICAL RESIN FOR 3D DLP PRINTING

Mircea Dorin VASILESCU [1],
[1] Polytechnic University Timisoara, Mechanical Faculty, Department MMUT, Sq. P. Victoriei, no. 2, mircea.vasilescu@upt.ro

ABSTRACT: The purpose of this paper is to identify whether it is important to use a filtration system for 3D priming solution with eco-friendly resin. The experimental program uses an ANYCUBIC printer and a set of sensors which was positioned in the box of the printer and other output of them. From the experimental tests performed at the level of the space in which the printing process is made, the change of the level of emission for formaldehyde is greater during the printing process than in the output areas considered. It can also be seen that for better control of the emission, it is recommended to use one or more filtration solution in the printing process.

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

1. INTRODUCTION

In this study, the author proposes using sensors to measure emission, which are of the same type as the sensors used in commercial apparatus to measure indoor air conditions. Another aspect of novelty is determined by the fact that some of the sensors are inserted into the printing space at the top of the printing vat and another part of these sensors is arranged output of the box printing space in the enclosure.

The 3D printing process imposes excellent conditions for printing at a level between 25 and 30 degrees Celsius and between 45 and 60 degrees Celsius for post-cure resin structure [1]. It is important to note that in the study only the printing process is considered to determine the emission.

The author designed and created an enclosed structure in which the measuring system can identify the emissions between the printing zone and the outside space in which the process occurs. From a dimensional perspective, this solution must allow the printer to be in a good position inside the enclosure to determine the emission value. Some of the measuring devices used in air quality measurement are sensitive to these two parameters (humidity and temperature), so this must be controlled and adjusted.

In the literature on the mask stereolithography (MSLA) of resin, the roll of the filtration system is less investigated [2,3].

2. MATERIALS AND METHODS

2.1 Material used in this study

Preliminary research was conducted with the use of ecological resin for the 3D printing process product of ANYCUBIC [4]. The resin, which can be used in 3D MSLA printing, has complex chemical structures, and can produce reactions in the printing process to obtain the printed parts. According to the ecological resin data sheet from the point of view of the chemical structure, the resin has a composition of elements obtained from the synthesis of a vegetal solution. First, there is the ecological element (45% is soy material that is obtained from soybean oil). The second elements are two chemical components obtained by a petrochemical process, which are 45% of the total elements. The type of solid colour elements (5%) placed in the clear resin can determine the level of particle emission. Last, are 5% of the photo initiator of the printing process. From a mechanical point of view, the bending strength is 59 – 70 MPa and the elongation at the break is 11% - 20%.

2.2 Printer used

The printer is an ANYCUBIC PHOTON printer [5]. The printed used is based on a system-type mask stereo lithography (MSLA) and uses a liquid crystal display (LCD) to allow the passage of light to carry out the photopolymerization process.

2.3 Sensor for gas emission

During the investigation of the experimental tests performed, a comparative test between emission measurements in a printing space and in the enclosure, structure is made using the same type of sensor MS1100 [6]. After processing the measured values according to the calculation formula of the formaldehyde emission sensor determined by the sensors and with ARDUINO program, it can be observed that the first two regions show a linear development trend.

Inside the printing room is also arranged a sensor for measuring gas emissions of type BME680 type [7] that cannot determine what type of gases are emissions but can identify if there are increases of them gases using a resistive system as the basis of measurement.

The program and how to determine the values for both sensor the BME680 and the MS1100 was detailed in the works [8.9.]

2.4 Data processing system

To retrieve the signal generated by the sensors considered in the study, two ARDUINO MEGA 2560 modules [10] were used. One for measuring the data inside the box of the printer and the second for retrieving and saving the data for the enclosure space made Figure 1.

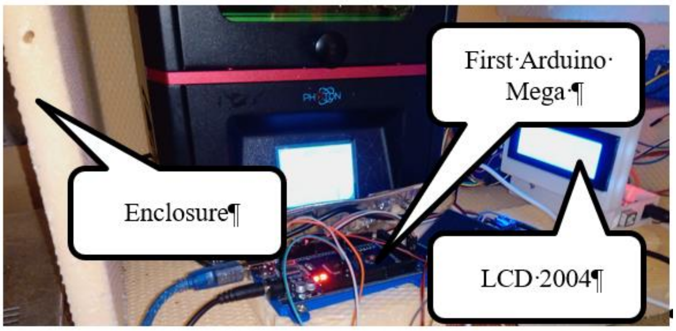

Figure 1. The printer in enclosure with ARDUINO MEGA 2560 module

The data processed according to the software related to each type of sensor is transferred to SD Card support [12] and can be viewed on LCD2004 [10] respectively Figure 2.

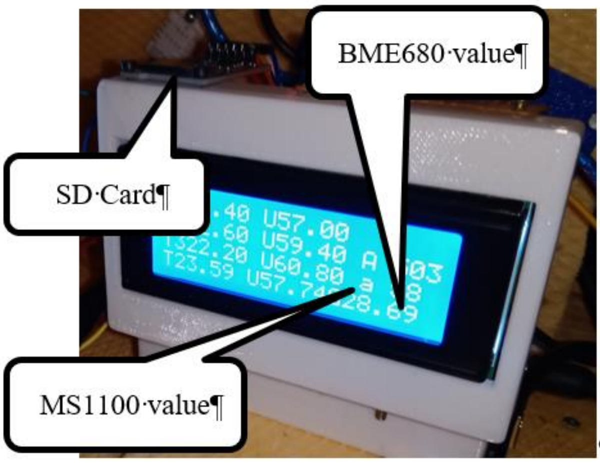

Figure 2. The ARUINO MEGA 2560 module with SD Card and LCD 2004 display

3. RESULTS

It should be borne in mind that the data were measured at an interval of 5 seconds each measurement and determined an average value at each minute of measurement. It should also note that the determination of the evolution of emissions was made by dividing the study areas into three parts, namely the first seven-minute period for the beginning phase of printing, the second for the printing part of the smallest volume of material and the last part for printing the part itself.

Although in the solution of taking over in the consideration the emission values determinate with the BME680 sensor does not allow one to identify the type of elements emitted. This type of sensor can tell us if there are gases emission and their amplitude. Thus, it can be seen that on the generation side of the base layer Figure 3, after a slight increase at the beginning of printing, a tendency to flatten at the final part of the process in relation to the analysed area follows.

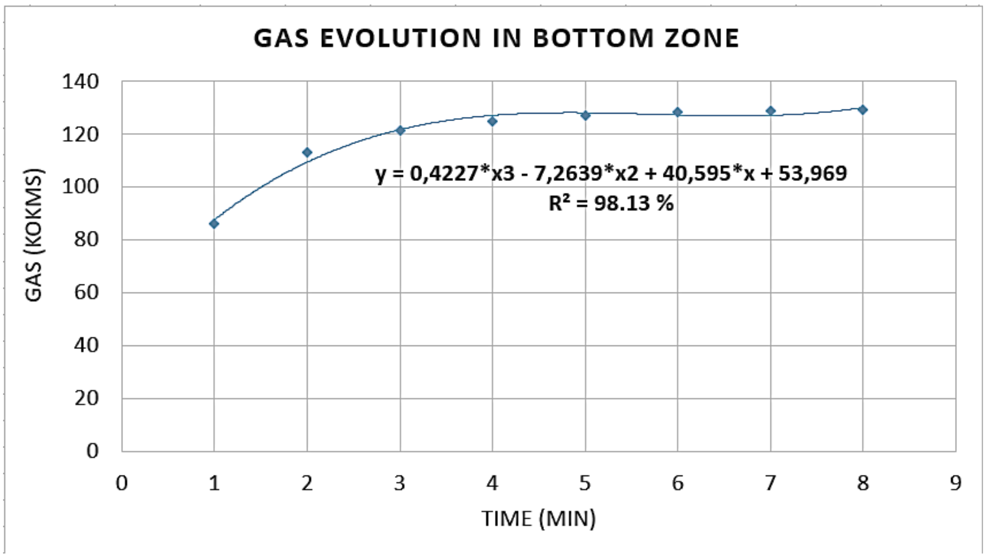

Figure 3. The evolution of the gas emission measured with BME 680 in first zone

In the second stage of the printing process of part Figure 4, the gas emission has a parabolic evolution with a maximum point in the final printing area of the process of printing the supports.

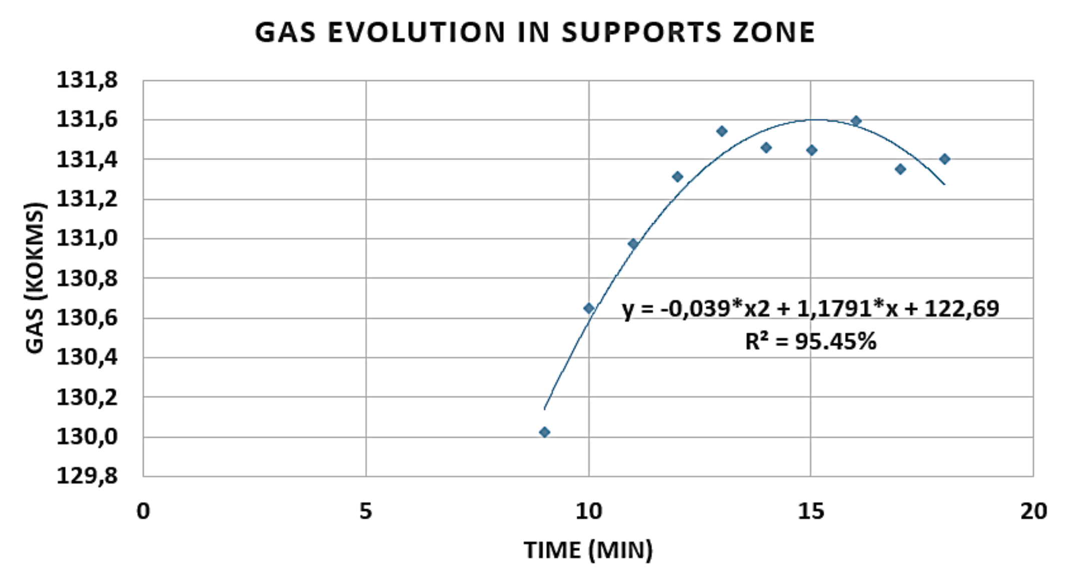

Figure 4. The evolution of the gas emission measured with BME 680 in second zone

From the point of view of the level of emissions, it can be seen that in the last part of the printing process, that of making part body Figure 5, the process is decreasing with a slope of about 30%.

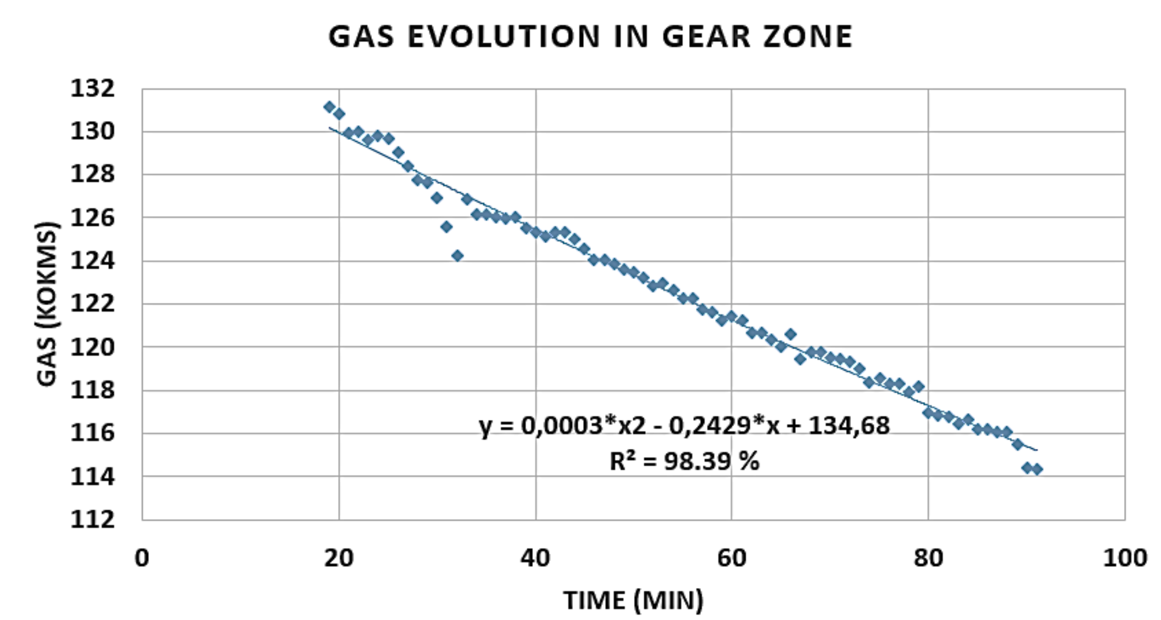

Figure 5. The evolution of the gas emission measured with BME 680 in last zone

The comparative measurement of formaldehyde emissions made with the two MS1100 sensors shows in the first part an increasing trend Figure 6. In the second zone the increasing trend is greater Figure 7. In the last zone the trend is slightly increasing trend of emissions with oscillations of minimum and maximum in the second area Figure 8.

4. DISCUSSION

An important direction that the author of the study took into account was that of analysing the evolution of emissions in the space where the printing process takes place. The first of the analysis is carried out with the help of the BME680 sensor that allows us to determine if there are emissions and their level with the help of universal software.

From the point of view of the comparative analysis of the gas emission determinate in the printing space with BME680 sensors, it can be seen that the maximum percentage is in the bottom zone of the printed structure. The minimum values are in the supports zone Figure 9.

The air quality from the point of view of the HCHO measured with MS1100 can be determined in rapport with the data from Figure 11 [13].

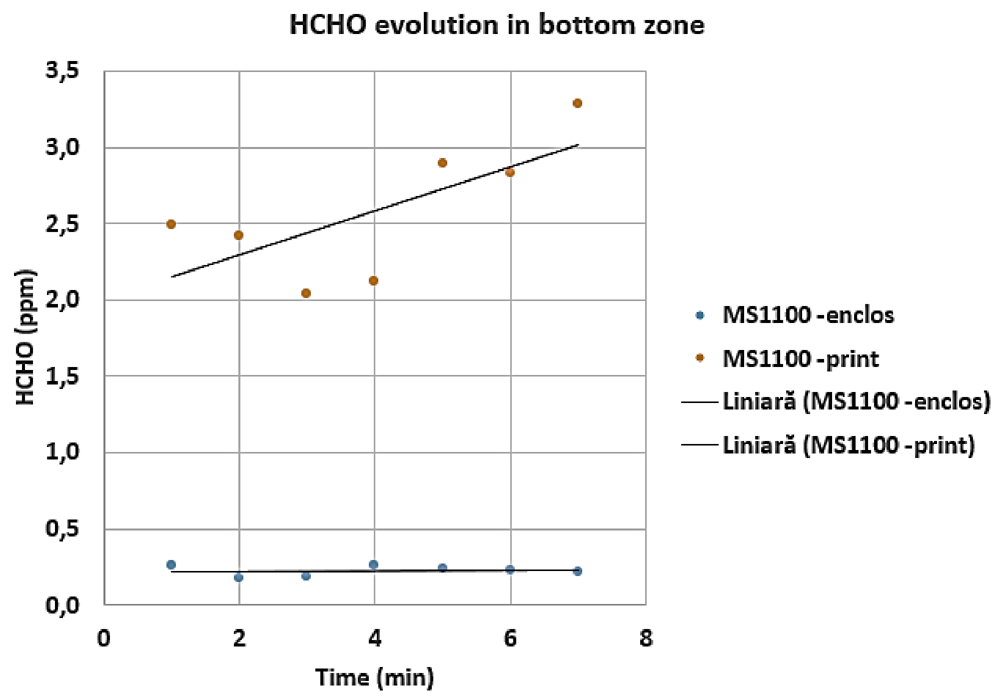

Figure 6. The evolution of the HCHO emission measured with MS1100 in first zone

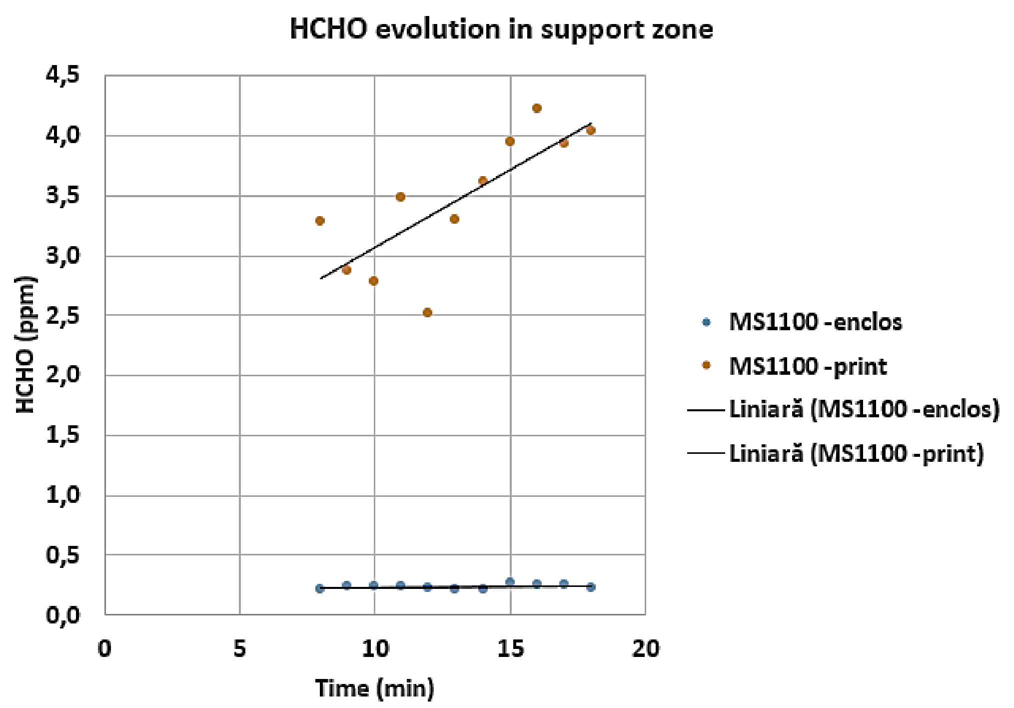

Figure 7. The evolution of the HCHO emission measured with MS1100 in second zone

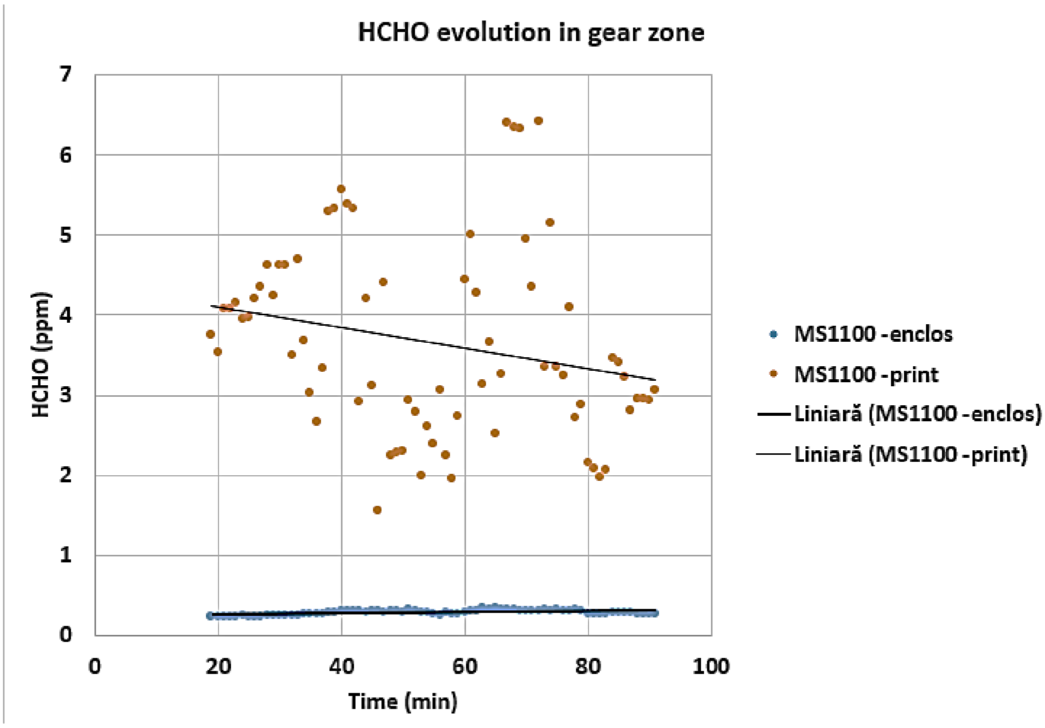

Figure 8. The evolution of the HCHO emission measured with MS1100 in last zone

Zone	BME680 gas			
	Min	Max	ΔU	%
Bottom	86,01	128,70	42,69	69,94%
Suport	130,03	131,60	1,57	2,57%
Gear	114,38	131,15	16,78	27,49%
Total			**61,03**	

Figure 9. Evolution of gas emission for BME680 sensors

Given the existence of gas emissions in the paper printing space, the experimental process was extended by conducting an assessment of the emissions compared to those in the printing space and those in the structure of the type of HCHO ones Figure 10.

Zone	MS1100			
	Min	Max	ΔTVOC	%
Bottom	0,18	0,26	0,08	31,58%
Suport	0,21	0,26	0,05	20,07%
Gear	0,23	0,35	0,12	48,36%
Total			0,25	

Zone	MS1100 printing			
	Min	Max	ΔTVOC	%
Bottom	2,04	3,29	1,25	15,92%
Suport	2,52	4,23	1,71	21,83%
Gear	1,55	6,42	4,87	62,25%
Total			7,83	

Figure 10. The evolution of the HCHO emission measured with MS1100 in the two zone

From the comparative study of the emission level, it can be seen the reduction of this level by up to 600% by using the filtering system.

Air Quality Pollution Level Reference Table

HCHO	0-0.08	0.081-0.1	0.101-0.2	0.201-0.5	0.501-1.0	1.001-1.999
	Excellent	Good	Slight Pollution	Moderate Pollution	Heavy Pollution	Serious Pollution
TVOC	0-0.5	0.501-0.6	0.601-1.5	1.501-3	3.001-6	6.001-12
	Excellent	Good	Slight Pollution	Moderate Pollution	Heavy Pollution	Serious Pollution
CO2	0-450	451-1000	1001-1500	1501-2000	2001-3000	3001-5000
	Excellent	Good	Slight Pollution	Moderate Pollution	Heavy Pollution	Serious Pollution
AQI	1	2	3	4	5	6
	Excellent	Good	Slight Pollution	Moderate Pollution	Heavy Pollution	Serious Pollution
ENVIROMENT	1 GOOD	2 GOOD	3 POIIUTE	4 POIIUTE	5 POIIUTE	6 POIIUTE
	Excellent	Good	Slight Pollution	Moderate Pollution	Heavy Pollution	Serious Pollution

Figure 11. AQI for gas emission

Zone	Enclosure	Box	Enclosure	Box
Bottom	0,18 to 0,26	2,04 to 3,29	Slight Pollution	Serious Pollution
Suport	0,21 to 0,26	2,52 to 4,23	Moderate Pollution	Serious Pollution
Gear	0,23 to 0,35	1,55 to 6,42	Moderate Pollution	Serious Pollution

Figure 12. Level of emission in rapport with AQI value

5. RESULTS

Another direction that could be considered is the development of a system based on the ARDUINO module to be able to control the emissions process and to ensure the best possible level of protection from the point of view of pollution of the printing space. If taken into account, these aspects are related to the process of making parts, and this technology is the most efficient in the additive manufacturing part.

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