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Characterising Damages of the Main Pressing and Heat Transferring Element within the Hybrid Contact Laser Sintering Process

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Abstract
The Hybrid Contact Laser Sintering Process is advantageous for manufacturing micro and small scale work pieces out of amorphous metal powder. Thereby a sapphire stamp as the main construction element is used for force and laser power transmission. Preliminary tests show two types of damages: material removal from the powder contacting surface due to temperatures above the decomposition limit and two forms of cracks caused by manufacturing tolerances and material removal. In case of low material removal and slight cracks the sapphire stamps could be further used.

Laser, sintering, powder, wear

1. Introduction

Due to the absence of grains, amorphous metal is not underlying the size effect which is called "grain size/thickness" ratio. This effect leads to decreasing accuracy of the part dimensions during manufacturing processes, so amorphous metal is advantageous to be used as material for small scale and micro parts, providing high hardness, elasticity and stability [1,2].

To successfully manufacture parts from amorphous metal powder, the Hybrid Contact Laser Sintering (HCLS) Process was developed [3]. The heat source is a laser beam which is transmitted through stamps out of sapphire to directly heat the metal powder (see figure 1).

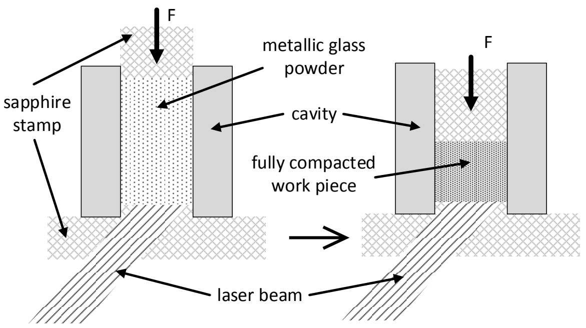

Figure 1. Setup of HCLS-Process

The aim of this paper is to present first results of the preliminary tests using aluminum powder. The focus is laid on wear effects of the sapphire stamp when using high pressures, laser intensities or a combination of both to evaluate the process boundaries. As a result a definition is made whether the damaged sapphire stamp can be further used or not.

2. Sapphire stamp and methodology

A functional analysis (see figure 2) shows the importance of the sapphire stamp for both main functions of the process: *powder compacting* and *powder heating*. In case of *powder compacting* it is the last element in the force transmission chain that has direct contact to the metal powder. So there are special needs: high compressive strength and high hardness to be resistant from scratches on the surface.

In case of *powder heating* the power transmitting element needs a low transmission factor in the range of the used laser wavelength of 1070 nm.

Table 1 shows the material properties of sapphire. The comparison to values of heat resistant and hardened steel underlines its applicability as material for both: *powder compacting* and *powder heating*.

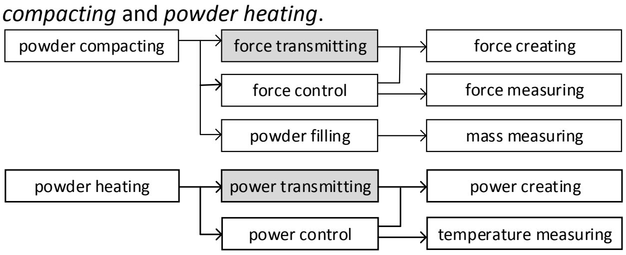

Figure 2. Main Functions of the HCLS-Process and the importance of the sapphire stamp as construction element for force and power transmission

Table 1 Material properties of sapphire [4] compared to hardened heat resistant steel [5], given ranges due to varying researches

	sapphire	heat resistant, nitrated steel
compressive strength [N/mm²]	2100	600-1500
hardness [HV]	1600-1800	900-1400
transmission factor (1070 nm)	0.88	0.00

To characterise different types and to give a definition whether the damage is tolerable or not, tests with different laser intensities and pressing forces are performed. The occurring damages are analysed under a confocal microscope. Afterwards the transmitted laser power is measured and compared with the power transmitted by a sapphire stamp without damages. Thereby the rotational position of the sapphire is also considered.

3. Damage characterisation and results

3.1. Material removal from sapphire surface

Material removal from the upper sapphire surface that has contact to the metal powder is one kind of sapphire damage. The removal is located where the laser spot is heating the metal powder. The reason for this can be found in the high local temperature above the decomposition limit of sapphire (>2000 °C [4]) caused by high laser intensities of 66 W/mm^2 or higher. Figure 3 shows two different stamps with a) small area of material removal (d = 450µm) and b) large area of material removal (d = 1200µm). The filled area is a measure for laser power in dependence of the laser beam direction. It is shown that a slightly damaged sapphire transmits 100% of the laser power and a highly damaged sapphire about 90% with no significant dependence from the direction of the laser beam.

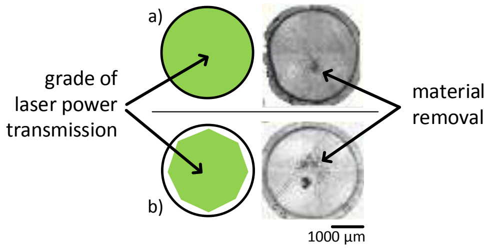

Figure 3. filled area in left circles: transmitted laser power in dependence from laser beam direction; a) stamp with small area of material removal; b) stamp with large area of material removal

3.2. Crack of sapphire stamp

The second damage that occurs is a crack of the sapphire stamp. There are two types: a) crack that is caused by manufacturing tolerance and b) crack that is caused by a hole where material removal took place.

Type a) is shown in figure 4a. This crack mostly occurs at the bottom of the sapphire that has contact to the force transmitting surface of the base machine. The reason can be found in not exactly plane-parallel aligned surfaces so there is a point or line shaped contact between both surfaces causing high pressures above the material stability. In all cases the crack is little and has no effect on the transmitted laser power.

Type b) is shown in figure 4b. This crack comes from a hole caused by material removal and occurred when reaching compressive strengths of 80-120 N/mm^2. The crack runs through half of the sapphire towards the nearest outer zone. In this case the transmitted laser power is significantly reduced to 32 %. It is also shown that this is highly dependent from the rotational orientation of the sapphire stamp (32-100%). This variance is caused by laser deflection on the breaking edge within the sapphire stamp.

Further usage of type b) cracked stamps results in complete separation of both sapphire parts. The stamps with crack type a) can be used for several times where both parts are still bonded.

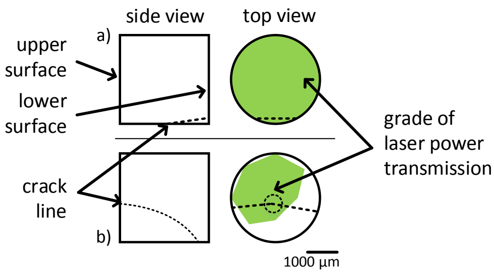

Figure 4. filled area see figure 2; a) crack type a); b) crack type b)

3.3. Wavy sapphire surface

Non used sapphire stamps may have a wavy surface caused by manufacturing processes that lay within the requested manufacturing tolerances (see figure 5). The difference from the highest to the lowest point is about 3.9 µm. The tests show no significant influence on the transmitted laser power in case of a fully transparent surface without scratches. Therefore this kind of surface characteristic is tolerable. Further tests may show if the crack building is enhanced by those waves.

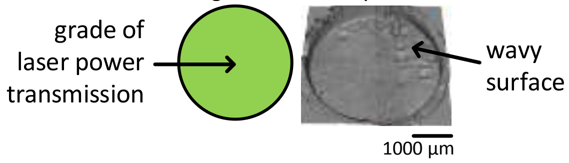

Figure 5. filled area see figure 2; wavy surface of new sapphire stamp

4. Evaluation

The tests show that, in general, material removal is affecting the transmitted laser power. Slightly damaged stamps may be further used since the transmitted laser power is nearly 100 %. Stamps that have large and deep areas of material removal may be used further by adjusting the laser power. But the sintered material now flows into the existing hole and causes variations in dimensions of the manufactured part. So if there is any material removal this has to be measured and evaluated whether the resulting dimensional variation is acceptable or not. But if the process needs larger pressures than 80 N/mm^2 the sapphire stamp would break (see 3.2.). In this case the stamp should not be further used.

The tests also show that crack type a) is not affecting the transmitted laser power or the dimensions of the manufactured part because the crack is at the bottom of the stamp. In this case it could be further used unless the two parts are still bonded together. Stamps that cracked with type b) should not be further used for the transmitted laser power significantly depends on the rotational orientation of the stamp.

5. Conclusion

This paper characterizes the occurring damages of the sapphire stamp used within the HCLS-Process. There are the following types: material removal and two types of cracks. Only in case of low material removal and crack type a) the stamp can be further used.

This work is the base for an economic view on the process as it defines the change time of the sapphire stamp. Future work has to define the number of tests that can be performed without damages within the process boundaries to evaluate the material costs per manufactured part.

References

[1] Montag T and Wulfsberg J 2015 *Proceedings of the 15th euspen International Conference*, Leuven, 2015, 197-198

[2] Quin Y 2010 Micro-manufacturing engineering and technology (Oxford, Elsevier) 115-118

[3] Wulfsberg J, Terzi M, Kuhn A, Bruhns F 2008 Verfahren zum strahlungsgeschützten Urformen, Umformen, Fügen und Trennen mittels aufgesetzter, kraftübertragender Kontaktoptik Patent DE102006051333A1

[4] Erhardt R 2004 Laserunterstütztes Umformen miniaturisierter Bauteile am Beispiel des Tief- und Kragenziehens, *Berichte aus Produktion und Umformtechnik* **60** (Aachen, Shaker) 17

[5] Weißbach W, Dahms M and Jaroschek C 2015 Werkstoffkunde (Wiesbaden, Springer Vieweg) 255