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Determining Machining Accuracy of Quadratic Bézier Surface with respect to Control Points

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***Abstract*—** Bézier surface is a powerful design tool for automation in production of various machine elements. Quadratic Bézier surface is generated by 11 control points. Its generated with computer aided manufacturing software SurfCAM 11 cases of Bézier surface is taken by varying control points in X and Y direction. These surface is transferred into Unigraphics NX Software to generate tool path and CNC machine code according to prescribed cutting parameters and simulation. It gives the how actual machining will be done. Modification can be done before actual machining as needed. This codes are transferred into CNC Vertical Machining Center (VMC) machine controller and machining work has been done on three different material Aluminum, Wood and Nylon. Generated surfaces are measured with the help of Hexagon global Co-ordinate Measuring Machine (CMM). Each surface are compared with the actual and measured dimensions. Analysis for accuracy of machining and conclusion is given based on this are done

Keywords- *Quadratic Bézier surface, Control points, CAM Software (SurfCAM, Unigraphics NX), Tool path, VMC, CMM.*

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I. INTRODUCTION

Bézier curve is powerful design tool for automated manufacturing for various types of part using cubic, quadratic etc... Bézier curve formation needs control points and one starting and end points. While extruding the Bézier curve it forms a surface. In modern CNC machine tool need of new surfaces on CAD software is increased, to machine a surface using advanced CNC machine prerequisite of small no of linear and circular block for curve or surface are used in CNC machine, machining accuracy and efficiency of machined part is increased by using parametric interpolation [1,2,3]. Bézier surface is one of the design tools which is widely accepted CAD/CAM system. In digital world the product data transferred in digital form and interchange the conversion between different modelling software's and vice-versa. The reduction in Bézier surface degree is sufficiently useful to compress the data without affecting smoothness. Using this phenomenon to define intersection between two or more surfaces can be possible also between two planes and rendering; is more nearly too realistic [4]. Application of Bézier surfaces in automobile, airplane, turbine blade, propeller, airplane wings, casting mould and dies and home appliances to get variability in aesthetic free-form surface are involved with product performance. The machining of such complex geometry is basic problem in CAM due to existing NC machines are limited to their software's in linear and circular motions [5]

II. LITERATURE SURVEY

There is a large body of work in the field of surface machining (Bézier). Here considered, most important cases of them. Bézier surface often appears in mechanical, electrical and home appliance parts in the form of external surface. The fast and effective machining of sculptured surface needs good or high quality cutting tools as well as to reduce the cutting time recent advancement in CAD has satisfied their demand. In digital display the results are seen in display and modification are done according to need. Surface is generated by addition and bit shift function and tool path is generated by hybrid of offset surface and an object surface this CNC code are transferred in to CNC machine for machining process with ball ended cutting tool of 10 mm diameter and smaller cups height observed on machined surface [6]. Condition of proper sculptured surface machining (SSM) given by describing set of six necessary and sufficient condition of machining, these are enhanced on multi-axis machine. General methodology is applied for various surface. For effective and accurate machining of surface need to fulfill the dimensional accuracy in CAD model [7]. Minimum distance algorithm for sculptured surface machining SSM using CNC machine done by deriving algorithm. It graphically simulate the tool path of model surface and generate the CNC machining code.

Complex surface like Bézier, b-spline machining is difficult in CNC machine. Derived algorithm used in SurfCAM software and high accuracy of machining surface is achieved with desired tolerance and smoothness. Also capable of tool path simulation in terms of tool size, tolerance value and number of NC points [8]. Master cutter path (MCP) strategy for maximum and minimum curvature locus of surface and it is divided into zones of similar curvature and machined surface. It gives the reduction in machining time, Cutter Location (CL) size. MCP in maximum convex curvature reduces machining time and maximum flatness reduces the Cutter Location (CL) data file [9]. Look ahead algorithm resolve the error of circular contraction, corner error and de-acceleration limit with prescribed federate and machining parameters enhanced by multi blocks or Continues Short Block (CSB) used in Bézier surface for two criteria. First corner angle and bi-chord error as result cutting parameter are in good continuity. Also it gives rational federate profile for CSB with required precision. Machining federate and efficiency improved [10]. Isoscallop machining with edge based master cutter path (MCP) not ensure the uniform surface roughness. It is overcome by optimization of cutter path through generic algorithm. Result shows the reduction in machining time [11]. Fast Bézier interpolation solve contour linear segment problem occurs in convectional CNC machine. Continues short block of ‘G01’ fitted into cubic Bézier curve and interpolated for smooth machining. Simulation of FBI (Fast Bézier Interpolation) is compared with real time lookahead function. FBI gives high accuracy in interpolated position command. In addition (Continues Short Block) CSBs gives more efficiency and acceptance in FBI [12]. Tool path for free form surface using Bézier curve and surface. It is done by two core steps forward and side step. Machining of several parts have been done on CNC milling machine. Analysis with desired part gives high accuracy. This approach is suitable for sculptured surface machining [13]. Free form surface generated using milling machine, cups height are major factor to maintain small enough for precision work on entire surface. First Riemannian manifold assigned and geodesic parallel traced on it. Result gives accurate constant cups height tool path [14]. Co-ordinate measuring machine in computer integrated manufacturing increased rapidly. Measurement done by sample point location. Accessibility analysis is determine between the work piece and probe model [15].

III. MATHEMATICAL FORMULATION

First, Quadratic Bézier surface is formulated by two way first using 12 control points and second draw curve using 1 control points and 1 starting and end points, and extrude is in z – direction. Here second method is considered Quadratic Bézier curve is drawn using equation

$$P(u) = \sum_{i=0}^{2} P_i B_i(u) \quad \ldots (1)$$

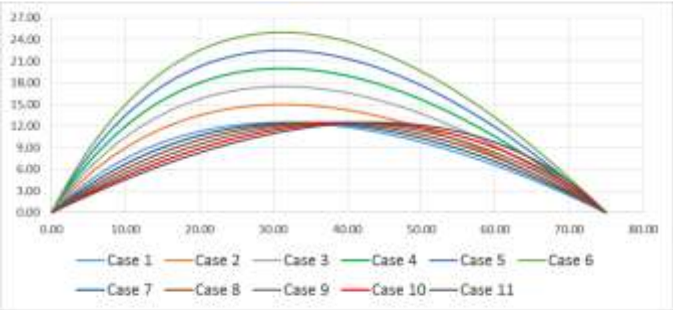
Where, P = control point and u = parameter range from 0 to 1 and B_i = Bernstein polynomial. Curve in parametric form, value of u is varies from 0.001 to 1. Control points of Quadratic Bézier curve are shown in table 1.

TABLE 1 CONTROL POINTS

Cases	P0		P1		P2	
	X0	Y0	X1	Y1	X3	Y3
Case 1	0	0	25	25	75	0
Case 2	P0		P1		P3	
	X0	Y0	X1	Y1	X3	Y3
	0	0	25	30	75	0
Case 3	P0		P1		P3	
	X0	Y0	X1	Y1	X3	Y3
	0	0	25	35	75	0
Case 4	P0		P1		P3	
	X0	Y0	X1	Y1	X3	Y3
	0	0	25	40	75	0
Case 5	P0		P1		P3	
	X0	Y0	X1	Y1	X3	Y3
	0	0	25	45	75	0
Case 6	P0		P1		P3	
	X0	Y0	X1	Y1	X3	Y3
	0	0	25	50	75	0
Case 7	P0		P1		P3	
	X0	Y0	X1	Y1	X3	Y3
	0	0	30	25	75	0
Case 8	P0		P1		P3	
	X0	Y0	X1	Y1	X3	Y3
	0	0	35	25	75	0
Case 9	P0		P1		P3	
	X0	Y0	X1	Y1	X3	Y3
	0	0	40	25	75	0
Case 10	P0		P1		P3	
	X0	Y0	X1	Y1	X3	Y3
	0	0	45	25	75	0
Case 11	P0		P1		P3	
	X0	Y0	X1	Y1	X3	Y3
	0	0	50	25	75	0

Now each curve is extruded in z-direction from 0 to 15 mm to generate surface or profile. Using SurfCAM R12 software each surfaces are generated example shown in figure 1. Tool path, simulation and CNC machining code are generated in next section.

Graph 1. Cumulative Quadratic Bézier curve



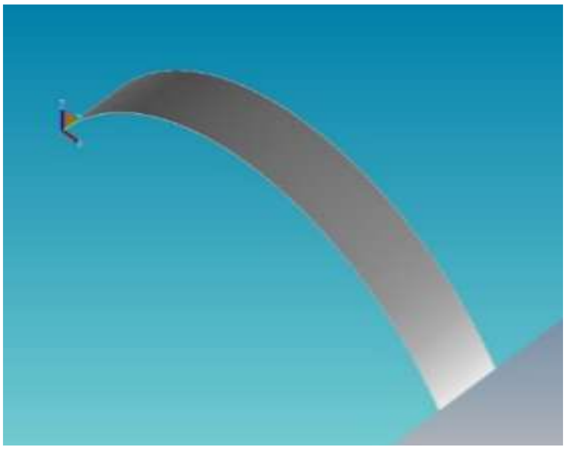
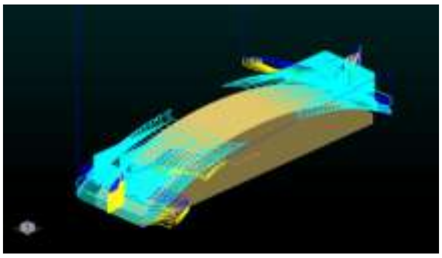


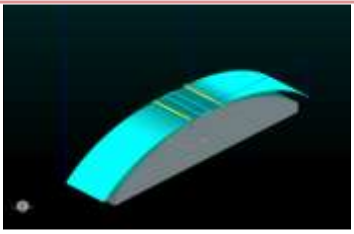
Figure 1. Case 1

IV. TOOL PATH NC CODE GENERATION AND SIMULATIONS

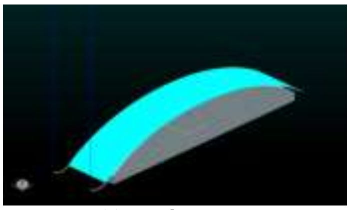
Tool paths are generated using Unigraphics NX software in three stages i.e. first cavity, second Z and third finishing path or cut. Tool used 12 mm diameter, 4 flute and carbide material flat ended for first two stage and finishing cut ball ended with same specification used for finishing cut. Throughout simulation of the tool path it is detected that case number 2 to 6 are mirror image of 7 to 11 number case respectively with accuracy of 0.001mm and error free. Therefor machining will done for case 2 to 6. Case 1 is not identical so, machining has been done on this case also. Tool path has been generated using short block algorithm, based on that NC codes are generated according to the VMC controller of Siemens. Tool path of case 1 are shown in Figure 2 and rest of all cases followed same procedure.



(a) Cavity cut



(b) Z-Rough cut



(c) Finish cut

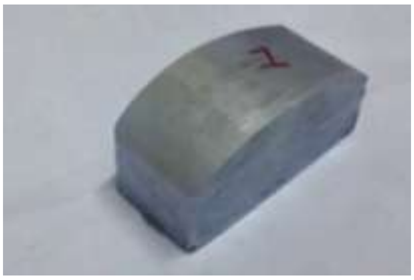
Figure 2. Tool path for case 1

V. EXPERIMENTAL PROCESS

A. *Machining process*

Machining process is done on three materials Nylon, Wood and Aluminum as in previous section. On VMC. Machine

1) Holding the work-piece on machine fixture.
2) Inserting the cutting tool of given specification in machine spindle as per tool path or cut (i.e. cavity, z and finishing).
3) Setting work piece co-ordinate points are taken from sides, length and datum of work piece that are set at zero-zero position.
4) Inserting the machining code for each cases in controller of machine.
5) Machining code for each cut are executed step by step.
6) Giving command of machining mode in VMC, machining will starts.
7) Machining images of one case of each materials are shown in Figure 3.Number equations consecutively.



(a) Case 1 (Aluminium)

(b) Case 2 and 7 (Nylon)

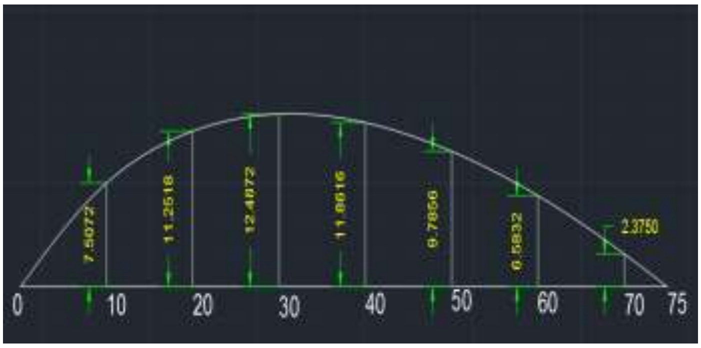
(c) Case 6 and 11 (Wood)

Figure 3. Machined surface

B. *Measurement process*

Measurement of Bézier surface was done on Hexagon Global Advantag CMM at Jaivel Synergic Pvt. Ltd., Rajkot. The measured surface case 1 is shown in figure 4 (a) and for remaining case same procedure followed. First, job was fixed on table using mechanical vice and reference plan points were taken from front, back, right and left side each side of four points. It side forms four plans. Now Hexagon machine probe touches the surface at middle and put points in x-directions for each machined case. On Delnet software complete measurement shown in figure 4 (b), Now measured dimensions has to be compensate as per probe radius of 1.5 mm as per machine specifications.

(a) Measurement process on Hexagon CMM

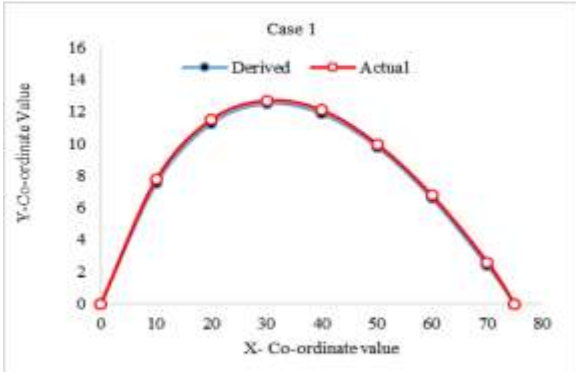


(b) Ploted delnet software readings

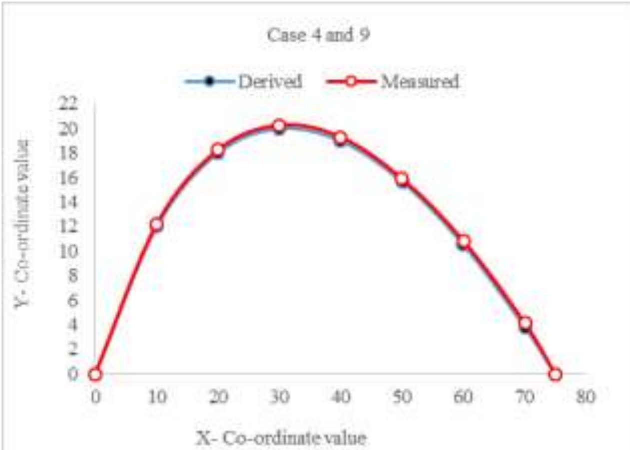
Figure 4. Measurement of case 1

A machining accuracy are shown in table 2, in percentage of error variation comes due to control points were varies in X and Y direction in step of 5 mm shown in table 1. The graph of each machined case for dimension variation are shown in graph from 2 to 5, shaded cells in table 2 are error of percentage is actual and reaming error of percentage is achieved by langrage's linear interpolation method.

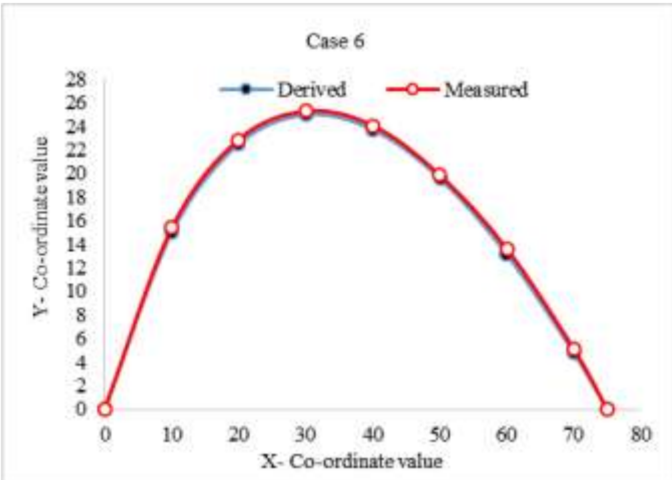
Graph 2 : Derived and measured dimension of surface for case 1, material aluminium



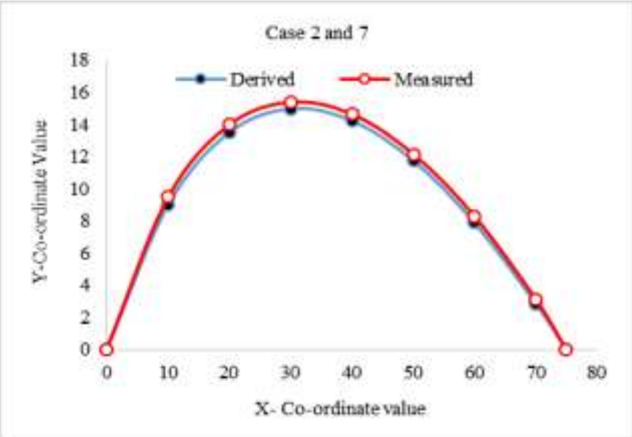
Graph 3 : Derived and measured dimension of surface for case 4 and 9, material sluminium



Graph 4. Derived and measured dimension of surface for case 4 and 10, material wood



Graph 5. Derived and measured dimension of surface for case 2 and 7, material nylon



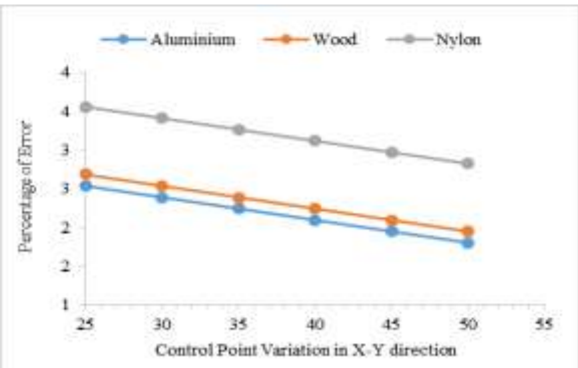
VI. ANALYSIS OF MACHINING ACCURACY

Compared with the case 1 in table 5.6 the percentage variation of CBS for Aluminium Wood and Nylon materials, more percentage of variation in Nylon compared to Aluminium and Wood. Whereas Aluminium and Wood have a very little percentage variation found. Deviation comes in Aluminium is varies between 1.8045 to 2.5380 percentage of error, similarly Wood and Nylon varies between 1.9510 to 2.6845 and 2.8253 to 3.5588 percentage of error respectively. The graph is plotted between percentage of error and control points variation in X and Y directions. While control points varies in X-Y direction the accuracy of Aluminium and Wood is constantly increases with little variation in accuracy as shown in graph 6, for Nylon accuracy is also constantly increase but varies about one percentage.

Table 2. Percentage of variations of cubic Bézier surface

Cases	Control Points		Aluminium	Wood	Nylon
	(X)	(Y)			
1	25	25	2.5380	2.6845	3.5588
2	25	30	2.3912	2.5378	3.4121
3	25	35	2.2446	2.3911	3.2654
4	25	40	2.0979	2.2444	3.1187
5	25	45	1.9512	2.0977	2.9720
6	25	50	1.8045	1.9510	2.8253

Graph 6. Control points varies in X-direction



VII. CONCLUSION AND FUTURE SCOPE

A. *Conclusion*

1) Error of percentage in machining is increases as the complexity of curve is increases. From result is drawn a pattern in machining accuracy proportional to reducing the error.
2) In this experimental process the surface has been machined for materials Aluminium, Wood and Nylon`s accuracy is increase from 2.5380 to 1.8045, 2.6845 to 1.9510 and 3.5588 to 2.8253 respectively, percentage with varying control points.
3) Accuracy of Aluminium, Wood and Nylon are increases from 2.1713, 2.3177 and 3.1921 respectively, are close arguments are found.
4) Accuracy for case 2 – 3 – 6 for Aluminium, for wood 1 to 5 and for Nylon 1 and 3-6 has been derived using Lagrange's linear interpolation method. These accuracies holds the hypothetical accuracy. It will gain same upon performing machining

B. *Future Scope*

1) Complexity of Quadratic Bézier curve is increases from third power in the order of cure
2) Same work can be done for study about the precision and what patter will followed in next order of curve.
3) Curve may be change like Spline, Hermit curve, NURBS curve and required blending.

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