A Study of Integrated CAD/CAM System with CNC Desktop Machine

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DECLARATION

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree

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LIST OF ABBREVIATIONS

2D	Two-dimension
3D	Three-dimension
CNC	Computer Numerical Control
CAD	Computer-aided Design
CAM	Computer-aided Manufacturing
CAPP	Computer-aided Process Planning
CATIA V5	Computer Aided Three-Dimensional Interactive Application
NC	Numerical Control

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ABSTRAK

Kesepaduan CAD/CAM telah meningkatkan kecekapan dan prestasi mesin CNC dengan sangat ketara. Bahagian yang rumit boleh direka dengan pantas dan tepat dengan menggunakan perisian yang membolehkan pengguna untuk melihat bahagian dan dimensi secara visual. Pakej CAM membolehkan bahagian yang rumit ini boleh dibawa ke dunia realiti dengan mengira laluan mata alat dan menulis kod untuk proses pembuatan bahagian ke atas mesin kawalan computer berangka (CNC) yang dipanggil sebagai G-kod. Mesin meja kisar CNC dicipta bagi membolehkan pemesinan di tahap kecil. Untuk meningkatkan had dan proses pemesinan mesin, beberapa komponen ditambah kedalam kawalan pemesinan di mana kelajuan kawalan gelendung yang mengaktifkan kod M03 untuk gelendung hidup dan mati manakala kod S untuk kelajuan. Kepentingan CAM/CAM dalam mesin CNC seperti ditunjuk di dalam projek ini dengan mewujudkan simulasi untuk pemesinan dalam FUSION360. Simulasi ini adalah untuk mengesahkan laluan mata alat untuk pemesinan dan menjana kod G yang diguna untuk mengawal mesin CNC. Model poket terbuka dicipta sebagai bahagian ujikaji untuk mengesahkan kepentingan parameter yang telah ditetapkan dalam pemesinan yang tertumpu pada variasi kelajuan gelendung menggunakan ujian kekasaran permukaan. Dari ujian ini, kekasaran permukaan meningkat dengan penurunan kelajuan gelendung. Set parameter untuk 1200 RPM diguna sebagai rujukan untuk perbandingan. Peratusan penurunan terhadap kekasaran permukaan jika kelajuan maksimum gelendung, 2000 RPM diguna meningkat sebanyak 8.09% manakala kelajuan minimum gelendung yang diguna untuk ujikaji, 400 RPM kekasaran permukaan meningkat dengan ketara sebanyak 40.42% dan menunjukkan pengaruh yang besar terhadap kelajuan gelendung terhadap kualiti permukaan pemesinan sesuatu produk..

ABSTRACT

Integration of CAD/CAM has significantly increased the efficiency and performance of CNC machining. Complex part can be designed quicker and accurately with software that enables the user to visually see the part and its dimensions using CAD. CAM packages allow these complex parts to be brought to life by calculating tool path and writing the code to manufacture the part on a Computer Numerical Controlled (CNC) machine that called G-code. The CNC Desktop milling machine created to allow the machining at small level. To improve the limitation and machining process of CNC Desktop milling machine, the few component are added into the machining controller that is spindle speed controller that activate the M03 code for spindle on and off and S code for the speed. The important of CAD/CAM in CNC machining are shown in this project by creating simulations for machining in FUSION360. The simulations are to verify the toolpath for machining and generate a G-code that used to control the CNC machine. An open pocketing modeling were created as the part for the experiment to verify the importance of the parameter that set in machining focusing on the spindle speed variation using surface roughness test. From the surface roughness test, the surface roughness is increased with the decreasing of the spindle speed. A set of parameter for 1200 RPM used as the reference for comparison .The percentage of the improvement on surface roughness if the maximum spindle speed, 2000RPM used is increase by 8.09% while when minimum spindle speed used for experiment, 400RPM the surface roughness increase significantly to 40.42% showed that the higher spindle speed with lower feed rate provide much better result for surface roughness quality.

CHAPTER 1

INTRODUCTION

1.1 Background

CAD/CAM has history in assisting in designing and high-speed manufacturing. Complex part can be designed quicker with software that enables the user to visually see the part and its dimensions using CAD. This allows complex designs to be made quicker, and more accurately. CAM packages allow these complex parts to be brought to life by calculating tool path and writing the code to manufacture the part on a Computer Numerical Controlled (CNC) machine such mill, lathe or EDM machine.

Highly automated CNC machine are needed so that human error is reduced and higher accuracy can be attained when manufacturing part that would be difficult to produce manually. The CNC Desktop Machine is a quite simple machine that is accessible for small and simple type of machining with some of limitation. Going through industry 4.0 where it will be more automated and less human engagement manually, it is important to overcome the limitation and be fit in the industry.

The integration between CAD/CAM becomes a thing that important in industry. The integration increases the accuracy, the quality of the components produce and also the manufacturing production rate. It’s not only shortens the times in production but also in the creation of NC programs for new component. This integration CAD/CAM integration allow the companies to quickly adapt to customer requirement and flexible in changing part production in industry. Main advantages of CAD/CAM systems include speed of creation of NC program for parts with complex shapes as well as the simulation of a whole machining process.

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1.2 CAD/CAM

Computer Aided Design (CAD) involves the use of computer hardware and graphics software to generate design drawings. Modern CAD equipment enables the designer to quickly produce very accurate and realistic images of products to be manufactured. Computer Aided Manufacturing (CAM) is a system that uses the models and assemblies created in CAD software to generate solutions that drive machine tools to turn designs into physical parts. CAD and CAM work together in that the digital model generated in CAD is inputted to the CAM software package that help replace the traditional that more prone to error and inaccurate.. The CAM software needs to know the physical shape of the product (CAD model) before it can compose a proper set of fabrication instructions to turn designs into physical parts. Although there a lot of stand-alone CAD and CAM software, there also companies that offer integrated of both application into one single system to help in reduce time and improve data transfer for drawing and simulation.

1.3 CNC Desktop Machine

CNC machines (machines that operate using Computer Numerical Control) expend mush more than realm of manufacturing shops especially the desktop CNC machines that are small enough to use and maintain at home. However, a variety of standard industry-size machines that commonly perform routine operations in the manufacturing industry, like milling and drilling. Desktop CNC versions of these machines also enable the user to perform similar routines for smaller part.

Desktop series of smaller, light weighted machines often offer by the companies that specialize in manufacturing CNC machine. Although Desktop CNC machines are slower and less precise, it can handle soft materials, such as plastic and foam very well. Machines featured in a desktop series are design to resemble the larger industry standard, but have size and weight that make them better suited on small applications.

Figure 1-1 EMCO F1 MILL

The CNC milling machine is an EMCO F1 CNC Mill produced in 1991 and is an educational 3-axis vertical / horizontal milling machine type of machine. This machine can machine part dimensions up to maximum 200 x 100 x 50 mm. It has 3 – 15 mm milling tools diameters and the tool changing is manually done. Feed drive for the step motors in X/Y/Z with a resolution of 0.01mm and the feed rate are 0 – 400 mm/min with rapid traverse 600 mm/min. the spindle speed can rotate maximum 2000 rpm. This machine use ISO CNC – RS274D as programming language with RS 232 – 300 bps PC communications.

The CNC machine is programmed using the ISO CNC language, known as G-Code. Moving instruction generate a line or an arc. Each moving instruction has as parameter the destination point coordinates. The moving instructions that generate circular trajectories include also the circle (arc) center coordinates.

1.4 Problem Statement

CNC Desktop Machine is a 3-axis machines that fairly standard and quite simple that designed for simple and small milling process. This machine has few limitation and disadvantages that may affect it performance and quality of part produce such as still part that needed require human involvement in the machining process. The limitation may disturb the machining process so it should be functioned fully automated by improving machine component part that manually functions. There are few CAD/CAM software are being used for integrating with CNC machining in setting up the parameter of machining and provide simulation before actual machining , so it is need to utilize to find the best machining parameter in designing and manufacturing product using CNC Desktop Machine.

1.5 Objectives

This project has objectives that need to achieve based on designing and also the fabrication. The objectives of this project are:

- To investigate the limitation and the disadvantages of CNC Desktop Machine, EMCO F1 Mill.
- To design a solution to overcome the limitation by integrating with CAD/CAM system.
- To verify the important machining parameter in improving machining quality on CNC Desktop milling machine.

1.6 Scope of the Project

The scopes of work were focusing on to develop a solution to overcome the limitation and the disadvantages occur on the CNC Desktop Machine at Proton Lab. Literature research into EMCO FI mill and few commercial CNC desktop machines was conducted and benchmarking analysis are done to compared the feature and performance.

A few components were added as result in solution that developed. The new designed improvement is integrated into CAD/CAM to generate the CNC G-codes to move the component. A simulation on machining parameter was done in the Fusion360 software verified then G-code is generated to produce part by the EMCO F1 mill. An experiment are based on the machining parameter focusing on spindle speed are conducted. All the planning process step involves in this project are described in the methodology.

1.7 Outline of Thesis

This thesis consists of 5 chapters which are:

Chapter 1

This chapter includes project background, problem statement, project objectives, scope of project and thesis organization.

Chapter 2

This chapter includes all the review of the other literatures that had done the research which is related with this project.

Chapter 3

This chapter will explain about the methodology of the project. The content includes the flow chart of project, benchmarking, concept scoring, and component use, integrating process, G-code generation, machining simulation and testing.

Chapter 4

This chapter will include the result and discussion of the project. The data that acquired from this project will be analyzed and will be compared.

Chapter 5

The last chapter is about the conclusion and also the future work will be included in this chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

With the rapid development of manufacturing technology, a lot of researcher has done study on this integration and machining topic .This chapter explains the literature review of the integration of CAx chain, CNC controller software evolved in the market, CNC machine and others. In CAx chain, the integrated is constructed consist of development of CAD, CAM, CAPP and CNC technologies. Besides that, the theory of CNC machines is also explained and illustrated in this chapter. In addition, the review is based on the searching information from other sources which is comprised into three main sources such as internet websites, book, and journal or article. Suitability is required to make sure information obtained is adaptable and beneficial for the further step.

2.2 Integration of CAx

CAx system is the combination of various IT-systems that contain the general product development that is divided into three phase: creative, conceptual and engineering phase [1]. The system is done in flow chart and the integration of those systems together called CAx chain. Figure 2.1 show the three step in shows the flow which involves in CNC software.

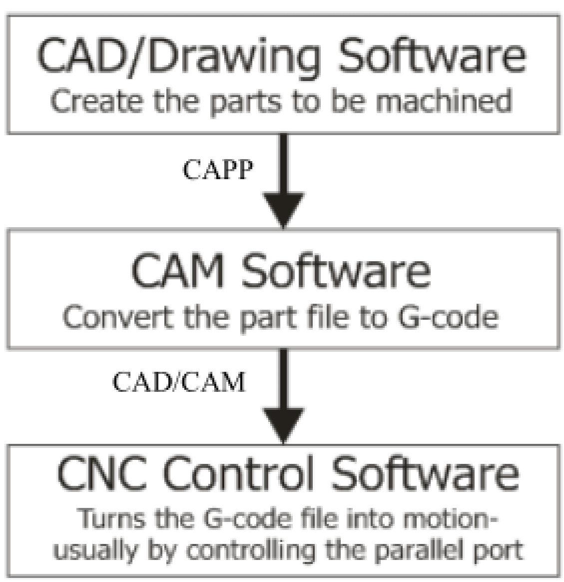

Figure 2-1 Basic flow process involves in CNC software

Computer-aided design (CAD) is the use of computer to aid in the creation, modification, analysis, or optimization of a design [2]. The early version of Computer Aided Design (CAD) systems were designated in especially for two-dimensional drawing and drafting. Before the development of cad system, computer has been long used for engineering calculation. In 1963, Dr. Ivan Sutherland, an American scientist has developed Sketchpad system at MIT that later becoming a major turning point in CAD systems. The Sketchpad is considered as the starting of the modern CAD and computer graphic as well. It supported the manipulation of objects using a light pen, including grabbing objects, moving them, changing size, and using constraints. It contained the seeds of myriad important interface ideas [3].

Entering the new era of CAD system in the 1970s, CAD are going from only able to create basic 2D drafting to able to create three-dimensional (3D) wire-frames, to 3D surfaces and also complex 3D solid modelling .3D solid modelling especially is gaining more attention [3]. It creates unambiguous and complete geometric representations of objects unlike wire-frame models that are ambiguous in the sense that several interpretations might be possible for a single model. With the unambiguous and complete geometric representation of object, an engineering analysis also can be performed on the model created. Solid modelling has few type of method used but most commonly used is two basic methods that is Constructive Solid Geometry (CSG) methods, and Boundary Representation (Brep) methods. CSG uses solid primitives (rectangular prisms, spheres, cylinders, cones, etc.) and Boolean operations (unions, subtractions, intersections) to create the solid model. Solid modelling has become more popular and develops so much until now and become common practice in commercial CAD software to design and analysis models. Nowadays CAD is not limited to drafting and rendering, and it ventures into many intellectual areas of a designer's expertise, such as engineering analysis and assembly simulation.

The CAM technology research and development happens after the invention of NC machine tools were first introduced in the early 1950. In industry, CAD techniques are extensively used to design products, and CAM techniques are used to manufacture the products. Computers were introduced into manufacturing to compute and control the cutter motions of machine tools. New languages are being developed to understand and to extract the shape information of a part design from engineering drawings. Current NC programming is based on ISO 6983 (ISO 6983 1982) [4] called "G-code", where the cutter motion is mainly specified in terms of position and the feed rate of axes. The G-code used extensively on CNC machine to specify a sequence of cutting tool movements as well as the direction of rotation, speed of travel and various auxiliary functions. These NC program is difficult to create of edit by hand since it is so long and every step movement involve must be specify precisely. A simple NC program can be done manually but with the help of calculator. If larger and complex program, it is almost impossible and very time consuming to create it. The manually generated NC program also subjected to error due to human mistake [5]. CAM was developed to get the NC program to generate automatically on the computer.

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N0010 G40 G17 G90 G70
N0020 G91 G28 Z0.0
N0030 T01 M06
N0040 G00 G90 X4.2445 Y-9.8098 S500 M03
N0050 G43 Z5.9207 H00 M08
N0060 G81 Z5.7644 R5.9207 F10.
N0070 G80
N0080 M09
N0090 G00 Z8.
N0100 X3.6 Y-9.2
N0110 M02
```

Figure 2-2 NC programs for a drilling operation [6]

The integration of CAD/CAM is important to the industry as it is use very widely to assist designing and manufacturing process [7]. A study on the critical success factors for integration of CAD/CAM by using the ERP system was addressed that the effective implementation of CAD/CAM systems offers manufacturers a number of benefits such as: cutting design costs, reducing cycle time, reducing matching time and improving information flow. To achieve success, a set of critical success factors (CSF) proposed for the integration of CAD/CAM with ERP systems.

Later on, CAD/CAM technologies have continued to evolve. Current major commercial CAD/CAM systems such as Unigraphics, Pro/E, and CATIA V5 have many specialized modules packed together and running on their own proprietary databases. The study the implementation CAD/CAM system CATIA V5 and proves the relevance and coherence of the new technologies, materials, machinery, progressive methods and information tools that enable more efficient use of starting materials to produces lower costs [8]. The manufacturing process was first designed using CAD system and simulated using the CAM system. A significant reduction in production time contributed towards lower production costs. Machining process is based on empirical and theoretical relationship between cutting conditions. Manufacturing operations and instruments were chosen with respect to the geometry and the required precision assembly.

Data exchange is the one of the important part in integration between CAD/CAM systems. To share a share feature-based computer-aided design (CAD) models has always been challenging problem [9]. A study has done to present a new asymmetric strategy to enrich the theory of feature-based interoperability, especially when describing singular feature or singular sketch. From experiment, the new approach purposed manages to maintain a sufficiently high geometric fidelity, and ensure that the exchanged model of the target CAD system can be parametrically edited. With the development of technology, different vendors of CAD/CAM and CNC may cause the rise to a heterogeneous application environment in data exchange [10]. To support the data Flow STEP (ISO 10303) and STEP-NC (ISO 14649) data models are used. A study has develop a mechanism that can provide the right amount and right level of product data subset to the users based on these models that enables the users to work on desired scope of data without interfering other data.

Processed planning is the key that connects between CAD with CAM system.it is a process of determine detailed operation information and use it to transform an engineering design into the final part [5] Processed plan before often can only generated by the skillful experienced person that has plenty of manufacturing information knowledge. CAPP is being developed by computer technologies to simplify and improve process planning information effectively. The goal of CAPP is to generate a sequenced set of instructions used to manufacture the specified part, which then can be applied to downstream applications, like CAM.

The usage of integration of CAPP with CAD/CAM focuses on enhancing the link between process planning and machining [11]. Product, process planning and also machining feature information are transferred from FBMach to UG through the integration layer. With the process plan, machining operation is created and tool path are generated in UG. Machining feature is utilized to define machining geometries and eliminate the user involvement. Tool paths are automatically generated once the features are recognized and the process plan is generated from the solid model the information.

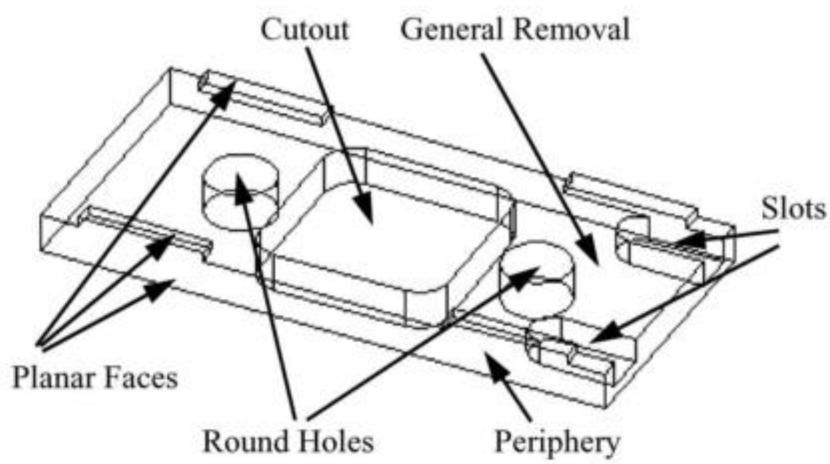

Figure 2-3Type of machining features in the test

In CAD/CAM integration process feature recognition is the important link. It forms the basis for extracting the design features generated from the CAD files and relates them to the CAM in a more meaningful way. An attempt to introduce a computer-integrated system for design feature recognition in order to achieve automatic process planning are being developed [12]. Two modules were proposed; (1) STEP feature recognition module to extract a solid design model, which is converted to group technology (GT) code that can be used as input data to recognize feature patterns. (2) Rule-based process planning module to map the features.

A study are done to addressed issues related to automating the task of process planning and of integrating this automated CAPP system with a commercial CAD/CAM system (I-DEAS) [13] .CAPP is achieved by automatically extracting machining features from the CAD model and then using the machining knowledge stored in these features to carry out process planning. The integration of the CAPP with commercial CAD/CAM systems results in significant reduction in user effort and time spent compared with the existing commercial CAD/CAM systems. All the process planning tasks of identifying faces to be machined, selection of tools and operations, machining parameters, etc, which need to be done manually in the commercial CAM systems are automated. This also allows people with less experience to be capable of producing reasonable process plans with minimal effort.

Process planning also useful in manufacturing of complex and continuously changing process [14]. An integration of automatic feature recognition and group technology is used to eliminate manual planning and shortening the planned lead time. This method are managed to prove the 90% reduce the working time are achieved.

2.3 CNC Machining

For several years, rigorous research has been conducted in the area of CNC milling machine from diverse perspectives.

A literature survey that captured the important area of pocket machining, which includes the machining of mechanical parts, dies and moulds are reported[15]. The relationship among shape, cutter, machine tool and cutting conditions in the optimization process of cost and lead time of pocket milling are investigated. The results of their review showed the geometric aspects of pocket extraction and tool path generation with the optimization of cutting conditions as an impact to the process planning of the CNC machining of pockets.

NC tool-path generation presented strategy having a tool engagement control system that reduces machining time and tool wear suitably fit for use in high-speed machining [16]. The system was designed for arbitrary complex discrete part geometry. The authors developed the tool-path computation based on image models for design part, raw stock and cutting tool. The pixel-base simulation of the milling process also involved. This method is claimed successfully compared to the previous one.

Surface roughness prediction from extended from the author previous work to incorporate the step over ratio integrated with cutting speed, speed rate and depth-of-cut. The study focused on the role of the step over ratio in surface roughness prediction studies in flat end-milling operations. ANN was applied using the experimental data collected from the study, with its structures trained and tested by using the measured data for predicting the surface roughness [17]. It was concluded that the model, which incorporated step over ratio was capable of predicting the average surface roughness (Ra) with a good accuracy. Process controlled presented using the CNC milling machine-tool together with CAD/CAM master Cam system and a smooth forming tool [18]. The study has defined the experimental testing and measurement with and without a full-size model.

The influences of the tool path strategy are discussed on the cycle time of high-speed milling operations [19]. Pocketing operation with a zigzag toolpath is focused in the experiment that quantifying significant discrepancy between programmed feed rate and the actual average feed rate. Mechanic approach for cycle revolution is followed on work. The mechanistic model is constructed based on the experimental measurement of the machine tool acceleration and specific geometric assumptions regarding tool motion. the influence of the zigzag tool path orientation on the machining cycle time are manage to be captured using this approach.

To reduce machining time in roughing process in production, a study has carried out on two software that use in designing and producing NC CODE of tools, CATIA V5 and MASTER CAM [20]. This study simulate tool-path planning based the machining time display by the both software then verified the most suitable toolpath strategy that consume less machining time.

A practical approach to generating accurate iso-cusped tool path in the process planning of sculptured surface parts was contributed [21]. The authors noted that the approach has implementation feasibility in manufacturing industry where it could be integrated in to the computer–aided manufacturing software systems, which will ultimately promote the usage iso-cusped tool paths.

A theoretical and experimental methodology for the efficient planning of finishing end-milling operation for machining a pocket-type contour are reported [22] with the focus was to overcome human error in the system and generate better cutting conditions for given tool path. With the development of geometric relationship among the cutting tool, corner– milling operation and machine surface, a mathematical model that described the cutting phases during the corner cutting was developed, optimized and experimentally verified. It was concluded that the optimized model was efficient, exhibiting "in-tolerance" accuracy and surface roughness.

An in-process surface recognition system is use to measures surface roughness during end-milling [23]. Intelligent hybrid software-fuzzy-nets are used as the framework of the system and the hardware components that consist of a sensor tested, which assesses the real-time surface of a work piece with which information on the achievement of quality standard could be met.

. A single-response study provided base in determining the parameters that were studied. The case studies conducted at the laboratory have prompted for the real-time studies and to find the solution for the manufacturing firms around the place. Gene expression programming method are claimed can be used to predict the surface roughness of milling surface with related cutting parameters (i.e. cutting speed, feed and depth-of-cut of end-milling operations) [24]. The work concluded that the linear equation developed suitably predicted the surface roughness of the work piece from experimental study.