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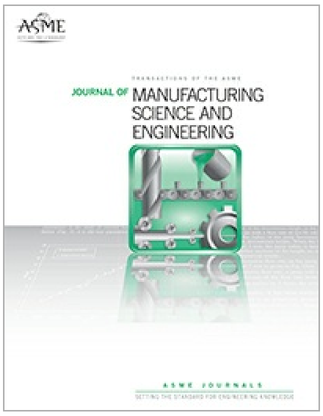

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TECHNICAL PAPERS

A Curvilinear Tool-Path Method for Pocket Machining

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A novel curvilinear tool-path generation method is described for planar milling of pockets. The method uses the solution of an elliptic partial differential equation boundary value problem defined on a pocket region. This mathematical function helps morph a smooth low-curvature spiral path in a pocket interior to one that conforms to the pocket boundary. This morphing leads to substantial reductions of tool wear in cutting hard metals and of machining time in cutting all metals, as experiments described here show. A variable feed-rate optimization procedure is also described. This procedure incorporates path, tool-engagement, and machine constraints and can be applied to maximize machine performance for any tool path.

Issue Section: Technical Papers
Keywords: machining, cutting, partial differential equations, boundary-value problems, image morphing
Topics: Machinery, Machining, Optimization, Cutting, Boundary-value problems, Shapes

1.

Bieterman, M. B., and Sandstrom, D. R., 1996, “A Strategy for Prescribing High Speed Pocket Machining Tool Paths,” Technical Report SSGTECH-96-020, The Boeing Company.

2.
Bieterman, M. B., and Sandstrom, D. R., 1998, “Curvilinear Spiral Tool Path Trajectories for High Speed Pocket Machining,” Technical Report SSGTECH-98-031, The Boeing Company.

3.
Bieterman, M. B., and Sandstrom, D. R., 2002, “A Curvilinear Tool-Path Method for Pocket Machining,” ASME IMECE2002-MED-33611.

4.
Bieterman, M., 2001, “Curvilinear Tool Paths for Pocket Machining,” presentation at the University of Minnesota Institute for Mathematics and its Applications, March 16, 2001 (see http://www.ima.umn.edu/industrial/2000-2001/bieterman.html).

5.
Bieterman, M., 2001, “Mathematics in Manufacturing: New Approach Cuts Milling Costs,” SIAM News (News journal of the Society for Industrial and Applied Mathematics), **34**(7), Sept. 2001 (see http://wwwsiam.org/siamnews/09-01/milling.pdf).

6.
Bieterman, M., 2002, “Curvilinear Tool Paths for Pocket Machining,” *Proceedings of the Society of Manufacturing Engineers High Speed Machining Technical Program*, Los Angeles, CA, May 14–15.

7.
Zelinski, P., 2002, “Curvilinear Tool Paths for Pocket Machining,” Modern Machine Shop magazine, pp. 54–55, July (see http://www.mmsonline.com/articles/0702rt1.html).

8.
Held, M. 1991, *On the Computational Geometry of Pocket Machining*, Volume 500 of *Lecture Notes in Computer Science*, Springer-Verlag.

9.
Held, M., Luka´cs, G., and Andor, L., 1994, “Pocket Machining Based on Contour-Parallel Tool Paths Generated by Means of Proximity Maps,” *Comput.-Aided Des.*, 26(3), pp. 189–203.

10.
Persson, H., 1978, “NC Machining of Arbitrary Shaped Pockets,” *Comput.-Aided Des.*, 10(3), pp. 169–174.

11.
Kramer, T. R., 1992, “Pocket Milling with Tool Engagement Detection,” *J. Manuf. Syst.*, 11(2), pp. 114–123.

12.
Arkin, E. M., Held, M., and Smith, C. L., 2000, “Optimization Problems Related to Zigzag Pocket Machining,” *Algorithmica*, 26(2), pp. 197–236.

13.
Guyder, M. K., 1990, “Automating the Optimization of 2½ Axis Milling,” *Computers in Industry*, 15, pp. 163–168.

14.
Suh, Y. S., and Lee, K., 1990, “NC Milling Tool Path Generation for Arbitrary Pockets Defined by Sculptured Surfaces,” *Comput.-Aided Des.*, 22(5), pp. 273–284.

15.
Preiss, K., and Kaplansky, E., 1985, “Automated CNC Milling by Artificial Intelligence Methods,” *J. Manuf. Syst.*, 4(1), pp. 51–63.

16.
Dragomatz, D., and Mann, S., 1997, “A Classified Bibliography of Literature on NC Milling Path Generation,” *Comput.-Aided Des.*, 29(3), pp. 239–247.

17.
Unigraphics/CAM V18 User Manual, 2001, Cypress, CA.

18.
CATIA V5 Introduction User Guide, 2001, The CAD/CAM Partnership, UK.

19.
Wang, H., and Stori, J. A., 2002, “A Metric-Based Approach to 2D Tool-Path Optimization for High-Speed Machining,” ASME

IMECE2002-MED-33610.

20.
Stori, J. A., and Wright, P. K., 2000, “Constant Engagement Tool-Path Generation for Convex Geometries,” *J. Manuf. Syst.*, 19(3), pp. 172–184.

21.
Courant, R., and Hilbert, D., 1953, *Methods of Mathematical Physics*, Vol. I, Interscience Publishers.

22.
Farlow, S. J., 1982, *Partial Differential Equations for Scientists and Engineers*, John Wiley & Sons (reprinted by Dover in 1993).

23.
Strang, G., and Fix, G. J. 1973, *An Analysis of the Finite Element Method*, Prentice-Hall, Inc.

24.
Bathe, K. J., and Wilson, E. L., 1976, *Numerical Methods in Finite Element Analysis*, Prentice-Hall, Inc.

25.
The Math Works, Inc., 1996, 24 Prime Park Way, Natick, MA 01760-1500, *MATLAB Partial Differential Equation Toolbox User's Guide*.

26.
Jackson, J. D., 1962, *Classical Electrodynamics*, John Wiley & Sons, Inc.

27.
Renton, D., and Elbestawi, M. A., 2000, “High Speed Servo Control of Multi-Axis Machine Tools,” *Int. J. Mach. Tools Manuf.*, 40, pp. 539–559.

28.
Stori, J. A., and Ferreira, P. M., 2002, “Design of a High-Speed Parallel Kinematics X-Y Table and Optimal Velocity Scheduling for High-Speed Machining,” *Transactions of the North American Manufacturing Research Institution of SME*, XXX, pp. 447–454.

29.
Smith, T. S., Timar, S. D., and Farouki, R. T., 2002, “Specification of Time-Optimal Feedrates for Curved Tool Paths in 3-Axis Machining,” preprint, University of California, Davis, CA.

30.
Betts, J. T., 1998, “Parametric Tool Path Trajectory Optimization,” Technical Report SSGTECH-98-006, The Boeing Company.

J. Manuf. Sci. Eng (November,2000)

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J. Manuf. Sci. Eng (November,2001)

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Space-filling curves tool path generation technique presented in Chap. 4 has been designed for surfaces represented in such a way that the parametric coordinates are changing within a rectangular... A curvilinear tool-path method for pocket machining. Journal of Materials Processing Technology, 125(4):709–715.Google Scholar. [10]. 3.2.2 Curvilinear tool path. 4 History. 4.1 1780-1810. There are cutting tools typically used in milling machines or machining centers to perform milling operations (and occasionally in other machine tools). They remove material by their movement within the machine (e.g., a ball nose mill) or directly from the cutter's shape (e.g., a form tool such as a hobbing cutter). A diagram of revolution ridges on a surface milled by the side of the cutter, showing the position of the cutter for each cutting pass and how it corresponds with the ridges (cutter rotation axis is perpendicular to image plane). However, there are alternative classifications according to method of control, size, purpose and power source. Mill orientation[edit]. Vertical milling machine[edit]. The curvilinear tool path, at right, reduces wasteful acceleration and deceleration by minimizing sharp corners. As the drawing shows, this path is unrecognizable as a pentagon at first, but gradually assumes the shape of the pocket as the tool spirals outward. An application developed within Boeing converts pocket shapes into efficient tool paths such as this one. These approaches to pocket machining result in tool paths made up of straight lines and tight-radius corners. The corners exaggerate the influence of acceleration and deceleration on the total cycle time. While all of the cornering may not be significant at conventional feed rates, repeatedly slowing down for corners can dramatically reduce the efficiency of a pocketing operation that uses high speed machining.