IOP Conference Series: Materials Science and Engineering

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To cite this article: R.M. Pushparaj *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **561** 012062

IOP Conf. Series: Materials Science and Engineering **561** (2019) 012062 doi:10.1088/1757-899X/561/1/012062

Analyzing the cost drivers and process optimization in additive manufacturing

R.M.Pushparaj, S.Aravind Raj*, K.Jayakrishna, R.Vezhavendhan

Department of Manufacturing Engineering, School of Mechanical Engineering, Vellore Institute of Technology, Vellore - 632014, Tamil Nadu, India

E-mail :* aravindsakthivel@hotmail.com

Abstract. The cost involved in certain additive manufacturing processes is comparatively higher than traditional manufacturing. When the cost of additive manufacturing process is optimized, it will enable manufacturers to deploy the technology as an alternative for traditional manufacturing. Product life cycle analysis gives better understanding about the cost drivers in additive manufacturing. A better understanding of the cost drivers in additive manufacturing tends to optimize the parameters involved in the process. The difference in cost drivers can be compared before and after the implementation of cost optimization techniques by comparing the variation of cost drivers between standard and optimized production. In this study the cost drivers associated with additive manufacturing are analysed and optimized.

1.Introduction

Customization of products is one of the current trends in Industries [1]. To customize a product in conventional machining processes, the entire machine setup and process should be flexibly reformed. Certain complex designs with intricated internal features are almost impossible to fabricate in conventional manufacturing process. To resolve these glitches, an alternative way for manufacturing is necessary. Additive manufacturing process unravels all these glitches and is considered as an alternative for traditional manufacturing processes. The cost involved in certain additive manufacturing process is comparatively high when compared with traditional manufacturing processes because of its enormous initial investment. Identifying the cost drivers will aid in optimizing the cost within additive manufacturing [1]. Another problem in considering additive manufacturing as an alternative for traditional manufacturing is that the rejection rate in additively manufactured products are high because of drop in quality due to operator and machine failure but in certain higher order machines this issue can been resolved [2]. In higher order machines, machining cost is very high because of its initial investment and this demands a cost optimization of processes in additive manufacturing. In this study various cost optimization processes will be deployed to analyse the variation in cost between standard and optimized production.

2. Methodology

2.1 Costing model for additive manufacturing:

The cost model for this study was created for Fused Deposition Modelling (FDM) process. Development of a cost model will point out the major cost driving factors in FDM process. Before developing a cost model all the cost initiating factors in additive manufacturing are investigated and modelled. Figure 1 shows the various cost drivers involved in FDM process.

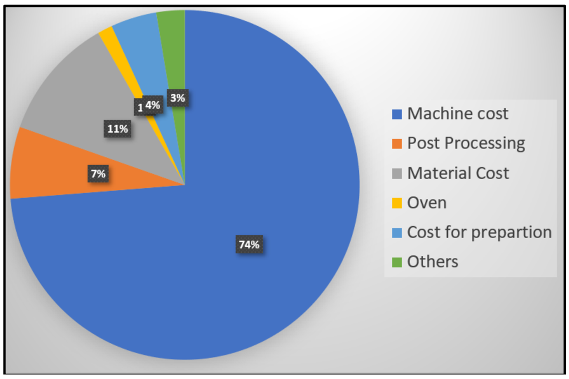

Figure 1 Cost drivers pertaining to FDM process.

An equationderived to compute the total cost correlated along with machining cost and machining hour [1].

$$\boldsymbol{Total\ cost = Fixed\ cost + \frac{Machining\ cost}{hour} \times Machining\ hours} - (1)$$

From the above formula, cost can be optimized by two ways

1. Optimizing machining hours.
2. Optimizing machining cost.

In order to optimize the machining cost and time, certain optimization processes instigated are:

Grouping

This process generally reduces the non-value-added time associated within additive manufacturing process such as loading and unloading time. Group production also reduces the machining hours, as the number of layers remains constant for “n” number of components, where “n” is a natural number. Figures 2 a) and b) depicts the difference between conventional and grouping in AM process.

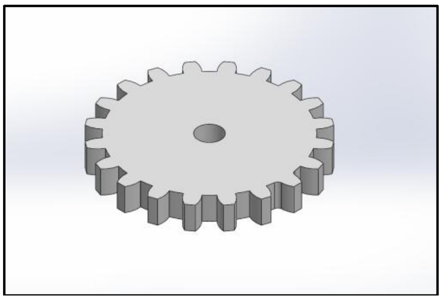

Figure 2 a) Conventional AM process

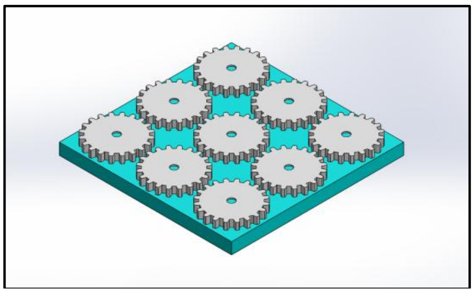

Figure 2 b) Grouping AM process

Slicing

From Fig 1, we can identify that 5% of the total cost is spent on support materials and slicing optimizes the use of support material thereby by reducing the cost and time allied with it. The drawback of this process is, that certain post processes are required to align the sliced material and the tensile strength of the component might be affected [5].

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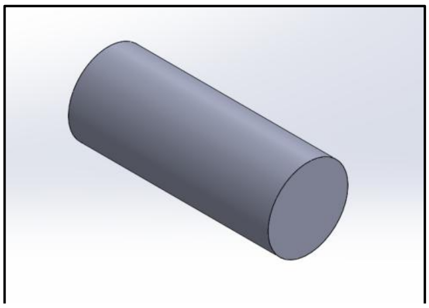

Figure 3 a) Conventional production of axis symmetric component.

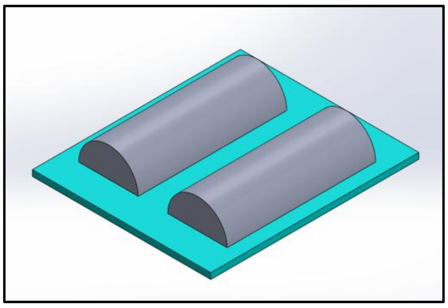

Figure3 b) Sliced production of axis symmetric component.

Slicing-group process
The combination of the above two process reduces both the machining hour and machining cost.

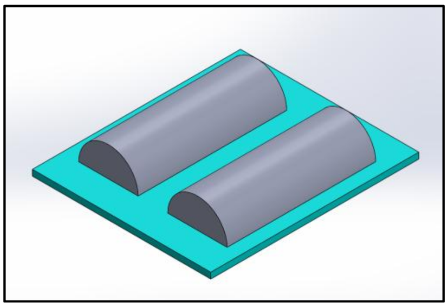

Figure 4 Combined slicing and group production.

Support fixtures for mass production application
From Fig 1, it can be found that 5% of the total cost is spend on support materials, and considering this fact, for mass production application, the concept of support fixtures will be obliged to optimize the cost associated with the process.

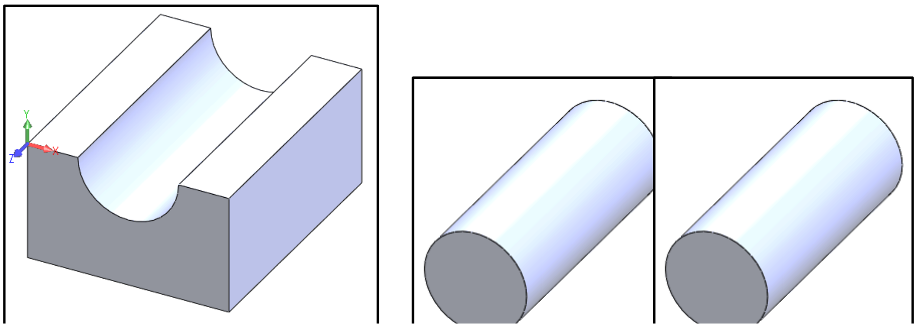

Figure 5 Support structure for complex parts

2.2 Cost estimation and interpretation of a sample part:

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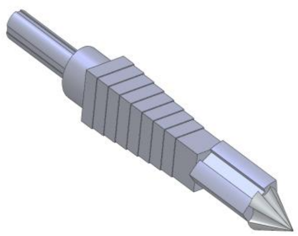

Figure 6 a)

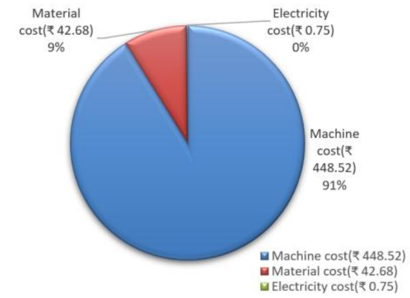

Figure 6 b)

Figure 6 b) illustrates the major cost driver for a sample component

From Fig 2, indicates that machine cost is about 91 % of that of the total cost and certain optimizing process such as grouping and slicing process will optimize the cost associated with machining hour and machining costs. Figure 7 shows the sequential process involved in AM. Figure 8 shows Value Stream Mapping (VSM) of conventional AM process.

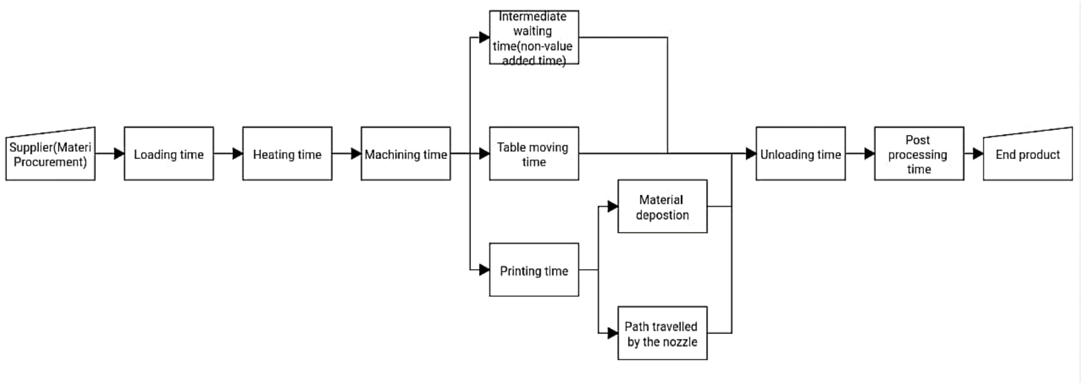

Figure7illustrates the time-consuming process involved in additive manufacturing

Value stream mapping of printing a sample model:

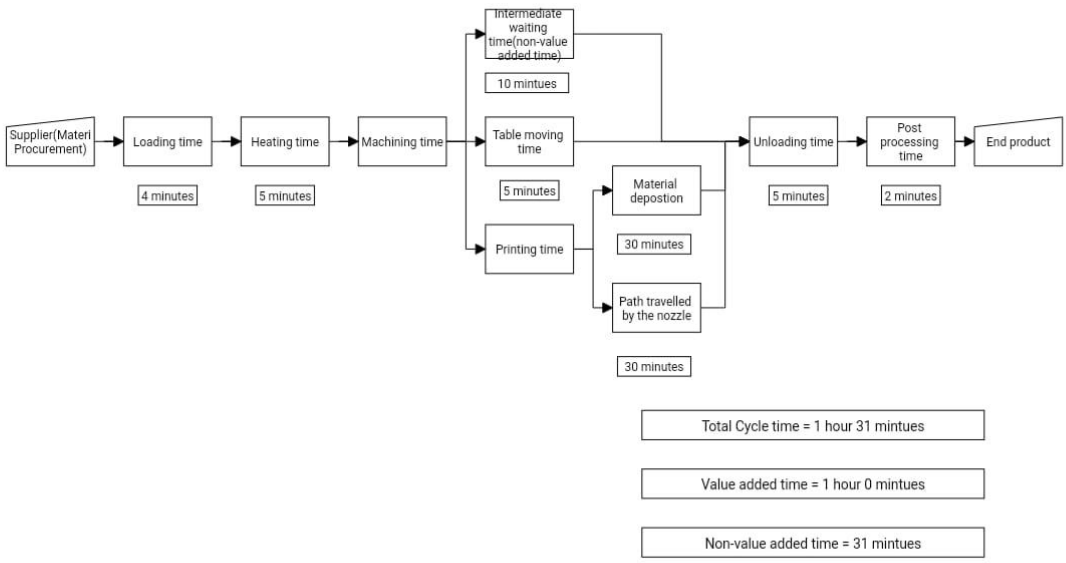

Figure8 VSM map for printing a sample model

Value stream mapping of printing grouped sample models simultaneously:

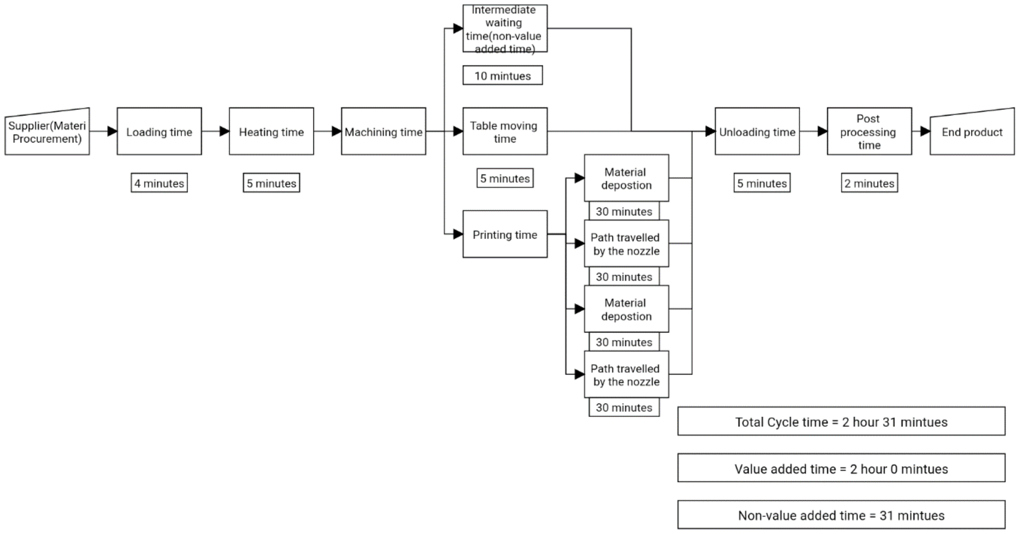

Figure9 VSM map for printing grouped model simultaneously

From Figure 8 and 9, it is evident that when two components are simultaneously printed, the value-added process is doubled but whereas the non-value added time remains the same. As the result of which almost 31 minutes of total cost is optimized while grouping. Greater the number of component grouped greater would be the machining time saved.

3.Results:

Table 1 shows comparative data obtained during conventional and optimized AM process. Real time data obtained from Duplicator 4S machine.

Table 1 Comparative chart between conventional and optimized process.

Feature	Single component	Two components	Three components	Four components	Eight components
Time taken per com.	1 hour 18 minutes	0 hour 58 minutes 30 second	57 minutes 30 seconds	57 minutes 25 seconds	57 minutes 25 seconds
Total Energy consumed	0.06 kWh	0.10 kWh	0.15 kWh	0.20 kWh	0.41 kWh
Total machining hour	1 hour 18 minutes	1 hour 57 minutes	2 hours 52 minutes	3 hours 51 minutes	7 hours 43 minutes
Cost of machining	₹ 260	₹ 195	₹ 191	₹ 190	₹ 190
Total energy saved	0 Wh	10 Wh	30 Wh	40 Wh	70 Wh
Total time saved	0 seconds	20 minutes 30 seconds	1 hour 2 minutes	1 hour 21 minutes	2 hours 41 minutes
Total cost saved	₹ 0	₹ 65	₹ 206	₹ 270	₹ 536

4. Conclusion:

In additive manufacturing the cost varies with respect to design, orientation and type of material for the same model, it's very complex to trace the cost associated in additive manufacturing. Table 1 indicates that the cost, energy consumption and machining time saved after implementing the grouping is INR 536, 70 Wh and 2 hours 41 minutes. The work on grouping can be further extended by grouping a greater number of components together and develop a relation between machining time optimized with number of parts printed. As the intermediate non-value-added time in machines plays a vital role in the optimized time and cost, it might vary on a machine to machine basis.

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