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PROPERTIES AND CHARACTERISTICS OF PARTS OBTAINED BY LASER SINTERING OF TITANIUM POWDER MIXTURES

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ABSTRACT
Laser generating of powder mixtures combines laser technology, powder technology and CAD-CAM. In this way, it is possible to produce complex 3D-objects for prototyping, tooling or manufacturing. This technique allows producing freeform solid parts, directly from a CAD database. In additive process, the part is built up in thin layers. Such techniques compete in low production number situations, as production of prototypes, visualization models, or part on demand. Titanium alloy has been studied more than other materials because of its particular properties, but the results of the study could be generalized for a large number of materials.
Keywords: laser beam-sintering, laser generating, powder mixtures.

1. SINTERING METHODS
Classical sintering process needs at least three units: a mixer in order to ensure the homogeneity of the powder, a pressing machine and a furnace [1].
Each of the mentioned units represents high cost of investment, high cost to operate and important amount of energy.
Years ago, the scientists came with a new ideea: spark sintering, which eliminate two of the mentioned units: the pressing machine and the furnace. This application represents an important progress in the domain of sintering, and it was applied especially in Japan and in the USA.

2. SINTERING WITH LASER BEAM
A relative new ideea come with: sintering by using a photon source as energy source. An energy beam could be directed onto selected areas of the energy beam from the powder blend layer. Then, a preform part is built up by iteratively preforming the spreading, melting, and resolidifying steps on additional adjacently formed layers.
A metal liquid phase sintering process is preformed at a temperature sufficient to melt the alloying metal but no the base metal or alloy.
By using the laser, three-dimensional parts are typically machined, using a molted block of material as a starting point, casting the block of material is a relatively cost efficient and accurate process, although forming the final part using past-casting machining and retooling processes can be long and expensive.
To create parts with potentially complex geometry, we could use selective laser sintering (SLS), but current commercial machines are designed for low-temperature processing. One approach to rapid manufacturing or functional parts is to use a suitably designed polymeric binder to hold a powder preform intact, followed by past processing binder, burn-out and subsequent infiltration of a second material.

A technique for increasing the end-use properties of rapid manufacturing parts is the infiltration. The part must have open porosity; that is, porosity that forms a continuous tunnel-like network throughout the part. Most properties are diminished by porosity. For that, it is generally desirable to eliminate as much porosity as possible. In traditional powder processing, hot pressing and other deformation processes are employed. For better densification, high temperature past–process sintering is sometimes useful.

In some cases it is preferred to infiltrate the part with a liquid material of lower melting point than the parent material. This results in a composite part with nominally full density. A key advantage over other full-density processing techniques is the ability to largely preserve part geometry, important for rapid manufacturing.

For this case, infiltration is usually a post-processing step wherein the porous part is heated in contact with the infiltrant to a temperature at which the infiltrant is molten and will wet the part. Upon cooling, the infitrant solidifies to produce the final part.

Authors made such research in order to explore the theoretical basis for spontaneous infiltration of a liquid into a porous preform.

Manufacturing with laser sintering means the fast, flexible and cost-effective production of parts directly from electronic data, which can include rapid prototyping, rapid tooling, parts on demand, all at a high quality. Especially interesting is the direct manufacture of end-use parts. For manufacturing small parts, we may use also fiber lasers. In this way, the range of applications is much extended and also the quality of the part is improved. In the same time, we have better results, concerning the material properties, the machine productivity and cost-effectiveness of the process chain.

Laser generating comprising selective laser sintering and melting technologies allow generating complex 3D-prototypes by solidifying several powder materials like polymers, metals, ceramics and composites. Research on new material systems and their characterization for the laser generating process is crucial for qualifying new applications improving quality cost or/and time of production.

The final properties of laser generated layers and parts depend on selected process parameters and interaction between laser beam and powder material. In order to identify suitable process parameters for new material systems, time-consuming experimental validation of each powder can be significantly reduced by theoretical analysis of the laser generating.

A theoretical model of laser generating describes powder material and dominant phenomena of laser - material interaction. The mathematical physical simulation is validated by experimental measurements. The process parameters determine the part quality.

Laser aided direct metal/material deposition (DMD) process builds metallic parts layer-by-layer directly from the CAD representation. The process uses powdered metal/materials fed into a melt pool, creating fully dense parts. To obtain designed geometric dimensions and material properties, delicate control of process parameters is critical (figure 1). This technique allows producing freeform solid parts directly from a CAD database. In an additive process the part is built up in thin layers. These techniques compete in low production number situations such as production of prototypes, visualization models or parts on demand.

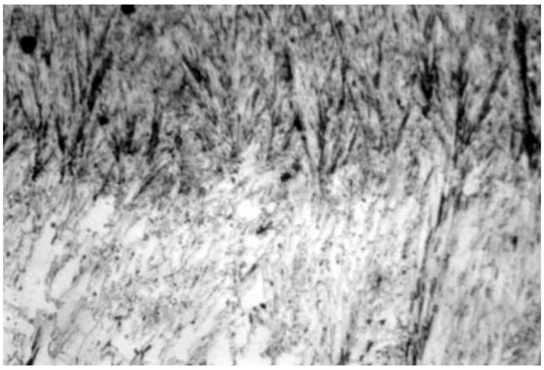

Figure 1. Base metal and laser deposited layer (x500)

Laser generating creates objects layer by layer with an exposure of laser beam [2] joining powder particles. In this way it is possible, to build parts with complex geometrical shapes such as freeform surfaces or integrated channels and undercuts.
A first computer model of the part is sliced in thin layers transforming the 3D-data into a series of 2D cross sections. The laser generating process can be divided in two steps: first, the powder is deposited on the part, and next a laser beam scans the powder surface.
The laser beam is controlled by the system like drawing the 2D-slices with the laser on the powder bed and partially melts the powder particle. Outside this area, the powder remains loose and can be recycled after the process. Next powder layer is deposited and scanned controlled by the CAD-model until the entire part is produced.
Any material can be used in the laser generating process, provide that the powder particles tend to fuse or sinter when heat is applied. The suitability of this process for polymers, metals, metal/polymer and ceramics has been demonstrated recently.
Many developments are made since 1986, to use homogenous metal powder like stainless steel or titan alloys for same properties as conventional produced parts. Another goal of further developments is to use materials or material systems for new applications improving cost and/or time of production.

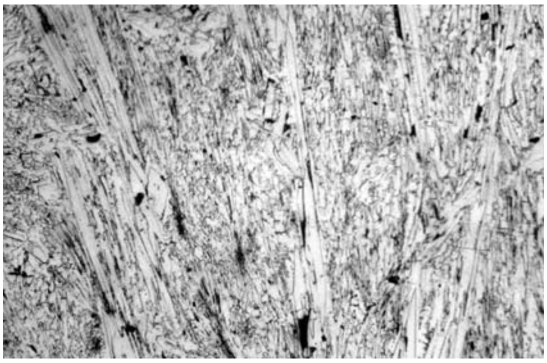

Figure 2. Structure of deposited layer (x500)

Final properties of parts fabricated in laser generating process depend on the operating conditions as well as on the powder characteristics (figure 2). Optimizing a process with respect to a large number of operating parameters is a complex task. This cost and time-consuming experimental validation can be reduced by theoretical analyses of the laser generating process.
The approach of suitable process parameters like laser beam parameter exposure techniques and an exposure pattern is an iterative procedure by experiments. Therefore a reliable optimization procedure is desirable. A systematic approach should include a simulation to identify a processing window and with respect to the results of the simulation a design of experiments.
The physical modelling is important for the development of new materials and suitable powder characteristics. A theoretical study of the process behavior must be done.
With a simulation for each interested material, the influence of processing system could be discussed and acceptable process parameters identified. The developed model will be validated on selected metals and metal ceramic composites.
The characteristics of a laser material interaction should be analyzed by modelling the physical phenomena occurring during the process. The simulation can predict the system behavior qualitatively and quantitatively.
Laser generating is being qualified for industrial applications. In order to achieve a high reproductibility of these quality attributes for laser generated SLM (Selective Laser Manufacturing) parts, the design rules developed must be applied and functional parts will withstand defined loads in required tasks.
The main issue is that the parts receive the highest density obtainable. Density as well as other properties is influenced from lack of heat conduction. Thus, a choice of suitable powder material is important that includes balancing of thermal elongation, heat conductivity viscosity of the melt, particle wettability and modification of the crystal lattice. Therefore some new developments of single

component powder materials from metallic alloys customized for the SLM process should be expected for the near future. E-Manufacturing is already being used successfully for production of end -use parts in a variety of applications. It is to be expected that the number and range of suitable applications will continue to expand. There are general market trends towards increased number of product variants and also shorter product lifetimes, which result in smaller number of pieces required per variant. E-manufacturing has a natural advantage in this situation, and the ongoing improvement in the productivity of laser-sintering systems and process chains means that the break-even points are continuously improving. In this way the quantities are increasing for each e-manufacturing of a given geometry is more economical than conventional production.
Another important success factor is the quality of laser-sintered parts, and this has been continuously improving due to innovations in materials and process developments as well as the use of new kinds of hardware such as the fiber laser.
The qualification of a material configuration can be an expensive and time-consuming process. Using an interactive procedure between a theoretical calculation of the material behavior with respect to laser radiation and experimental optimizing of process parameters time and/or costs can be reduced significantly. Using mathematical models of the temperature distribution versus effective factors of the process a region of acceptable operating conditions for the laser generating process could be found. This strategy leads to a rather small number of required experiments to develop a new material. This concept is feasible only if the database for heat capacities and thermal conductivities at the various temperatures of the laser generating process is accurate. For solids, the functions are available in literature, but for powder beds or composites there is an approximation.
The results of the temperature determination are only as accurate as possible by the approximation of the thermal properties. As shown by development of the CMMC (Ceramic reinforced Metal Matrix Composites) material configuration there has been developed a method to decide suitable process parameters for the laser generating process without numerous iterations.

3. CONCLUSIONS

In the laser generating process we can use a lot of materials. The suitability of this process for polymers, metals, metal/polymer and ceramics has been demonstrated recently. It were been used mainly homogenous metal powder like stainless steel or titan alloys for same properties as conventional produced parts. Another goal of further developments is to use materials or material systems for new applications improving cost/or time of production.
The characteristics of a laser material interaction should be analyzed by modelling the physical phenomena occurring during the process.

4. REFERENCES

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