14th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2010, Mediterranean Cruise, 11-18 September 2010

THE USE OF LENS TECHNOLOGY FOR PRUDUCING IMPLANTS

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ABSTRACT
Biomaterials that are used to produce implants such as dental or orthopaedic implants must possess the right properties to achieve the necessary biocompatibility. Materials such as titanium and its alloys are widely used because of the low density and good mechanical properties. In the beginning the implants were made with conventional production techniques, but today more advanced technologies with a lot of advantages are used. LENS^{TM} (Laser Engineered Net Shaping) represents a modern generic technology for the fabrication of near net-shaped parts. The process builds metal parts layer by layer directly from a CAD model using a high-power laser beam and metal powder. This process is similar to other rapid prototyping technologies and is capable to produce fully dense metal components. The most common materials used by LENS are stainless and tool steels, Ni-based super alloys, Ti alloys and wear resistant alloys based on W, Co, Al and Mg. A major advantage of this process is the capability to deposit composite and functionally graded materials. For demonstration an artificial hip was produced with this technology.
Keywords: laser deposition, rapid prototyping, metal components, implants.

1. INTRODUCTION

Laser Engineered Net Shaping is a new procedure for making metal components directly from CAD models. This process in similar to other additive techniques for rapid prototyping where components are manufactured with stacking individual layers. With the LENS technology it is possible to produce fully dense components with mechanical properties that are equal or better than the properties of forged components. The potential of this technology is the fact that it is possible to lower the production times and costs to produce a functional component. It is also possible to produce parts that are impossible to manufacture with conventional techniques. One of the advantages of this technology is that the process parameters influence the properties of the part. This means that it is possible to create parts with different mechanical properties from the same metal powder. Until recently implants were produced with milling, followed by surface modification of the finished parts [1]. The implants had to be coated to improve stability and enhance bone integration. The very good precision of the LENS technology allows joining together very thin sections, which means that it is possible to build very complex parts with a gradient of porosity. The difference of material density allows the implant to have the same stiffness as the human bone which avoids stress shielding of the residual bone. For improving the biological responses methods like acid etching can be used for roughening the surfaces of the implant. The process of direct laser deposition presents a promising production technology which can drastically reduce the time needed from an idea to a functional component. To successfully integrate this technology in the production of a company, a lot of research has to be done to fully understand the process.

2. HOW LENS WORKS

There are several technologies on the market which can produce components from metal powders [2]. The technologies are very similar and differ just in detail such as laser type, powder delivery system, protection from oxidation, etc. Deposition of material with the LENS technology is done with a special laser head which is shown on figure 1. In the laser head is a lens which focuses the laser beam on the surface where it creates a small molten pool. In the molten pool powder is blown with the help of a carrier gas. Some of the powder bounces of the surface and some is caught by the molten pool. The powder melts quickly when entering the molten pool and solidifies when the laser head moves away. The solidification is very quick because the heat is rapidly conducted away from the melt pool. The material is deposited in a shape of a line, which dimensions are set by the process parameters. One layer is made of a number of lines of deposited material. When one layer is finished, the laser head moves up for one layer thickness and begins building the next layer. This procedure continues until the whole part is completed. Because the material in the process is melted, oxidation must be prevented. That is why the process takes place in an airtight chamber filled with an inert gas such as nitrogen or argon.

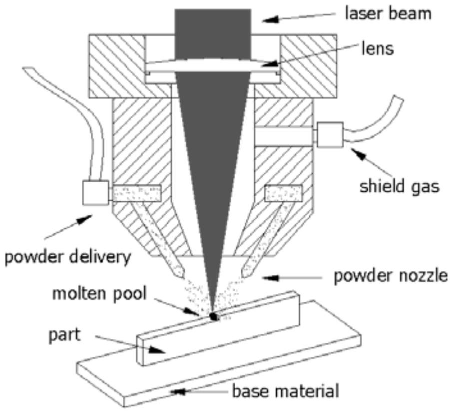

Figure 1. Laser head

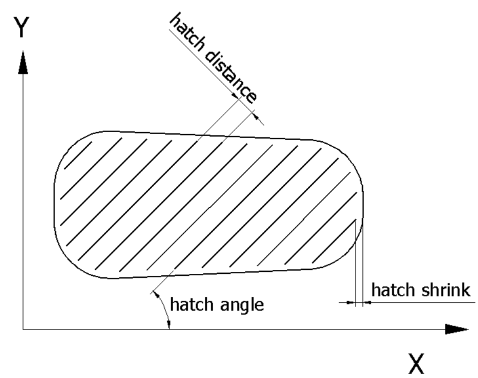

Figure 2. Layer of the hip

3. MATERIAL PROPERTIES

The LENS system is capable of processing a large number of materials. It is mainly used for building or repairing parts from titanium alloys, nickel alloys, tool steel and many more. The studies show, that it is possible to build parts with very good mechanical properties that can surpass the properties of forged parts. The parts have excellent mechanical properties because of the fine microstructure which is obtained with the LENS technology. To understand the formation of the microstructure and the properties of finished components, good knowledge of heat transfer is needed. Each component made with the LENS technology has a very complex history. The material is subjected to constant reheating and cooling as the part is being built. Process parameters such as laser power and velocity of the laser head have great influence on the cooling rate and thermal gradient which control the microstructure of the part. It is also possible to achieve a porous structure in a part by optimizing the distance between two successive scans of the laser [3]. By changing the hatch angles of each layer the pores can be oriented layer by layer leading to a 3D interconnected porosity. The walls in these structures are solid and provide better strength to the structure at relatively bulk densities. Because of the complexity of the process it is very difficult to link the parameters to the resulting microstructure [4]. Many positive results were obtained just by trial and error. The best way to predict the process variables on the resulting microstructure are simulations which include data that was gathered during the deposition of the material. This data can be acquired with different types of thermal sensors and thermal cameras.

4. HIP BUILDING

The artificial hips were build with a LENS 850-R. This machine uses a 1kW fibre laser from IPG Photonics with a wavelength of 1 µm. The hips were built from a stainless steel 316 L powder which grain size is from 45 µm up to 150 µm, in a chamber which was filed with argon. The chamber is equipped with an oxygen absorber, which removes oxygen from the chamber, so that the oxygen level was never higher than 15 ppm during the production of the parts.
All rapid prototyping technologies adopt the same basic approach when it comes to part building. There are five steps needed to produce a part [5]. These steps are: 3D modelling, data conversion, checking and preparing, building and post processing.

4.1. 3D modelling

The first step in the process chain is modelling. For this step modelling software is needed. When modelling a part it is necessary to take into account the limitations of the machines on which the part will be made. Because it is not possible to use support material in the LENS technology, only overhangs up to 30° are possible to build with a 3 axis movement.

4.2. Data conversion

In this step the 3D model has to be converted in a file that can be read by the RP software. In our case the model is converted into a .stl file. This step is relative simple, because all modern modelling software enables to save the models in various formats.

4.3. Checking and preparing

Sometimes errors are made while the model is converted into the .stl model. The most common errors are unwanted holes in the surface of the model which have to be patched. Before the next step the model has to be checked and repaired with appropriate software. When we are satisfied with the model it is time to slice it in layers. In the slicing program we have to specify slicing parameters such as layer thickness, hatch shrink, hatch distance, hatch angles, etc. A layer of the hip is shown on figure 2. Each line on the layer presents a path of the laser. Values for the slicing parameters must be chosen wisely because they have a great affect on the final product. If we want that the foreseen layer thickness will be equal to the actual deposited thickness, the hatch distance must be just right. Of course it is possible to affect the deposition during building with changing of the laser power or translation speed of the laser head. After the appropriate values are given, the program slices the model and saves it in a .sli file. Before we can start to build the part, the .sli file has to be converted into a G – code or a DMC code. This is done with the control program of the LENS machine. In this step we have to specify some additional parameters such as acceleration and deceleration for individual axes, building resolution, number of the powder hopper from which the powder will be delivered, mass flow of the powder, etc.

4.4. Building

The laser head must first be taken to the start position and lowered on the focal distance from the base material. When the process is started the operator must carefully observe the deposition of the material and adjust the process parameters so that the building of the part goes as planned. The trick is that the focal distance between the laser head and the part is maintained all the time. The operator must adjust the parameters so that the layer height being deposited is equal to the distance which the laser head moves up when a layer is finished. The building process of our test hip is shown on figure 3. The distance between the laser head and the part is maintained by changing laser power, powder mass flow or translation speed of the laser head. Decreasing the laser power or the mass flow will result less material deposition; on the other hand decreasing the translation speed will increase the layer thickness.

4.5. Post processing

After the hip was built, it had to be separated from the base material. This is usually done with wire erosion. If any material has adhered on part walls, it must be removed. Then the part is ready for processing with conventional techniques such as milling or grinding. If necessary, the hip can also be heat treated.

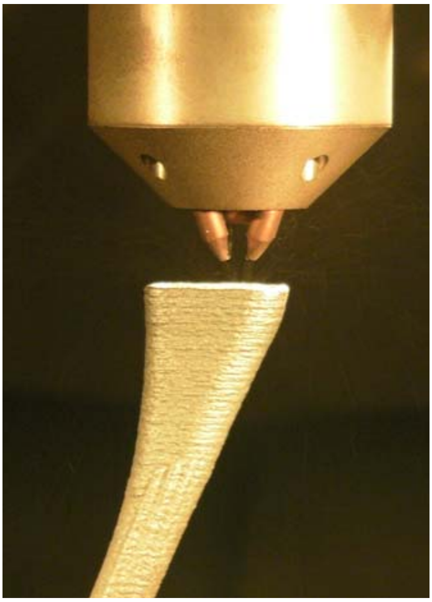

Figure 3. Building of the artificial hip with the LENS technology

Figure 4. Two artificial hips different sizes made from stainless steel

5. RESULTS

In this paper the technology LENS was shortly presented and two test hips were made. On figure 4 the two artificial hips are shown made from stainless steel. The hip on the left is made of 614 layers and the building took approximately five hours. The right hip in made of 534 layers and it took four and a half hours to build it. Both hips have maximum overhangs of approximately 26^0. This is why the contour of each layer was built at only 250 mm/minute. If the speed had been greater, there would not be enough material deposited on the overhangs and the part would collapse. As told, this technology has a great potential also in the implant industry because of the many positive characteristics of the final products.

6. ACKNOWLEDGE

The Research is partially funded by the European Social Fund. Invitations to tenders for the selection of the operations are carried out under the Operational Programme for Human Resources Development for 2007-2013, 1. development priority: Promoting entrepreneurship and adaptability, the priority guidelines 1.1: Experts and researchers for enterprises to remain competitive.

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