

Comparative Analysis of Additive Manufacturing over Conventional Manufacturing

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Abstract. Over several years additive manufacturing has grown and displaced traditional methods. Present market was occupied by 3D printers in rapid prototyping field. Numerous examples are indicated where additive manufacturing has entered new markets and picked up larger part advertise. In this task we investigate the use of additive manufacturing over customary assembling and the possibility of the disturbance of conventional techniques like injection molding. The possibility is dictated by a similar examination of the cost to influence parts according to bunch premise. We at that point decided the make back the initial investment point and the relationship to the general cost structure.

Keywords: Injection Molding, Additive Manufacturing, Anova, Minitab.

1. Introduction:

Conventional Manufacturing – Injection Molding

In 1920, Injection Molding is the primary utilized a modern creation innovation. From that point numerous organizations began utilizing this innovation for generation of parts in different businesses like car to regular usable things. A standout amongst the most vital creation technique is Plastic Injection Molding (PIM). Despite the fact that numerous individuals see this procedure as straightforward and normal assembling process yet PIM is one of the mind boggling process because of numerous sensitive changes required. Material choice, Mold plan and process parameter settings chooses the nature of item. The infusion shaping procedure incorporates four stages: plasticization, infusion, pressing and cooling. Additive Manufacturing.

2. Literature

IM is critical process in the assembling of plastic parts which is finished by compelling softened plastic in to a form pit until the point when it cools and structures a particular plastic shape [1]. IM is a procedure in the assembling of plastic parts is finished by constraining liquefied plastic in to a shape depression until the point that it cools and structures a particular plastic shape [2]. This paper portrays segment of stream reducer where decided for far reaching configuration audit and shape stream analysis[3]. Development of little infusion forming machine for framing little plastic articles in little



scale ventures was considered [4]. Injection shaping is a standout amongst the most conspicuous procedures for large scale manufacturing of plastic segments [5]. The Rapid Product Development Association of South Africa (RAPDASA) communicated the requirement for a national Additive Manufacturing Roadmap. Considerably, the South African Department of Science and Technology charged the advancement of a South African Additive Manufacturing Technology Roadmap [6]. His paper explores how Additive Manufacturing (AM) advances, as a procedure development, may add to work creation. Further, the different instruments in which AM may add to an expansion in work creation and in addition the sorts of employments are analysed [7]. Conventional auto fabricating is amazingly capital and vitality escalated [8]. There are three essential viewpoints to the financial matters of added substance producing: estimating the estimation of merchandise delivered, estimating the expenses and advantages of utilizing the innovation, and assessing the reception and dissemination of the innovation [9]. The utilization of AM has expanded altogether in earlier years. Added substance fabricating is utilized by different industry subsectors, including aviation, hardware, engine vehicles, apparatus and therapeutic items [10].

3. Scope of Project Work:

So in this project we are designing a bottle cap which is cap with all the design specifications mentioned and modelled in Solid works, which is then saved in .STL format for the 3D printing the model, by this we will get the exposure to the trending technology i.e. conventional and additive manufacturing by which we identified various industries related to AM processes and measurement techniques to reduce cost and time from design to manufacture. This technology enabled the prototyping as easy as print words on the paper. By designing and manufacturing the bottle cap we will compare temperature parameters, cost and production criteria, time based analysis and advantages in comparison.

4. Design Specifications:

4.1 Bottle Cap Specifications

Table 4.1: Bottle cap Specifications

1. Outer Diameter	2.5cm
2. Inner Diameter	2cm
3. Height	1.1cm

4.2 Modelling in Solid works

All the geometric parameters including dimensions are mentioned in design specifications. Based on all the assumptions and calculations bottle cap profile is modelled as shown in the figure below

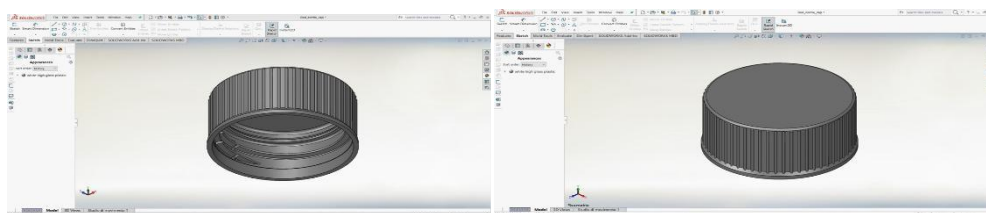


Figure 4.1: Bottle Cap Design

5. Conventional Manufacturing – Injection Moulding Manufacturing Process

5.1 *Material Used for Manufacturing of Injection moulding Bottle Cap*

High-thickness polyethylene (HDPE) or polyethylene high-thickness (PEHD) is polyethylene thermoplastic produced using oil. It is once in a while called "alkathene" or "polythene" when utilized for funnels. HDPE is commonly recycled, and has the number "2" as its resin identification code. Because of high strength-to-density ratio, HDPE is utilized as a part of creation of plastic container tops, erosion safe channelling, geomembranes, and plastic wood.



Figure 5.1: Hydraulic Plastic Injection Moulding Machine

5.1.1 *Manufacturing Working Process:*

Injection molding makes use of heat softening characteristics of thermos plastic materials. When heated, these materials get soften and re harden when cooled. No chemical change takes place when the material is heated (or) cooled. For this reason the softening and re hardening cycle can be repeated any no. of types.

- The granular trim material is stacked container where it is metered out in a warming chamber by a bolstering gadget.
- The correct measure of material is conveyed to a barrel, which is require to fill the form totally.
- Set the die in position provide spacing plates if necessary. Clamping the die using hydraulic operate ram.
- The injection pressure is set by rotating (clockwise) regulator knob to suit the requirement of moulding the container.
- Switch on the heater. Timers is set for required timings, for top and middle heater. The temperature is set by adjusting automatic temperature controller to control the bottom heater. Allow sufficient time to stabilizer. When required temperature is reached, operate the handle lever valve to inject the material.
- Apply injection pressure on the heated material using plunger rod.
- The injection ram pushes the material in to the warming barrel and in doing as such drives a little measure of warmed material out of the opposite end of the chamber through the spout and screw bushing and into the depression of shut form.
- The material is cooled in an inflexible state in the shape.
- Release the injection pressure. In clamp the die using hydraulic operated ram.

- The mould is then opened and I ejected the piece out



Figure 5.1.1: Injection Molded Manufactured Bottle Cap

5.2 3D Printing Manufacturing Process

To make for all intents and purposes design a question which can be made in a CAD document utilizing a 3D demonstrating program or with the utilization of a 3D scanner (to duplicate a current protest). A 3D scanner makes a 3D advanced duplicate of a question utilizing diverse advances to create a 3D model, for example, organized/balanced light, time-of-flight, volumetric checking and some more.

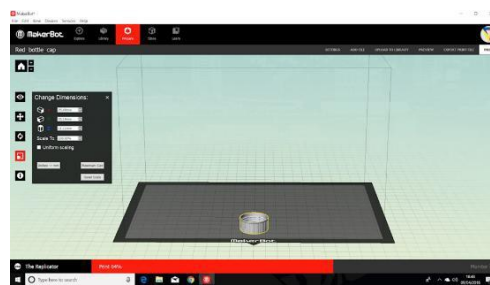


Figure 5.2: 3D Printing Software Bottle Cap Design

5.2.1 Material Used for manufacturing of Bottle cap in 3D Printing Software:

PLA Material:

Polylactic corrosive or polylactide (PLA) is a biodegradable thermoplastic aliphatic polyester got from sustainable assets, *for example, corn starch (in USA and Canada), chips custard roots, or starch (in Asia), or sugarcane (in whatever is left of the world).*



Figure 5.2.1: PLA Material Filament

5.2.2 Bottle Manufacturing Process:

The principal popularized 3D printing process is Stereo lithography (SL). It is a laser-based process that works with photopolymer gums that respond with the laser and cure to shape a strong in an extremely exact manner to deliver exceptionally precise parts.

The modelled bottle cap CAT part is converted into Stereo lithography file by saving the part file in the .STL format. This STL format file is imported into the CURA software for slicing the model into several number of layers and G code is generated for 3 D printing.

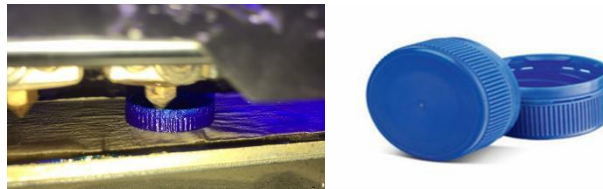


Figure 5.2.2: 3D Printed Manufactured Bottle Cap

6. Cost Analysis in Injection Molding and Additive manufacturing

Injection Molded Parts Cost Calculation

Product Unit Price = material cost + processing costs

Material cost = (weight of material) * Material Unit Price

Processing cost = (weight of the material per unit * mold cycle) + (volume per piece * cavity number).

For special packaging requirements, add packaging costs.

Additive manufacturing Parts Cost Calculation

Product Unit Price = material cost + processing costs

Material cost = (actual weight + loss weight) * Material Unit Price

Processing cost = (weight of the material per unit * volume) + (machine cost * build time).

For special packaging requirements, add packaging costs.

Material Cost:

Material determination is an imperative factor to some degree cost. In everything except the most minimal volume parts the cost of the tar straightforwardly represents a set bit of the per-part cost. Since your parts stay consistent in volume paying little respect to the quantity of depressions, the main approaches to lessen this segment of the part cost is to pick a temperate material or plan the part to limit volume.

Table 6.1: Parameters

Density o PLA Material	1.25 gm/cm ³
Volume of Material Per unit	7.77 cm ³
Total weight of Material	9.7025gms
Material Cost per unit	33.633 INR

7. Comparative Analysis of Additive Manufacturing over Conventional Manufacturing

Software Used for Analysis: **Minitab (Version: 18)**

Minitab is an insights bundle created at the Pennsylvania State University by scientists Barbara F. Ryan, Thomas A. Ryan, Jr., and Brian L. Joiner in 1972. It started as a light form of OMNITAB, a factual examination program by NIST. It works with other Minitab, Inc. programming.

7.1 One-way ANOVA: *MeltingTemp_IM (degC), MeltingTemp_AM (degC)*

Method

Null hypothesis - All means are equal

Alternative hypothesis - Not all means are equal

Significance level (α) = 0.05

Equal variances were assumed for the analysis.

Factor Information

Factor	Levels	Values
Factor	2	MeltingTemp_IM (degC), MeltingTemp_AM (degC)

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Factor	1	3920	3920.0	9.93	0.002
Error	78	30800	394.9		
Total	79	34720			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
19.8714	11.29%	10.15%	6.68%

Means

Factor	N	Mean	StDev	95% CI
MeltingTemp_IM (degC)	40	248.00	19.51	(241.74, 254.26)
MeltingTemp_AM (degC)	40	234.00	20.23	(227.74, 240.26)

Pooled StDev = 19.8714

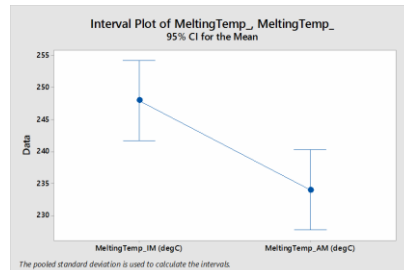


Figure 7.1: Interval Plot of Melting Temperature IM & AM

7.2 One-way ANOVA: Time_IM, Time_AM Method

Null hypothesis - All means are equal

Alternative hypothesis - Not all means are equal

Significance level (α) = 0.05

Equal variances were assumed for the analysis.

Factor Information

Factor	Levels	Values
Factor	2	Time_IM, Time_AM

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Factor	1	4307	4307.1	12.75	0.001
Error	78	26343	337.7		
Total	79	30650			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
18.3773	14.05%	12.95%	9.59%

Means

Factor	N	Mean	StDev	95% CI
Time_IM	40	51.10	21.04	(45.32, 56.88)
Time_AM	40	65.78	15.26	(59.99, 71.56)

Pooled StDev = 18.3773

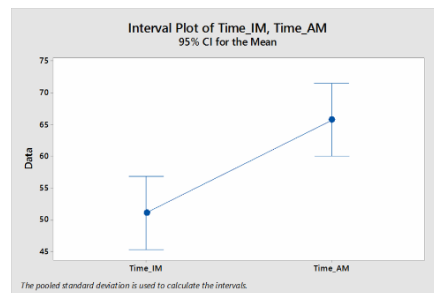


Figure 7.2: Interval Plot of Time IM & AM

7.3 One-way ANOVA: Production Cost_IM, Production Cost_AM

Method

Null hypothesis - All means are equal

Alternative hypothesis - Not all means are equal

Significance level (α) = 0.05

Equal variances were assumed for the analysis.

Factor Information

Factor	Levels	Values
Factor	2	Production Cost_IM, Production Cost_AM

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Factor	1	74420	74420	5.03	0.028
Error	78	1153119	14784		
Total	79	1227539			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
121.588	6.06%	4.86%	1.18%

Means

Factor	N	Mean	StDev	95% CI
Production Cost_IM	40	537.4	122.8	(499.1, 575.6)
Production Cost_AM	40	598.4	120.4	(560.1, 636.6)

Pooled StDev = 121.588

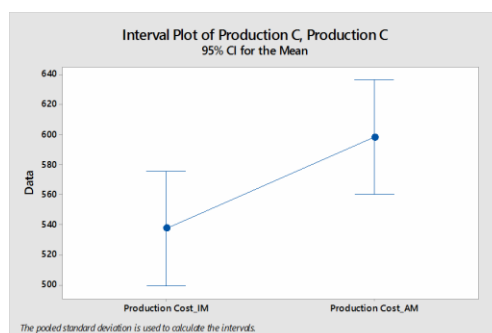


Figure 7.3: Interval Plot of Production Cost IM & AM

8. Results

Regression Analysis: Production Cost_AM versus Time_IM, Time_AM

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	2	459992	229996	81.10	0.000
Time_IM	1	265	265	0.09	0.762
Time_AM	1	99198	99198	34.98	0.000
Error	37	104927	2836		
Lack-of-Fit	33	102739	3113	5.69	0.051
Pure Error	4	2188	547		
Total	39	564919			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
53.2528	81.43%	80.42%	74.24%

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	137.5	44.5	3.09	0.004	
Time_IM	0.255	0.835	0.31	0.762	4.24
Time_AM	6.81	1.15	5.91	0.000	4.24

Regression Equation

Production Cost_AM	=	137.5 + 0.255 Time_IM + 6.81 Time_AM
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Fits and Diagnostics for Unusual Observations

Production					
Obs	Cost_AM	Fit	Resid	Std Resid	
1	1000.0	841.3	158.7	3.24	R
5	740.0	904.6	-164.6	-3.54	R X

R Large residual

X Unusual X

9. Conclusion

Preliminary Analysis has done in order to find out the Material cost. In the comparison of injection molding to additive manufacturing the material that is considered is PLA (poly lactic acid) which has a density of 1.25 gm/cu.cm, as per the design dimensions. The volume of the material per unit piece is calculated to be 7.77 cu.cm. Total Weight of material per unit is 9.0725 gms. Material cost is calculated to be Rs.33.633. Statistical Analysis is performed for the parameters that has a crucial role in both additive manufacturing and injection molding. For the Analysis Melting temperature(degC) of the material, time taken for the Molding the part in injection molding, time taken to print the part by adding it layer by layer and total production cost. See in chapter 6, Using Minitab One way Anova test is performed on Melting Temperature of material the result showed the P-value of 0.002 which is less than significance level of 0.05 which represents we can reject Null hypothesis representing that all means in the data are not equal, Which clearly represents the Melting temperature required is significantly less in additive manufacturing compared to injection molding. The P-test result for time taken in additive manufacturing and injection molding is P-value is 0.001 this p value represents both the processes are different. Even though it is Proven Physically that the Printing Rate of the 3-d Printers is less in order to get better efficient products. Test for the Production Cost shows p-value of 0.028, as production cost includes Material cost, Processing Cost, Labour Charges, Secondary Machining Process in Case of Injection molding, cost of power used for printing the Product in 3-d Printing. Clearly P-value defines both the Processes are different though the cost of the product Produced is more in additive Manufacturing but it saves secondary machining processes costs and time. In Chapter 7 Regression Model is performed on the data set in order to find the relations between the parameters, the relation resulted as production cost is dependent on time factor. By this Statistical model we can clearly define that both the injection molding and additive manufacturing are different from one another and also shown that additive manufacturing is more efficient than injection molding in order to manufacture complex shapes and designs with a lot of flexibility.

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