Annals of the University of Oradea, Fascicle: Environmental Protection, doi.org/10.5281/zenodo.4362296, Vol. XXXIV, 2020
Analele Universității din Oradea, Fascicula: Protecția Mediului, doi.org/10.5281/zenodo.4362296, Vol. XXXIV, 2020

ASPECTS REGARDING THE PROCESS OF WOODEN SURFACES ON 3-AXIS CNC MILLING MACHINES WITH SPHERICAL TOOL

Derecichei Laura*, Lucaci Codruţa*, Cheregi Gabriel*

*University of Oradea, Faculty of Environmental Protection,
26 Gen. Magheru St., 410048 Oradea, Romania

Abstract

The paper deals with the geometry of wood surfaces processed on 3-axis CNC milling machines.

It analyzes everything that means CNC driven equipment with or without hierarchical control by external computer, generating parts through CAD-CAM procedures that are more and more efficient, modeling and simulating the virtual generation of the part on the future machine tool and using future equipment expected technologies, the software with which the machine tools are endowed in order to be able to lead the processing process.

Key words: CNC, wooden surfaces, 3-axis processing

INTRODUCTION

In the case of machining wooden surfaces on 3-axis CNC milling machines, during machining the direction of the tool axis remains constant.

The movement of the tool can be uniquely determined by the movement of an arbitrary point C (t) chosen on the axis of rotation.

The problems to be solved are:

- how to position the piece on the table;
- how to design trajectories that minimize processing time.

The 3-axis programming methods are divided into 3 categories:

1. Processing of surfaces whose slope varies substantially, e.g. $0° < \alpha < 90°$. A spherical tool can be used, but for $\alpha < 10°$, the cutting speed decreases drastically. (Ganea, M., 2010, Ganea, M., 2000)

2. Processing of almost horizontal surfaces ($\alpha \cong 0$). The widest width of the strip (between tools with the same diameter) is obtained by using a thoroidal tool with radius r <0.2, but this is limited by the appearance of thinning when processing concave surfaces.

3. Processing of almost glass surfaces ($70° < \alpha < 110°$). To obtain wide strips, the barrel tool can be used, but thinning can occur if the surface has a curvature comparable to that of the tool. (Derecichei et al., 2014, Derecichei et al., 2015, 2016)

MATERIAL AND METHOD

Spherical tool machining

It is assumed that the tool has a unit radius for simplification.

The processed region (Derecichei L. et al., 2017, Lucaci, C., 2017)

Let the tool be positioned tangentially to the surface P (u, v) as seen in fig. 1.

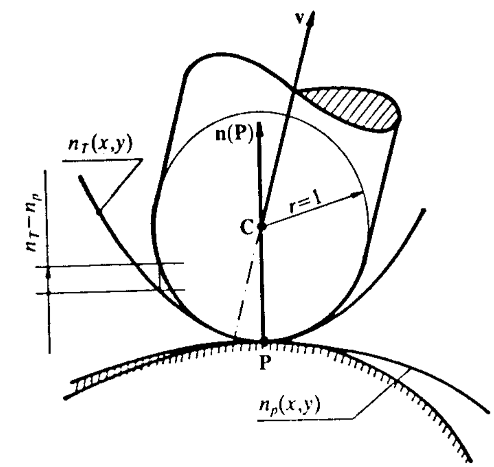

Fig. 1 Spherical tool

Let be the coordinate system (P, x, y, n), so that the vertices x and y are parallel to the main directions in P. (Marciniak K., 1991; Yoshimi I., 2008)

If the main curves of the surface are k_x and k_y, then the surface can be approximated with the oscillating paraboloid:

$$n_p=½\cdot(k_x\cdot x^2+k_y\cdot y^2)$$

The surface of the tool represented by the equation:

$$x^2+y^2+(n_T-1)^2=1$$

can be turn in approximated with the oscillating paraboloid in P:

$$n_T=½\cdot(x^2+y^2)$$

It results that the coordinates (x, y) of the points of the processed region satisfy the condition:

$$0\le n_T-n_p\le h\ ,$$

where h is the processing tolerance. (Derecichei L. et al., 2016)

The edge of the processed region can be approximated with the equation $n_T - n_p = h$, or equivalent: $(1-k_x)\cdot x^2+(1-k_y)\cdot y^2=2h$.

Result, the curvature of the tool is greater than that of the surface (k=1/r=1), so the undercutting does not appear, and the equation represents an ellipse:

$$\frac{x^2}{a^2}+\frac{y^2}{b^2}=1$$

where: $a=\sqrt{2h/(1-k_x)}$ si $b=\sqrt{2h/(1-k_y)}$ are the semiaxes. It should be noted that the shape of the region:

$$\varepsilon=\frac{a}{b}=\sqrt{\frac{1-k_y}{1-k_x}}$$

does not depend on tolerance h. The size of the ellipse is approximately equal to $\sqrt{h}$.(Derecichei L. et al., 2014, Derecichei L. et al., 2015)

RESULTS AND DISSCUSIONS

The effect of a small change in tolerance on the processed region of wooden parts. (Derecichei L. et al., 2015)

Because the shape of the ellipse is independent of tolerance, we can limit ourselves to any linear dimension, for example a. We have the relation:

$$\frac{\Delta a}{a}\cong\frac{da(h)}{dh}\cdot\frac{\Delta h}{a}=\frac{\Delta h}{2h}$$

valid for small values of Δh in relation to h. (Derecichei L. et al., 2017, Derecichei L. et al., 2018).

Errors in approximating the processed region

The elliptical processed region resulted due to the approximation of the tool and the piece with the oscillating paraboloid. To show how the error is estimated in this approximation, we will study the normal section of the part in the x direction. The other intersections are analyzed similarly.

It is assumed that the point of contact moves along the surface, so that the slope Pt tangential to a contact curve makes the angle γ with the slope x of the main direction of the surface. The width of the processed strip is defined by:

$$d(\gamma)=2\sqrt{a^2\sin^2\gamma+b^2\cos^2\gamma}$$

It is assumed that $k_x \leq k_y$, then for γ = 0 the function has a maximum d_{max} = 2b and for γ = π/ 2 it has a minimum of 2a.

The widest band (2b) is obtained when the point of contact moves along the main direction x. (Derecichei et al., 2018, 2019)

If the point of contact moves in an inclined direction with respect to x with the angle γ, then the width of the strip is reduced by the factor:

$$\varepsilon(\gamma)=d/d_{max}=\sqrt{\varepsilon^2\sin^2\gamma+\cos^2\gamma}$$

In most situations the curves of the surfaces satisfy the condition -

0.3 < k_x <0.3, which implies 0.73 < ε <1.0.

It can be seen that for these values of ε the effect of the direction of the tool movement on the machined belt can be neglected in practice. However, there may be concave-convex surfaces for which ε is small.

Fig. 2 shows a model that can be processed on CNC in 3 axes and post-processing sequences for the processing operation in 3 axes CNC generated by the SprutCam program (www.sprutcam.com, 2020):

CRUCIFIX02_18
(GENERATED BY SprutCAM)
(DATE: 27.02.2020)
(TIME: 15:01:02)
……………………………………..
X151.66Y19.288Z-92.454
X153.631Y18.939Z-93.449
X154.143Y18.85Z-93.715
X156.044Y18.517Z-94.738
X156.431Y18.45Z-94.952
X160.981Y17.669Z-97.616
X161.253Y17.623Z-97.784
....
X33.534Y-10.551Z-25.544
G01X34.25Y-8.701

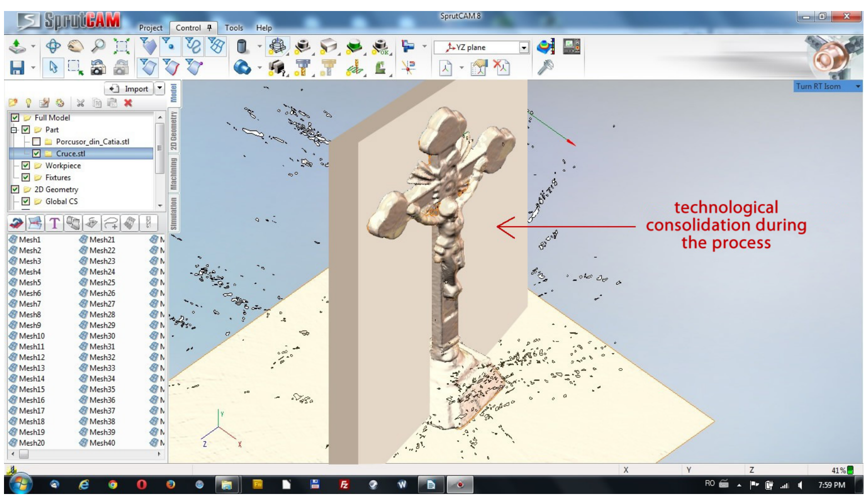

Fig. 2 Geometric model imported in the Sprutcam program - watermark surfaces; 1- additional addition of soft wood (lime) for technological consolidation during surface processing

CONCLUSIONS

It can be seen that small changes in tolerance lead to twice as small changes in the size of the processed region.

Cutting time can be reduced by using small machining steps, but this increases the cutting time and as a result decreases the cutting efficiency.
The problem of collision between the non-cutting element (mandrel) and the workpiece must be taken into account.

REFERENCES

1. Derecichei L., Lucaci C., Cheregi G., Lustun L., Galis I., 2014, Contributions to Processing the Surface Wood Carvings, International Sympozium “Risk Factors for Environment and Food Safety”, Analele Universității din Oradea, Fascicula Protecţia Mediului, vol.XXI, anul 19, Editura Universităţii din Oradea 2014,pp.399-404 ISSN 1224 – 6255
2. Derecichei L., Lucaci C., Cheregi G. Lustun L., 2015, Modeling and simulation of 3D surface finishing wood carvings- International Sympozium “Risk Factors for Environment and Food Safety”, Annals of University of Oradea, Fascicle Environmental Protection vol.XXIV, 20 year, University of Oradea in 2015, pp. 333-338 , ISSN 1224 – 6255
3. Derecichei L., Lucaci C., Cheregi G., Lustun L. 2016, Issues About Processing of the Wood Carving Surfaces In 5 Axis CNC - International Sympozium “Risk Factors for Environment and Food Safety”, Analele Universităţii din Oradea, Fascicula Protecţia Mediului, vol.XXVII, anul 21, Editura Universităţii din Oradea 2016, pp. 401-408 , ISSN 1224 – 6255
4. Derecichei L., Lucaci C., Cheregi G., Lustun L. 2017, Simulation of Sculptural Surface Processing in Wood in 5 Axis CNC With Sprutcam Program- International Sympozium “Risk Factors for Environment and Food Safety”, Analele Universităţii din Oradea, Fascicula Protecţia Mediului, vol.XXVIII, anul 22, Editura Universităţii din Oradea 2017, pp.165-172, ISSN 1224 – 6255
5. Derecichei L. Lucaci C., Cheregi G., 2018, Issues Related to the Use of SPRUTCAM in Wood Processing - International Sympozium “Risk Factors for Environment and Food Safety”, Analele Universităţii din Oradea, Fascicula Protecţia Mediului, vol.XXXI, anul 23, Editura Universităţii din Oradea 2018, pp.133-140, ISSN 1224 – 6255
6. Derecichei Laura M., 2014, Contribuții la prelucrarea în lemn a suprafețelor sculpturale în conceptul de prelucrare în 5 axe simultane. Teză de doctorat, Universitatea din Oradea, Şcoala Doctorală de Ştiinţe Inginereşti, 190 pp, Oradea,
7. Derecichei Laura, Lucaci Codruţa, Cheregi G., 2019, Study on circumferential processing on milling machines in 5 axis CNC - International Sympozium “Risk Factors for Environment and Food Safety”, Analele Universităţii din Oradea, Fascicula Protecţia Mediului, vol.XXXIII, anul 24, Editura Universităţii din Oradea 2019, pp. 123 -133, ISSN 1224 – 6255

8. Ganea, M.,2010, Machinery and Technology for Processing Surface Echipamenre 4 and 5 Axis CNC, ISBN 978-606-10-0041-8, University of Oradea Publishing House, 2010
9. Ganea, M. Et al., 2010, Constructive and technological objectives of the resources flow (working parts, tools, programs) at the flexible manufacturing cell; TMA AL 550, Scientific Session University of Oradea
10. Ganea M., Ganea C., 2000, Tehnologia prelucrării suprafeţelor curbe spaţiale, Editura Universităţii din Oradea, ISBN 973-8083-95-8
11. Jain, A. K, 1989, Fundamentals of Digital Image Processing, Prentice Hall, Englewood Cliffs NJ
12. Lucaci C., Lustun L., Cheregi G., Derecichei L., 2015, About Using the Solidworks in the Woodworking Engineering - International Sympozium "Risk Factors for Environment and Food Safety", Annals of University of Oradea, Fascicle Environmental Protection vol.XXV, 20 year, University of Oradea in 2015, pp. 367-372, ISSN 1224-6255
13. Lucaci C., Cheregi G., Derecichei L., Lustun L. M., 2016, Study On Making Decorative Items Carved Wood - International Sympozium "Risk Factors for Environment and Food Safety", Analele Universităţii din Oradea, Fascicula Protecţia Mediului, vol.XXVII, anul 21, Editura Universităţii din Oradea 2016, pp. 429-436, ISSN 1224 – 6255
14. Lucaci C., Cheregi G., Derecichei L., Csiszar A., 2018, Aspects of Designing a SCA Folding Chair Using the CAD-SOLIDWORKS Program - International Sympozium "Risk Factors for Environment and Food Safety", Analele Universităţii din Oradea, Fascicula Protecţia Mediului, vol.XXXI, anul 23, Editura Universităţii din Oradea 2018, pp.147-154, ISSN 1224 – 6255
15. Lucaci C., Cheregi G., Derecichei L., Nemes I., 2019, Contributions regarding the Processing of a craft object with the CNC STEPCRAFT 2D 840- International Sympozium 迭isk Factors for Environment and Food Safety -Analele Universităţii din Oradea, Fascicula Protecţia Mediului, vol.XXXII, anul 24, Editura Universităţii din Oradea 2019, pp. 127 -135, ISSN 1224- 6255
16. Marciniak, K., 1991, Geometric modeling for numerically controlled machinig, Oxford University Press
17. Yoshimi, I., 2008, Modular design for machine tools. MCGraw Hill Companies, SUA, ISBN 978-0-07-149660-5
18. http://www.sprutcam.com/sprutcam-and-solutions/sprutcam/geometrical-model,2020
19. http://www.sprutcam.com/sprutcam-and-solutions/sprutcam/machining-methods,2020
20. http://www.sprutcam.com/sprutcam-and-solutions/sprutcam/technological-machining ,2020