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ScienceDirect

Physics Procedia 83 (2016) 549 – 559

Physics Procedia

9th International Conference on Photonic Technologies - LANE 2016

Hybrid additive manufacturing technologies - An analysis regarding potentials and applications

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- Invited Paper -

Abstract

Imposing the trend of mass customization of lightweight construction in industry, conventional manufacturing processes like forming technology and chipping production are pushed to their limits for economical manufacturing. More flexible processes are needed which were developed by the additive manufacturing technology. This toolless production principle offers a high geometrical freedom and an optimized utilization of the used material. Thus load adjusted lightweight components can be produced in small lot sizes in an economical way. To compensate disadvantages like inadequate accuracy and surface roughness hybrid machines combining additive and subtractive manufacturing are developed.
Within this paper the principles of mainly used additive manufacturing processes of metals and their possibility to be integrated into a hybrid production machine are summarized. It is pointed out that in particular the integration of deposition processes into a CNC milling center supposes high potential for manufacturing larger parts with high accuracy. Furthermore the combination of additive and subtractive manufacturing allows the production of ready to use products within one single machine.
Additionally actual research for the integration of additive manufacturing processes into the production chain will be analyzed. For the long manufacturing time of additive production processes the combination with conventional manufacturing processes like sheet or bulk metal forming seems an effective solution. Especially large volumes can be produced by conventional processes. In an additional production step active elements can be applied by additive manufacturing. This principle is also investigated for tool production to reduce chipping of the high strength material used for forming tools. The aim is the addition of active elements onto a geometrical simple basis by using Laser Metal Deposition. That process allows the utilization of several powder materials during one process what enables the tailoring of the tools materials mechanical properties. Another aspect is the possibility of Laser Alloying of the tools surface to reduce abrasive and adhesive wear. This technique is especially interesting for tools used in hot stamping production.

Peer-review under responsibility of the Bayerisches Laserzentrum GmbH

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Peer-review under responsibility of the Bayerisches Laserzentrum GmbH
doi:10.1016/j.phpro.2016.08.057

Keywords: additive manufacturing; hybrid processes; process combination

1. Introduction

As the costumers desire on individual products increases, the companies offer a large portfolio of customized products [Rastogi (2009)]. To produce the small lot sizes of these parts in an economic way, the established manufacturing methods like chipping production and forming technology are limited. Especially forming processes with the need of high cost intensive tools cannot fulfil the requirements of short changeover cycles by producing affordable products. An innovative, very flexible manufacturing technology with a high degree of geometrical freedom is the additive manufacturing technology. The required part is build up by adding material. To produce a solid part the geometry is sliced into layers and by generating these layers successively the product is built up. This manufacturing technology is called a 2 ½ D-process. The principle allows an optimal utilization of material as the part can be topologically optimized on the occurring forces [Gibson (2015)]. In the last few years the researches for additive manufacturing increase conspicuously as some of the patents for Fused Depositon Molding (FMD) [Crump (1989)] ran out and so called "3D-Printers" were affordable for small costumers. A similar development is expected for machines working with selective Laser Beam Melting (LBM) as in January 2014 [Deckard (1994)] patents that protected this technology expired. Both of these and various more technologies are judged economically viable for commercial development.

2. Processes for additive manufacturing of metal

For the manufacturing of metal parts that could replace parts manufactured by forging, processes with a high amount of energy are required to process the metal material. Within the last decades several technologies for additive manufacturing of metal parts were developed and investigated. The most common ones are described in the following.

2.1. Selective powder melting

To take advantage of the high geometrical freedom of additive manufacturing the best manufacturing principle is the selective melting of the material inside a layer of loose metal powder. The process conventually is conducted inside an air dense process chamber with a building platform that can be adjusted in Z-direction. To build a three dimensional part a sequence of three steps is repeated successively. First the building platform is lowered by the height of one layer. Afterwards a closed layer of loose powder is applied by a so called recoater. The actual building of the part is conducted by melting selected areas of the powder bed with a high energy beam. Two processes are known to realize this manufacturing principle.

A laser based additive manufacturing process of three dimensional metal parts is the selective Laser Beam Melting (LBM), where the required energy to melt the metal powder is provided by a high energy laser. The laser is directed into the process chamber by a 2D scanner that allows a fast movement of the laser beam. To protect the molten material from oxidation the process chamber is flooded with an inert gas like nitrogen or argon [Meiners (1999)].

The second process that works with the same manufacturing principle but with an electron beam to melt the powder is the Electron Beam Melting (EBM). Besides the energy source the main difference is that the process chamber is vacuumed as the electrons would be distracted by air molecules or gas atoms [White (1980)].

2.2. Laser Beam Deposition Welding

Another industrial used concept is additive laser beam welding. For this principle a laser beam is focused rectangular on a workpiece surface to melt the workpiece material. The material added to the melt pool can be applied by wire, similar to a conventional welding process, or as powder by using an injection nozzle. The melting pool is protected from oxidation by an inert gas cover similar to conventional MIG-welding. The main advantage