Investigation of Fused Deposition Modeling Process on Dimensional Accuracy of Bezier Shaped External Part Surface

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Abstract: **One of the Additive Manufacturing technology is Fused Deposition Modeling. It is successful manufacturing technology in the world as one of the processes are suitable for prototypes and end products. Investigation of Bezier shaped parts through Fused Deposition Modeling keeping all process parameters constant and by varying shape of part. The innovation in part design can be introduced with different curves, the Bezier curve are very widely used in engineering design because of flexibility in shapes. There are four control points in Cubic Bezier Curve, in which three control points are kept fixed and one is varied.**

Keywords: Fused Deposition Modeling, Bezier Curve, Dimensional accuracy

I. INTRODUCTION

The FDM based models are fabricated by RP technique is widely used for producing prototypes and can be used for the inspection and evaluation. Fused deposition modeling is one of the Rapid Prototyping processes which is built a part of required complex geometry. FDM Process is easy with technology which has its ability to built complex parts having different varieties in appropriate material shapes with the build time. There are different factors like dimensional accuracy, surface roughness, mechanical strength and also functionality of built parts which are dependent on many type of process variables and their settings. Additive manufacturing (AM) technology is allows the production of different and functional parts at the minimum speed. 3D scanning is one of the best technology which has enabled the mirror image of real objects without using costly molds. Also the costs of additive manufacturing systems are decreases. This technology may change the way which is helpful for the consumers as well as for the producers. The customizing products will require the increased data which collects from the end user.

Stratasys is developed by one of the rapid prototyping systems namely, Fused Deposition Modeling. It fabricates function parts in ABS, elastomers, and also in investment casting. The deposition of the extruded material is coming out from a nozzle using feedstock filaments from a spool [1, 3].

There is an extrusion head which deposits the plastic filament to produce each layer with a particular tool path. The FDM head processes in the coordination directions x and y and it is very accurate. Also by lowering the platen in the z-direction, manufacturing layer by layer is possible. Support material is used to provide a build substrate if the component part shows an overhang, offset or cavity. This additional material prevents the component part from collapsing during the building process. The support material itself can easily be removed after the building process by breaking it off or dissolving it in a warm water bath and at last each finished layer at the base platform is decreased to lower and deposited the next layer.

Fused deposition modeling (FDM) is one of RP Process which can produces complex geometries by extruded materials, such as durable plastic. The model material is initially in the form of a flexible filament in FDM process. The deposited material is cools with the help of coolant and the adjoining material also solidifies with it and finally it deposited an entire layer. The platform moves downward along in the z-axis which is equals to the filament height and the next layer is deposited on top of it. Fig.1 shows the basic FDM Process.

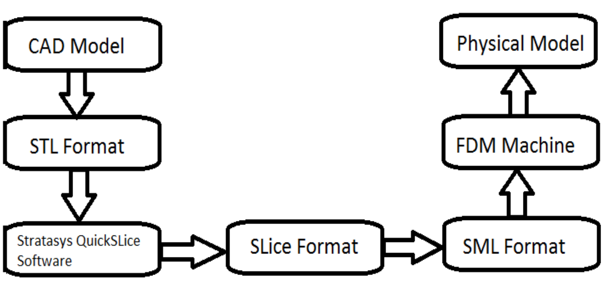

Fig. 1 Basic FDM Process

The complexity of FDM parts is dependent of 3D model on CAD feature and applied curves while Sketching. The normal curves are line, arc, spline etc. but Bezier curve can bring smoother in non-geometrical shapes [4, 5].

II. MODELING OF BEZIER CURVE BASED PARTS

The present work considers 3rd order Bezier curve is used with four control points as expressed in equation (1). The four control points P_0, P_1, P_2 and P_3 are assumed arbitrary with constrain of specimen preparation in FDM process, and they are depicted in Table 1.

The equation is:

$$U(t) = (1-t)^3 P_0 + 3t(1-t)^2 P_1 + 3t^2(1-t)P_2 + t^3 P_3 \qquad (1)$$

Table: - 1

		x	y
Bezier Curve points	P0	0	0
(dimensions are in mm)	P1	8.75	17.5
	P2	26.25	17.5
	P3	35	0

The point (P_1) is varied by 1 mm increment in x-direction to generate the variety in shape of curve to investigate for machining dimension response. The remaining three points (P_0, P_2, and P_3) are kept fixed for all eight cases. The value of P_1 is substituted using equation (1) to generate coordinate of points on curve with increment of 0.1 in parameter t. The coordinate of points by P_0, P_1, P_2 and P_3 reported in Table 2. The variation applied through P1 for x coordinate 8.75, 9.75, 10.75………. till 16.75 can be similarly calculated and their shapes for all eight cases is shown in Fig. 2. The generated curve through parametric points is used further for modeling.

Table: - 2

t	x	y
0	0	0
0.1	2.87	4.725
0.2	6.16	8.4
0.3	9.765	11.025
0.4	13.58	12.6
0.5	17.5	13.125
0.6	21.42	12.6
0.7	25.235	11.025
0.8	28.84	8.4
0.9	32.13	4.725
1	35	0

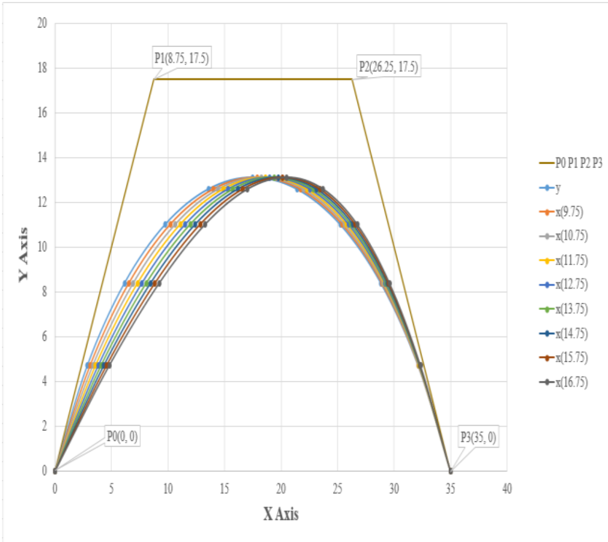

Fig. 2 Graph from different values

3D Model Creation

The Bezier curves generated by varying P1 x coordinates are exported to 3d modeling sketcher environment to create curve, which is converted closed profile for making solid model using 3D modeling software. The created models for all eight cases are shown in Fig.3

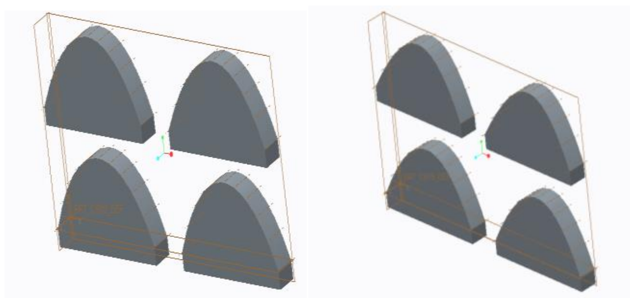

Fig. 3 3D Models of Specimens

III. EXPERIMENTAL WORK

Fused Deposition Modeling built Parts:

The models are converted in to stl file format and export to slicing software for layer by layer preparation with machine specific G codes. This code generate path for extruder to feed material. The code file is prerequisite for FDM machine to built the part. This process is used to built the specimens and such parts are highlighted in Fig. 4. The models built are from ABS material spool which in normal practice [6].

Fig. 4 FDM based prototypes of Specimens

Digital mapping for dimension measurement:

The image of each part for case 1 to case 8.are prepared and images are imported to drafting environment to extract concerned points by mapping the actual dimension with image dimension, such image insertion is shown in Fig.5. . The measured y coordinate is compared with calculated y coordinate to observe deviation in part dimension if any. The values of such deviation for built parts are reported in table 3 to 10.

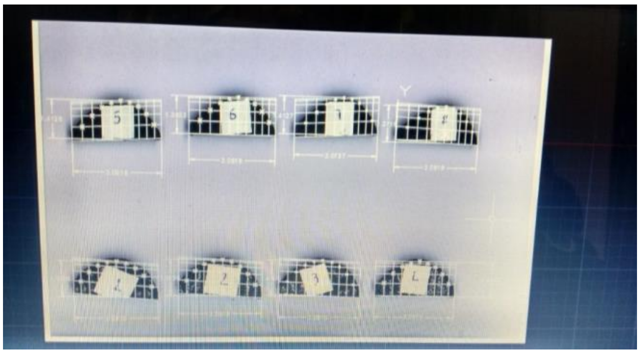

Fig. 5 Snap of Digital Mapping

Table: - 3

P1 (8.75, 17.5)				
t	**x**	**y**	**y’(measured)**	**Δ = (y – y·)**
0	0	0	0	0
0.1	0.254	0.508	0.505	0.003
0.2	0.544	0.902	0.892	0.01
0.3	0.863	1.184	1.162	0.022
0.4	1.2	1.354	1.347	0.007
0.5	1.546	1.41	1.408	0.002
0.6	1.892	1.354	1.347	0.007
0.7	2.23	1.184	1.162	0.022
0.8	2.548	0.902	0.892	0.01
0.9	2.84	0.508	0.505	0.003
1	3.0919	0	0	0
				Av= 0.0086

Table: - 4

P1 (9.75,17.5)				
t	**x**	**y**	**y’(measured)**	**Δ = (y – y·)**
0	0	0	0	0
0.1	0.254	0.508	0.488	0.02
0.2	0.544	0.902	0.862	0.04
0.3	0.863	1.184	1.121	0.063
0.4	1.2	1.354	1.266	0.088
0.5	1.546	1.41	1.298	0.112
0.6	1.892	1.354	1.216	0.318
0.7	2.23	1.184	1.023	0.161
0.8	2.548	0.902	0.718	0.184
0.9	2.84	0.508	0.301	0.207
1	3.0919	0	0	0
				Av= 0.1193

Table: - 5

P1 (10.75, 17.5)				
t	**x**	**y**	**y’(measured)**	**Δ = (y – y’)**
0	0	0	0	0
0.1	0.254	0.508	0.505	0.003
0.2	0.544	0.902	0.892	0.01
0.3	0.863	1.184	1.162	0.022
0.4	1.2	1.354	1.315	0.039
0.5	1.546	1.41	1.349	0.061
0.6	1.892	1.354	1.273	0.081
0.7	2.23	1.184	1.079	0.105
0.8	2.548	0.902	0.769	0.133
0.9	2.84	0.508	0.346	0.162
1	3.0919	0	0	0
				Av = 0.0616

Table: - 6

P1 (11.75, 17.5)				
t	**x**	**y**	**y’(measured)**	**Δ = (y – y’)**
0	0	0	0	0
0.1	0.254	0.508	0.51	-0.002
0.2	0.544	0.902	0.903	-0.001
0.3	0.863	1.184	1.18	0.004
0.4	1.2	1.354	1.341	0.013
0.5	1.546	1.41	1.385	0.025
0.6	1.892	1.354	1.314	0.04
0.7	2.23	1.184	1.128	0.056
0.8	2.548	0.902	0.826	0.076
0.9	2.84	0.508	0.409	0.099
1	3.0919	0	0	0
				Av = 0.031

Table: - 7

P1 (12.75, 17.5)				
t	**x**	**y**	**y’(measured)**	**Δ = (y – y’)**
0	0	0	0	0
0.1	0.254	0.508	0.509	-0.001
0.2	0.544	0.902	0.904	-0.002
0.3	0.863	1.184	1.187	-0.003
0.4	1.2	1.354	1.317	0.037
0.5	1.546	1.41	1.414	-0.004
0.6	1.892	1.354	1.317	0.037
0.7	2.23	1.184	1.187	-0.003
0.8	2.548	0.902	0.904	-0.002
0.9	2.84	0.508	0.509	-0.001
1	3.0919	0	0	0
				Av = 0.0025

Table: - 8

P1 (13.75, 17.5)				
t	**x**	**y**	**y'(measured)**	**Δ = (y – y')**
0	0	0	0	0
0.1	0.254	0.508	0.532	-0.024
0.2	0.544	0.902	0.949	-0.047
0.3	0.863	1.184	1.23	-0.046
0.4	1.2	1.354	1.444	-0.09
0.5	1.546	1.41	1.521	-0.111
0.6	1.892	1.354	1.484	-0.13
0.7	2.23	1.184	1.332	-0.148
0.8	2.548	0.902	1.067	-0.165
0.9	2.84	0.508	0.689	-0.181
1	3.0919	0	0	0
				Av = -0.0942

Table: - 9

P1 (14.75, 17.5)				
t	**x**	**y**	**y'(measured)**	**Δ = (y – y')**
0	0	0	0	0
0.1	0.254	0.508	0.501	0.007
0.2	0.544	0.902	0.892	0.01
0.3	0.863	1.184	1.17	0.014
0.4	1.2	1.354	1.337	0.017
0.5	1.546	1.41	1.393	0.017
0.6	1.892	1.354	1.337	0.017
0.7	2.23	1.184	1.17	0.014
0.8	2.548	0.902	0.892	0.1
0.9	2.84	0.508	0.501	0.007
1	3.0919	0	0	0
				Av = 0.0113

Table: - 10

P1 (15.75, 17.5)				
t	**x**	**y**	**y'(measured)**	**Δ = (y – y')**
0	0	0	0	0
0.1	0.254	0.508	0.533	-0.025
0.2	0.544	0.902	0.958	-0.056
0.3	0.863	1.184	1.256	-0.072
0.4	1.2	1.354	1.446	-0.092
0.5	1.546	1.41	1.521	-0.111
0.6	1.892	1.354	1.483	-0.129
0.7	2.23	1.184	1.329	-0.145
0.8	2.548	0.902	1.064	-0.162
0.9	2.84	0.508	0.684	-0.176
1	3.0919	0	0	0
				Av = -0.0968

Table: - 11

P1 (16.75, 17.5)				
t	**x**	**y**	**y'(measured)**	**Δ = (y – y')**
0	0	0	0	0
0.1	0.254	0.508	0.474	0.034
0.2	0.544	0.902	0.84	0.062
0.3	0.863	1.184	1.097	0.087
0.4	1.2	1.354	1.247	0.107
0.5	1.546	1.41	1.285	0.125
0.6	1.892	1.354	1.218	0.136
0.7	2.23	1.184	1.041	0.143
0.8	2.548	0.902	0.754	0.148
0.9	2.84	0.508	0.358	0.15
1	3.0919	0	0	0
				Av = 0.0992

IV. RESULTS AND DISCUSSIONS

The deviations are focused to observe the effect of one control point transformation in x direction and that too in one direction towards center. The pattern of deviation for all eight cases if shown in Fig.6.

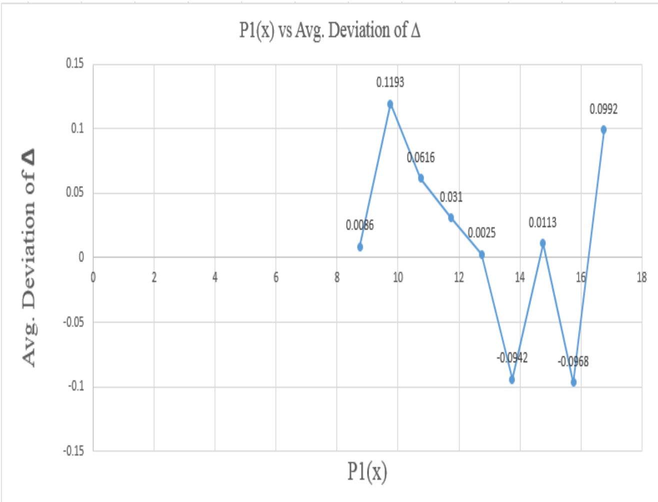

Fig.6 Graph of $P_1(x)$ vs Avg. Deviation of Δ

The deviation observed is within ± 0.1 mm, which is near to built accuracy of 100 micron. The observed dimension hold good precision and does not find any significant effect of transformation of control points on output profile response. This may be due to capability of FDM process within presumed dimension limit and shape.

ACKNOWLEDGEMENT

First and foremost I offer my sincerest gratitude to my guide, **Prof. Jaypalsinh Rana,** Assistant Professor, Indus Institute of Technology & Engineering, Ahmedabad whose constant inspiration, guidance and cooperation from the preliminary to the concluding level enabled me to develop an understanding of the present project work. Their perfectionism has made me strong on my decision and able to do this project.

I would like to thank our Director and other faculty members in Mechanical Engineering Department especially **Dr. Anil Bisen,** Head of the Department and again **Prof. Jaypalsinh Rana** for their valuable suggestions. I am thankful to Indus Institute of Technology & Engineering, Ahmedabad from the bottom of my heart.

I am especially thankful to **Sardar Vallabhbhai National Institute of Technology (SVNIT)** who had permitted for doing experiment in CAD/CAM Lab. I would also like to thank **Dr. A. A. Shaikh**, Coordinator (Svnit, Surat) for provide me the permission and his valuable suggestions, guidance cooperation to carry out my paper work.

I sincerely acknowledge the altruistic help of my friends and colleagues for them support throughout the work.

ISSN: 2278-0181
NCIMACEMT - 2016 Conference Proceedings

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