MILLING PROCESS OF LASER SINTERED WORK PIECES

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Rezumat: *Este bine cunoscută nevoia de prelucrare mecanică suplimentară a pieselor obținute prin sinterizare. O cercetare în domeniu este necesară pentru a determina un nou parametru specific pentru postprocesarea pieselor obținute prin sinterizarea cu laser, acesta fiind un răspuns adecvat pentru nevoile tehnice actuale. Determinând densitatea şi compoziția chimică a materialelor hibride ale pieselor complexe, acestea vor fi analizate, inclusiv tensiunile interne, pentru a determina viteza de prelucrare a acestor materiale. În procesarea ulterioară, chiar dacă se pot determina unii parametri, mai sunt multe elemente încă puțin cunoscute. Cel mai important dintre acestea este viteza de prelucrare, deoarece toate modificările în densitatea şi structura materialului pot afecta în mod direct forța de aşchiere necesară pentru prelucrarea piesei.*

Abstract*: A growth in the need of mechanical post-processing in sintered pieces is well documented. A research in the area where a new parameter can be determined, a parameter for the post-processing by milling the pieces obtained from laser sintering, represents a true, focused and a fast response for the needs of the engineering world. A thorough look to determine the density and the chemical composition of the hybrid materials of the complex shaped work pieces will be brought into discussion for the purpose of using them, alongside the internal stresses, to determine a cutting speed for these materials. In the future processing even if the density and concentration of the parts can be determined there is still much more to learn. One of the most important facts is the cutting speed, because all the changes in density and concentration of the material can influence directly the cutting force needed to machine the part*.

Keywords: laser sintering. Milling process.

1. Introduction

The implication in the last few years has been massive in the area of additive manufacturing [1], even if the technology is quite old now, and the systems that are now on the market tend to surpass many of the last century's expectations. The applications for this area are in continuous ascent, and also the materials that can be used now are much more applied in industry than in the typical commercial use. In laser sintering the materials are harder and have better properties than the laminated version, and the idea that strikes now is: how can these parts be used as functional parts. As functional part, laser sintered material must be post-processed and it must be applied to a technological usage. Here is where the conventional manufacturing combines with this technology.

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2. General Considerations

The latest trend in the work piece manufacturing sector is that of using additive manufacturing to create parts from ground up. Usually, the pieces are created on a platform that has the purpose of enhancing the cooling properties of the new work piece that is created, and also it plays an important role in keeping the work piece from bending due to internal forces. Another solution is to build the pieces right on top of a machined piece, that way having the precision of a machined part but also it has a complex shape like a sintered one.

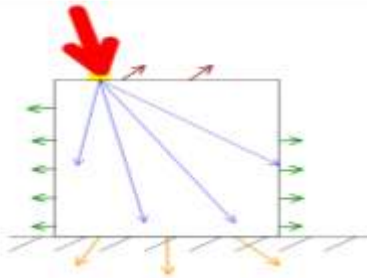

Fig. 1: Cooling platform

Red arrow - Laser beam, Yellow spot - Meltpool, Blue arrow- heat dissipation through the material, Green arrow - heat transmission between part and powder, Brown arrow - heat transmission between part and air, Orange arrow - heat transmission between part and platform.

Fig. 2*a:* Platform building parts from ground up

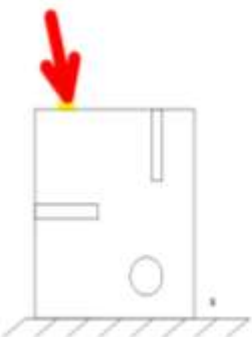

Fig. 2*b:* Tooling platform - building a part on top of an existing work piece

It is useless to deny that the additive manufacturing is taking proportions. It has many benefits, but also it is very restrictive due to price, space, conditions of using the machines, and last but not least the knowledge needed to use the machine. Being quite old on the market, this technology has some benefits: by using the knowhow of different companies that make this kind of machines, we arrive at a very powerful parameter setting.

Being close to the process one can say that it is not an easy task to imagine a part that can be well designed, well ventilated, protected by rough tensional matrix dispersion.

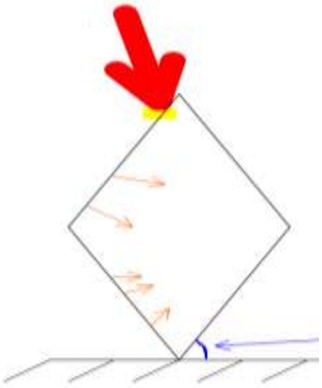

Fig. 3: Part platform.

Orange arrow - internal tension, Blue arrow - minimal angle needed to make upskin.

First of all the platform must be thick to disperse the heat that is coming from the laser that is making the part [2].

Second to this parameter, the platform must be stable in order to sustain the tension that the heating-cooling process is introducing in the built part.

Describing those two elements allows a better understanding of the idea that it is not an easy process to make a part by additive manufacturing, all the more so by using a laser sintering technique.

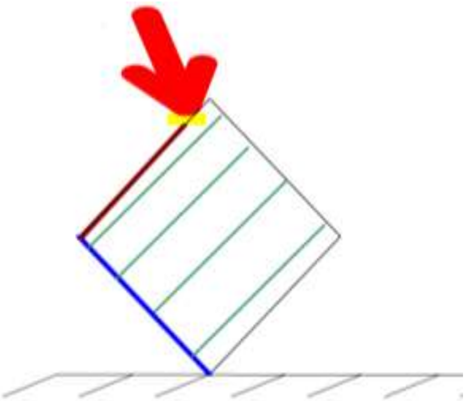

Fig. 4: Contour upskin, downskin, hatch.

Blue line - Downskin, Brown line - Upskin, Green - Internal Hatching.

By using these two photos one can analyze the pattern of the laser. There are three elements of a laser toolpath: the contour of the part - that is used to control the surface finish of the part, the hatch - that is used to fill up the part, and the precontour or skin - that is used to control changes in angle of the part, which has the purpose of creating an additional layer used for the contour, to be held in place.

3. Density

As described above, the process using a laser as a heat source has many parameters that must be taking into account. The most straightforward and most visible ones are the speed and power of the optical system.

Depending on the speed and power of the laser, the hatch can determine the density of the part. This can be determined by looking at the meltpool.

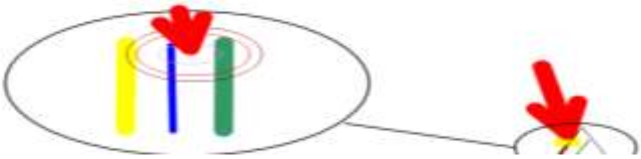

Fig. 5: Meltpool 1.

Yellow line - Outer contour, Blue line - Contour, Green - Internal Hatching, Red circles - Meltpool.

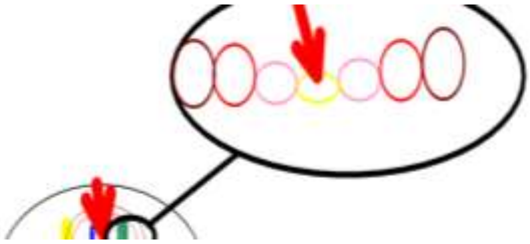

Fig. 6: Meltpool 2

Brown circle - Full grain, Red circle- partially sintered grain, Yellow circle - melted grain.

The power of the laser indicates the quantity of energy that can be focused in one place, it is half important to be quantifiable, because based on this measurement one can melt one kind of material or another. But being able to melt is not sufficient; one must know when to stop. So the second parameter must be quantifiable as well, i.e. the time.

Taking it out of theory, we use the term of speed. That is due to the fact that the laser is always moving, putting a certain amount of energy on a spot for a certain amount of time then moving to the next spot, and so on.

4. Concentration

Concentration is half discussed in the chapter above, being closely related to the particle that forms the part, the density of the material represents how thick a part can be, and contain a certain amount of particles.

Another impressive thing about concentration is that the graphic is always in motion, the main reason for this being the heat. Being able to change the speed and the power of the process one can get lots of different results.

First of all – let us talk about the speed. If one varies the speed in making the process in a way that the laser lasts longer on a certain point, and does not vary the power, the meltpool will receive more energy. Making that way the next few layer to take again some of the energy, in many cases this usage of the speed is preferred to make a more adhesive layer and a denser part. But the shortcoming of this method is that the part will receive a new amount of energy making it hot again, and the cooling process will not be finished. The conclusion of this first step is that it can be useful to reduce the speed but only partially with small walls.

The second in line is power. Varying the power of the process in a way that more power is introduced in the part can sometimes be the case of an alloy or a hybrid material. Due to the difference in melting points of the materials, choosing the highest temperature is mandatory. The problem appears in burning the material that has a lower melting point.

Varying the power in a way that less power is introduced in the part can have the same effect as increasing the speed of the laser movement. The layers will not be fully sintered, they will not fuse between them, and some harder to melt particles, as mentioned earlier, will not be melted.

Once the temperature is varied, the dimensions of the grains are adjusted. Once the grains are modified in shape and size that means the density varies as well. Varying the density means that the amount of the grain in a specified unit of space is modified, meaning that the concentration has changed.

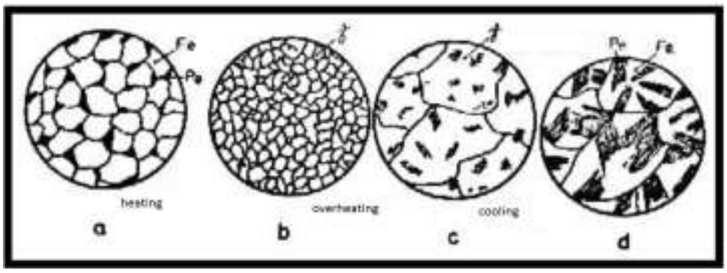

Fig. 7: Dimensions of grains.

The Figure 7 shows the difference between grains at the processes of heating, overheating and cooling.

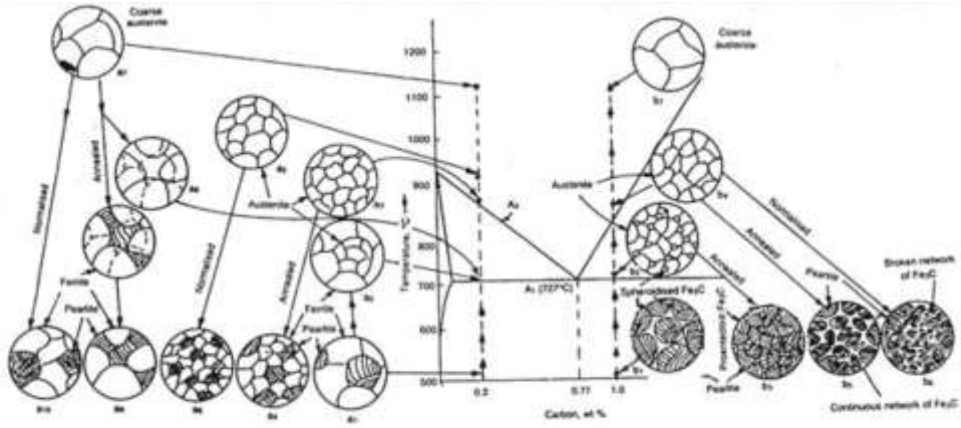

Fig. 8: Grains after annealing [3]

The picture shows the difference between grains dimensions after different types of heat treatment on the material.

In conclusion the importance of the temperature is obvious, which is translated by the amount of energy delivered in a certain amount of time, on a surface, and important factors of the process that we can vary by doing small adjustments of the temperature of the process.

5. Internal Stresses

Starting from this point we can discuss the temperature inside the meltpool and the effects that it has on the material. Judging by the form of the meltpool and its surroundings it can be very well considered from the point of view of a metallurgist engineer.

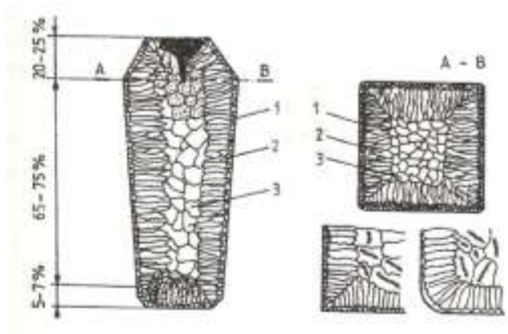

Fig. 9: Grains after solidification.

The picture shows the difference between grains dimensions after solidification.

When the part is heated, the part tends to expand. This dilatation can very well be performed on any kind of a geometrical body. The body tends to expand at the extremities, causing, by the influence of the variation of the temperature, the grain expansion. As the heat reaches the core of the part, more and more grains tend to expand.

As mention earlier the grains from the extremities are the first to expand. And the advantage is that they can only expand outside the part. The ones inside the body, being enclosed and restricted from expanding, create internal stresses. This kind of internal stress is not beneficial for the part, because it tends to tear it apart. When someone drills a hole in the part micro-cracks will appear near these grains.

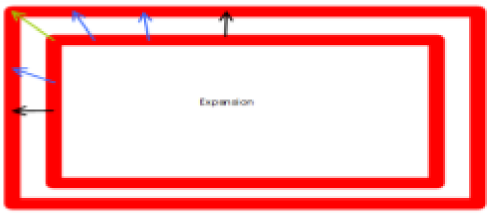

Fig. 10: Dilatation.

Green arrow - longest deviation, Black arrow - smallest deviation.

For this type of application a heat treatment is used called stress relieving. This treatment is used to change back the grains, and to give them a proper way to expand and contract over a period of time, because the quick melting caused by the laser energy and the quick cooling caused by the heat transfer between the meltpool and the air, last layers and the proximity powder.

The unfortunate result in the laser sintering technology is that the part is built on a building platform. First causing the grains to expand but they are tied up by the building platform and this is causing the first internal stress. After cooling down the pressure is applied to the part but in the bottom corners, as shown in the next picture, the material cannot move so it is the second string of the internal stress which is applied to the part.

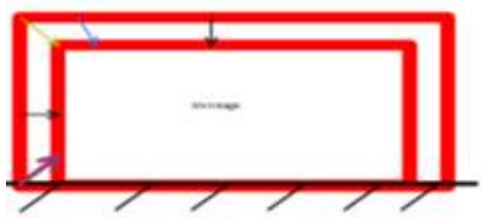

Fig. 11: Contraction.

Green arrow - longest deviation, Black arrow - smallest deviation, Purple arrow - no deviation, but maximum internal stress.

In this stage, the usual approach is to cut down the part from the building platform, with the precaution and observation for dimensional changes that will appear at the cutoff, due to the first and second string of internal pressure. And as mentioned earlier attention must be paid to micro-cracks that can be developed in the process.

After separating the two, the part will sustain a stress relieving heat treatment so cracks will not appear in the further machining. It is documented that in the stress relieving process a shrinkage will appear. On the steel parts it is expected a 1.85% shrinkage.

6. **Conclusions**

After all the experiments that have been conducted on these types of materials, there are still many more things to be learned. Doing just temperature variations on the process of making sintered parts, it has opened a new field of studies that nowadays can easily be performed by a CAE user. Nonetheless one must pay very close attention to the changes that nature is making and computer software is not yet prepared to anticipate. Bringing alongside all kinds of fields of expertise the variation can finally be measured of the density and concentration of the material depending on the energy intake in the sintering process. But this study is based on the study of the successive internal stresses applied to the part, and the outcome of the melting process of the powder, and its effects on the final part that can give functional parameters for the cutting process. One of the main findings of this study was that by rotating the toolpath with a certain degree, we can achieve lower vibrations on the machine.

7. **Next Step - Measuring Vibrations**

In the future processing even if the density and concentration of the part can be determined there are still much more to learn. One of the facts is the cutting speed. Because all the changes in density and concentration of the material can influence directly the cutting force needed to machine the part.

One study that will be performed on these types of materials will be done by performing a machining based on the empiric studies, with the ability to slightly change the parameters of the cutting process. And at the same time, the study proposes to take specific measurements of the voltage of the motors and a measurement based on sensors with accelerometer and gyroscope function to increase the capability to recognize the difference between the cuts. As shown below in Figures 12 and 13, the graphs can be spread on each axis, on the left of the photo, and also could be combined, on the right of the photo. The combined graphic allows the viewer to determine which axis is stressed more, and thus to be able to decide whether to increase or decrease each parameter of the cutting process.

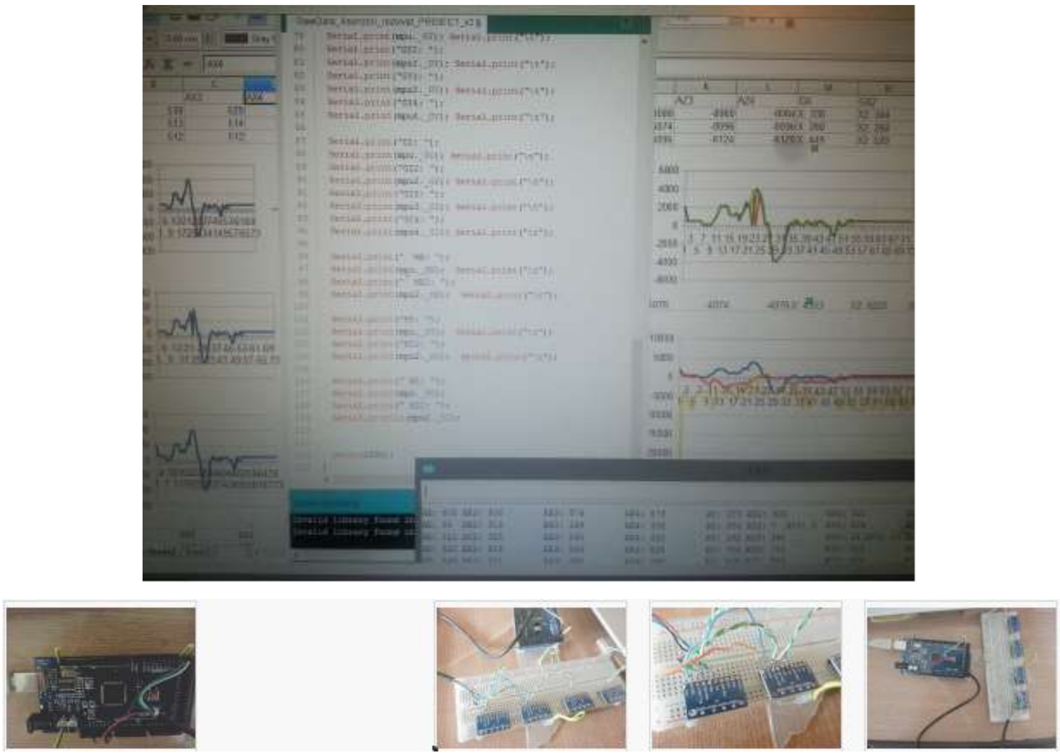

Fig. 12: Platform for vibration measurements.

The graphs are generated by an Arduino platform 3 that includes 4 sensors Accelerometer and Gyroscope that will be mounted on the every axis of the machine.

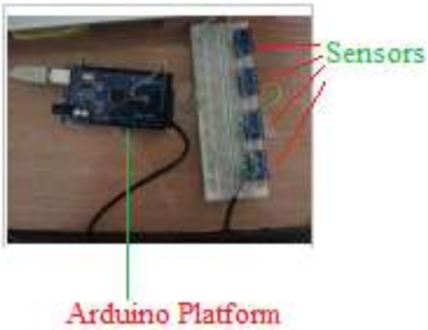

Fig. 13: System that allows to record vibrations.

On the right side the sensors are shown and in the left side there is the Arduino Platform [2]

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