An Aerospace Business Case on Additive Layer Manufacturing Technologies in Aerospace and Defense Supply Chain

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Abstract*— This paper provides an overview of activity-based costing for the end-to-end additive layer manufacturing or 3D printing process. It explains to understand the cost drivers associated with additive layer manufacturing process. Using activity-based costing, we can breakdown the cost drivers and understand the cost levers associated with additive layer manufacturing process. This can help us in finding the innovative ways to enhance the additive layer manufacturing process operation's efficiency. It also helps to assess the machine true value. We have considered an aircraft bracket manufacturing using the direct metal laser sintering process as a business case for our market analysis on 3D printing supply chain. The 3D printed components associated cost can be divided into various steps such as component design, component production, component post-processing, and component qualification. Each step in the 3D printing process performs at one place or across a supply chain based on the various internal and external suppliers. Also, there are overhead costs associated with each step of this 3D printing process. This paper explains the cost involved in the component design and its relevance to supply chain. It explains the cost involves in the component production such as materials cost, machine setup cost, machine run time cost, and final build plate removal cost. It's also explains the cost involves in the post-processing such as heat-treating cost, machining cost, and surface finish cost. The component process cost is required to qualify based on its end use. The component qualification cost is required to add significantly to the component overall cost including the labour cost and computer tomography scan cost. The overhead cost is depending on the individual operation and it assigns these costs appropriately. It computes the activity-based costing for an aerospace component and concludes with analysis to make a convincible business case for the use of innovative technology and enable to identify the cost drivers and levers, so it can drive business with more efficiently.

***Keywords*—** *Activity Based Costing, Additive Layer Manufacturing, Aerospace and Defense, Aerospace Business Case, 3D Printing, Supply Chain Management*

1. Introduction

The manufacturing technologies are undergoing a change in much faster with disruptive technologies such as 3D printing (3DP) or additive layer manufacturing (ALM).

The conventional process involves high cost and more process time than the 3DP process. This 3DP process also allows printing with less weight composite raw materials and less process time. Hence, the use of 3DP now revolution in manufacturing industry [1].

In USA and Europe, this technology has already made a lot of growth in manufacturing industries and now increases the use of this technology in India [2].

In last few years, the Indian 3DP market is also increased in manufacturing prototypes in aerospace & defense, automotive, medical, and consumer electronics industries. Due to increase in use of rapid prototyping and 3D modelling across various industry sectors, the potential growth of 3DP technology is gradually increased for domestic manufacturers, local assemblers and distributors. In 2014, "Make in India Campaign" is anticipated to drive the future growth of the Indian 3DP market [3]. By 2021, the Indian 3DP market is expected to reach $79 million [4].

The commonly available ALM technologies in the market are [5], [6]: selective laser sintering (SLS), fused deposition modelling (FDM), multi-jet modelling (MJM), stereo lithography (SLA), direct metal laser sintering (DMLS).

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Amongst all ALM technologies, DMLS technology has more advantages, such as i) high speed, ii) complex geometries, and iii) high quality.

In this paper, explains the full breakdown of cost associated with the 3DP process.

The sections of this paper are organized as follows: Section 2, Analysis on Indian 3DP Market in Aerospace and Defense Supply Chain. Section 3, An Aerospace Business Case on Indian 3DP Market based on the Activity-Based Costing. Section 4, Activity-Based Costing Analysis on Indian 3DP Market. Section 5, Conclusions.

2. Analysis on Indian 3DP Market in Aerospace and Defense Supply Chain

This section provides an analysis on the Indian 3DP market in aerospace and defense supply chain.

Recently, the Indian market is started investing on 3DP technology, but likely to grow larger quickly. At present, the 3D printer costs are relatively high, decrease of raw materials cost, increase of start-ups and support from government are the main driving factors in 3DP market growth in India [7].

The strengths, weaknesses, opportunities, threats (SWOT) analysis on the Indian 3DP market in aerospace and defense supply chain, is as shown in Fig. 1.

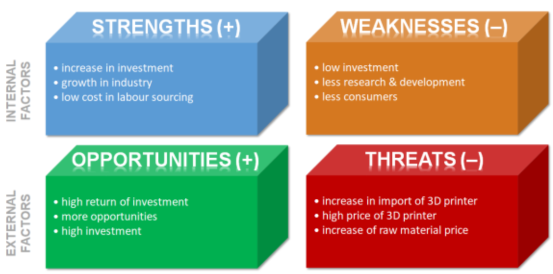

Figure 1. A SWOT Analysis on the Indian 3DP Market

Strengths are: increase in information technology spending, growth in industrial construction, low cost in labour sourcing. Weaknesses are: high investment, less research & development centres, low consumer awareness. Opportunities are: high in return of investment, early growth opportunities, high investment opportunities. Threats: increase in import of 3D printer, high price of 3D printer, high price of raw material.

The 3DP market share by region, is shown in Fig. 2 [8].

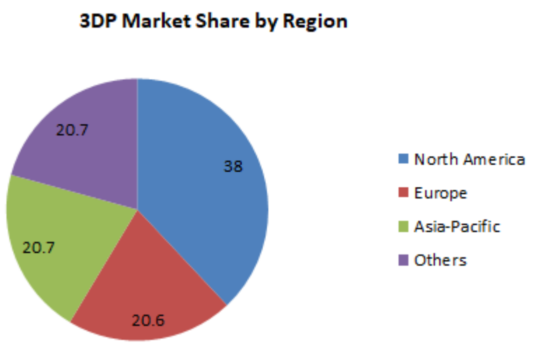

Figure 2. 3DP Market Share by Region

The 3DP market share by location, is shown in Fig. 3 [8].

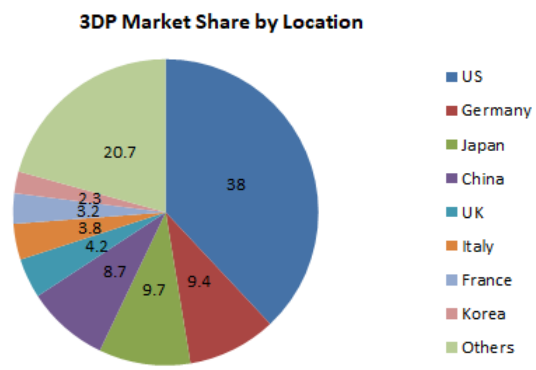

Figure 3. 3DP Market Share by Location

The aerospace and defense significantly impacted on supply chain in terms of increased responsiveness, flexibility, logistics optimization, demand uncertainty, and inventory reduction, mass customization, and customer empowerment.

3 An Aerospace Business Case on Indian 3DP Market based on the Activity-Based Costing

This section provides an overview on the activity-based costing (ABC) for the ALM process. Also, it calculates and breakdowns the cost drivers. The cost levers can enhance the business operations efficiency. It can also help to assess the machine true value in terms of speed, sensors, lasers, quality, and powder [9], [10], [11], [12], [13], [14], [15].

We considered an aircraft bracket manufactured using DMLS with titanium (TI64), is as shown in Fig. 4.

Figure 4. Aircraft Bracket using DMLS with Titanium (TI64)

The costs associated with ALM process can be divided into the following cost drivers: i) component design cost, ii) component production cost, iii) component post-processing cost, iv) component qualification cost, and v) overhead & consumables cost.

3.1 Component Design Cost

The component design is a primary stage in the 3DP component manufacturing process. The component design is to provide the end-user benefits such as increase in product strength, and reduce in product weight. The main investment of companies in component design is to purchase the machines. Due to these machines, the companies can reduce the component redesign cost. Also, it increases the end-user benefits such as supply chain efficiency.

We assumed one bracket design time is one month. The associated 3DP component design cost of a bracket is as follows: The design engineer salary is $120000 per year. The Catia/computer aided design (CAD) software license cost is $8000. Also, the Catia/CAD software subscription is $2000. We assumed the Catia/CAD software useful life is 10 years. Hence, the usage of Catia/CAD software per year is ($8000/10) $800 per year.

The bracket design cost depends on the total number of brackets to be designed at a time which plays a major role in business case cost benefit analysis.

3.2 Component Production Cost

The component production is divided into the following steps: material cost, machine setup cost, machine run time cost, and final build plate removal cost.

3.2.1 Material Cost

At present, the material cost of powdered metal is slightly higher, but powdered metal cost is gradually reducing every year. The material raw powered weight and scrap are to be considered in the part of material cost.

The associated 3DP component material cost of a bracket is as follows: The price of TI64 is $200, bracket weight is 1 kilogram, scrap rate is 10%. The total bracket material cost is $220 (1kg x 1.1) x $200).

We assumed material received with qualification test has been already done.

3.2.2 Machine Setup Cost

Initially, we need to setup the machine in our shop floor. It costs in terms of setup the machine, selection of the right powder, prepare a new build plate for the build.

The associated 3DP component machine setup cost of a bracket is as follows: The setup machine time is 2 hours. The operator cost is $120000 (2000 hours per year). The total machine setup cost is $120 (2 hours x (120000/2000hrs)).

The machine setup cost depends on the total number of brackets being produced, which plays a major role in business case cost benefit analysis.

3.2.3 Machine Run Time Cost

The machine run time cost is calculated in terms of machine cost, yearly maintenance cost, capacity utilization rate, profit and payback period.

The associated 3DP component machine run time cost of a bracket is as follows: The machine cost is $750000. The yearly maintenance contract cost is $10000. The payback period is 24 months. The hurdle rate is 5%. The capacity utilization rate is 80%. The bracket print time is 40 hours. The monthly machine cost is $35208.33 (((750000 x (1 + (5% hurdle x 2 years))) + 20000)/24). The available monthly machine time is 576 hours ((30 days x 24 hours) x 80%). The hourly run time cost is $61.12 ($35208.33/576 hours). The total bracket machine run time cost is $2444.80 (40 hours x $61.12).

The machine runtime cost depends on the total number of brackets being printed, which plays a major role in business case cost benefit analysis.

3.2.4 Final Build Plate Removal Cost

The final build plate removal cost includes the operator cleaning cost, unused powder metal and removing the part from the build plate cost.

The associated 3DP component build plate removal cost of a bracket is as follows: The build plate removal time is 1 hour. The operator cost is $120000 (2000 hours per year). The total per bracket build plate removal cost is $60 (1-hour x (120000/2000hrs)).

The build plate removal cost depends on the total number of brackets being produced, which also plays a major role in business case cost benefit analysis. The total production cost per bracket is $2844.80 (material cost is $220 + machine setup cost is $120 + machine run time cost is $2444.80 + final build plate removal cost is $60).

3.3 Component Post-Processing Cost

The post-processing cost includes the component heat treatment cost for heat treating, machine runtime cost for machining, and surface finishing cost.

The associated 3DP component post-processing cost of a bracket is as follows: The component post-processing time is 3 hours. The operator cost is $120000 (2000 hours per year). The total per bracket heat treatment cost is $60 (1-hour operator cost x (120000/2000hrs)), machine runtime cost is $61.12 (total bracket machine run time cost is $2444.80 (40 hours x $61.12)), and surface finishing cost is $60 (1-hour operator cost x (120000/2000hrs)).

The component post-processing cost depends on the total number of brackets being processed, which also plays a major role in business case cost benefit analysis.

3.4 Component Qualification Cost

The component qualification cost includes the labour cost and computer tomography (CT) scan run time cost.

The associated 3DP component qualification cost of a bracket is as follows: The component qualification test time is 2 hours. The operator cost is $120000 (2000 hours per year).

The bracket qualification cost is $60 (1-hour operator cost x (120000/2000hrs)), and CT scan machine runtime cost is $60 (total bracket machine run time cost is $2400 (40 hours x $60)).

The component qualification cost depends on the total number of brackets being qualified, which also plays a major role in business case cost benefit analysis.

3.5 Overhead & Consumables Cost

The overhead and consumables cost include the rent, utilities (overhead cost) and energy, and inert gas (consumables cost).

The associated 3DP component overhead and consumables cost of a bracket is as follows: We assumed the component overhead cost is $60 and consumables cost are $60.

The overhead and consumables cost depend on the total number of brackets being produced, which also plays a major role in business case cost benefit analysis.

4 Activity-Based Costing Analysis on Indian 3DP Market

This section provides an analysis on the Indian 3DP market based on the activity-based costing (ABC) of an aerospace business case.

We considered an aircraft bracket manufactured using DMLS with titanium. The total cost based on ABC costing per bracket is as shown in Table 1.

Table 1. Activity-Based Costing of 3DP Process for Aircraft Bracket Manufacturing

Additive Layer Manufacturing Process: Activity Based Costing Per Bracket				
S. No. (Section No.)	**Cost Drivers**	**Activity**	**Cost (in $)**	**Total Cost (in $)**
01 (Section 3.1)	Component Design Cost	Labor cost (design engineer)	10000	10,233
		Software license cost (Catia)	233	
02 (Section 3.2)	Component Production Cost	Material cost per one kilogram	220	2,845
		Machine setup cost	120	
		Machine run time cost	2445	
		Final build plate removal cost	60	
03 (Section 3.3)	Component Post-Processing Cost	Labor cost for heat treatment	60	181
		Machining run time cost	61	
		Surface finishing cost	60	
04 (Section 3.4)	Component Qualification Cost	Labor cost for inspection	60	120
		CT scan machine runtime cost	60	
05 (Section 3.5)	Overhead & Consumables Cost	Overhead cost	60	120
		Consumables cost	60	

The overall ABC analysis performed on the Indian 3DP market in aerospace and defense supply chain based on Table 9, is as shown in Fig. 5.

The total cost depends on the total number of brackets being produced, which also plays a major role in business case cost benefit analysis.

The process of 3DP is an iterative and revision to make a correct component. The final component cost includes the number of iterations to achieve a qualifiable component. This is similar to the research & development cost or product development cost.

The main cost drivers associated with 3DP process are design cost and production cost. Hence, based on ABC analysis, we can understand the cost drivers and cost levers associated with the 3DP process.

This can help us in finding the innovative ways to enhance the 3DP process operation's efficiency. It also helps to assess the machine true value.

This ABC analysis provides a convincible business case for the use of innovative technology, so it can drive business with more efficiently.

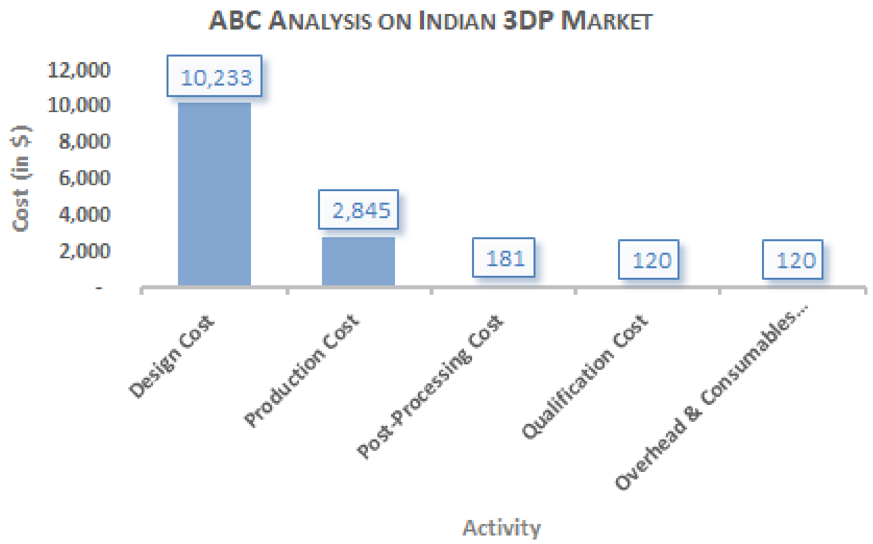

Figure 5. ABC Costing Analysis on the Indian 3DP Market

5 Conclusions

This paper concludes that the emerging additive layer manufacturing technologies can play a significant role in the aerospace and defense supply chain. This ALM technology will disrupt the Indian traditional industrial manufacturing process. The aerospace and defense industry can be a major beneficiary of this ALM technology in India. This paper provides an activity-based costing for end-to-end ALM process. It explains to understand the cost drivers associated with the ALM process. Using activity-based costing, we can breakdown the cost drivers and understand the cost levers associated with the ALM process. This can help us in finding the innovative ways to enhance the ALM process efficiency. It concludes with analysis to make a convincible business case for the use of innovative technology, so it can drive business with more efficiently.

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