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Cubic Bézier Surface Machining: A State of an Art Review

Gohil Milap M[1], Prof. (Dr.) Pravin P Rathod[2],Prof. Jay K Pandya[3], Prof. Sonara Vimal D[4]

[1]*Scholar,Mechanical Department, HJD Kera-Bhuj, milapgohil@hotmail.com*
[2]*Mechanical Department, Government Engineering College, pravinprathod@gmail.com*
[3]*Mechanical Department, HJD Institute of Technical Education and Research Kera-Bhuj, Pandyajayk@gmail.com*
[4]*Mechanical Department, Government Engineering College, Bhuj, sonaravimal@gmail.com*

Abstract : *Cubic Bézier Surface (CBS) is powerful design tool, used in various parts. Formulation using control points to evaluate surface by mathematical calculation. Improve surface accuracy using various parameters gives as variation in, convex hull property, curve interpolation etc. Condition for proper machining of surface gives smoothness and accuracy. Scallop height and tool selection gives exactness of machining. Tool path generation shows motion of the tool during actual machining process. Length of path depends on cutting tool diameter larger diameter have short path and vice-versa. During machining tool and surface contact must remain tangentially for smoothness. Generation of NC code for machining is based on tool path data using CAM software i.e. SURFCAM, it's easily generated by giving input data like machine controller, tool, scallop height etc.Applying this code to machine a surface on CNC milling machine gives pre-defined effect and measurement is taken on Co-ordinate Measuring Machine (CMM).*

Keywords: *Cubic Bézier surface, Tool path, NC code, SurfCAM software, CMM*

I. INTRODUCTION.

Pierre Étienne Bézier was French engineer, founder of solid, geometric and physical modelling as well as in the field of representing curves in CAD/CAM that curve known as Bézier curve. Paul de Casteljau is also French physicist and mathematician has developed an algorithm to evaluate calculation on definite curves called de Casteljau curve or Bézier curve in 1959. Bézier curve is powerful design tool for automated manufacturing that are various types as cubic, quadratic etc.Béziercurve formation needs two control points and one starting and end points. Extruding of Bézier curve makes surface.**Yang DCHet al. (1994), Shpitalni et al. (1994), Sung and Yang (2004)** [1, 2, 3]givesmodern CNC machine tool needs new surfaces on CAD software is increased now a days, to machine a surface using advanced CNC machine prerequisite small no of linear and circular block of given curve or surface are send to the CNC machine controller, machining accuracy and efficiency of machine has been increased using parametric interpolation.**Koren (1983)**[4]said Bézier surfaces are one of the design tools which is widely used in CAD/CAM processes. Application of Bézier surfaces in automobile, aerospace, turbine blade, propeller, airplane wings, casting mould and dies and home appliances to get variety of functions aesthetically free-form surface are engaged with product performance by filed where part is used. The machining of such shape geometry is basic problem in CAM due to available NC machines are limited by their software's in linear and circular motions.**Sacharow et al. (2013)**[5] suggest development of product with new design process in engineering. It`s requires optimization of product design to improve the quality of product. To modify the shape designer should adopt prototype on CAD software as well CAE software's. For mass production the modifications transformed in to CAD model work piece by reverse engineering. A CAD model modification is based on work piece measurement or simulated surface reconstruction.**Masood et al.(2006)**[6] gives An algorithm has been derived to make linear interpolation in sculptured surface with minimum distance. Surface is generated by basic cubic equation of Béziersstarts the minimum distance with $u = 0, v = 0$ and give step size of $u = 0.127$ mm, $v = 0$ curve Will draw between point a and b then find minimum distance between c and d among all from c. compared with given tolerance of NC machine afterwards step increment of $u = 0.0254$ mm up to 1mm curve will generate. Similarly increment in v taken as $1/20th$ diameter of cutting tool this value is constant for all v value. NC point calculated as same process from 0 to 1, u and v. Another method is using SURFCAM software to generate Bézier surface.**Omirou (2007)**[7] projected A Bézier curve is generated by simple formulation using control points, Bernstein polynomials with recursive algorithm of de Casteljau algorithm in parametric form. Taking offset of that curve will generates the surface with Equal distance space.Locus tracing algorithm is used to generate Bézier surface based on Bézier curve. It has avoided piecewise analytical method to take offset. According to Danielson's criteria locus property and steps calculation are used. General points of offset is defined by set of 8 steps in increment and mark normal to form new position of point to get concern point position.

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II. MACHINING OF CBS.

Radzevich(2002)[8] gives condition for proper machining of sculptured or complex surfaces are as:1) Design of cutting tool it may be conical, cylindrical, ball ended, flat ended, this tool not make the desired surface, to design a tool surface must know. 2) During machining the cutting tool must contact with the sculptured surface and contact between tool and surface is tangential in form of analytical mean it called equation of tangency. 3) To ensure that sculptured surface and tool must contact at their

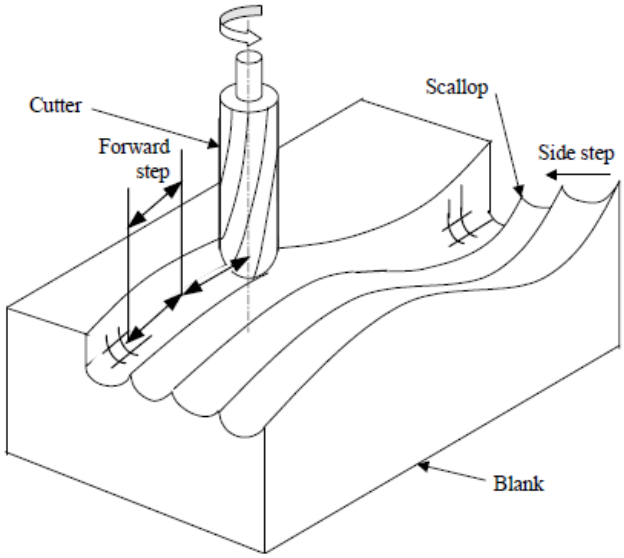

Figure 1 Sculptured Surface Machining Using Ball End Mill Cutter. Giri Et Al. [2005]

radius of curvature to normal. Convex surface has no problem in machining as in concave to overcome this use combination of these two are used. 4) Machining of sculptured surface the tool and surface may be lacking at interference at their contact to overcome this global interference is applied 5) Machining of surface at bottom and side it has to machine surface and neighbor,this two surface creates various locations of cutting tool relative to each other it's considered during design of tool. 6) During machining the sculptured surface and tool at defined point it's not smooth surface in this discrete by set of line on it. To remove this the cups height is selected by prescribed tolerance limit this apply only if both surface is not intersecting with cutting tool.

III. TOOL PATH GENERATION.

Tam et al. (2002) [9]provides NC programming for 3-axis CNC milling machine with ball end mill cutter. The tool path and programming for CBS will done by offsetting the CBC with equal distance on entire length of surface. Similarly for revolved surface using Bézier curve [7] with scallop height, cutting plane and start point on path for each succession steps are formulate. **Giriet al. (2005)** [10]expressed master cutter path generates same as in conventional method, but no relationship between the any point and surface, this will reduces the machining time by employing optimization in CL file size. Convectional process as shown in Figure 1 tool moves in zigzag pattern with equal distance and scallop height. In cluster region the line of locus near about parallel to X-Y plane to each other.The surface is devided in to zone and that differenate by MCP (Master Cutter Path) line inside each region path is generated in normal way. MCP developed in different stratrgies as : 1) One MCP for one surface and edge 2) if more MCP in curvature then devide into different zone 3) MCP divided zone is select the maximum flateness of suface or similar locu orientation. Based on this the surface is formulated as 1) Bézier surface generated by normal curvatue of surface. 2) Identified the MCP as curvature of surface locus 3) Tool pathe generation by isoscallop method.**Taejung Kim (2007)** [11] presentedreorientation of path and tool by surface embedded in work-piece as convectional machining process on milling machine; to avoid gouging tool must be tangential to surface during machining.**Ganet al. (1994)**[12] used G.A. to generate the sculptured suface machining, it gives the best suitable path fo MCP for minimum machining distance among all possible path. For minimum path distance at starting the no of possible solution are there or may be created to apply the opjctive function to each selected pathbased on fitness to make MCP.

IV. NC CODE GENERATION.

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Masood et al. **(2006)** [6] NC code is generation using SURFCAM software it's easy to operate by giving control points and surface is generated, in operation menu click on List all gives dialog box for controller of CNC machine click on appropriate controller gives NC code in new window. Copy that code in CNC software i.e. Cutviewer and simulate it before going to actual machining. This software gives the code for 3-axis, 4-axis and 5-axis CNC machine. Precise tolerance increasing the number of NC points for tool diameter 6 mm with same number of pass. Keeping tolerance constant and varying tool diameter increasing the NC points and pass as diameter of tool reduces.

V. ADDITIONAL ASSOCIATED WORK.

Azizet al. (1990)[13] did Intersection of Bézier surface is important problem in modelling design. The two Bézier surfaces are divided recurrence and each steps are compared for proper intersection. This process continues until gets proper approximation surface. Intersection needs some common points in both surfaces. Relation between two surfaces is determined by convex hull property and cuboidal smallest convection hull property in both the cases intersection of segment of line done by approximation final patch by first order cubic Bézier patch and planer triangle and then intersection done using recursive subdivision and incremental tracing. **Sundaram and Srinivasan (1995)**[14] contribute Experimental investigation of Bézier surface machining using circular interpolation instead of line as CNC uses best. Ten sample were machined on 3-axis CNC milling machine and compared with the machining time, cutter location file size, dimensional accuracy, algorithm error, undercut and surface irregularity. It's find 95% of accuracy in statistical significance.**Sohel et al. (2005), Yau et al. (2005), Sohel et al. (2005)**[15,16,17] offers Enhance Bézier curve, Dynamic Bézier curve and halfway shifting Bézier curve method imposed to combine local and global shape information by making parametric shift between gap of Bézier curve and control point shifting is determined by distortion. It not increase the computational complexity order by viewing on various parts machining and found qualitative and quantitative improved than generalize Bézier curve. Extrude or ruled of Bézier curve makes Bézier surface respective of degree. Evaluate the comparison all with the classical Bézier curve.**Dejdumrong(2007)**[18] expressed Cubic Bézier curve parametric forms shape preservation is difficult and various parameters effects like position and order of curve, types of curve, weight of curve and duplication of control points. A technique is derived based on these to preserve shape of CBC by normalizing total positivity and corner cutting algorithm. Two lamina and algorithm with proof derived to preserve shape of curve and said previous extrude of (Cubic Bézier Curve) CBC makes CBS. Bernstein polynomial preservation is better than Ball polynomial. **Cheng and Wang (2008)**[19] given Merging of multiple Bézier segment approximated gives continues curve as per requirement to make long smooth and aesthetic Bézier curve. It's done by discrete the property of BC; making matrix representation of precise merging of first and last control point.**Hongping and Zhaoyu (2012).**[20] provides Classical Bézier curve is drawn by four control points as we know and then middle of line between point (last two) P_2 and P_3 mark a point P_{23}, same for next curve first two points using de Casteljau algorithm gives smoothness and good result and also avoids the cuspidal point.**Kaewsaiha and Dejdumrong (2012)**[21] deliver Bézier curve by linear and circular arc interpolation to plot a curve instead of giving pixel to pixel movement. This will work better and reduces the curve in to small segment with flexibility in tolerance, reduces the computational time and faster than earlier. An algorithm is made based on monomial form to get more efficiency and flexibility. Its also based on de Casteljau algorithm.**Kawabe et al. (1980)**[22] prepared Measurement of sculptured surface (Bézier) using co-ordinate measuring machine, making solid model from geometric model Hosaka`s method is used to measure Bézier surface and this geometric data is used to tool path generation, machining carryout successful and smooth design of product shape.**Jackman and Park (1998).**[23] Co-ordinate Measuring Machine (CMM) plays important role in Computer Integrated Manufacturing (CIM) in this situation considering location of one point taken from work piece model from design. Analysis done to find out interference between work piece model and probe model. Probe orientation derived using visibility and creativity for flat and general surface. This method used without operator intervention and measurement taken based on probe orientation.**Li and Gu (2004)** [24]gives Bézier surface measurement is done by various technique like contact and non-contact types, inspection planning, geometric data etc. comparison technique of free form surface used 3D transformation to measure data for model or product. They have included all major processes of measuring the Bézier surface.**Elkottand Veldhuis(2005)**[25] shows measurement of sculptured surface using Iso parametric line and its location are taken from surface CAD model and accuracy is measured by maximum deviation between geometry and surface CAD model. The method employed in automatic sampling and surface curvature based sampling. These two methods gives alternative solution to sample plan. For this an algorithm has been derived and it reads .IGES format file. **Lee and Shiou (2010)**[26] gives cross curve moving mask method used to find out unit normal vector based on control points of Bézier surface and probe radius compensation. Different curve fitting method are used through this control points such as Bézier, B-spline etc. three surface tested to check accuracy of determined unit normal vector these are spherical, cosine and shoe-shape this method gives angular deviation is increased when pitch distance is increased, and deviation increase the curvature radius of surface is increase, this method is suitable for reverse engineering.

VI. CONCLUSION.

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In this section presenting a summary of findings in cubic Bézier surface machining literature survey. The following conclusions have been drawn from literature survey.

1) Most of papers focus on the accuracy of surface generation and machining using mathematical formulation and ball ended milling cutter respectively. Tool path development of Bézier surface`s objective of which is to minimize geometrical machining error between tool engagement area and designed surface. Great development has been achieved based on academic and industrial colleague.
2) Cubic Bézier surface machining widely used in various parts, to develop surface using ball ended milling tool. Moreover some methods have also treated to machine a free form surface. Error from tool path planning may be negligible for these surface.
3) The basic objective of Cubic Bézier surface is to improve the part performance and accuracy in defined task. It's done by maintaining the tangential contact between tool and surface during machining and effectively designed tool path and cutting tool.
4) The issue of geometrical error has been reduced by mathematical formulation of Cubic Bézier surface. When transferring this tool path into machine then kinematic error will be introduced, also dynamics factors. Therefore main attention focus on the tool path generation gives exactness in tool path gives accuracy in machining.

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