ED 3152
Precision Processes and Systems

Literature Review
Hybrid Additive Manufacturing

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Introduction

The trend of light weighting is extensively assimilated in every sector including automotive, aerospace etc, there is a need for much more flexible manufacturing process, suiting the modern needs. Hybrid machining processes takes advantage of the least wastage of material from the additive manufacturing and the precision and control of CNC machining to get the best out of them. With the growth of demand for manufacturing processes which can produce complicated components at a fast rate, hybrid additive manufacturing technology is growing at their conjunction[2]. Though research is being carried on in this field commercialization of Hybrid Manufacturing systems are still in their primitive stages. Thought additive manufacturing has moved from prototype manufacturing stage to used end product deployment, especially in aerospace applications, it has its own inherent limitations. The surface finish, long cycle time, poor accuracy, material isotropy and grain alignment are some of the shortcomings of AM[2]. Implementation of AM gives us geometrical freedom and optimized utilization of material. Below are some examples of additive manufacturing:

Examples of Additive Manufacturing (AM)

Stereolithography (SLA)

Very high end technology utilizing laser technology to cure layer-upon-layer of photopolymer resin (polymer that changes properties when exposed to light).The build occurs in a pool of resin. A laser beam, directed into the pool of resin, traces the cross-section pattern of the model for that particular layer and cures it. During the build cycle, the platform on which the build is repositioned, lowering by a single layer thickness. The process repeats until the build or model is completed and fascinating to watch. Specialized material may be needed to add support to some model features. Models can be machined and used as patterns for injection molding, thermoforming or other casting processes.

Fused deposition modeling (FDM)

Process oriented involving use of thermoplastic (polymer that changes to a liquid upon the application of heat and solidifies to a solid when cooled) materials injected through indexing nozzles onto a platform. The nozzles trace the cross-section pattern for each particular layer with the thermoplastic material hardening prior to the application of the next layer. The process repeats until the build or model is completed and fascinating to watch. Specialized material may be need to add support to some model features. Similar to SLA, the models can be machined or used as patterns. Very easy-to-use and cool.

Multi Jet Modeling (MJM)

Multi-Jet Modeling is similar to an inkjet printer in that a head, capable of shuttling back and forth (3 dimensions-x, y, z)) incorporates hundreds of small jets to apply a layer of thermo-polymer material, layer-by-layer.

3D-Printing (3DP)

This involves building a model in a container filled with powder of either starch or plaster based material. An inkjet printhead shuttles applies a small amount of binder to form a layer. Upon application of the binder, a new layer of powder is sweeped over the prior layer with the application of more binder. The process repeats until the model is complete. As the model is supported by loose powder there is no need for support. Additionally, this is the only process that builds in colors.

Selective laser sintering (SLS)

Somewhat like SLA technology Selective Laser Sintering (SLS) utilizes a high powered laser to fuse small particles of plastic, metal, ceramic or glass. During the build cycle, the platform on which the build is repositioned, lowering by a single layer thickness. The process repeats until the build or model is completed. Unlike SLA technology, support material is not needed as the build is supported by unsintered material.

Review

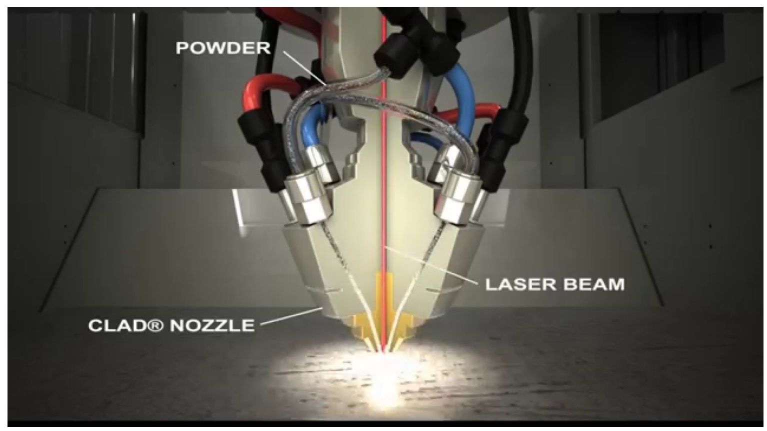
Hybrid manufacturing processes per se do not have a base definition but by and large they involve processes with similar objectives like material removal rate, surface finish, precision of the components etc. to augment the end result of the process[4]. Discussing the possibilities, manufacturing researchers have involved laser drill and EMC which drastically reduced wear rate of the tool. Additive manufacturing is used to describe the manufacturing processes involving addition of material in terms of various layers to form a 3 dimensional object from a computer aided design model. Designers have made use of the multiple processes from various domains like additive, subtractive, conservative techniques to manufacture complex components and precise equipment. This literature review is an effort to bring in all the techniques involving present state of the art and industrial perspective of Hybrid Additive Manufacturing Processes[9].

Direct Energy Deposition with inbuilt CNC:

Direct Energy Deposition is a group of processes where the raw material is directly deposited on the final location in the product. The raw material is either deposited as wire or powder of the required material.The raw material is brought into the heated zone,either created by a laser, electron beam or an ionized gas. *[5]*It is one of the complex process in 3D printing technologies and commonly used to repair or add additional material to existing metal components. Generally the build materials used in the DED process are in the form of wire or powder. Using a raw material in the form of powder instead of wire gives us advantage because powder particles do not have any predefined shape as compare to a wire.

The steps involved in this process are briefly explained below

1. A 4 ar 5 axis arm with nozzle revolves around the workpiece. When a 4 or 5 axis machines, the movement of the feed head will not change the flow rate of material, compared to fixed, vertical deposition.
2. The raw material which is either wire or powder is deposited on the surface of workpiece.
3. The deposited is melted. The method of material melting varies between a laser, an electron beam or plasma arc, all within a controlled chamber where the atmosphere has reduced oxygen levels.
4. The 3D printer further keeps on adding the material layer by layer until the required feature is obtained on the product.
5. The product now obtained will have a rough surface and the surface finish is given using a CNC machine.

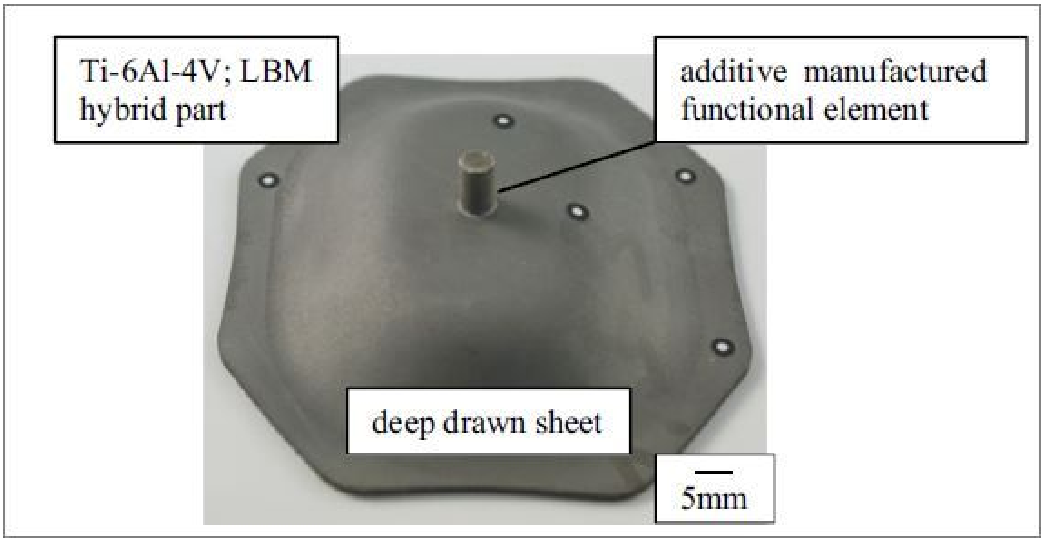


An important property of a deposited track is the dilution, geometrically this is a percentage that defines the area that has melted into the base material. Dilution is important comparison factor for different DED processes.

One of the commercially available DED is Sciaky Electron Beam Additive Manufacturing (EBAM) cell. The Sciaky EBAM cell uses an electron beam to generate a melt pool which is supplied by either single or dual wire enabling a functionally graded component or higher deposition rates with the same material. Other DED machines are made by Norsk Titanium which uses plasma arc to melt the raw material which is wire and RPM solutions which uses laser to melt the powder.

Sheet Metal Forming and Laser Beam melting:

This work done by Schaub et. al. focuses on combining the potential of sheet metal forming and AM to reduce lead times. Major work has been done on the alloy Ti-6Al-4V as it is a medical and aerospace grade metal. The work demonstrated that instead of using EBM application of LBM had more influence due to the oxides during the first few layers of formation.



Surface Treatment for wear reduction in stamping tools

Ultra high steel is manufactured using hot stamping. During the process the stamp undergoes very large thermo-mechanical stresses, which cause abrasive wear on the stamping during quenching. To repair the such deformations a laser and wire based alloying method is implemented. In this study it was found that for such an application usage of wire was very much efficient than powder.

Forging tools using laser metal deposition

To achieve precision state of the art forging tools are required, but to achieve such precision is generally linked with a cost cap. Such tools are manufactured through milling processes which again include a lot of material wastage. Initial tests were done using high grade steels, which are used in the application of injection moulding, and then the components used for hot forging were tested eventually. The tools were analyzed under various experimental conditions mimicking the true stresses it would acquire during work cycle. An approach to mechanical characterization has been attempted.
In few independent studies it has been shown that combination of laser heating and forming reduces the spring back in the metal forming behavior.

Arc Welding and mechanical machining:

In this application the usage if arc welding process along with metal inert gas (MIG) or metal active gas (MAG) a face milling machine was used to slice of the formation due to them. But there have been claims that this would increase the time required for manufacturing and also that the parts made using this method are inferior than the ones in the conventional method[5].

Laser sintering and Injection moulding with sheet metal and polymer

A sheet metal is forced into the injection mould die. It then would take the shape of the die when the polymer beads are injected into it and laser sintering is used to produce and adhesive effect between the layers. The same laser is also used for layer erosion of the solidified layer[7].

Akula et. al. have integrated the Gas Metal Arc Welding with the CNC milling system. Achievement of the final hybrid process, milling is done after each and every deposition stage. After the achievement of a near net shape the whole part is milled together. Such a system would drastically bring down the costs involved in moulds and die making. Production time has also been cut down drastically. Future research is being done in automatic tool changing so that it can accommodate the decoupling of the welding tool during milling process.

A fully automated process has been developed by the Fraunhofer Institute of Production Technology to repair the die once it is worn out. This also has a laser triangulation, to calculate the tool wear and then the tool is welded and repaired using the LMD and milling capabilities.

Challenges faced in Hybrid Manufacturing

Hybrid Manufacturing is one of the latest trends which many companies are applying to improve their efficiency of their products. Hybrid Manufacturing processes will have substantial impact on future innovations. These processes have very few limitations but have some complex challenges that needs to be overcome[15]. One of the main challenges faced is the defects due to the residual stresses for which to solve one requires the understanding of complex mathematical understanding and advanced material characterization. Production using the Hybrid technologies is difficult because for each part of the product a separate machine code needs to written[16]. This reduces the potential for customised parts. Also in fields like automobile industry application of hybrid technologies they require the engineers to finish some special courses for better production[17]. These courses in depth training on how to install and handle hybrid-specific components.

Summary:

Hybrid technologies are used in multiple domains like joining, forming, subtractive, transformative and additive technologies**.** This paper discusses the present applications, current research and the avenues for the application of Hybrid additive manufacturing techniques. Such techniques reduce the lead time and also have an advantage over the conventional manufacturing in saving material costs and gives a better control to the designer[8]. Various manufacturing processes like, DED and CNC, face milling and arc welding, sheet forming and laser sintering, injection molding and sintering, polymer based sintering etc. are discussed.

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