Study on the variation of the argon volume and the degree of loading of the paper filter in a 3D printer type MYSINT 100 during the process of selective laser melting of metal powders (SLM)

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Abstract. *The paper presents an experimental study on the variation of argon volume and degree of loading in a 3D printer type MYSINT 100 during the process of selective laser melting of metal powders (Selective Laser Melting) to perform dental work (dental crowns). The first part of the paper presents a series of information on the construction, operation, installation, working conditions and technical characteristics of the 3D printer type MYSINT 100. Also presented a number of aspects related to the performance of dental work using the process selective laser melting of metal powders (SLM), the importance of argon in this process. The variation in the volume of argon and the degree of loading of the paper filter with residual metal powder was determined experimentally over a number of 30 cycles of operation of the 3D printer.*

Keywords: MY Sint100, argon, dental

Introduction

The MYSINT100 3D printer performs a process of Selective Laser Melting of metal powders. 3D Laser Metal Fusion Technology is an additive manufacturing process that uses a 3D CAD file, as a source of digital information, and energy, in the form of a high-power laser beam, to realize three-dimensional metal objects through the fusion of thin layers of metallic powder (3d.sisma.com). Each layer of metal powder (10 - 30 µm) is deposited by a special device, which collects the material from one cylinder, called the feed cylinder and deposits it on a platform in another cylinder, called the working cylinder. Once the layer is deposited, the laser melts the figure corresponding to the processed section.

Details about MYSINT 100

The 3D printer must be installed inside an industrial building, with adequate lighting and ventilation, as well as a suitable floor. The machine is suitable for operation in environments with temperature between +15°C and +30°C and relative humidity <50%, without condensation. Thus, an air-conditioned environment is needed, with the possibility of lowering the humidity level, if necessary (Operator's Manual SISMA S.p.A).The device requires the operation of technical gas (nitrogen or argon), ensuring the connection to a system according to current standards and has the characteristics defined in the specifications of the printer. The technical gas supply

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must have a pressure of max. 5 bar, 35l/min. The gas circuit inside the machine is equipped with an inlet pressure regulator: the pressure indicated by the reducer at the inlet of the circuit is always 2.5 bar (0.25 MPa) (Operator's Manual SISMA S.p.A). All technical characteristics of the MYSINT100 3D printer are presented on paper (3d.sisma.com). Using this 3D printer, a wide range of parts used in the technique can be made from metal powders (Cobalt chrome, precious metal, bronze, steel alloys), but also a lot of dental works (Figure 1).

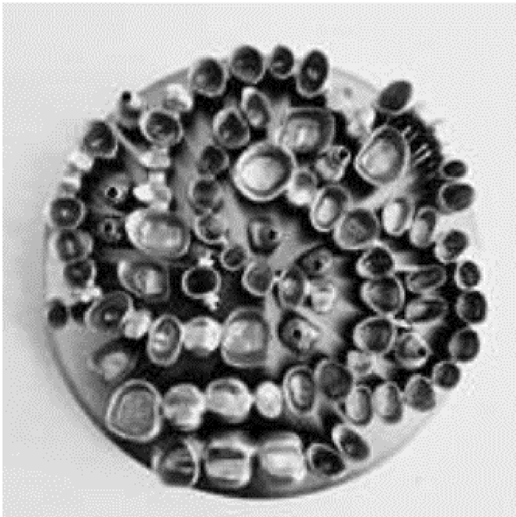

Figure no. 1. Some dental metal works that can be made with MYSINT100
Source: Authors' own research

The importance of argon in the SLM process. Case study

In Selective Laser Melting (SLM) process, inert gas flow, for example, argon or nitrogen is needed to maintain the atmosphere within the build chamber. The inert gas flow is needed to minimize contamination of the parts during high-temperature processing and to remove the condensate produced during the melting process. Condensate formed within the build chamber can result in reduction in the effective laser energy reaching the powder bed by absorption and laser scattering. It has been shown that the flow rate, flow direction and type of gas will introduce changes to the resultant microstructure and porosity of the metal parts, which in turn, affects the mechanical properties of the fabricated parts. Hence it is important to verify the effect of this utility during qualification of the laser-melting system. Argon infiltration is a well-known problem of hot isostatic pressed components. Thus, the argon content is one quality attribute which is measured after a hot isostatic pressing process. Since the SLM process takes place under an inert argon atmosphere; it is imaginable that argon is entrapped in the component after SLM processing. Despite using optimized process parameters, defects like pores and shrink holes cannot be completely avoided. Especially, pores could be filled with process gas during the building process. Argon filled pores would clearly affect the mechanical properties. Based on these considerations, we consider it necessary to monitor the variation of the argon volume and the degree of loading of the paper filter in a 3D printer during the SLM process.

An inert blanket of gas prevents any chemicals in the operation from reacting with oxygen and other substances present in air. Argon is a colorless, odorless, tasteless gas. Its density is 1.784 grams per liter. The density of air, for comparison, is about 1.29 grams per liter. Argon changes from a gas to a liquid at -185.86°C (-302.55°F). Then it changes from a liquid to a solid at -189.3°C (-308.7°F) (Argon, Chemical Element - reaction, uses, elements, metal, gas, number, name, symbol, 2021) This machine (MYSINT100) uses as inert gas, argon, with direct involvement in the SLM process. This study focused on monitoring argon consumption over 30 cycles of the 3D printer; the results obtained are presented in Table no 1.

Table no 1. The amount of argon consumed vs. Cycle time

Cycle number [a)]	Cycle time [b)] [min]	The amount of argon consumed [c)] [liters]
1	203	41,342
2	118	50,192
3	149	47,336
4	376	40,951
5	312	48,236
6	167	44,473
7	194	45,839
8	257	47,842
9	180	51,497
10	162	46,443
11	304	39,414
12	186	46,253
13	91	47,282
14	414	50,261
15	117	52,111
16	268	49,881
17	291	49,577
18	409	38,584
19	358	44,322
20	128	46,943
21	310	46,195
22	453	47,610
23	209	53,810
24	201	42,519
25	228	46,390
26	392	59,244
27	383	60,688
28	410	66,445
29	332	57,003
30	303	62,349
[a)] [n]	[b)] [x]	[c)] [y]

Source: Authors' own research.

In Table no 1, the execution times of the platform corresponding to the example in Figure no 1 were noted, in depending on the case, as well as the amount of inert gas (argon) consumed in each cycle. The average execution times were calculated with the formula:

$$\bar{x} = \frac{203+118+149+\cdots+332+303}{30} = 263{,}5\ min \qquad (1)$$

The average gas consumption used during these SLM processes was calculated with the formula:

$$\bar{y} = \frac{41{,}342+50{,}192+\cdots+62{,}349}{30} = 49{,}034\ L \qquad (2)$$

In order to observe the trend of gas consumption, over time, the graph from Figure no 2 was made, to observe the variation of the execution times of the metallic works for the 30 cycles, respectively the graph from Figure no 3, which shows the variation of the gas quantity during the 30 cycles.

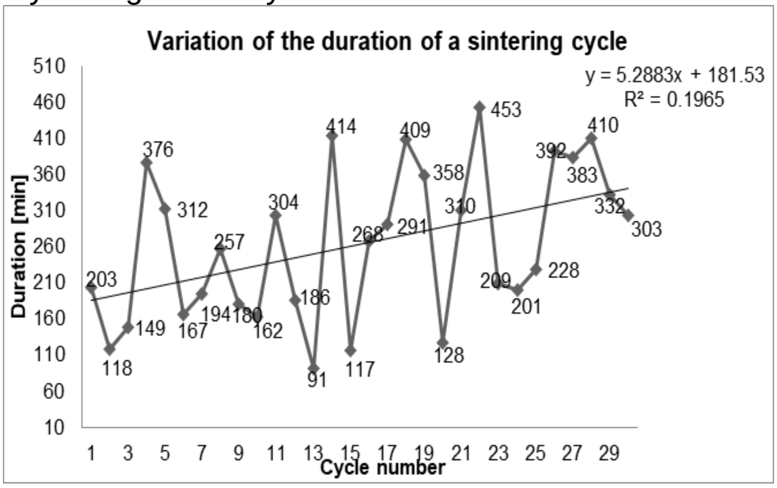

Figure no. 2. Variation of the duration of a sintering cycle

Source: Authors' own research

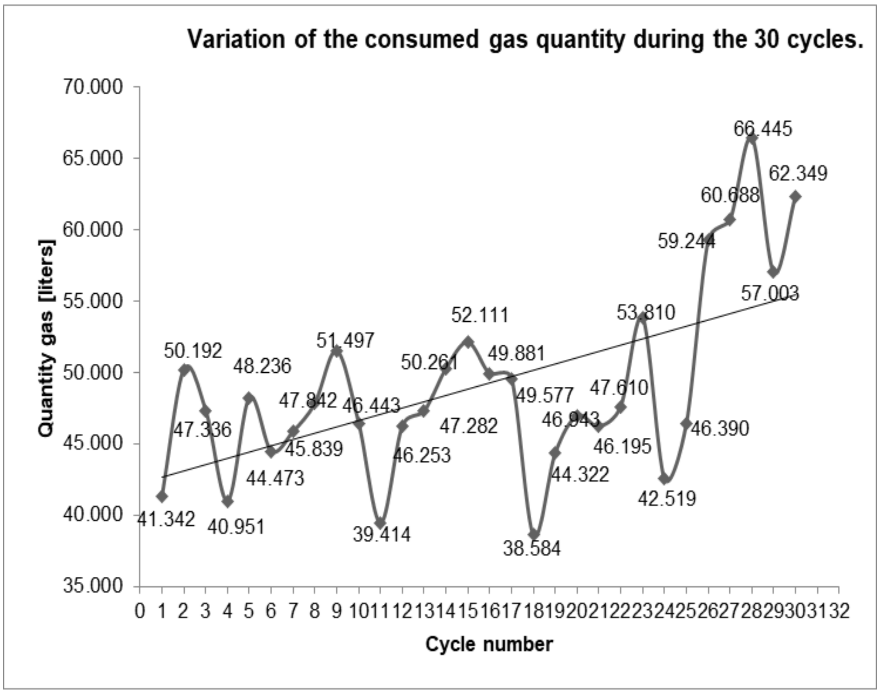

Figure no. 3. Variation of the consumed gas quantity during the 30 cycles

Source: Authors' own research

In the graph in Figure no 2, we find the simple linear regression, denoted y, with the value y=5.2883x+181.53 as well as,R^2, representing the square of the multiple correlation coefficient, with the value R^2=0.1965. Because the device has a recirculation of metal dust, in the piping and the level of the filters, the degree of loading at the level of the paper filter, the most exposed to damage, is studied. Table no 2 is made, with the life of the paper filter (degree of loading), which is in front of the argon circulation pump in the device, after the 30 cycles. The average amount of gas used during the 30 sintering processes was calculated with formula:

$$\bar{z}=(16{,}3+12{,}3+\cdots+39{,}9)/30=24{,}2\ \% \qquad (3)$$

Table no 2. Degree of charge with residue of the metal powder of the paper filter

Cycle number[a)]	**The filter at the beginning of the process**[b)]	**The filter at the end of the process** [c)]	**Filter loading degree**[d)]
1	1.8	18.1	16.3
2	9.2	21.5	12.3
3	2.6	19.6	17
4	2.4	31.5	29.1
5	0.5	13.3	12.8
6	9.8	23.2	13.4
7	11.3	29.3	18
8	1.7	22.7	21
9	2.1	20.9	18.8
10	2.3	19.9	17.6
11	2.9	28.8	25.9
12	1.9	21	19.1
13	12.2	27.9	15.7
14	2.5	35.1	32.6
15	16.7	43.8	27.1
16	5.2	17.8	12.6
17	1.2	21	19.8
18	1.5	28.4	26.9
19	1.6	29.6	28
20	1.9	18.8	16.9
21	2.3	28.2	25.9
22	2.3	36.4	34.1
23	2	27.4	25.4
24	5.1	31.8	26.7
25	13.2	33.7	20.5
26	2	36.2	34.2
27	2	38.6	36.6
28	2.8	45	42.2
29	3.3	44	40.7
30	18.3	58.2	39.9
Average	4.8	29.1	24.2
[a)][n]	[b)][%]	[c)][%]	[d)][%]

Source: Authors' own research.

The variation of this filter loading degree can be seen in the following graph – Figure no 4.

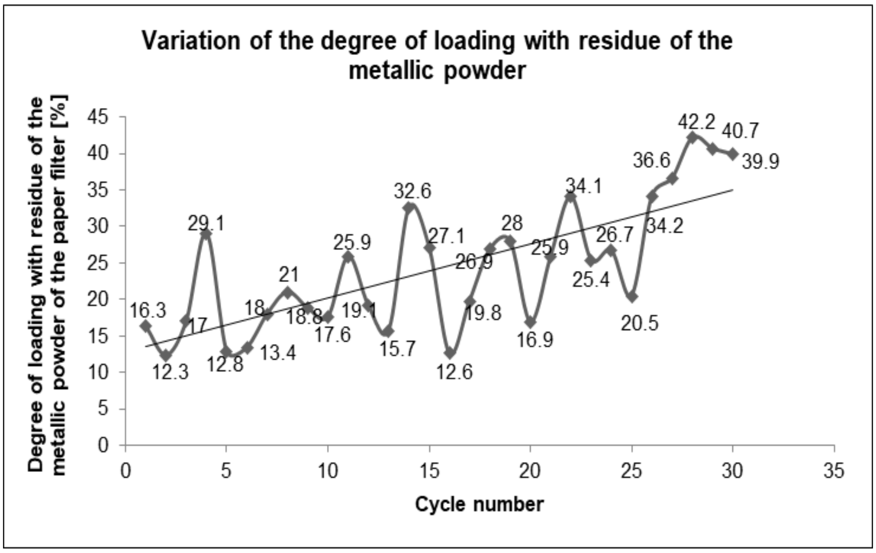

Figure no 4. The variation of the filter loading degree
Source: Authors' own research

Concluding this case study, we can see how, with the help of graphs, we will identify the life of the paper filter (figure no 4), when it needs to be changed so that the 3D printing process does not show errors.
At the same time, it is observed that, during the process, there is an additional gas consumption (figure no 3), which keeps the quality of the dental works in the best 3D printing conditions.
The accuracy of the device is very high, it has a number of sensors, with which it performs fast and high quality processes.

Conclusion

In this study, it was highlighted, how the amount of inert gas used is important in the selective sintering process, the values indicated allow a high quality of dental work, the physico-chemical process is easier with this gas. Following the graphs made, it can be seen how the volume of gas varies depending on how long the sintering process takes, it influences the degree of loading of the paper filter, which is a first exposed element of the burned metal powder. The represented device is a new and innovative one on the dental market, thus it considerably reduces the execution times of the dental metal works.

References

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