Journal of Multidisciplinary Engineering Science and Technology (JMEST)
ISSN: 3159-0040
Vol. 2 Issue 9, September - 2015

Optimization of Plotting Process of CNC Machined Workpieces

Barabas Bogdan Florin
Faculty: Technological Engineering and Industrial Management, Univ. Transilvania
Brasov, Romania
bogdan.fb@gmail.com

Florescu Fota Adriana
Faculty: Technological Engineering and Industrial Management, Univ. Transilvania
Brasov, Romania
afota@unitbv.ro

Barabas Sorin Adrian
Faculty: Technological Engineering and Industrial Management, Univ. Transilvania
Brasov, Romania
sorin.barabas@unitbv.ro

Calefariu Gavrila
Faculty: Technological Engineering and Industrial Management, Univ. Transilvania
Brasov, Romania
afota@unitbv.ro

***Abstract*—This paper presents theoretical and experimental researches, referring to comparing mathematical models of drawing images according to parametrical curves B-Splines and Beziers achieved in order to improvement the processing performing CNC machines with abrasive jet. The research of the results leads to optimization of abrasive water jet process contributing to redistribution of tensions arising in critical areas, thus to reduction the appearance of micro-cracks in brittle materials. Thus, drawing and processing of 2D images on the abrasive jet cutting systems is made in two stages, First, is plotting regular stage who converting bitmap to vector image, the second stage is mathematical modeling of approximation type curves, B-Splines and Beziers. These researches have led to the possibility of achieving an optimization methods for tracing process. Processing of work pieces mathematically modeled after parametric curves, highlighting the structural analysis of the material and reducing the development of micro-cracks in risk areas.**

Keywords—approximation curves; B-Spline; Bezier; abrasive waterjet

I. INTRODUCTION

Processing of brittle materials using abrasive jet cutting technology presents special problems in many cases especially regarding the shape and size of work pieces. Appearance of micro-cracks in sharp and narrow areas, are common finally leading to breaking the material in those areas. Abrasive jet machining technology has been successfully used in the production of small series examples being the execution of artistic design products allowing small adjustments in shape in order to reduce the stress concentrator and eliminating the possibility of developing micro-cracks.

The modifications also allow solving the potential collision occurred due to scaling or traced image problems due to the thickness of the jet. Thus, optimizing product design is based on robust concepts to removal the negative factors using mathematical modeling of the contour of polygonal shape resulting from tracing and his conversion after parametric curves.

Mathematical models used in this paper are those that generate free-form Bezier curves, and those that generate B-Spline curves.

Processing was done on Maxiem 1530 JetMachining Center and software used for tracing is OMAX Intelli-Max. It was developed the algorithm for optimization method, conversion to parametric models was performed using Power Shape DELCAM software. The theoretical results obtained were confirmed by experimental observations.

II. THEORY

In Bezier modeling is considered that a segment of the curve is determined by points and any point on the curve can be obtained by evaluation of the next polynomial of the form:

$$C(u) = \sum_{i=0}^{n} P_i \; f_{i,n}(u) \qquad (1)$$

where: $0 \le u \le 1$, P_i are points of the curve, $f_{i,n}(u)$ are weighting functions of Bernstein polynomials form:

$$f_{i,n}(u) = \frac{n!}{i!(n-i)!} u^i (1-u)^{n-i} \qquad (2)$$

B-spline curves have the following analytical form:

$$C(u) = \sum_{i=0}^{n} P_i \cdot B_{i,k}(u) \qquad (3)$$

where: P_i are control points, $B_{i,k}(u)$ are mixing functions B-spline with grade $k-1$ and continuity order $k-2$

$$\begin{cases} u_i = 0 & \text{for } i < k, \\ u_i = i - k + 1 & \text{for } k \le i \le n, \\ u_i = n - k + 2 & \text{for } i > n, \end{cases}$$

where: u_i is the vector of values of nodes

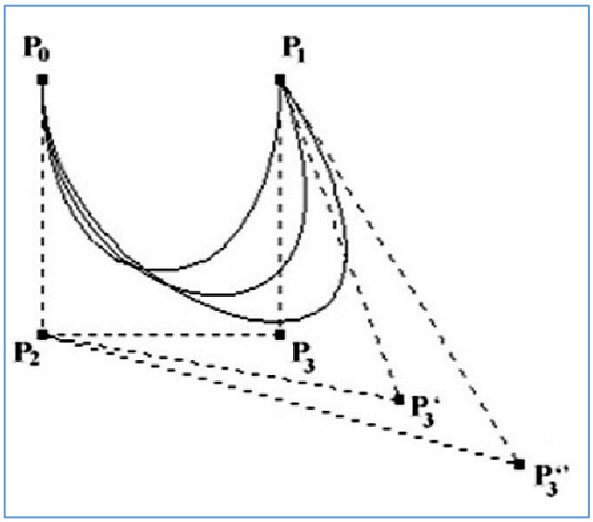

Fig. 1. *Modification of Bezier curve (3 fixed points)*

Bezier modeling disadvantage is that by modifying the coordinates of a point changes the whole curve. (Fig.1).

To resolve this is used B-Spline modeling based on curves defined by the polynomial functions in sections, thus offering the possibility of independent control of points. (Fig.2)

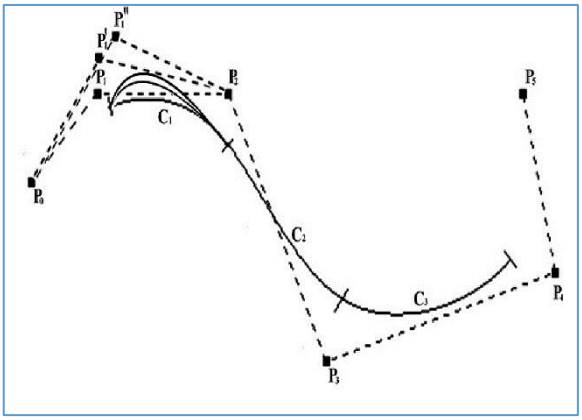

Fig.2. *Modification of B-Spline curve (one mobile point)*

Drawing curves induces different types of discontinuities, G1 in nodal areas, to Bezier curves. Discontinuities type G2 to B-Spline curves, shows line forms, curvature continuity is ensured. Bezier tracing mode has the advantage of mathematical models easier to solve and a very accurate picture implementing. B-Spline tracing mode uses a software more complex and elaborate but having the advantage of eliminating discontinuities. In the nodal points where major discontinuities appear, stress concentration and the appearance of stretching can generate micro cracks very dangerous for brittle pieces.

Modeling B-Spline, by used algorithm, leveled stress peaks, eliminating abrupt steps, allowing the hypothesis that this modeling could lead to better results in processing of brittle materials

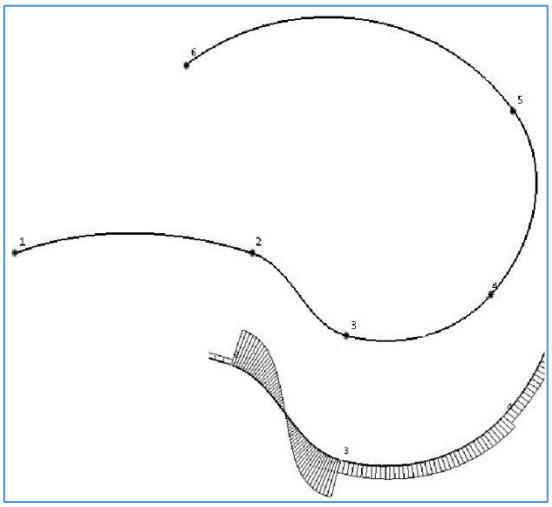

Fig.3. *Stress concentrations appearing in the regions nodal to Bezier curves*

Tracing of stress concentrations with Power Shape, DELCAM, software, allows jumps viewing (Fig. 3) and leveling these in case of B-Spline curves. (Fig. 4)

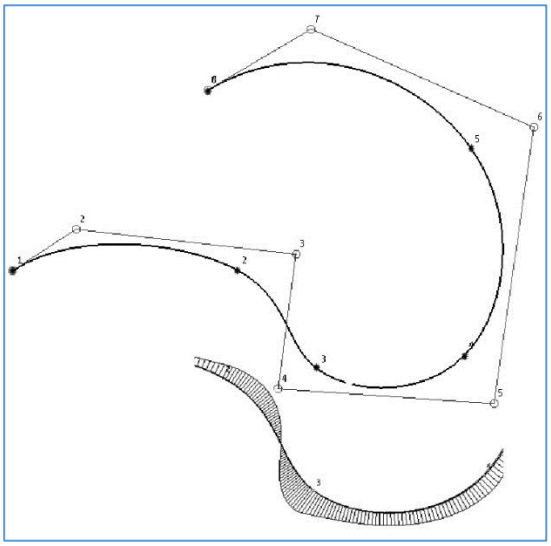

Fig.4. *Stress concentrations appearing in the regions nodal to B-Spline curves*

Development of abrasive jet cutting and machining a typology extremely varied of materials with this technology, give rise to problems. The material removal process is done by contact between the abrasive particles and work piece. Due to the speed and pressure of the jet, in contact zone, appear

severe shock causing the appearance of micro cracks in brittle materials. These micro cracks are due to the emergence in exposed areas, of internal stresses induced in work piece material.

Research suggests a method for reduction the risk of developing these primers cracking, caused by the speed and pressure of the jet, observed to processing of steel plate which they were executed covers for hollow rollers of large bearings. Mounting them by welding and subsequent heat treatment caused conditions to appearance of deformations and micro cracks bigger in the areas of discontinuity of the contour processed. The possibility of developing major defects, during bearings operation demonstrates the need for this method.

III. Experiments and Discussions

For experiments were used samples of white marble with thickness 20 mm and machinability 400. Abrasive type is garnet (8Moh). The working pressure is 3000 bar and positioning distance between nozzle and work piece is 1 mm. It was selected a form that shows both convex and concave curves. (Fig. 5). The material from which have been executed the samples, has the dimensions 50x50 [mm]

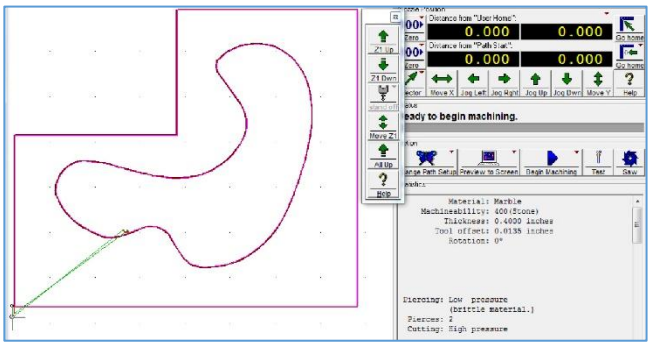

Fig.5. *Processing samples on Maxiem 1530*

20 samples have been executed, 10 samples with Bezier modeling and 10 with B-Spline modeling. Drawing and modeling executed in DELCAM Power Shape is shown in Fig. 6 for Bezier modeling and Fig. 7 for B-Spline.

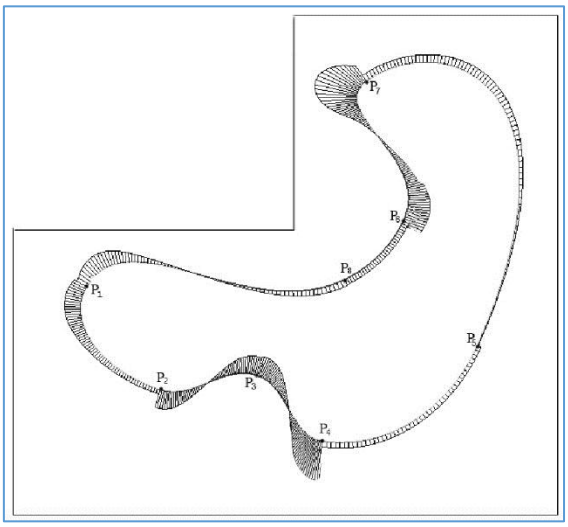

Fig.6. *Points of discontinuities to the samples traced in Bezier*

Microscopic research has been done in the points with big stress level namely P2, P4, P6, and P7.

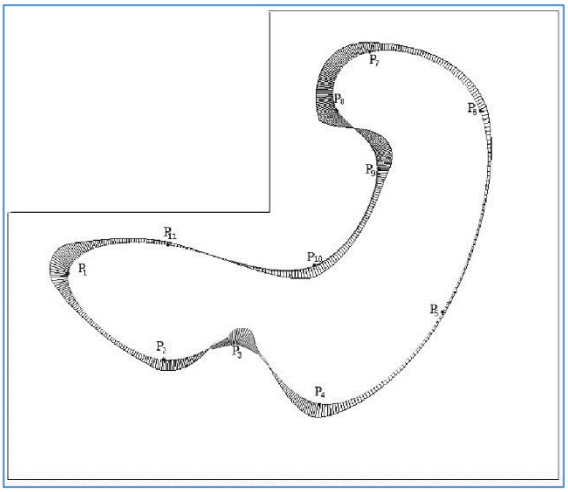

Fig.7. *Points of discontinuities to the samples traced in B-Spline*

The samples were washed and dried with a flow of air, after processing. Microscopic research has been done using an electronic microscope, ESEM, and consisted in in the detection of micro cracks in points P2, P4, P6, and P7.

Development of micro-cracks, their length and number was classified in Table 1.

TABLE I. Number of micro-cracks after waterjet cutting

Sample		Nodes							
		P_2		P_4		P_6		P_7	
		N	L	N	L	N	L	N	L
Bezier	1	0	-	2	>50	3	>50	1	>50
	2	2	>50	3	>70	3	>50	2	>50
	3	0	-	2	>70	4	>50	2	>50
	4	3	>50	3	>70	2	>50	4	>70
	5	2	>50	0	-	3	>50	2	>50
	6	0	-	1	>50	1	>30	0	-
	7	3	>70	0	-	0	-	1	>50
	8	4	>70	0	-	2	>50	1	>30

	9	1	>30	3	>70	3	>70	3	>70
	10	1	>50	2	>50	3	>50	2	>50
B-Spline	11	0	-	1	>50	0	-	0	-
	12	0	-	0	-	1	>30	1	>30
	13	0	-	0	-	1	>30	1	>30
	14	0	-	0	-	0	-	1	
	15	1	>30	0	-	0	-	0	-
	16	1	>30	0	-	0	-	0	-
	17	0	-	1	>50	0	-	0	-
	18	1		0	-	0	-	0	-
	10	0	-	0	-	1	>30	0	-
	20	0	-	0	-	0	-	1	>30

where N is numbers of micro-cracks and L is length of micro-cracks in μm.

Theoretical analysis performed is confirmed by practical results, namely, mode of tracing the curves influence the jet trajectory and quality of machined surfaces. The incidence of micro cracks is evident to the Bezier type drawing, confirming fact as discontinuity points induce additional stress concentrations in the material processed.

IV. CONCLUSIONS

In the process of cutting with an abrasive jet to choose the optimal cutting speed it is necessary to establish input parameters that determine the quality, precision and accuracy of the technological operation. This way we can mention the following input data: depth of cut, abrasive type, pressure and velocity of the jet, machinability of the material. The values of the first 4 parameters are precisely measured or predetermined depending on the cutting machine characteristics. Machinability is a characteristic of the material that is influenced by other factors like hardness, composition, type of technology development, microstructure, not defined in quantitative terms, the value being established in comparison with a standard value.

In setting of abrasive jet cutting system, quality and type of piece design has been less researched. Results from table 1 shows a micro cracks growth for some modeling of trace. Of course, influence affect the work speed and complexity of computing. These results provide an addition by setting influence of tracing method on the quality of work piece.

ACKNOWLEDGMENT

This work was partially supported by the strategic grant POSDRU/159/1.5/S/137070 (2014) of the Ministry of Labor, Family and Social Protection, Romania, co-financed by the European Social Fund – Investing in People, within the Sectorial Operational Programme Human Resources Development 2007-2013.

REFERENCES

[1] A. Luque, E. Ruiz-Agudo, G. Cultrone, E. Sebastian, S. Siegesmund "Direct observation of microcrack development in marble caused by thermal weathering" Environ Earth Science, 62, pp. 1375–1386, 2011.

[2] Barabas, S., Florescu, A., Calefariu, G., Sarbu, F., Optimization of Abrasive Water Jet Cutting for Carburized Pieces // Advanced Material Reseach, Vol. 1128, Advanced Technologies and Material Reseaches, 1128(2015), pp 293-303.

[3] A. Momber, R. Kovacevic: Principles of abrasive water jet machining Springer, Duisburg, 1998.

[4] I.Y. Kim, B.M., Kwak, Design Space Optimization Using a Numerical Design Continuation Method, International Journal for Numerical Methods in Engineering, Vol. 53, Issue 8, pp. 1979-2002, 2004

[5] C. Ramakrishnan "An Introduction to NURBS and OpenGL" https://www.cs.duke.edu/opengl_nurbs, 2002.

[6] S. W. Chae, K. Y. Kwon "Quadrilateral mesh generation on trimmed nurbs surfaces" KSME International Journal, VoL 15 No.5, pp. 592-601, 2001

[7] M.Y. Yang, J.H. Park "A Study on an Open Architecture CNC System with a NURBS Interpolator for WEDM" International Journal of Advanced Manufacturing Technology 19, pp. 664–668,2002.