Title:
Integrated Approach for Milling Impeller Parts

Authors:
Than Lin, thanlin@ait.ac.th, Asian Institute of Technology
Aruna Premarathna, asaranga225@gmail.com, Asian Institute of Technology
Erik L.J. Bohez, bohez@ait.ac.th, Asian Institute of Technology

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Abstract:
This paper presents an integrated approach for 4-axis milling impeller parts. Impeller blades are designed with a rule surface which is twisted to achieve the required performance. It can be undercut, overcut and collision problems during machining. A method to manufacture impeller parts on a 4-axis machine is presented. Impeller 3D CAD models are implemented using geometric design parameters and CAM for 4axis Point Milling and Flank Milling are prepared under the SIEMENS UG NX. A postprocessor for desktop 4-axis CNC Mill using MATLAB® and a virtual machine tool simulator using VeriCUT® has been developed. Actual machining for impeller blades are done with Desktop 4-axis CNC Mill for the verification and validation purposes.

Introduction:
Advanced Technology is emerging now a day to minimize time and scrap which is major concern in industries. Most complexed models can be fabricating by CNC machines like turbine blades, impellers, and propellers [8]. Recent advances in computer numerical control (CNC) machining technologies are discussed in [5]. The blade of impeller is usually designed with a rule surface which is normally twisted in design to achieve the required performance. It can be undercut, overcut and collision problems during machining. The issues to satisfy the quality requirements, to reduce the machining time and to avoid the occurrence of collision become an integral problem [2]. The multi-axis toolpath generation using flank milling method has been discussed for the rule surface of helical rotor [3]. Authors discussed 5-axis machining on rule surface in [4]. Post-processing technology is the key to CNC automatic programming technology and important module of the CAD/CAM system. The NC machining Post-Processing technology based on Siemen UG NX is explained in [6]. Post-processing of tool path for multi-axis milling machines, generated by the CAD/CAM system is a critical activity in engineering work [10]. The technological process is important to enter the process of manufacturing of various precision engineering components of complex shape designed for the needs of automotive and aerospace industries [1]. A specialized program supporting new approach to integrated design and manufacturing processes in CAD/CAM systems plays a vital role in concurrent engineering concept, particularly when virtual processes are concerned [9]. Companies are always looking for new ways to increase productivity. 4-axis and 5-axis machines are just one of many alternatives that could possibly help increase productivity [7]. This paper describes an integrated approach from design to manufacturing using CAD/CAM technologies and developed post-processing program and virtual machine tool simulator.

Main Idea:
The idea of an integrated approach (See Fig.1) is to satisfy the quality requirements, to shorten lead time of pre-manufacturing and to avoid the occurrence of collision. Impeller parts 3D CAD models are implemented by geometric design parameters and 4-axis milling (point milling and flank milling) is

applied for manufacturing impeller blades. Under the MATLAB® environment, a post processor is developed using transformation equations from workpiece coordinate to machine coordinate. A virtual simulator for desktop 4-axis CNC Mill is implemented using CAD models of machine tool. Verification and validation are done by virtual simulation and actual cutting. Maximum size of overcut and undercut are checked after virtual cutting. If designer satisfy the result, actual cutting will be performed using machine and workpiece setups. If not satisfied, design and manufacturing parameters will be reviewed again and update the information. A new model will be processed until the acceptable level is reached. Finally, actual machining will be finalized.

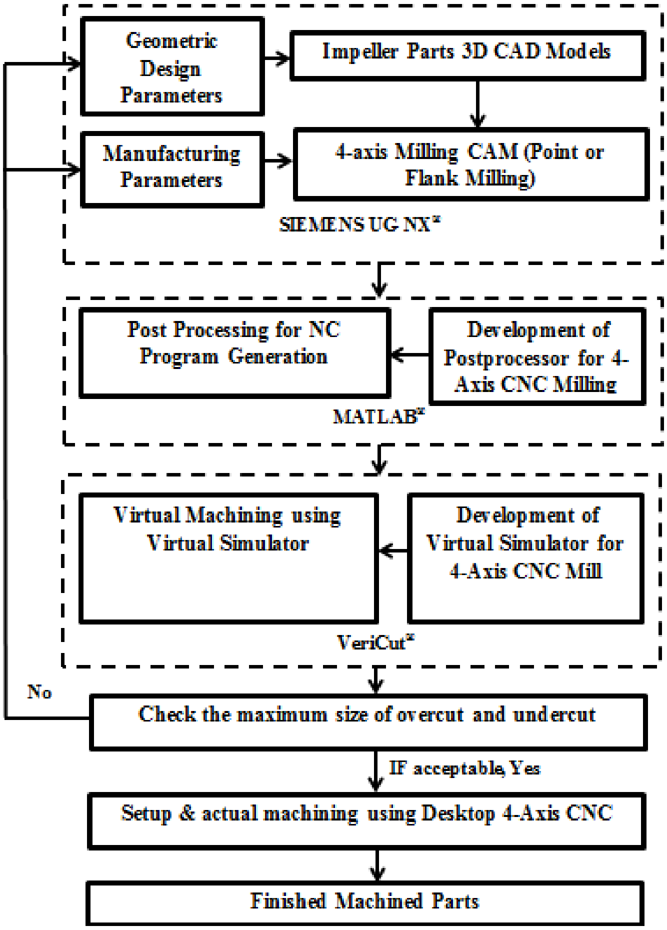

Fig. 1: An integrated approach for milling impeller parts.

<u>Development of Post-Processor for Desktop 4-axis milling CNC:</u>

This section describes how we apply inverse kinematics for post-processing. The kinematics chain diagram (Fig. 2) is drawn following to the real desktop 4-axis CNC Mill (Fig.4). Fig.3 presents a virtual model of desk 4-axis CNC Mill which will be used for the development of virtual simulator. Coordinates of frames shown in Fig. 5 are set for the transformation matrix equations (see Equations (1-14). Inverse kinematics is used and a program is developed in MATLAB®.

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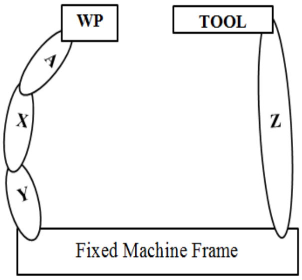


Fig. 2: Kinematics Chain Diagram.

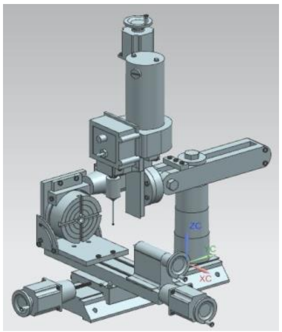


Fig. 3: A Virtual Model of Desktop 4-Axis CNC Mill.

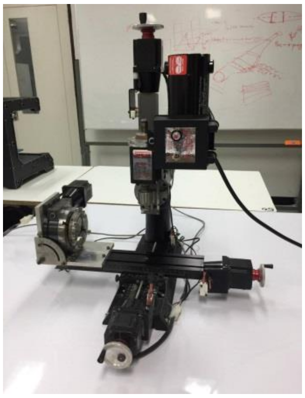


Fig. 4: A Real Desktop 4-axis CNC Mill.

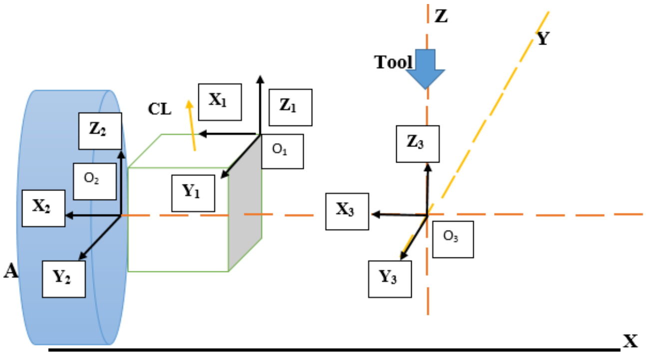


Fig. 5: Coordinates of frames for Post-processing.

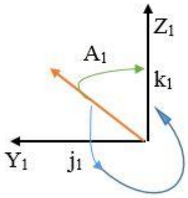
- O_1 to O_2 Coordinate Transformation

$X_2 = X_1 + X_2^1$ ……… (1) $\quad Y_2 = Y_1 + Y_1^2$ ……… (2) $\quad Z_2 = Z_1 + Z_1^2$ ……… (3)

- O_2 to Rotation A

$X_2(A) = X_2$ ……….. (4) $\quad Y_2(A) = Y_2 \, Cos\, A - Z_2 \, Sin\, A$ …… (5) $\quad Z_2\,(A) = Z_2 \, Cos\, A + Y_2 \, Sin\, A$ ……… . (6)

Inverse Kinematics for A



$A_1 = \arctan(\frac{j_1}{k_1})$ ……….. (7) $\quad A_2 = 2\pi - A_1$ ………. (8)

- O_2 to O_3 Coordinate Transformation

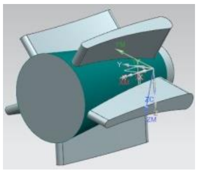
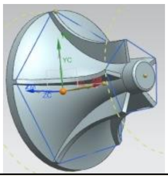
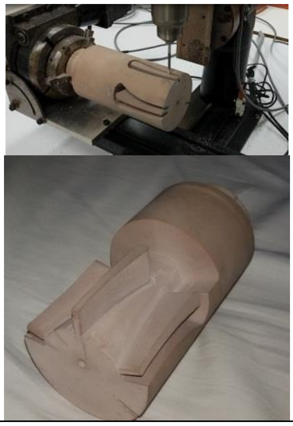
$X_3^w = X_2(A) + X_2^3 + X$ ……… (9) $\quad Y_3^w = Y_2\,(A) + Y_2^3 + Y$ ………. (10) $\quad Z_3^w = Z_2\,(A) + Z_2^3$ …… (11)

- O_3 to Tool Coordinate Transformation

$X_3^T = 0$ ……… (12) $\quad Y_3^T = 0$ ……… (13) $\quad Z_3^T = Z_T^3 + Z$ ……….. (14)

Development of Virtual Machine Tool for Desktop 4-Axis CNC Mill:
A virtual machine tool (see Fig.6) is constructed using VeriCut® after importing CAD models of Desktop 4-axis CNC Mill. Kinematic links are set and machine setup and parameters are set following to the real CNC machine. After verification and validation of the model, virtual cutting on impeller parts (Type 1 &2) are performed (See Fig. 7 & 8).

Results and Discussion:
Tab.1 shows the parameters and results of 4-axis machining on impeller blades. By using this approach, designer can check the output of maximum undercut and overcut until target is achieved.

Impeller 3D CAD Models using geometric design parameters	Impeller Model Type 1	Impeller Model Type 2
		
Manufacturing Parameters set for toolpath generation in CAM & Actual Cutting		
Type of Milling	Flank Milling	Point Milling
Drive Method	Streamline or Surface Area	Surface Area
Projection Vector	Toward Line (+XC)	Normal to Drive
Tool Axis	Away from Line (+XC) or Swarf Drive	4-axis relative to Drive (+XC)
Feed rate (mm/min)	80	90
Tool Dia (mm)	3 mm Flat End Mill	3 mm Flat End Mill
Results of Actual Cutting on an Impeller Blade		
Finished Blade after Actual Cutting on Desktop 4-axis CNC Mill		
Machining Time (min/Blade)	31	50
Maximum Size of undercut (mm)	0.64	0.31
Maximum Size of overcut (mm)	4.98	4.77

Tab. 1: Result and parameters of 4-axis machining impeller blades.

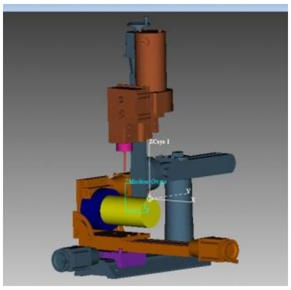


Fig. 6: Completed model implemented in VeriCut®.

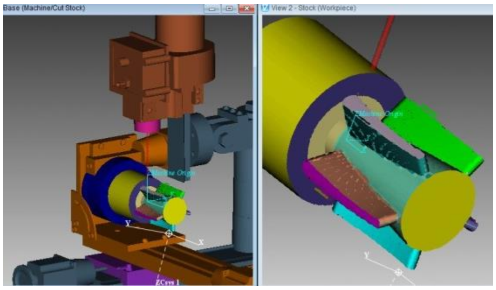


Fig. 7: Virtual Cutting Simulation for Impeller Type 1.

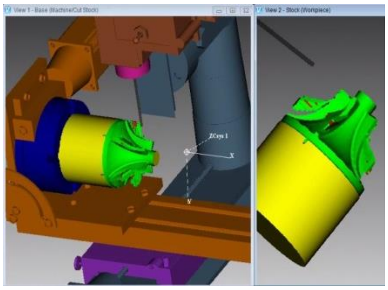


Fig. 8: Virtual Cutting Simulation for Impeller Type 2.

Conclusion:

An integrated approach for milling impeller blades are discussed and presented. A post-processor for desktop 4-axis CNC Mill and virtual machine tool simulator has been developed for a real 4-axis CNC. By using CAD/CAM technologies and developed programs, actual cutting on impeller blades are performed. Programs are verified and validated. By using this approach, reducing lead time, increasing quality and avoiding collision can be achieved. Besides this advantage, this tool can be used for teaching students as an educational tool.

References:

[1] Dubovska, R.; Jambor, J.; Majerik, J.: Implementation of CAD/CAM system CATIA V5 in Simulation of CNC Machining Process, Procedia Engineering, 69, 2014, 638-645. https://doi.org/10.1016/j.proeng.2014.03.037.

[2] Young, H. T.; Chuang, L. C.: An Integrated Rough Machining Approach for a Centrifugal Impeller, The International Journal of Advanced Manufacturing Technology, 21, 2003, 556-563. https://doi.org/10.1007/s00170-002-1382-3.

[3] Lee, J. N.; Huang, C. B.; Chen, T. C.: Toolpath Generation Method for four-axis NC machining of Helical Rotor, Journal of Achievements in Materials and Manufacturing Engineering, 31(2), 2008, 510-517.

[4] Lin, T.; Lee, J.-W.; Bohez, E.: A New Accurate Curvature Matching and Optimal Tool Based Five-axis Machining Algorithm, Journal of Mechanical Science and Technology: 23, 2009, 2624-2634. https://doi.org/10.1007/s12206-009-0724-6.

[5] Li, Y.; Lee, C.-H.; Gao, J.: From computer-aided to intelligent machining: Recent advances in computer numerical control machining research, Journal of Engineering Manufacture, 229 (7), 2015, 1087-1101. https://DOI.org/10.1177/0954405414560622.

[6] Magambo, S.; Ying, L.: The NC Machining Post-Processing Technology Based on UG, Journal of Science and Research, 2(9), 2013, 131–134.

[7] Sherman, D.; Cleve, A. V.: The Decision Process of Transitioning from a 3-Axis to a 4-Axis or 5-axis Milling Machine, A Senior Project, California Polytechnic State University, May 2013, 1-31.

[8] Vineethkar, J.-J.; Umasekar, V. -G.: Multi Axis Machining of Turbine blade Using 4-Axis Machining Center, International Journal of Engineering Science and Computing, 6(9), 2016, 2311-2314.

[9] Zietarski, S.: System Integrated Product Design, CNC Programming and Postprocessing for Three-Axis Lathes, Journal of Materials Processing Technology, 109, 2001, 294–299.

[10] Zivkovic, S.: NX CAM Post Processing Errors: Machine Data File Generator vs. Post Builder, FME Transactions, 44, 2016, 159–164.