Additive Manufacturing : The current trend in manufacture of complex parts in Aerospace

T. Harilal
Consultant
Aircraft Materials & Processes
Email : harilal@triomaerospace.com

As the last in a series of articles on 'Metals in the world of aviation', in this issue we will have a look at the current trends in processing of parts in Aerospace industry using the additive manufacturing, or more commonly known as 3-Dimensional (3D) printing. Fig.1 shows a typical complex geometry that can be fabricated using 3D printing technology.

Historically, majority of the parts,

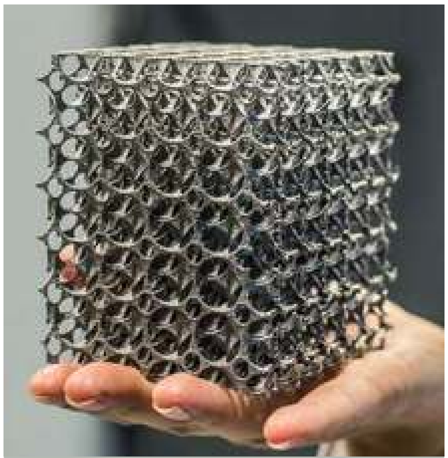

Fig.1. A complex structure fabricated by 3D printing to demonstrate its capability
Source : *MIT Sloan School of Management*

however complex, had been produced by removing material from a raw material stock to the required engineering design dimensions & geometry. The starting material is usually in the form of extrusions, castings etc directly from mill. This is akin to a sculptorchipping off stone to craft the bust of a statue. The same statue can be built by addition of material layer-by-layer until the statue is fully formed.

The advancements in digital technology has helped automatically control where the material is to be deposited in each layer. The complex parts were built in conventional manufacturing by assembly of less complex subassembly parts. This is where 3D printing has a huge advantage over conventional machining. Complex parts can be fabricated in much shorter time and cost. Metal powders used in fabrication of parts can be pre-alloyed to meet the bulk composition requirement and is instantly fused with high energy lasers instantly to form a solid part. The post processing requirement for 3D printed parts mainly involve machining to final dimensions, heat treatment, surface protective treatments etc . Critical parts undergo Hot isostatic pressing to produce parts of high structural integrity. General Electric, USA few days back tested the first engine with large number of 3D printed components. Ref. Fig.2 below

Fig.2. GE Aviation's Advanced Turboprop (AT) engine successfully first test run on December 22, 2017.

The AT is the first commercial aircraft engine with 3D-printed components. Printed components make 35% of the Advanced Turboprop engine parts. According to GE , 3D printing technology combined with other new technologies, allowed the reduction of 855 conventionally manufactured parts to only 12 additive parts. These parts include sumps, bearing housings, frames, exhaust case, combustor liner, heat exchangers and stationary flow path components. Additive components reduce the AT's weight by 5% and improves specific fuel consumption (SFC) by 1%.

Many Aircraft , Engine & Industrial Gas turbine manufacturers and their part vendors have made significant progress in recent times with the

Fig. 3. Turbine blades laser - sintered with EOS DMLS (left) and polished (right) with the Micro-Machining

Additive Manufacturing

Turbine blades manufactured with 3D printing : The high performance gas turbine components are produced using Additive Manufacturing.

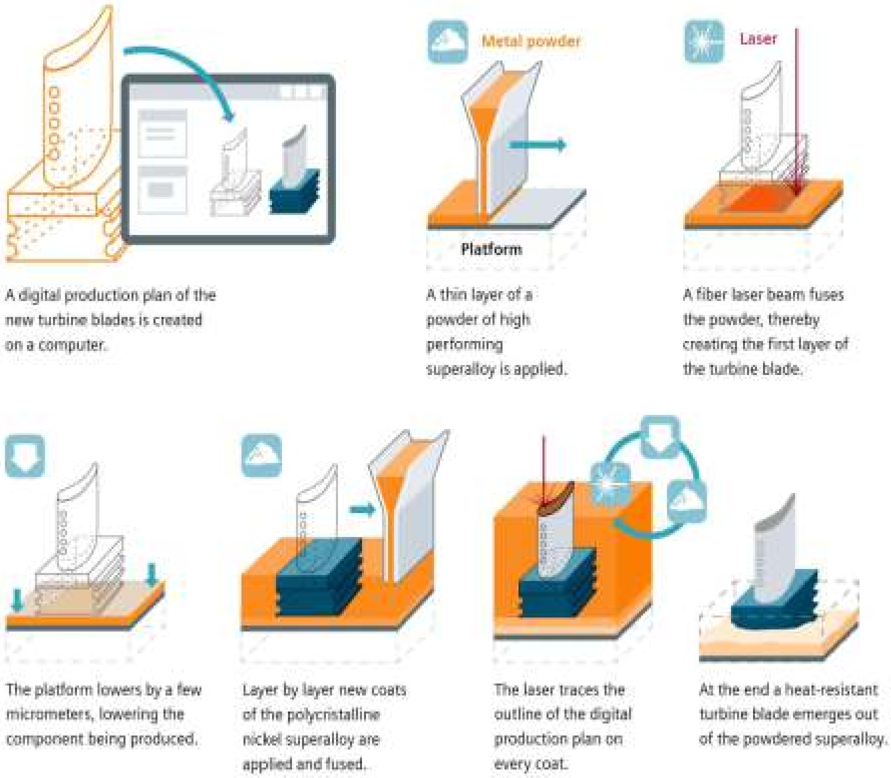

Fig. 4. Additive manufacturing process involved in production of a Turbine blade through Laser Deposition on Metal

(a) **(b)**

Fig.5 (a) & (b). Some parts made by Laser Melt Deposition of metal powders. The picture of the part in (b) shows a part manufactured in a conventional method on top and redesigned and built by 3D printing resulting in less material use and weight.

Fig. 6. Laser machines are already printing "bionic" aircraft parts like wing brackets for Airbus A350 XWB jets (above) resulting in weight savings.
Source: Airbus Operations

Fig. 7. The GE fuel heater is honeycombed with tiny complex passages for the Advanced Turbo prop Engine. This heat exchanger was manufactured by Additive Manufacturing Process.

Materials /Alloy	Alloy Description	Typical powder layer thickness in Microns
AlSi10Mg	Casting Grade Aluminium	30
Co28Cr6Mo	Medical Grade Cobalt Chrome	20 & 40
IN 718	Nickel Based Alloy	20 & 40
IN 625	Nickel Based Alloy	40
MS1	Tool Steel	20 & 40
316L	Stainless Steel	20 & 40
PH 1	Age Hardening Stainless Steel	20
Ti 6Al 4v	Titanium Grade 5	30 & 60
Ti -CP	Commercially Pure Titanium	30 & 60

Table 1. Typical powders currently used for fabrication of parts through Direct Laser Melting route

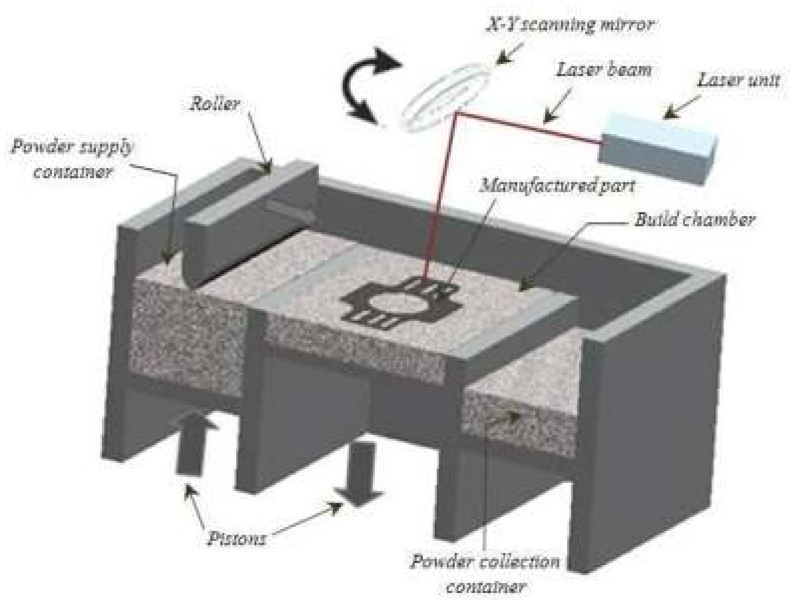

Fig. 8. Principle of additive manufacturing by Direct Laser Melting method.

manufacture of highly critical parts like Turbine blades. Ref Fig.3. An overview of the Additive manufacturing process involved in production of a Turbine blade through Laser Deposition of Metal is shown in Fig.4.

The Process

The Additive manufacturingprocess gained popularity in 1980's and was mainly used to produce prototypes and not as afunctional part or component. This process was then commonly known as 'rapid prototyping' because it allowed creating prototypes in a shorter timeframe with reduced cost.

The process of fabrication of a part starts with the design of a component as per the engineering requirem This is typically done using computer aided design, or CAD, software. Of late, laser scanning equipment has also been used to duplicate a model from an available part. The scanner digitizes the part model.

Dedicated Software then translates the design into a layer-by-layer framework (or thin slices) for the additive manufacturing machine to follow. The data isthen sent to the 3-D Laser additive machine similar to that done for metal cutting in a CNC machine. The machine sequence starts with the powder of required material spread as a thin layerfollowed by a laser traversing on the areas where metal is to be melted and the consequent material formed as shown in Fig.8.

Once the first layer is completed the machine build platform is lowered to accept the powder for the next layer/slice. A powder spreader spreads the next layer of powder evenly over the previous layer and the laser immediately melts and solidifies the powder on required areas as directed by the software. This process is repeated until the part is completed to its full dimensions and the unmelted powder on the platform is retrieved by vacuum suction. The Table.1 shows the typical powders used with their respective powder layer thicknesses.

Table 1. Typical powders currently used for fabrication of parts through Direct Laser Melting route

The advantages of Additive manufacturing are as follows:

1. Design to Part in a very short timeframe

2. Lower cost for assemblies requiring complex parts

3. Highly complex assemblies can be built in shorter time with fewer, if not nil sub assembly parts needed.

4. Can make graded or functionally graded parts. Parts requiring varying properties can also be made. For example parts requiring high surface hardness on certain areas can be made with high electrical conductivity in the interior.

5 . Design alteration and change as required can be easily incorporated into a part.

Fabrication of parts and even larger structures are being tried. The day is not far when we will have large structures built through the Additive manufacturing process.