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Additive manufacturing: the key issue for production engineering in future

Automotive and aerospace industries opt for 3D printing

Additive manufacturing is the key issue for production engineering in future. Conventional manufacturing technologies are being supplemented to an ever increasing extent by three-dimensional printing, which is already in successful operation in many sophisticated fields like the medical engineering, automotive and aerospace industries. The foundry, steel and aluminium industries have also recognised the potential of 3D printing. For this reason, the four Düsseldorf trade fairs GIFA, METEC, THERMPROCESS, NEWCAST 2019 (25. to 29. June 2019) are devoting a special show of its own to the subject of "additive manufacturing".

A look under the bonnet of the demonstration vehicle shows the potential that industrial 3D printing has for the automotive industry: few components but with more functions and considerably less weight. The new crash-proof front end structure of the old VW Caddy, which weighs 34 kg, is made from the extremely strong and tough high-performance alloy Scalmalloy from the Airbus subsidiary APWorks using a 3D printer supplied by the German company EOS. The 3iprint project that was carried out under the leadership of the development service provider csi won the "German Innovation Award 2018" in mid-June. The aim of the Caddy concept is to indicate what is technologically possible in automotive production using new design methods and new materials with the help of additive manufacturing.

Three-dimensional manufacturing processes, which is the general term used for the various additive production technologies with all the different kinds of 3D printing systems, are where the future lies. Additive manufacturing with plastics, metals and ceramics is already an essential feature of industrial production today. Almost 40 per cent of the German companies surveyed in 2016 already used 3D printing, as the consulting

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firm EY determined. The potential in all the different fields is tremendous. 3D printing with concrete could revolutionise the construction industry, while the bioprinting of living tissue is already possible – and even the printing of human organs is an issue that is the subject of serious research.

3D printing is creating new opportunities for the metal industries from aluminium and steel to titanium and special materials – whether foundries and steel mills or forging and sheet processing companies are involved. With 3D printers, structures are produced layer by layer on the basis of digital design data. Material is only used where it is needed. Additive technologies have their strengths where conventional manufacturing processes like casting, milling or forging reach their limits. 3D printing gives designers unlimited geometric freedom. Complex components with a bionic structure and integrated functions can, for example, be produced with varying wall thicknesses, cavities and honeycomb structures – like the heavy-duty, lightweight metal, automotive structure from the 3iprint project outlined above.

The production of small batches and even of individual components is economically viable with 3D printing too. Die casting moulds or forming tools are not needed, which can quickly lead to tool cost savings of several tens of thousands of euros. Individualised components, prototypes and spare parts that are rarely needed are therefore considered to be the domains of additive manufacturing. 3D printing is not, however, the universal “assault weapon” for attacking the bastions of established production engineering. The manufacturing expert Franz-Josef Wöstmann from the Fraunhofer Institute IFAM in Bremen says: “Additive manufacturing is a supplement not a substitute.”

3D printing reaches its limits at the latest where large product quantities can be made economically with conventional manufacturing processes. This is primarily the case in the high-volume segment of the automotive industry. Additive manufacturing with metal is not productive enough for mass production in series at the present time. Dr Stefan Geisler, Innovation Manager at KSM Casting Group in Hildesheim, is certain: “3D printing will be increasing for premium vehicles and for a limited number

of components, but it will not succeed in replacing foundries." He is convinced that the quantities needed in the volume market cannot be reached even with the faster layering speeds possible, for example, using additive manufacturing with wire. Geisler points out: "What is often forgotten is that additive manufacturing cannot overcome the laws of physics either. In the final analysis, all that are involved there too are processes: melting and cooling. There are limits to the speed at which this is possible." In addition to this, the printed articles need to be machined into finished functional components.

Another definite disadvantage of additive manufacturing with metal is the high energy consumption involved. Dr Wolfram Volk, Professor of Metal Forming and Casting at Munich Technical University, calculates that about twice as much energy as in conventional casting is required for the laser melting of metal, from powder production to the finished component.

Additive processes are becoming an increasingly common element of existing process chains. How additive manufacturing and machining can be combined to carry out comprehensive, hybrid processing in a single machining centre is demonstrated by, for example, the machine tool manufacturers DMG Mori and Hermle. World market leader DMG Mori supplements laser metal deposition by subsequent machining in the form of turning and milling. Its competitor Hermle extends a multiaxis machining centre by a thermal spraying process using its MPA (metal powder application) technology, in which metal powder is applied in layers to produce a soundly built component.

The Berlin company Gefertec is looking to increase manufacturing speed in the additive processing of metals. The 5-axis lines produced by the expert for additive manufacturing technologies weld wire in layers by the electric arc process. The workpieces produced in this way have outlines that are very close to the final shape, which reduces the time and tooling operations required for subsequent machining.

Foundry: direct and indirect additive manufacturing processes

The foundry industry can benefit from additive processes in several different ways. Direct additive manufacturing processes give foundries the opportunity to include individual parts or parts that are needed in small

quantities in their product portfolio too. In the case of indirect processes, on the other hand, they use additive technologies to produce moulds and cores out of sand as well as models out of plastic. Hybrid technologies involving a combination of conventional casting and additive manufacturing processes have further potential.

In order to take greater advantage of the potential that aluminium has to produce lightweight structures in automotive manufacturing, the aluminium producer Trimet is working on the development of a hybrid process chain to link die casting and additive manufacturing. The approach adopted in the context of the joint “CastAutoGen” project specifically involves the incorporation of 3D printed structures in a die cast component.

German industry holds a prominent position among the producers of additive manufacturing systems, as the BDI (Federation of German Industries) concludes in a position paper. The country’s market share is about 70 per cent with powder bed systems. The world leaders among 3D printing manufacturers include Concept Laser (metal), EOS (metal and plastic), SLM Solutions (metal) and Voxeljet. Voxeljet has specialised in foundries and markets 3D printers for the production of sand moulds and cores as well as of plastic models for investment casting by the lost-wax process.

In order to produce a casting, what are needed are a mould and the appropriate cores to form the cavities in the component that is being cast. In classic sand casting, the moulds and cores are made from quartz sand, which is strengthened by a special bonding agent. While fully automatic moulding machines and automatic core shooting machines are standard features at modern foundries for the mass production of car engines, for example, it is rarely an economic solution to use automatic equipment for prototypes and small batches. 3D printing is an increasingly common alternative here. Sand moulds and cores of any complexity are manufactured from the CAD dataset via a layering process. Toolless manufacturing of this kind provides high flexibility as regards numbers, design and versions and permits the production in exactly reproducible quality of complex moulds and cores with practically any geometry.

Voxeljet talks about cost savings of up to 75 per cent in the 3D printing of moulds and cores made from sand for small batches.

The printing of sand moulds and cores is a highly suitable option for development operations. The iron foundry Düker with locations in Karlstadt and Laufach in Germany, for example, does not use models any more in the casting it carries out for customers. The CAD dataset is all that is needed to produce the sand moulds that are manufactured additively. As a result, new products can be implemented in castings from computer files within a short time and can then be machined for trial purposes. Geometric adaptations are simple to carry out and recasting is then possible once the design data have been changed and another mould has been printed. Düker reports that development time is reduced significantly by this process. It is apparently standard procedure to produce initial samples within a few weeks, for which months are needed in the series process.

Die casting with reusable moulds made from tool steel benefit from 3D printing too. “Additive manufacturing is creating tremendous opportunities for die casting companies”, as Dr. Ioannis Ioannides, CEO of the die casting machine manufacturer Oskar Frech, who is both Board Chairman of the VDMA foundry machine trade association and a member of the board of the VDMA additive manufacturing task force, stresses in an interview with the magazine Giesserei. For example, Frech uses 3D printing to produce a complex key component for its low-sprue FGS tool technology that economises on recycled material (e.g. aluminium or magnesium).

The mould plays a key role in the die casting process. It is important that the castings solidify as quickly as possible. The process time for a component can be shortened by faster cooling, while the quality of the casting is improved at the same time too. This depends on adequate heat removal in the casting mould, which is traditionally achieved via cooling holes. Due to process constraints, however, there are limits to how close to the shaping surface that cooling holes can be produced. Additive manufacturing can help here, because cooling close to the surface is

possible even in critical areas of the mould thanks to the tremendous amount of design freedom the process provides.

Steel industry: numerous opportunities with 3D printing

The situation in the hot forming of steel plate is not much different than in die casting. Cooling close to the surface increases productivity and quality here too. Additive manufacturing has therefore been a standard process in the tool production operations of German car manufacturers for a long time now.

Steel companies are discovering additive manufacturing as an additional area of operation to an increasing extent. The Austrian technology and steel company voestalpine, for example, chose Düsseldorf to be its corporate centre of excellence for metal additive manufacturing two years ago. Initial results have been achieved. Together with the development service provider Edag and Simufact, the specialist for simulation software, the Austrian company has developed a lightweight bonnet hinge with integrated pedestrian protection that is produced by additive manufacturing.

Rosswag from Pfinztal near Karlsruhe, the biggest open die forging company in Southern Germany, demonstrates with additive manufacturing how the best of two worlds can be combined. The long-established company manufactures new products by linking the two manufacturing processes forging and selective laser melting of steel powder. Solid, material-rich, conformal components are made by open die forging. The production of a heavy-duty, forged workpiece with appropriate grain flow is followed by additive manufacturing via a 3D printer in order to supplement the complex structures. In the case of an impeller with additively manufactured vane structures, for example, channels were incorporated to influence flow characteristics.

Steel plant manufacturers: significant reduction in the weight of dynamically moving components

The most recent member of the additive manufacturing club is SMS group, the specialist for metallurgical machine and plant manufacturing. The leading manufacturer of steel and rolling mill technology has installed

a new pilot plant for metal powder production at its location in Mönchengladbach, Germany. The company has several objectives with the powder atomisation plant. On the one hand, SMS aims not only to produce high-purity metal powder for additive manufacturing on behalf of customers but also to develop and test new materials. The company can take advantage in this context of decades of experience with the atomisation of iron powder and/or sintering. The extensive metallurgical know-how available within the corporate group and the wide-ranging expertise in thermal process engineering are a good basis too. On the other hand, the plant manufacturer would like to supply the rapidly growing market for metal materials for additive manufacturing processes by marketing powder atomisation equipment.

Last but not least, the in-house metal powder production facilities are a link in the company's additive manufacturing process chain. The plant manufacturer has already started to exploit the potential of this innovative new technology by producing additively manufactured spraying nozzles for swaging presses. Spraying nozzles remove scale from dies, cool the surface, apply lubricants and dry the dies. The original spraying nozzle was a solid and heavy component. Very light and compact spraying nozzles can be produced by three-dimensional printing that are customised precisely to meet the requirements of individual dies. The company reports that use of the 3D spraying nozzles, which can be produced either from plastic or from metal in accordance with the customer's needs, leads to a reduction in cycle time as well as to an extension of tool service life in the swaging process.

SMS reveals that the results of other projects are no less promising. A conformal design with integrated nozzles is an outstanding feature of a new roller cooling pipe for wire rolling mills, for example. Thanks to the use of alumide, a combination of aluminium and plastic powder, the structure is easier and more cost-effective to produce than conventional components. In the steel converter field, it has been possible to reduce the size of the SIS injectors used for molten steel by 60 per cent, while they can be produced from a single part instead of eight parts. And pipe welding machines from SMS group can also produce pipe diameters of 14 inches or less in future thanks to printed parts, because smaller but

more efficient lubricating rings for the expander tools are possible in a hybrid structure produced in a combination of additive and conventional manufacturing.

Special additive manufacturing show at GMTN 2019

Messe Düsseldorf is supplementing the metallurgical trade fairs GIFA, METEC, THERMPROCESS and NEWCAST, which are being held from 25. to 29. June 2019, by a special additive manufacturing show. Exhibitors from all over the world will be presenting new developments about additive processes on the GIFA site. Other participants are software companies, which will be highlighting solutions from 3D visualisation and modelling to data processing, as well as metal powder suppliers and producers of machines, equipment and processes for additive processing and subsequent machining.

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Metal powder: a strength of long-established European companies

With annual production of 550,000 tonnes, the Swedish company Häganäs considers itself to be the biggest manufacturer of metal powder in the world. Metal powders made from stainless and tool steel, nickel and cobalt alloys are produced for use in the standard metallic additive manufacturing processes, such as binder jetting, laser deposition welding and selective laser melting. Since the additive manufacturing operations of the German powder manufacturer H.C. Starck were taken over, the product portfolio has also included such technology metals as molybdenum, tantalum, niobium and tungsten.

Market researchers like the 3D printing experts at SmarTech Publishing are certain that aluminium alloys have a successful future ahead of them. AlSi10Mg is considered to be one of the materials that is used most frequently for additive manufacturing today – from prototypes to series production. Special aluminium alloys for additive manufacturing, like the scandium-aluminium alloy Scalmalloy, are very strong and as light as aluminium, while they match the stretch properties of titanium – although they are very expensive. Aluminium manufacturers like the Russian company Rosal, the main producer of the precious alloy element scandium, are therefore working on new materials for 3D printing involving a less expensive alloy formulation.

Traditional names from the German and European metals industry can be found on the powder metals market. The Austrian company voestalpine produces the necessary powder metals at its stainless steel subsidiaries Böhler in Austria and Uddeholm in Sweden. Companies like Deutsche Edelstahlwerke, the former Krupp subsidiary VDM Metals, which claims to be world market leader for high-alloy stainless steel and nickel-based alloys, and the long-established stainless steel and special metals company Heraeus also manufacture metal powders.

The steel forging company Rosswag discovered the market for itself four years ago and produces its steel powders itself from forging residue of its 400 different alloys. Last year, Rosswag also announced that it was co-operating with the 3D printer manufacturer SLM Solutions and the stainless steel recycling company Cronimet on the development of special and high-performance alloys for additive manufacturing applications.