Investigation of roughing machining simulation by using visual basic programming in NX CAM system

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Abstract. This paper outlines a simulation study to investigate the characteristic of roughing machining simulation in 4th axis milling processes by utilizing visual basic programming in NX CAM systems. The selection and optimization of cutting orientation in rough milling operation is critical in 4th axis machining. The main purpose of roughing operation is to approximately shape the machined parts into finished form by removing the bulk of material from workpieces. In this paper, the simulations are executed by manipulating a set of different cutting orientation to generate estimated volume removed from the machine parts. The cutting orientation with high volume removal is denoted as an optimum value and chosen to execute a roughing operation. In order to run the simulation, customized software is developed to assist the routines. Operations build-up instructions in NX CAM interface are translated into programming codes via advanced tool available in the Visual Basic Studio. The codes is customized and equipped with decision making tools to run and control the simulations. It permits the integration with any independent program files to execute specific operations. This paper aims to discuss about the simulation program and identifies optimum cutting orientations for roughing processes. The output of this study will broaden up the simulation routines performed in NX CAM systems.

1. Introduction

In conventional approach, Computer Numerical Control (CNC) requires a significant human intervention and efforts to execute the cutting processes [1]. Machining operator need to understand the 3D design in Computer Aided Design (CAD) and develop the process planning in terms of tool selection, toolpath planning, machining strategies and fixturing method. After all the desired information has been obtained, the data will be entered into the Computer Aided Manufacturing (CAM) system to produce the CNC machine code. In CNC machining, the machined parts features is important to be defined first, in order to create a set of processes to obtain a geometry according to the required accuracy [2]. In today's competitive industry, automation in process planning becomes crucial with aim to enhance the efficiency reduce lead time and improve productivity and quality. Current methods of machining process planning is highly depend on the machinist experience [3,4]. A demand to increase productivity is the main challenge in global manufacturing and each of the companies will compete to achieve the targets. When dealing with new machining process, the trial and error approach is one of the common methods. Although the trial and error approach seamlessly applicable, but it will cause a major impact on productivity in terms of machining time and cost [5].
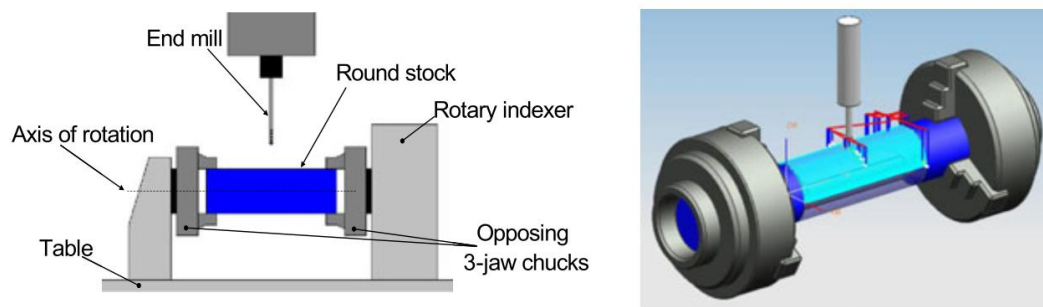
There are few ways to improve the current approach with the new and practical one. The development of computer graphics has improved the simulation capabilities. For example, in the

generation of NC codes from machining processes. Instead of using the conventional practice, there are few other methods that can be employed by the integration of advanced tool and programming codes. Lack of technical knowledge and integration capability of CAM system is one of the reasons why most manufacturers suffered in their production. Therefore, an independent Computer Aided Process Planning (CAPP) has been introduced as a communication platform between CAD and CAM systems. Computer-Aided Process Planning (CAPP) is the system where computers are used to assist or replace human intervention in order to produce a better process plans in optimum time [6]. The basic fundamental concept of CAPP is to automate the process planning, where the time and efforts of process planning will be reduced and high process consistency achieved.

2. Overview of CNC Machining Simulation

The development of Rapid Prototyping by using CNC Machining (CNC-RP) is one of the effective technique in implementing the machining simulation processes [7]. With this method, process plans for machined component is allowable to be automated. A 3-axis milling with fourth axis indexer devices was employed in CNC-RP and act as a clamping device that permits the parts to be rotated in one rotation axis. The aim of CNC-RP method is to machine all parts surface within specific set of orientation without re-fixturing [8]. **Figure 1** shows the indexer setup for 1 axis rotation. This approach allows a round stock of material to be clamped between 3-jaw chucks and rotary indexer will rotate the material between the operation sequences. This method is able to propose an optimal cutting angle within set of orientation until real part shape is visible.
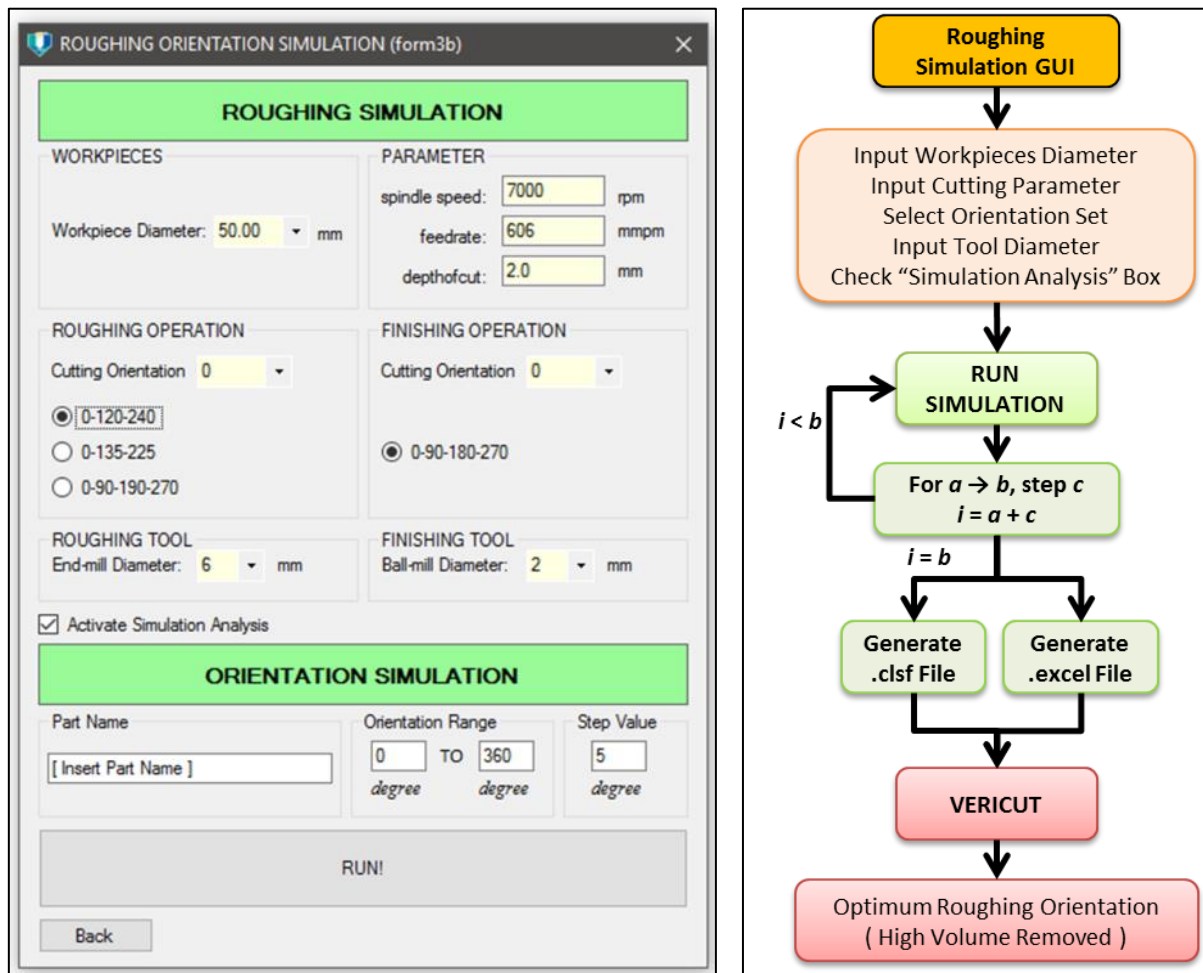

Figure 1. Rotary Indexer Setup

A recent study has proposed several approaches to further improve the roughing machining operation in CNC-RP (Nafis et al. 2014). It was successfully executed by simulating a set of orientation with 3 orientation (0°-120°-240°) (0°-135°-225°) and 4 orientation (0°-90°-190°-270°). Cutting angle with set of 4 orientations has proven to be able to execute roughing operation more efficiently in terms of machining time [9]. This approach improves the previous method by splitting roughing orientation from finishing orientation and incorporating with other orientation. For each orientation, roughing and finishing operation are performed in sequence with different value of cutting angle and parameter.

3. Roughing Simulation Methodology

4. In this study, process planning simulation is executed by customized program using Visual Basic programming in NX CAM system. Machining operation in the form of automation can be developed in NX CAM system where it is equipped with a programming tool that corresponds to the proposed simulation. In NX CAM system, advanced tool called "Journaling" able to record and translate the command or instruction into Visual Basic, JAVA and C++ language [10].

Figure 2 shows a roughing simulation GUI and simulation algorithm. It was developed in Visual Basic Studio using a windows form application template. The GUI has several text boxes and drop-

down lists where user can input selected parameter, workpiece diameter, cutting parameter, set of orientation and cutting tool size. The "Activate Simulation Analysis" box needs to be checked in order to enable the simulation mode. Simulation algorithm has been programmed behind the system to execute the simulation based on user input.

Figure 2. (a) Roughing Simulation Graphical User Interface (GUI) (b) Simulation Algorithm

In this simulation study, the orientation range is set from 0°to 360° with 5° step value. Therefore, for each set of orientations, 72 results will be obtained and analysed by the system which will then be exported to cutter location source file (.clsf) files and excel files, as shown in

Figure 3. CLSF files works as a communication tool between NX and VERICUT software to validate the simulation output [11]. In this study, CGTech VERICUT 8.0 applications have been used to analyse the excess volume left on parts after machining [12]**.**

Orientation	Cutting Length (mm)	Cutting Time (min)	Volume Removed (mm³)	Orientation	Cutting Length (mm)	Cutting Time (min)	Volume Removed (mm³)
5	44,615.94	88.52	102,671.91	185	44,563.60	88.42	102,653.14
10	44,793.58	88.88	102,686.30	190	44,282.67	87.86	102,665.71
15	44,202.80	87.70	102,813.63	195	44,357.32	88.01	102,650.43
20	44,331.95	87.96	102,625.67	200	44,302.97	87.90	102,615.58
25	44,302.93	87.90	102,657.07	205	44,648.03	88.59	102,650.14
30	44,504.48	88.30	102,661.47	210	44,610.28	88.51	102,639.85
35	44,568.62	88.43	102,692.05	215	44,699.62	88.69	102,704.97
40	44,526.92	88.35	102,727.98	220	44,445.90	88.19	102,717.90
45	44,428.58	88.15	102,756.10	225	44,533.82	88.36	102,708.93
50	44,891.33	89.07	102,710.44	230	44,216.88	87.73	102,684.85
55	44,762.72	88.81	102,689.57	235	44,229.82	87.76	102,651.03
60	44,703.75	88.70	102,677.43	240	45,617.22	90.51	102,633.58
65	44,392.85	88.08	102,639.12	245	44,725.78	88.74	102,613.52
70	44,157.27	87.61	102,663.77	250	44,706.07	88.70	102,646.83
75	44,034.72	87.37	102,663.85	255	44,112.15	87.52	102,645.98
80	44,283.86	87.86	102,674.29	260	44,325.41	87.95	102,658.02
85	44,609.89	88.51	102,693.82	265	44,698.42	88.69	102,680.07
90	44,444.84	88.18	102,707.70	270	45,374.25	90.03	102,641.06
95	44,211.51	87.72	102,703.09	275	44,677.47	88.65	102,685.25
100	44,391.86	88.08	102,633.35	280	44,625.52	88.54	102,657.82
105	44,380.86	88.06	102,766.54	285	44,170.72	87.64	102,660.09
110	44,627.53	88.55	102,654.40	290	44,195.77	87.69	102,668.54
115	44,527.38	88.35	102,669.13	295	45,659.53	90.59	102,169.68
120	44,259.97	87.82	102,667.65	300	44,680.72	88.65	102,682.30
125	44,446.12	88.19	102,691.31	305	44,848.46	88.99	102,690.15
130	44,314.89	87.93	102,691.92	310	45,082.05	89.45	102,755.27
135	44,452.77	88.20	102,718.44	315	44,844.79	88.98	102,779.74
140	47,464.88	94.18	102,674.81	320	45,155.24	89.59	102,724.19
145	44,307.07	87.91	102,662.33	325	44,872.89	89.03	102,712.00
150	44,587.81	88.47	102,651.96	330	44,478.79	88.25	102,663.54
155	44,510.04	88.31	102,615.23	335	44,279.26	87.86	102,636.97
160	44,445.34	88.19	102,646.86	340	44,632.35	88.56	102,717.53
165	44,666.56	88.62	102,616.24	345	44,431.49	88.16	102,645.96
170	44,446.16	88.19	102,658.91	350	44,568.19	88.43	102,675.54
175	44,554.92	88.40	102,677.87	355	44,535.70	88.36	102,683.22
180	44,603.31	88.50	102,640.50	360	44,349.27	87.99	102,716.84

Figure 3. Sample of information extracted from developed program

5. Results and Discussion

Virtual simulation was conducted by using a developed program. Experiments are carried out on four part models with 3 simulations for each model; Baby Toy, Lego, Fan Blade and Gear. Model selection is based on characteristics and geometry, consisting of flat surfaces and non-flat surfaces. **Table 1** summarizes the simulation results for the selected models. For each model, first and second column represents the result of three roughing orientation approach which is (0-120-240) and (0-135-225). The third column represents the result of four roughing orientation approach, (0-90-190-270). Comparisons were made through all the simulation approach that differs in roughing orientation set.

A value of cutting angle proposed by the developed program is dependent by machined parts geometry. Each part has different geometry features which influence the value of cutting angle within orientation set. It is based on the region that can be accessed by cutting tools to complete machine the cylindrical workpieces. The result shown in Table 1 portray that the developed program is capable to adapt with various geometrical parts, where the "stickiness" function inside the program is customized into a free-features function. This customization allows flexibility to the developed program in order to executing the simulation with various parts. At the same time, the developed program manages to analysis and extracts a large number of information from the simulation within less planning processes. In conventional practices, there is no doubt that virtual machining simulation will take a long planning processes as each simulation for each parts needs to be repeated several times manually, in order to obtain a required results. By utilizing this program, the orientation values for each simulation are changing automatically, until the entire desired cutting angles have been analyzed.

Table 1. Simulation Results

Result	BABY TOY			LEGO		
	3 orientation (0-120-240)	3 orientation (0-135-225)	4 orientation (0-90-190-270)	3 orientation (0-120-240)	3 orientation (0-135-225)	4 orientation (0-90-190-270)
Roughing Orientation (degree)	155° 275° 35°	100° 235° 325°	165° 255° 355° 75°	300° 60° 180°	315° 90° 180°	90° 180° 280° 0°
Roughing Cutting Time (min)	81.95	79.82	102.15	71.88	69.12	83.77
Finishing Cutting Time (min)	72.92	75.95	59.15	34.3	36.65	28.8
Machining Cutting Time (min)	154.87	155.77	161.30	106.18	105.77	112.57
Roughing Volume Removed (mm³)	168,888.45	168,470.44	172,530.24	146,978.76	147,848.89	149,660.64
Total Volume Removed (mm³)	187,249.22	187,052.31	187,346.71	162,307.53	162,331.04	162,338.57
Percentage of Volume Removed (roughing)	90.2%	90.1%	92.1%	90.6%	91.1%	92.2%

Result	FAN BLADE			GEAR		
	3 orientation (0-120-240)	3 orientation (0-135-225)	4 orientation (0-90-190-270)	3 orientation (0-120-240)	3 orientation (0-135-225)	4 orientation (0-90-190-270)
Roughing Orientation (degree)	250° 10° 130°	25° 160° 250°	225° 315° 55° 135°	155 275° 35°	340° 115° 205°	225° 315° 55° 135°
Roughing Cutting Time (min)	34.17	34.27	47.20	48.88	48.92	58.82
Finishing Cutting Time (min)	22.65	22.93	19.10	96.28	91.03	84.72
Machining Cutting Time (min)	56.82	57.20	66.30	145.16	139.95	143.54
Roughing Volume Removed (mm³)	67,676.94	67,596.11	68,501.70	83,540.09	84,001.73	87,764.52
Total Volume Removed (mm³)	73,008.13	72,893.77	73,103.93	120,266.06	120,254.71	120,250.19
Percentage of Volume Removed (roughing)	92.7%	92.7%	93.7%	69.5%	69.9%	73.0%

6. Conclusion
In this research paper, the outcomes of the simulation are generated through the application of Visual Basic Programming, NX CAM and VERICUT tools. A developed roughing simulation program offers another solution for machining simulation routines in CAM environment. Integration of Visual Basic programming language in NX CAM system manages to optimize the process planning and able to execute multiple simulation routines effectively. This approach is considered as an alternative way to determine an optimum cutting orientation, in terms of high volume removed in roughing operation before proceed to finishing processes. As conclusions, the developed program managed to improve the efficiency of simulation routines and shorten the processing time in NX CAM system.

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