Direct metal printing

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Research centers and companies have shown in recent years a strong interest in new production methods.

The current socio-economic context is strongly characterized by flexibility, production maximization, reduction in time, waste, costs and the necessity of protecting and enhancing environment to safeguard planet's resources both today and for future generations.

Thus emerges one of the fastest-growing and potentially most important fields of contemporary research: the study of additive technologies.

The main advantage of these techniques is the ability to obtain high geometrical complexity components that are impossible to make with traditional techniques .

Among additive technologies, additive metal fabrication technologies allow to passing from prototyping phase to final components realization, characterized by mechanical properties comparable to those obtainable with traditional processes.

There are several "Direct Metal Printing" or "Metal Additive Manufacturing" techniques such as "Direct Metal Laser Sintering", "Electron beam melting", "Selective Laser Sintering (SLS) ", "Selective Laser Melting", "Electron Beam Freeform Fabrication (EBF)" and fields of applications range from the advanced mechanics sector to aeronautical and aerospace industries, medical, jewelery.

In the paper will be discussed concrete applications of metal 3Dprinting.

Пряко метално 3D печатане (Масимилиано Ди Лече). *Изследователски центрове и фирми показаха през последните години силен интерес към нови методи на производство. Сегашният социално-икономически контекст се характеризира с гъвкавост, производствено максимизиране, намаляване на времето за производство, на отпадъците, разходите и необходимостта от опазване и подобряване на околната среда, за да се запазят планетните ресурси сега и за бъдещите поколения.*

Така се очертава една от най-бързо растящите и потенциално най-важните области на съвременните изследвания: изследване на технологиите с добавяне на метал. Основното предимство на тези техники е възможността за получаване на висококачествени геометрично сложни компоненти, които е невъзможно да се направят с традиционни техники.

Сред адитивните технологии, технологиите за получаване на изделия от метал с добавяне на метал позволяват да се преминава от прототипи фаза до крайната реализация на компонентите, характеризираща се с механични свойства, сравними с тези, получени с традиционните процеси.

Има няколко техники за "Директен метален 3D печат" или "Производство с добавяне на метал", като например, "Селективно топене с електронен сноп" "Директно лазерно синтероване на метални прахове", "селективно лазерно синтероване (SLS)", "селективно лазерно топене", "електроннолъчева изработка в свободни форми (EBF)" и областите на приложение варират от сектора на съвременната механика към въздухоплавателната и космическата индустрия, медицински инструменти и импланти, бижута.

В тази работа ще се обсъдят конкретни приложения на металното 3D печатане.

Introduction

There are a number of different technologies used in the metal Additive Manufacturing systems available today.

Systems can be classified by the energy source or the way the material is being joined, for example using a binder, laser, heated nozzle etc. Classification is also possible by the group of metal materials being processed. The feedstock state, with the most common ones being solid (powder, wire or sheet) or liquid, is also used to define the process [1].

A. Different metal additive manufacturing technologies

In this section, we consider the main metal additive manufacturing techniques.

The common denominator among all is the deposition (or solidification) of layered material, but the similarities stop there: the materials used, their initial state, the undergoing treatments to reach the finished part change from technology to technology.

Each method has advantages and disadvantages, but generally the criteria to consider in selecting a method or another are related to the speed of production, the cost of the machine, the cost of the model obtained [2].

Characteristics of process technologies

Direct process powder-bed systems are known as laser melting processes and are commercially available under different trade names such as Selective Laser Melting (SLM), Laser Cusing and Direct Metal Laser Sintering (DMLS). The only exception to this process principle is the Electron Beam melting (EBM) process, which uses an electron beam under full vacuum.

Selective Laser Sintering (SLS)

The laser sintering, once also called SLS (Selective Laser Sintering), uses a laser to sinter the materials used for the construction of the prototype. Initially it is left a thin layer of dust by a special apparatus and laser provides the sintering where needed. The table lowers the desired amount, is spread another layer of powder and then it repeats. The advantage lies in the fact that you can use various types of powders and there is not necessary to provide supports since the non-sintered powder provides to support the upper floors. At the end of the process, the workpiece must be freed from the excess powder, which is not very complex, and in the case of metal powders, also undergoes a thermal treatment to improve their characteristics.

Selective Laser Melting (SLM)

It is totally similar to the selective laser sintering, but it differs in the use of integral metal powders, without the aid of low fluxes. It follows that the laser is more powerful and at the end it has an object completely similar to series production, which requires no special superficial finishes and that can be quietly subjected to conventional processes. In order to prevent oxidation of the metals in the working chamber is recreated an inert atmosphere.

SLM does not use sintering for solidification of the powder granules, but totally melts the material selectively, using a high energy laser. You can create objects with the following materials: titanium alloys, cobalt-chromium alloys, stainless steel and aluminum.

One of the best qualities of this printing technique is that object mechanical and physical properties are virtually identical to those of a model obtained by traditional fusion, without the critical points (eg. Fragility) typical of sintered materials.

This process is an additive technique that represents the evolution of Selective Laser Sintering (SLS) process of metal powders. It enables the creation of near full dense metal objects with high geometric complexity. Born as a technique of Rapid Prototyping, SLM has recently evolved as technology of rapid tooling and manufacturing of final components, thanks to the ability to process different metallic materials (steel, aluminum alloys, titanium alloys, etc.).

Energy density, defined as energy per unit area, produces complete fusion in the processed powders by the SLM and partial melting in those processed by SLS. SLM process produces objects with near 100% density without additional post treatments.

Electron Beam Melting (EBM)

It is entirely similar to SLM, but it must create the vacuum in the working chamber to allow the correct focusing of the electron beam on the work surface , which also prevents the formation of metal oxides in the powders.

The electron beam, being able to concentrate a greater power than the laser spot, can melt high melting metal powders such as titanium.

A particular application achievable with this technique is the production of biomedical titanium prosthesis, through the use of titanium powders with high biomedical compatibility.

The melting process of the materials takes place at temperatures between 700 and 1000 °C so as to obtain parts substantially free of residual stress, therefore, do not require post-production treatments. This technique was developed by the Swedish company Arcam and is especially applied in the aeronautical, aerospace, and biomedical. The alloy with which you can create objects is the Titanium Alloy Ti6 Al4V or pure titanium.

Direct Metal Laser Sintering (DMLS)

It is an additive manufacturing technique that uses a Yb (Ytterbium) fibre laser fired into a bed of powdered metal.

This technology is used to manufacture direct parts for a variety of industries including aerospace, dental, medical and other industries that have small to medium size, highly complex parts and the tooling industry to make direct tooling inserts. Basically the same of SLS, changes only the print material, in fact you can print metalS. The objects are built layer by layer by means of the local laser melting of metal powder with a very fine particle size, such as to allow the construction with the layer up to 20 microns. With this technique one can create objects in many metal alloys including: Steel(GP1 17-4), Stainless Steel (PH1), Cromocobalto (MP1), Aluminum (AlSi10Mg) and titanium alloys (Ti64 Grade 5). The DMLS technology is extremely innovative and provides an opportunity to build prototypes and metal parts directly, with no need of the equipment development and to be tested and used in a functional way. The possibility of developing components with a high degree of detail and an accurate level precision allow to produce parts also for jewelry sector, favoring post-processing on the developed materials, leading to a saving of time and to a cancellation of the development costs of equipment.

Laminated Object Manufacturing (LOM)

Some 3D printers use laminate material , which constitute the processed layer with tangential cutting systems or laser, to separate the section that affects the model from the scrap material.. This in turn constitutes a valid support material, which will be removed in finished print. It's a rapid prototyping system developed by Helisys Inc. (Cubic Technologies is now the successor organization of Helisys) In it, layers of adhesive-coated paper, plastic, or metal laminates are successively glued together and cut to shape with a knife or laser cutter. Objects printed with this technique may be additionally modified by machining or drilling after printing. Typical layer resolution for this process is defined by the material feedstock and usually ranges in thickness from one to a few sheets of copy paper

LaserCUSING® refers to Additive Manufacturing with metal, also known as 3D metal printing. The term, composed of the C of CONCEPT Laser and FUSING (melt completely), describes the technology: the melting process generates complex parts layer by layer using 3D CAD data – with layer thickness between 15 and 150 µm. Metal in fine powder form is melted locally using high-energy fiber lasers. Mirror deflection units (scanners) create the part contour by deflecting the laser beam. After cooling, the material solidifies. Construction is carried out by lowering the build plate, adding new powder, and melting again. What makes the systems special is stochastic control of the slice segments (also called “islands”), which are processed successively. The patented method provides for a significant reduction in tension in the manufacture of very large parts.

LaserCUSING® layer construction process allows the fabrication of both mould inserts with close-contour cooling and direct components for the jewellery, medical, dental, automotive and aerospace sectors. This applies to both prototypes and batch parts.

Laser engineered net shaping or LENS

It is an additive manufacturing technology developed for fabricating metal parts directly from a computer-aided design (CAD) solid model by using a metal powder injected into a molten pool created by a focused, high-powered laser beam. This technique is also equivalent to several trademarked techniques that have the monikers Direct Metal Deposition (DMD), and Laser consolidation (LC). Compared to processes that use powder beds, such as Selective Laser Melting (SLM), objects created with this technology can be substantially larger, even up to several feet long. It can produce parts in a wide range of alloys,including titanium, stainless steel, aluminum, and other specialty materials; as well as composite and functionally graded materials. Primary applications for LENS technology include repair & overhaul, rapid prototyping, rapid manufacturing, and limited-run manufacturing for aerospace, defense, and medical markets. Microscopy studies show the LENS parts to be fully dense with no compositional degradation. Mechanical testing reveals outstanding as-fabricated mechanical properties.

The process can also make "near" net shape parts when it's not possible to make an item to exact specifications. In these cases post production light machining, surface finishing, or heat treatment may be applied to achieve end compliance.

Electron Beam Freeform Fabrication (EBF^3)

This is an additive manufacturing process (3D printing) being developed by NASA to create metal parts in space. This process create parts and tools, which will save NASA time and money by allowing scientists to create parts as needed instead of hauling materials on the space shuttle, which can be quite costly.

It builds near-net-shape parts requiring less raw material and finish machining than traditional manufacturing methods. It uses a focused electron beam in a vacuum environment to create a molten pool on a metallic substrate.

3D galvanic printer is an invention of an Argentine engineer, named Gastón Accardi. It is based on electrolysis process. The 3D Printer Accardi does not use laser sintering, or stereolithography, or filaments fusion as the vast majority of other 3D printers on the market today. Instead, it uses the simple concept of electroplating to manufacture metal objects.

Basically, the electrodeposition works with a power source and two poles. A pole is connected to the part that you want to be coated with the metal, while other is connected to the metal source that you want to use for the coating. An electric conductor solution is required and is used lemon juice as a weak acid or at times sulfuric acid as strong acid.

Copper electroplating, suggests that copper is diluted in solution, as this leads to much better results in the plating process.

Conclusions

Manufacturing companies are preparing to change that 3D printing will bring within them.

It will be the metal printing the key in the manufacturing future..

In particular, the aerospazionale industry and the medical field, are increasingly demanding the ability to use such materials, aluminum and titanium, light metals which, however, have a considerable resistance.

The benefits obtained by manufacturing companies that have already embraced the 3D media confirmed the impact of this technology is already significant, as well as measurable. There are still some fundamental problems to overcome in terms of the 3D printing of metals. These problems are generally not reported in the media. - Surface finish: This is a big one, and one of the things I get asked most about. The parts produced by SLM are very impressive, however in terms of surface finish for a part which may have to connect accurately or form part of a precise mechanical system it is simply not good enough. The surface of SLM formed material is inherently rough due to the attachment of partially melted metal particles, and the layer-by-layer way in which it is formed.

Additive manufacturing is hardly suitable on large series productions (it doesn't exist economies of scale) but it will be able to open up new possibilities to "mass customization."

These characteristics make it specific in the following cases.

- Productions in which it is the technology of choice, that is, when it allows to reduce the costs and made objects with the same or superior characteristics (what primarily occurs today in the production of blades for turbines and fuel injectors for aircraft engines) or to obtain standard unique qualitative, not obtainable with traditional techniques (as in the case of the production of orthopedic prostheses and components for racing cars and motorcycles).
- Productions in which the technology is cost competitive only in modifing the designed object. Modifications in design allow to maximize the potential of additive manufacturing without compromising (or improving) the technical characteristics of the object product. This occurs today mainly in the components in aeronautics. But this is a case with huge application potential in various sectors, provided that the design or re-engineering construction are consistent with the potential of additive technologies (think additive).
- Productions where technology is not competitive in absolute terms but may be economically advantageous for other reasons. Three cases are particularly relevant: 1. when 3D printed piece is more expensive but the additive manufacturing (thanks to its flexibility, the speed of production without the need for molds or other tooling) allows to "store file" (this occurs in firstly for the on-demand production of replacement parts, particularly in the aeronautical field); 2. when additive manufacturing can afford to respond to sudden and unexpected lack of components for the production line (in this case the component itself may be more expensive but the flexibility and the speed of the new technology for preventing far greater costs associated interruption of production); 3. when additive manufacturing allows the re-engineering of parts intrinsically more efficient (and more expensive) that help increase the productivity of existing industrial facilities.

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