University of Victoria | Graduate Studies

Notice of the Final Oral Examination
for the Degree of Doctor of Philosophy

of

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"Optimization of Toolpath/Cutter Orientation and Chip Volume/Cutting Force Calculations in 5-Axis CNC Machining of Free-form Surfaces Using Flat-end Mill"

Department of Mechanical Engineering

Wednesday, December 2, 2015
4:00 P.M.
Engineering Office Wing
Room 430

Supervisory Committee:
Dr. Zuomin Dong, Department of Mechanical Engineering, University of Victoria (Co-Supervisor)
Dr. Martin Byung-Guk Jun, Department of Mechanical Engineering, UVic, (Co-Supervisor)
Dr. Keivan Ahmadi, Department of Mechanical Engineering, UVic (Member)
Dr. Sue Whitesides, Department of Computer Science, UVic (Outside Member)

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Chair of Oral Examination:
Dr. Nicholas Bradley, Department of English, UVic

Dr. David Capson, Dean, Faculty of Graduate Studies

Abstract

The research forms the foundation for optimal tool path, cutter orientation and feed rate planning in 5-axis CNC machining of curved surfaces using a flat-end mill with high efficiency and surface quality potentials. An optimal tool path generation method by machining the curved surface patch-by-patch considering surface normal variations using fuzzy clustering technique is firstly proposed. This method allows fast CNC machining with reduced range of machine tool rotational axes' motions and eliminates sharp cutter orientation changes. The optimal number of surface patches or surface point clusters is identified by considering the accumulated changes of the relative angles to minimize the two rotation motions and simplify toolpath generation. An optimal and flexible tool orientation method based on the combination of Euler-Meusnier spheres (EMS) and surface normal variation control methods is then developed to avoid gouges and to improve machining efficiency. The EMS is applied to deal with concave surfaces to avoid local gouging by matching the largest cutter Euler-Meusnier sphere with the smallest Euler-Meusnier sphere of surface at each cutter contact (CC) point; the surface normal variation control method is used for convex surface due to its higher efficiency and no gouging issue; and selection of one of these methods in tool orientation determination for saddle shapes is based on the direction of the CNC tool path in relative to the surface curvature change. A NURBS surface with concave, convex and saddle features is used to demonstrate these newly introduced methods. Giving the optimized tool path direction and tool orientation, the maximum feed rate of machining, is identified to achieve maximum productivity. This work explored two approaches—tool based and voxel workpiece based methods to predict chip volume and cutting forces using a flat-end mill. A new parallel slice local volume modeling approach that extends the cutting chip geometry and volume prediction only Alpha-shape method has been introduced to predict instant cutting forces for feed rate determination. The Voxel workpiece is created to get undeformed chip geometry, chip volume and cutting forces by determining the intersections of tool envelope and continuously update workpiece during machining. The comparisons of these two approaches are made and several machining experiments are conducted to verify the simulation results.