"Lens: An Additive Manufacturing Technology"

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Abstract—For making metallic products through Additive Manufacturing (AM) processes, laser based systems play very significant roles. Laser-based processes such as Laser Engineered Net Shaping (LENS) are dominating processes. A new design often bounces back and forth several times between designers & production engineers until it transformed into something manufacturability. A new low-volume production technology "LENS Additive manufacturing Technology" reduces the manufacturing related limitations on design. Engineered LENS manufacturing Technology makes near net shape metal parts directly from CAD data. Depositing metals in an additive process, it produces parts with material properties equal to or better than those of conventional wrought material. Additive process involves addition of metal in form of thin layers one after another. LENS is layer manufacturing Technology which produces a fine weld bead, exposing the component to far less heat than conventional methods due to smaller and more controlled heat affected zone which does not damage the underlying part. Once a geometry & material or material combination has been identified LENS can rapidly produce a 3- dimensional prototype with good mechanical properties. The tool less process is driven directly from CAD data so prototype of a new design or design iteration can be produced in few hours providing significant time compression advantages.

Keywords:- Additive manufacturability, rapid manufacturing, Laser engineering net shaping.

I. Introduction

Additive Manufacturing (AM) is another name of Layer Manufacturing or Rapid Manufacturing/ Prototyping in which a product is made layer-by-layer. The process that builds up a component in layers, as opposed to a subtractive operation, which removes matter from a block of material to form a product. An increase in customer demand for customizable, quick turnaround, low cost products has opened the door for AM processes to enter the large scale production market once dominated by subtractive processes. As the subtractive operations have relatively high capital costs. Each layer corresponds to a cross-section of 3D CAD model of the product. The core problem in AM lies in making layers and joining successive layers.

II. Laser Engineered Net Shaping

Laser Engineered Net Shaping is a process for creating near-net shape metallic structures. Parts are fabricated by dispersing powdered metal over a molten pool of metal substrate. The molten substrate is created by a neodymium-doped yttrium aluminum garnet (ND:YAG) laser that operates at 500-600W in a closed argon gas system. The powder and laser dispersion pattern is dictated by a corresponding CAD model. The molten material solidifies and cools very quickly, resulting in materials that are fully dense. The LENS process is capable of producing materials that possess mechanical properties similar to or better than those for homogenous materials as a result of their densities. The ability to create fully-dense components eliminates the need for heat-treatment after processing, thereby reducing processing steps and time. In addition, LENS can produce components with complex geometries, which makes it an optimal solution for the fabrication of new or the repair of used components.

III. Principle Of LENS Technology

LENS is layer manufacturing technology which produces a very fine weld bead, exposing the component to far less heat than conventional methods due to smaller and more controlled heat affected zone which does not damage the underlying part. Once a geometry and material or material combination has been identified LENS can rapidly produce a 3-dimensional prototype with good mechanical properties. It enables the designer full functional and structural analysis. The tool-less process is driven directly from CAD data so a prototype of a new design or design iteration can be produced in few hours providing significant time compression advantages.

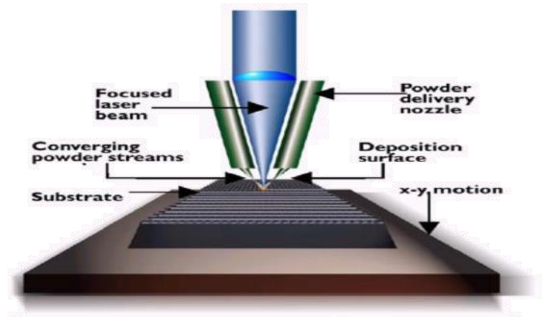

Fig. 1.1: LENS Technology

First the engineer designs the part using CAD. The resulting STL file is then processed using the proprietary PartPrep software which turns the CAD data into a digital tool path. This tool path drives the laser, at the heart of the process. The Work Station Control software controls the manufacturing process with the ability to adjust processing parameters in real time.

A schematic representation of the process is depicted in Figure. The process, uses a high power laser (Nd:YAG or Fibre laser) focused onto a metal substrate to create a molten melt pool. Powder is then injected into the melt pool to increase the material volume. The deposition head is then scanned relative to the component to write lines of the metal with a finite width and thickness. Rastering of the head back and forth creates a pattern and fill to complete the layer of material to be deposited. Finally, this procedure is repeated many times until the entire object represented in the three-

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dimensional CAD model is produced. In this fashion, a part is essentially built up from powders to form a solid object. The finished part is Near Net Shape and requires only final surface finishing. The build process is conducted in an inert Ar atmosphere. The following fig.1.2 shows the process steps in LENS Rapid Manufacture.

Engineering CAD Drawing | PartPrep Software | LENS Work Station Control Software | Deposition | Fabricated Part

Fig. 1.2: Process Steps in LENS Rapid Manufacture.

1. To start the process, a high – powered Nd:YAG laser beam strikes a tiny spot on a metal substrate, producing a molten pool.
2. A nozzle blows a precise amount of metal into the pool to increase material volume.
3. A layer is built to the CAD geometry as the positioning system moves the substrate under the beam in the XY plane.
4. The lasing and powder deposition process repeats until the layer is complete.
5. The system then refocuses the laser in the Z direction until the unit builds layer upon layer a metal version of the CAD model.

The LENS process (demonstrated in Figure 1.1) is capable of producing materials that possess mechanical properties similar to or better than those for homogenous materials as a result of their densities. The ability to create fully-dense components eliminates the need for heat-treatment after processing, thereby reducing processing steps and time. In addition, LEN can produce components with complex geometries, which makes it an optimal solution for the fabrication of new or the repair of used components.

IV. Component Design & Manufacture

High performance components are time consuming and expensive to produce using subtractive methods. In extreme cases, the defence industry quotes "buy-to-use" ratios for machined parts, highlighting the inefficiency and waste that is inherent in traditional manufacturing methods. LENS is an ideal alternative for producing such highly shaped components because additive manufacturing provides for lower processing costs, faster turnaround, and significantly reduced material waste. Additionally, the technique integrates well with other processes to create unique hybrid manufacturing solutions by adding high-resolution features to forged or cast components, or by adding layers of wear-resistant materials as a protective surface.

A. Tool-Less Rapid Manufacture.

Figure shows an example of functional prototyping in the aerospace industry. The component shown is a 1/6 scale gas thruster from a new design of military helicopter. For this new concept in rotary wing aircraft there is a need to eliminate the tail rotor to reduce radar profile, reduce noise levels and increase safety for ground crews. The thruster, manufactured from Ti 6-4, works using the engine exhaust gases and is designed to counteract tail movement. LENS was chosen to manufacture this part as the component requires high material integrity and fast delivery. The time to design and produce a titanium casting was 9 weeks, including rapid tooling via Selective Layer Sintering. The LENS part was delivered within 3 weeks (build time 8 hours) from date of order. The cost of the part vs. a cast part (including tooling cost) was approximately equal.

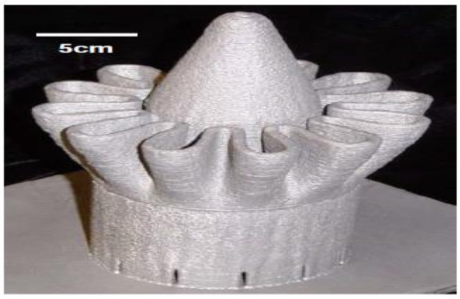

Fig. 1.3: Gas Thruster in Ti 6-4 Courtesy: Bell Helicopter Inc**.**

B. Reduced Cost.

The design criteria for components in defence systems often calls for high strength and light weight. Weight reduction can be achieved by selecting the correct material system and designing the part so that any excess material that is not contributing structurally is removed. Using traditional subtractive manufacturing techniques this often results in the high Buy:Use ratios. An analogous situation often arises in the F1 race industry. An example is suspension mounting brackets, Figure . These parts suffer from high material losses of 87% during machining from solid Ti 6-4. Building up with LENS results in a near-net shape part in a single step. The part is then finish machined in the traditional way with excess material being removed from each surface. In this way material losses are significantly reduced and the time to manufacture is cut by 50%, freeing up machining and operator capacity. On a low volume series basis, typically 10-20 parts in F1, it is calculated that a significant

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cost saving can be realised. By using increased laser power it is expected that this component can be built in less time.

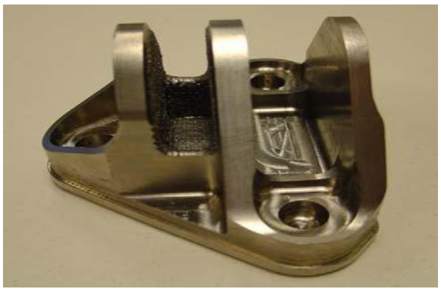

Fig. 1.4: Ti 6-4 Suspension Mounting. Courtesy Red Bull.

C. Agile Rapid Manufacture.

LENS produces the near net shape in a single step without tooling. Thus, a newly designed component can be produced, finished and in service in a matter of hours, offering significant time compression benefits. The process is both "agile" and "elastic": i.e. total flexibility in implementing design changes is offered and the financial risk associated with the continual development process is reduced. The fast design iterations required by the defence industry, can be accommodated by modifying CAD file manufacturing the new part, without the need for re-tooling. An example of the benefits of applying the process are shown in Figure. This is a defence application which required a housing to be built from 316 stainless steel. Due to the low volume (1-10 of each design) and rapid evolution of design the customer was having to wait in excess of 6 months for the components to be manufactured and faced high cost penalties. By using the LENS process the parts were manufactured within 3 days and the cost of manufacture was reduced by over 65%. As the process is CAD driven, the customer was able to change the design during manufacture.

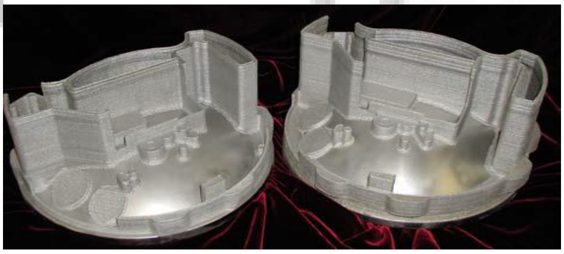

Fig. 1.5: A LENS manufactured housing (Courtesy of Sandia National Laboratory)

V. IMPROVED DESIGN FLEXIBILITY

CAD driven additive manufacturing allows the user to fabricate the part with features that cannot be readily produced by other methods, increasing design flexibility. An example of this is shown in Figure, a proof of concept demonstrator for a Dual Wall Exhaust Duct for a military turbine engine. This novel design manufactured with LENS will save both cost and weight versus conventional duct fabrication methods. This project is ongoing following successful rig testing of full scale demonstrator engine. LENS was applied to rapidly manufacture the prototypes for the design iterations and also the final flight article via a hybrid route. This component, with its skeletal structural framework and many thin-wall appendages (1mm) was difficult (if not impossible) to fabricate through conventional methods. The manufacture of the design was carried out several separate steps using a hybrid approach, Figure 1.6

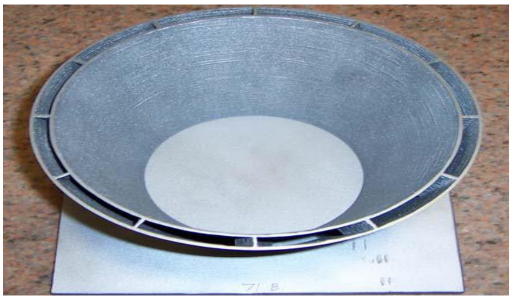

Fig. 1.6: Dual Wall Exhaust Duct in Ti 6-4. Courtesy: RPM & Associates Inc.

VI. MATERIAL & PROPERTIES

LENS is preferred over other additive manufacturing for obtaining high-strength products. LENS furnishes comparable strength, accuracy (50 to 100μ) and surface roughness (<10μ). Although, it exactly depends upon the machine type, materials and geometry of the products.

LENS uses mainly iron-, titanium- and nickel-based alloys. The metals used by SLM are significantly more than LENS. This is because SLM is able to make far more geometries than possible by LENS resulting in more products for varied applications.

VII. THE FUTURE OF AM

There is a rich landscape of available technologies and materials for metals AM. Parts in titanium alloys, nickel alloys, high-grade stainless steels, and many others are being produced using lasers techniques with a variety of consumable forms. This is a dynamic, constantly evolving field with many researchers and industrial users continually improving the state-of-the-art while moving to develop and qualify combinations of material and process for commercial exploitation.

Using AM to fabricate metal parts opens the possibility for reducing material usage that could enable overall reduction in cost and greenhouse gas emissions related to manufacturing. Promising case studies have been undertaken and there are a number of ongoing studies investigating how AM can enable "green manufacturing".

The most exciting possibilities for AM are for unique applications that could not be fabricated using standard machining practices. Examples include tailored medical implants that can be built with the exact bodily geometry output using an MRI or advanced turbine blades with application specific cooling channel designs. As a fundamentally enabling technology, novel applications that are just beginning to be imagined could be built. Novel functionally gradient materials could be generated using these techniques that could enable entirely new applications.

Mechanical properties of parts can vary greatly depending on the process used, parameters of the individual process, loading direction, and post-fabrication heat and surface treatments. Furthermore, different part geometries require special design considerations such as supports and heat sinks that ensure built parts maintain geometric accuracy. And depending on the technology used, the deposition path can affect the final properties.

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AM of metals is opening up new possibilities for lower cost manufacturing and novel integrated parts designs that cannot be made using current technology. This is generating a great deal of enthusiasm around the world for future high-value manufacturing applications. Currently, there are niche applications; particularly in the medical field and to a lesser extent aerospace where parts made using plastics AM and some metals are being put into initial evaluation of service. To meet the full potential of these processes, continued development to 'productionize' the machines for full manufacturing readiness and further understanding of the materials properties is essential. With the pace of advancement, this key emerging field is poised to grow rapidly over the coming years.

VIII. Process Advantages

The process offers following advantages over conventional manufacturing techniques:

– In contrast to machining that removes material from a block of metal, LENS deposits material only where needed thus eliminating material waste. In addition, it makes parts directly from CAD files, without intermediate steps. This reduces manufacturing costs, product development time and time to market.
– This technique can also be used in medical application such as titanium bone manufacturing in case of hip bone replacement. Unlike conventional milling and machining operation, LENS machines can make parts with wide range of complex internal geometrics including hollow and honeycomb interiors.
– The process also dispense different metals in combination to create mixed-material parts. This lets designers specify different materials for different areas of a part, depending on requirements.
– KENS can be used to create tools, or repair damaged tools that would normally be discarded by adding replacement material to the worm or fractured surface.

IX. Conclusion

– The additive manufacturing technology (LENS) offers the potential to rapidly manufacture of high performance products and effectively repair a wide range of these components.
– We can use this technology mostly in mould manufacturing, titanium part production, in aero-space industries, in plastic industries etc.
– A variety of material including titanium, stainless steel, tool steel, cobalt and inconel are candidates for the process. It gives better reproductivity, manufacturing cost reduction, high accuracy and precision.

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