STEP-NC CODE GENERATOR FOR DRILLING OPERATION USING GEN-M

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ABSTRACT

STEP-NC used to transfer machining data between STEP-NC compliant Computer Aided Design (CAD), Computer Aided Manufacturing (CAM) and Computer Numerical Controller (CNC). It has gain worldwide consent when International Standard of Organization (ISO) has established a new data model for ISO 14649. By implementing STEP-NC, profitable and intelligent manufacturing are very convincing. It overcomes G & M code weakness which has thousand lines of codes but none of them define the machining process. In order to create a complete chain of STEP-NC system to be a new way of producing product in manufacturing environment, a new CNC machine and CAM software that compliant to STEP-NC has to be developed. This research is a software development that name as GEN-M using Visual Basic.Net 2010. The success of GEN-M development contributed a new application to serve new manufacturing environment in generating STEP-NC code for machining. Although there are many researches produces new application software, GEN-M can be a variety of CAM software that compliant to STEP-NC. More over GEN-M have few attractive functions such as redirecting users to a website for seeking about STEP-NC information; email the generated STEP-NC program to other parties and more. GEN-M is successfully developed where the verification process which is the generated code by GEN-M is compared to ISO 14649 Part 11 gave less number of different with reasonable cause and more similarities for related entities. Therefore the software is capable to generate code for drilling referring to selected case study from Annex F (Example 1) in ISO 14649 Part 11. This research can be a stepping stone to the next level of research.

ABSTRAK

STEP-NC berfungsi untuk menghantar data pemesinan antara *Computer Aided Design* (CAD), *Computer Aided Manufacturing* (CAM) dan *Computer Numerical Controller* (CNC) yang mematuhi STEP-NC. Ia mendapat perhatian dunia setelah *International Standard of Organization* (ISO) mengeluarkan data model untuk ISO 14649. Dengan melaksanakan STEP-NC, pembuatan pintar dan memberi keuntungan kepada pembuatan lebih meyakinkan. Ia mengatasi kelemahan kod G & M yang mempunyai beribu baris kod tetapi tiada satu diantaranya mendefinisikan proses pemesinan. Untuk menghasilkan satu kitaran lengkap bagi sistem STEP-NC, mesin CNC dan perisian CAM baru yang mematuhi STEP-NC harus dihasilkan. Kajian ini ialah pembangunan perisian yang dinamakan sebagai GEN-M menggunakan Visual Basic.NET 2010. Kejayaan pembangunan GEN-M menyumbang satu aplikasi baru untuk bekerja pada persekitaran pembuatan yang baru bagi menjana kod STEP-NC kepada pemesinan. Walaupun terdapat banyak kajian bagi menghasilkan aplikasi perisian yang baru, GEN-M boleh menjadi satu variasi untuk perisian CAM yang mematuhi STEP-NC. Malah, GEN-M mempunyai beberapa fungsi yang lebih menarik seperti mengubah hala pengguna daripada GEN-M ke laman sesawang untuk mencari maklumat berkaitan STEP-NC; menghantar emel kepada pihak lain dan banyak lagi. GEN-M dianggap berjaya dibangunkan apabila proses verifikasi dimana, kod yang dijana oleh GEN-M dibandingkan dengan *ISO 14649 Part 11* memberikan jumlah perbezaan yang sedikit dengan sebab yang munasabah dan lebih banyak kesamaan untuk *entities* yang berkaitan. Oleh itu, GEN-M telah berjaya dihasilkan di mana ia berupaya untuk menjana kod STEP-NC bagi proses ‘drilling’ merujuk kepada kajian kes yang dipilih iaitu *Annex F (Example 1) in ISO 14649 Part 11*. Kajian ini boleh menjadi batu loncatan untuk kajian pada tahap yang seterusnya. .

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

ANSI	-	American National Standards Institute
CAD	-	Computer Aided Design
CAM	-	Computer Aided Manufacturing
CAPP	-	Computer Aided Process Planning
CNC	-	Computer Numerical control
DFX	-	Drawing Exchange Format
DWG	-	Drawing
EDM	-	Electric Discharge Machining
EIA	-	Electronic Industries Alliance
F	-	Feed rate
G	-	Preparatory functions
GUI	-	Graphical User Interface
IGES	-	Initial Graphics Exchange Specification
ISO	-	International Organization for Standardization
M	-	Miscellaneous
MDI	-	Multiple Document Interface
MIT	-	Massachusetts Institute of Technology,
NC	-	Numerical Control
PDM	-	Product Data Management
R	-	Radius
S	-	Spindle speed
SQL	-	Structured Query Language
STEP	-	Standard for the Exchange of Product model data
T	-	Tool
VB	-	Visual Basic
XML	-	Extensible Markup Language

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Research background

The revolution of Computer Numerical Control (CNC) started at the end of Second World War. It was first discovered by John Parson in 1949 (Seames, 2001). Early CNC machine received command from punch card and tape and later computer was introduced to aid the programming (Seames, 2001). CNC may be unfamiliar term to some people but without notice, it has touched a lot of aspect in the daily life where many types of equipment are machined by CNC such as medical equipments, cutleries, war weapons and transportation. In mass production, CNC seems to have met the requirement in giving profit to manufacturers. Products are easily, faster, and repetitively produced using automation system (Smid, 2003).

Current manufacturing cycle involve processes to machine a workpiece started by designing the part with Computer Aided Design (CAD). Then it transferred to Computer Aided Manufacturing (CAM) with variety of file format such as DFX/DWG, IGES, ACIS, Parasolid and native CAD. CAM will develop the machining process using postprocessor which convert the process to G & M code. In mass production, this code seems to be not practical to the manufacturers because thousand lines of G & M codes become a drawback and seem to be a bottleneck to CNC system. None of the line describes the overall process of the machining

(Thilmany, 2007) and the program is limited with information only on machine movement and some special features such as coolant. Data exchange with variety of file format is also sticky, when some file is broken and missing due to CNC vendor specific features. Therefore, it always needs new postprocessor every time to start new work piece machining. Due to the limitation of this code, STEP-NC was developed to replace ISO 6983 (Callen, 2002).

Modern manufacturing industries demand CNC a higher level input language than outdated G & M, and less proprietary vendor dependencies. In order to generate G & M programs for different CNCs, CAM tools need to know not only the particular brand and model of a CNC, but also need to have a detail description of the machine tool and their peripherals such as cutting tools and other auxiliary components (Xu et al., 2006).

This information is being handled by a special unit within a CAM tool called postprocessor. The ability to generate an Numerical Control (NC) tool path is now commonplace from CAD/CAM systems, but the technology used to program NC machines is still based on 1950's standards which is known as G & M code (Smid, 2003).

It is almost fifty years G & M code used in manufacturing industry to machine part (Suh et al., 2008b). Along the way, a lot of enhancement constructed to enhance the way data transferred between CAD/CAM and CNC so it is easier, faster and agile around the world. In fact, the data is adaptable and able to be used at any brand of CNC machine with ignorant to the vendor specific function. This way, the G & M code does not need to recode again. There is no doubt CNC machine is becoming more advance to machine part but the problem of limited information in G & M code and limited data transfer is still there.

ISO 14649 which also known as STEP-NC is still in improvement phase with various research around the world where there are striving to create data transfer medium (software) with a lot more features (International Organization for Standardization, 2003). Due to the low STEP-NC research and acceptance in Malaysia, research is at low level and a lot of thing is possible to explore. As a suggestion to boost the research activities, a group of expert should form a committee to share knowledge, experience and expertise.

The development of the ISO 14649 data model gains significant impetus on the way to becoming an International Standard, the issues of how to create

CAD/CAM system that are the ISO 14649 compliance and their levels of compliant will depend on the industrial use and software vendors acceptance of the standard (Smid, 2003).

Currently, research on STEP-NC is getting improved and when it is come to the implementation it is believed to be the remedy of G & M code's drawbacks. STEP-NC will affect the manufacturer and production that uses CNC's machine with G & M code program where the limitations of G & M codes make data transfer not agile and sharable with the CNC's machine commonly is vendor specific design. From 1996 where ISO 14649 has been established until today, STEP-NC had catch worldwide concern and many researchers had take an opportunity to explore the STEP-NC, which they believe to be the remedy of G & M codes (Ibrahim, 2010; Minhat et al., 2009; Suh et al., 2002; Yusof et al., 2009).

After many years of effort, adaptation of STEP-NC has not started yet. CAM vendors have to add system interface that write STEP-NC data while CNC machine makers have to add interface to read data (Thilmany, 2007). Moreover, without necessary demand vendors are hesitant to invest. CAD/CAM/CNC vendors make their system specific and special. They are unwilling to reveal their algorithms. However, to put STEP-NC becomes reality full collaboration between CAD/CAM/CNC vendors has to be developed. The research questions that describe the goal of this study are listed as following:

i. What is needed to understand the fundamental of STEP-NC?
ii. How to create software to generate STEP-NC codes?
iii. How to verify the generated STEP-NC program by developed software?

1.2 Research importance and impact

This research is important in order to bring a new machining environment in manufacturing industry especially in Malaysia. As STEP-NC can bring ease and agile data transfer, it is an opportunity to develop a system that may replace the old system thus it makes variety in manufacturing industry.

Other significant of this research is to promote the advantages of STEP-NC. This will open an opportunity to hold cooperation between researcher in universities, manufacturing industries, users, software developers and CNC vendors. Consequently, this research brings understanding to ISO 14649 fundamental and concept behind it as the standard is the brain to the key in developing software to generate STEP-NC code. This research is also to bring understand to ISO 14649 fundamental and concept behind it, as the standard is the brain to the key in developing software to generate STEP-NC code.

In the future, STEP-NC promising great profits to current manufacturing environment which it do not have to depend on CNC machine special function that has a postprocessor, where STEP-NC Controller is more to be more open, intelligent and interoperable (Xu et al., 2006). In this way, G & M code is no needed to be generated again and again due to many kind of CNC controller brand. Data transfer also can be done in anytime at anywhere. STEP-NC does not have to repeat the process cycle of machining again. Correction of machining data can be done directly in shop floor stage when STEP-NC controller is success to develop. Hereafter, with one click on the internet, data can be shared all over the world. STEP-NC controller not only can machine part due to the machine movement but it will understand the overall machining process including geometry and its machine technology.

1.3 Research objectives

The objectives of this research are:

i. To develop a software that capable to generate STEP-NC program for drilling in case study.

ii. To verify the generated program from the developed software with ISO 14649.

1.4 Research scope and limitation

The scope and limitation of this research will include as following:

i. The software is built to generate the STEP-NC code for drilling.

ii. This software is declared as non-commercialized application.

iii. The development of software is built using Visual Basic.Net 2010.

iv. The verification is a comparison of the generated STEP-NC program by GEN-M with the existed STEP-NC program in Annex F (Example 1) in ISO 14649 Part 11 for drilling.

1.5 Thesis organization

This thesis is organized into five (5) chapters. Brief descriptions of each chapter are as following:

Chapter 1 describes the purpose of this thesis which encompasses the background and problem statements, the importance and impact of research, objectives, scope, and limitation in this thesis. Basically it visualizes what the research is about.

Chapter 2 is focus on the deep explanation of research background that tells the revolution of CNC usage in manufacturing industry. A summary of history background on discovering of CNC will picture the significant of CNC usage in daily life. This chapter also comprises the theory and basic fundamental of STEP-NC. Other researches regarding STEP-NC were reviewed and self point of view is inserted. It also includes with the analysis of NC and STEP-NC program and it result. From the literature review, a specific goal and direction of this research is determined. It provides an understanding on the fundamental knowledge regarding STEP-NC and how the research has been done.

Chapter 3 presents the methodology used in this research. It mainly contains how the research was conducted. The chapter contains of the research procedure of GEN-M development, selected case study, instrument and verification procedure.

Chapter 4 shows the implementation of GEN-M and lastly is chapter 5 that recaps the research work and the contribution from this research. Lastly the suggestions to extend the research work and conclusion were made from what have been done.

1.6 Summary

This chapter gives basic overview of fundamental ideas on the research is about. It has outlined the objectives of the research, scope and limitations, and problem statements.

The following chapter is the anecdote of the research background that becomes a motivation to conduct this research.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This literature review chapter contains the review of researches that has been done in the past ten years. It also describes the revolution of machining from conventional skills and machinery to modern CNC. A brief description on STEP-NC is also included to picture how it was discovered.

A comparative study between NC and STEP-NC program is also included. The comparative study contains of NC and STEP-NC program analysis and the result of analysis. This research is also added with some interviews to gain information and suggestion regarding STEP-NC that might help this research. The interview work is included in Appendix A.

Critical review and author's opinion of the review are also included. Previous researches that have been focused to set the direction of this study are on fundamental content of STEP-NC. From this literature review, points that have been succinct are the revolution or development on STEP-NC around the world, the expansion of STEP-NC in Malaysia, and the programming language that has been used to develop software to generate the STEP-NC code. Besides that, research that has been patented was also been covered and explained. Therewith, this part will picture why this research is needed.

2.2 Manufacturing cycle

Basically, in manufacturing process, it started from generating ideas and then the idea will be depicted into a sketch drawing. Nowadays, CAD is used to visualize the idea. CAD assist engineer to design part from simple line to 3D solid model. After designing with CAD, the drawing will be sent to CAM to generate machining tool paths based on user instruction (Kalpakjian et al., 2006). CAM assembles a series of these commands into machining instruction and converts all of it to G & M code that the machine controller can understand with a postprocessor. Postprocessor is a translator that allows the CAM software to understand the way CNC system work (Smid, 2003). Figure 2.1 depict the flow of machining process using CAD until part is machined using CNC system.

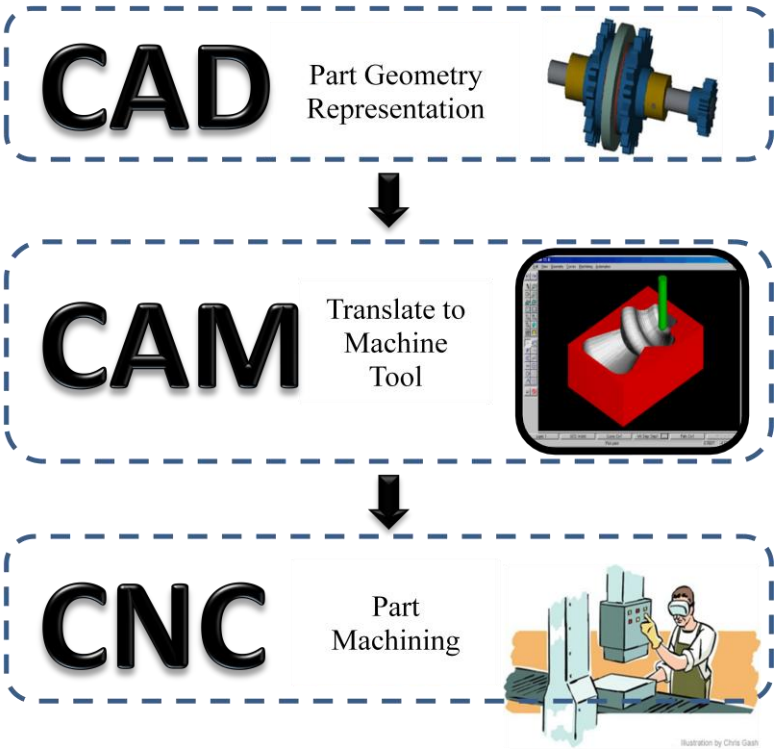


Figure 2.1: Manufacturing flow

2.3 G & M code weakness.

Manufacturing in its definition is “made by hand” (Kalpakjian et al., 2006). Inside a room, many things can be found which all of them manufactured by human. In real manufacturing industry, many components used to create products are made individually. An example is a printer where each component that builds a printer may be produced by different department or even different factory. All parts that are used to build one product will undergo basic manufacturing flow. It starts from consumer demand, designing, selecting raw material, production batch, inspection, warehouse and shipping to market. The manufacturing process will take a long way and time but in real world, manufacturing become rapid and productivity is one of important factor to ensure products will reach the market in the shortest time as possible. Looking back to the older times, manufacturing started since the primitive era where human survive their everyday life by carving tools and equipments by using their hand. They invent things to ease their everyday lifework. They use raw material such as wood, stone, gold, bronze and suitable material they can get. They carved stone, chiseled wood, and made pottery to create new things. A person instinctively knows how to create and innovate things to support their daily life. From time to time people start creating something that more advanced, sophisticated and ease their work by using high technology that are available in line with the manufacturing era. People start to know how to use technology where they come out with simple machine with mechanical features such as gear, level, handle and dial. Equipment such as spinning wheel, waterwheel, tackle and windmill help people decrease on the work force used while more output can be obtained.

When Industrial revolutions start in 18^{th} to 19^{th} century (Smid, 2003), it has a major impact on manufacturing, agriculture, transportation and culture of the society. It has changed the way people work and recognized as a major development for world history. They started producing products in enormous batch and selling their products all over the world. Transportation has become more agile and mobile. Horses and boats were not the main transportation, but it has been replaced by steam car and train. Textile industry has improved when spinning wheel is not used anymore but has been substituted with a machine that can produce a lot more products. All manufacturing process becomes more rapid and productive.

Numerical Control (NC) technology arrives when John Parson (1949-1955) (Smid, 2003; Olexa, 2001) at Massachusetts Institute of Technology (MIT) USA succeeded inventing rotor blade for helicopter where IBM computer was used and after few years later in 1955 NC is available in manufacturing industries. NC used a fixed logical function built in and permanently wired within the control unit. The function cannot be changed by machine operator thus its call as hardwired control. NC is an office environment where all changes are done away from the controller. In early NC system, punch tape was used as input for the programmed (Smid, 2003), CNC then arrived where it is called soft wired control (Smid, 2003) which used an internal microprocessor (a computer) but correction was still done away from the controller. There are various types of CNC machines that will do various task. Example of CNC machines that are currently available are mill and machining centers, lathes and turning centre, drilling machines, boring mill and profilers, Electrical Discharge Machining (EDM) machines, punch press and shears, flame cutting machines, routers, water jet and laser profilers, cylindrical grinders, and welding machines (Smid, 2003). As many of CNC machine type, plenty of machining work can be done repetitively without any concern to human weaknesses. The benefits (Smid, 2003) of using CNC machine are as the following list:

i. Setup time reduction
ii. Lead time reduction
iii. Accurately and repetitively
iv. Contouring of complex shape
v. Simplified tooling and work holding
vi. Consistent cutting time
vii. General productivity increase

Today manufacturing is far more advance and the competitiveness among manufacturer are very challenging. Without suitable technology, manufacturing process from design to production will be delayed and it cannot arrive in the market in the time demand. The intense of competition among manufacturers to deliver product into market in the earliest time made manufacturing environment face the rapid changes. The shifting involved many issues and the ultimate result is to achieve the highest technology, practicality in every production method and data

sharing between manufacturers is reliable as production of product may engage a few factories. CNC system is the brain of manufacturing system and allows a great deal of speed and precision, along with almost perfect repeatability. These factors combine to allow high tolerance parts to be created quickly.

Currently, many devices such as floppy disks, USB flash drives and local area networking has replaced the punch card on the NC controller; however there are controllers that still use punch tape to store machining data. Data transfer is an important thing to assure all parts design is linkable and can be read by others. However, G & M code has become a bottleneck for manufacturing process and even to develop a new generation of CNC system (Xu et al., 2006). There is no doubt that CNC system becoming more advanced and sophisticated but the drawback of the system is it still uses the old code which is the G & M code to transfer data. G & M is under ANSI standard (Kramer, 2007) code was developed by Electronic Industry Association (EIA) in the early 1960s. The code was revised and approved in year 1980 (Kramer, 2007). G & M code was also known as ISO 6983 and RS 247D (Kramer, 2007; Xu et al., 2004). CNC system should have replaced the used of the old code, to make the system more intelligent, autonomous and multifunctional (Xu et al., 2004).

2.4 Analysis of NC vs. STEP-NC program

From the analysis between NC and STEP-NC program, the analysis depicts the difference of each program. The finding that going to be explained will render on the character of code, the code arrangement, information that include in coding and the similarity of the code.

2.4.1 Code arrangement

STEP-NC program have more information regarding machining is put inside the program. The program must start with project and workplan as it is the executable to the whole program. It is not a compulsory that the arrangement of code is set up in certain line but it may be any line in the program. However, the entity in the program is linked to each other.

In NC program, the program start with the selection of tool and changing of tool is needed. After selecting the tool, the spindle speed and its rotation is selected. Then the position of tool is decided due to the XY plane. Tool length offset will be set and for every time of features machining the CNC system will on the coolant. When starting the machining process, the machine is first determine the fixed cycle, Z cutting motion and define the feed rate of tool. For each time of end features machining the tool will go back to Z0 and spindle motion is stop. In between the program, there will be the temporary stop for machining and lastly the CNC system end the machining process. The program is read line by line down forward where it also called as one dimensional data flow.

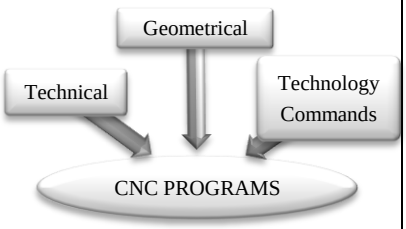
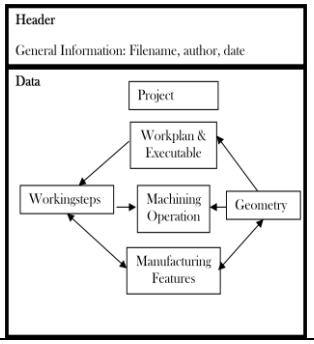
2.4.2 Character of code

Each program obviously shows the differences of the characteristic. STEP-NC program is written with respectively identifier to each entity that symbolized with # and followed by number.

NC program is written line by line and the line of command is called block. Each block will include with Word and followed by Number. The Word symbolized the function to command machine to do the machining. For G function which also preparatory function and M function the numbering also symbolized a command for machine. Other numbering symbolized the type of tool, amount or value needed for each function. In machining, it can conclude that the compulsory wording needed in

machining is G, M, T, S, and F. In NC programming there are few symbols to command the machining. From the analysis there is few special token used for NC operation (Seames, 2001). The differences are depicted in Table 2.1.

Table 2.1: Character of code

CHARACTER	NC PROGRAM	STEP-NC PROGRAM
Developer of codes	EIA and NIST	International Standard Organization (ISO)
Other name	ISO 6983 / RS 274 D	ISO 14649
What build the codes	Binary number	Express Schema
Code structure	Made up from sets of block that contains words which is an address registrar and followed by value. 	Consist Project, a set of workingstep and workplan 
Code character	• Depend on operator skills • Proprietary dependency • One way data flow • Long command line for simple geometry • Unintuitive commands • Difficult to exchange information • Difficult to update and reusability • Data sharing is impossible.	• High level language (EXPRESS) • provides a complete and structured data model linked with geometrical and technological information • No information is lost • No post processor • No vendor specific
Programming language	Low level language (binary code/machine language)	High level language
Data Format	O0000 (ANNEX F DRILL) G21 G0 G17 G40 G80 G90 / G91 G28 Z0. / G28 X0. Y0. / G92 X250. Y250. Z250.	ISO-10303-21; HEADER; FILE_DESCRIPTION(('ISO 14649-11 EXAMPLE 1', 'SIMPLE PRORGRAM WITH A PLANAR FACE, A POCKET, AND A ROUND HOLE'), '1'); FILE_NAME('EXAMPLE1.STP', '2002-02-02', ('YONG TAK HYUN','JOCHEN WOLF'), ('WZL, RWTH-AACHEN'), $, 'ISO 14649', $); FILE_SCHEMA(('MACHINING_SCHEMA','MILLING_SCHEMA')); ENDSEC; DATA; #1= PROJECT('EXECUTE EXAMPLE1',#2,(#4),$,$,$); #2= WORKPLAN('MAIN WORKPLAN',(#10,#11,#12,#13,#14),$,#8,$); #4= WORKPIECE('SIMPLE WORKPIECE',#6,0.010,$,$,$,(#66,#67,#68,#69)); #6= MATERIAL('ST-50','STEEL',(#7));

2.4.3 Information in coding

The analyses it can be recognized that information in both program is vary from each other. The information and its differences are pictured in Figure 2.2.

In NC program that involved in CNC most information is regarding to the machine setting rather than to describe the part that going to be machined. Less information is on tool and the part. In CAM and CNC system users can check the information of part from CAM software which has detail information inside. However not everybody is able to use and understand to run the CAM software.

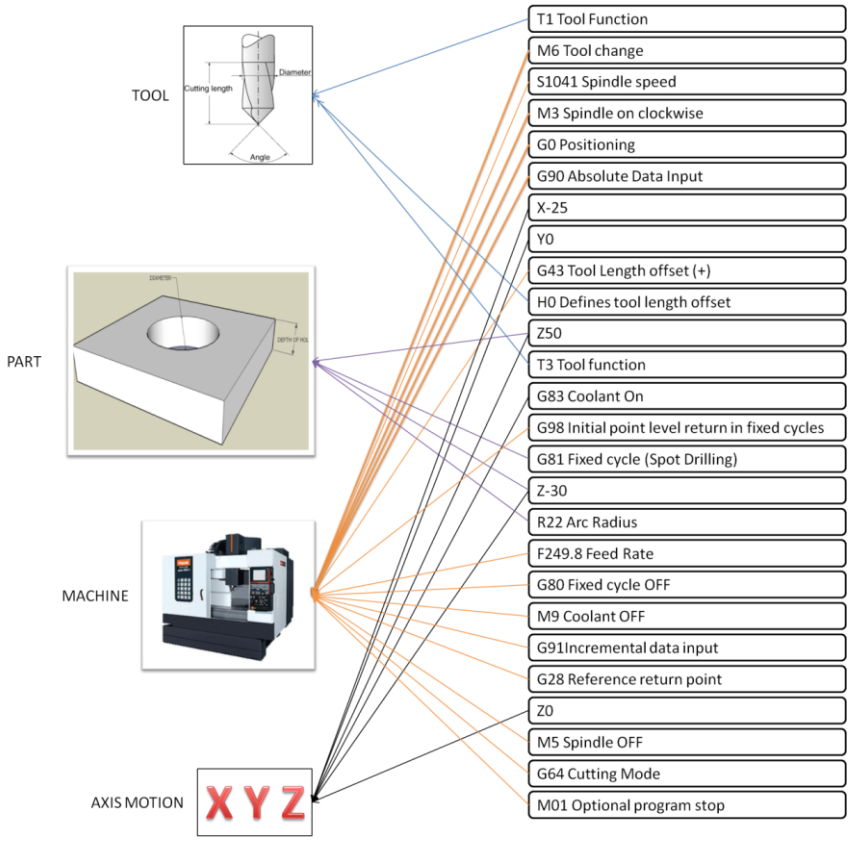


Figure 2.2: Information include in NC Program

Contrary with STEP-NC program most information is render on part which is going to be machined as visualizes in Figure 2.3. The Information included are pictures the features, steps of machining rather than NC program which needed the

skillful person to read the program as the program is written in word and number only. However in STEP-NC program, the readable and understandable word can guide the users to describe what is going to be done easily.

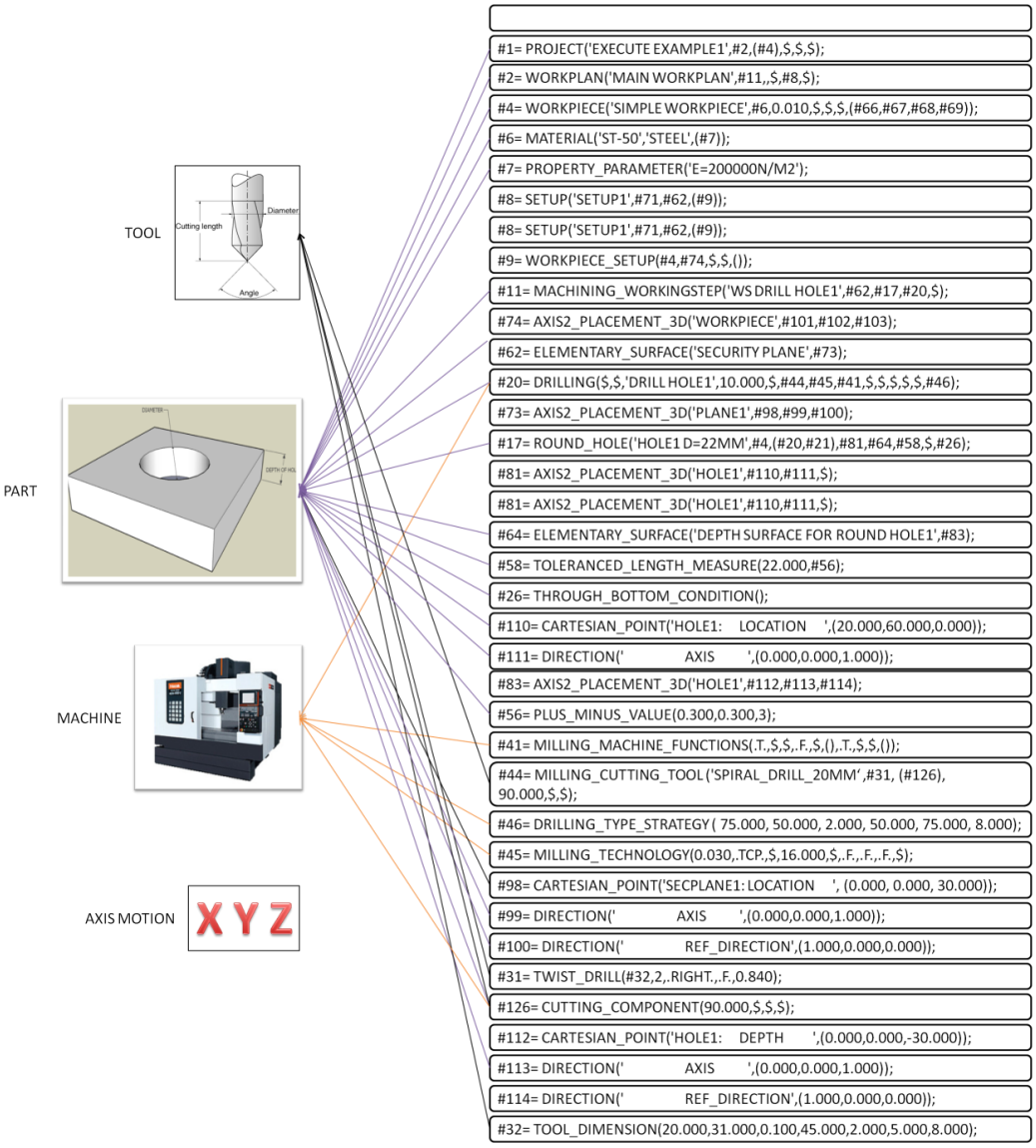


Figure 2.3: Information include in STEP-NC Program

From the analysis, here it has been listed type of information that composes each program to machine the part. It has been summarized into Table 2.2 and Table 2.3. STEP-NC program it include the detail information of workpiece definition, manufacturing process catalogue of machining features, catalogue and

dimension of tool body, technology specific information, axis placement and its dimension.

Table 2.2: The ability of NC and STEP-NC program

Comparison Chart of NC and STEP-NC program (ABILITY)	
STEP-NC Program	**NC Program**
Anybody can read	Depend to operator skill to read the program
Standard and natural	Vendor specific
Bidirectional data flow	One way data flow
Rich of machining data	Limit of machine data
Know the machining (circle, line, etc)	Only read axis motion

Table 2.3: Information in NC and STEP-NC program

Comparison Chart of NC and STEP-NC program (INFORMATION)		
Type of Information	NC Program	STEP-NC Program
Workpiece Definition		√
Manufacturing		√
Catalogue and machine body		√
Catalogue and dimension of tool body		√
Technology	√	√
Axis Placement	√	√
Setup		√
Machine Function	√	√

2.5 STEP-NC: Newcomers to manufacturing cycle

STEP-NC is an enhancement of STEP technology. Pioneer of this study started when WZL of Aachen University investigated 3D milling on STEP. The project name was OPTIMAL (ESPRIT III 8643) (Suh et al., 2008c). They extended the study to 2.5 (prismatic) milling and other operation like turning and Electronic Discharge Machining (EDM) from previous studies on European Project (ESPRIT IV 29708) which is STEP-NC (Suh et al., 2008c). The STEP-NC project has gained worldwide consensus, and was promoted to international IMS (Intelligent Manufacturing Systems) composed of Europe, USA, Korea and Switzerland from

2002. Recently, research and development for commercialization have been actively and collaboratively contributed by a large number of nations including Brazil, Canada, China, France, Germany, Japan, New Zealand, Pakistan, South Korea, Switzerland, UK, USA and so on (Suh et al., 2008c). Until today, research and development are still ongoing and no native STEP-NC machine has been build. However countries such as Germany, New Zealand, South Korea, Switzerland, USA, and UK has been succeeded developing a prototype of a native STEP-NC machine (Suh et al., 2008c).

With unpredictable change to market environment, there are demand to make CNC system to be interoperability, agile, adaptable, reconfigurable and sharable world widely and STEP-NC is believed to be its remedy. The data transfer issues is the most important reason STEP-NC is developed. STEP-NC means a new interface language for data exchange between CAM and CNC system. STEP-NC is also known as ISO 14649 which is an international standard specifying the data model for STEP-NC. It specifies information content and semantics for various manufacturing process and resources including the cutting tools and machine tools (Suh et al., 2008c).

The basic concept of STEP-NC is enables a product model database to serve as direct input to a CNC machine tool. There are no separate files of tool paths without G or M codes. The proprietary of postprocessor function can be avoided to machine a part. STEP-NC standardizes how information about CNC machining can be added to parts representation in the STEP-NC product model. STEP-NC provides an object oriented data model for CNC with a detailed and structured data interface that incorporates feature based programming where there is a range of information such as the feature to be machined, type of tools used, the operations to perform, and work plan. STEP-NC is very comprehensive and includes the information about features, operations, strategies, cutting tools, and so on (Albert, 2002).

STEP-NC contains the required functional information, such as workingstep, machining feature, machining operation, machining tool, machining strategy, machine function and work piece. In other words, STEP-NC includes much richer information set including ‘what-to-make’ (geometry) and ‘how-to-make’ (process plan).

The aim of STEP-NC is to provide consistent standards for automatic and quality oriented CNC component manufacture (Roberto et al., 2002). STEP-NC was

introduced to solve the interoperability issues where the next generation of CNC machine is to be interoperable and adaptable which they can respond quickly to the changes in market demand and the manufacturing needs of customized product (Yusof, 2009).

The concept of STEP-NC is to enable data transfer around the world. The possibility is, with one click on the internet, data can be shared all over the world. STEP-NC controller not only able to machine part due to machine movement but it will understand overall machining process including geometry and its machine technology. Therewith, this new breed of data transfer method which known as STEP-NC will become new intelligent manufacturing system. Figure 2.4 shows the possibilities using STEP-NC in global arena.

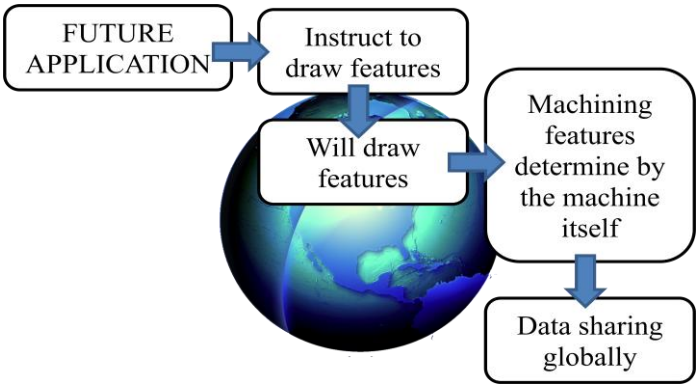


Figure 2.4: Possibility using STEP-NC

2.5.1 The advantages of STEP-NC

Most of the researchers agreed that STEP-NC gives benefit in term of producing profit to the manufacturing industry (Callen, 2002; Suteja, 2005; Thilmany, 2007; Xu et al., 2004; Yusof, 2009). It gives benefit to time and cost when STEP-NC data can be shared and transferred globally through the internet or any sharing method without missing data. STEP-NC is believed to be intelligent manufacturing system

with smart data machining. STEP-NC promises the possibilities of sharable and exchangeable machining data among manufacturer.

Ma (2005) stressed that STEP-NC provides a complete and structured data model linked with geometrical and technological information (Ma, 2005). No information is lost between the different stages of the product development process. Its data elements are adequate enough to describe task oriented NC data. Machining time for small to medium sized job can be reduced a lot because intelligent optimization can be built into the STEP-NC controllers. Post-processor mechanism will be eliminated, as the interface does not require machine-specific information. Machine tools are safer and more adaptable because STEP-NC is independent from machine tool vendors. Modification at the shop - floor can be saved and fed back to the design department hence bi-directional information flow from CAD/CAM to CNC machines can be achieved. XML files can be used as an information carrier and enables Web-based distributed manufacturing (Ma, 2005).

While Jaya Suteja (2005) explained when manufacturing using STEP-NC, the link off all information in supply chain of manufactured product will be flexible, faster, easier, safer and more reliable (Suteja, 2005). STEP-NC shows some advantages in managing information within supply chain. STEP-NC allows internal and external supply chains to use the same data format and reduces the time needed to do rework in transferring data. The data format contains all information needed to plan manufacturing process and can be optimized in every function in supply chain. STEP-NC makes manufacturing set-up faster and more flexible because there is no need to specify specific machine tools in CAM system. By using information and communication technology, e-collaboration and the e-manufacturing can be easily performed. As a result, the delivery time to market can be shortened, the quality of the manufactured product produced using the STEP-NC will be increased, and the cost of manufactured product will be reduced because optimization of the product and the process can be done in every function in supply chain (Suteja, 2005).

2.5.2 Application of STEP-NC in manufacturing

Although it has been a few years standard for STEP-NC has establish, the implementation to industries is quit slow (Thilmany, 2007). The specific features of CNC machine for each vendor will be no longer used if STEP-NC is utilized. The specific features make users stay for their technology and give more profit for vendors. STEP-NC provides a standard data format that can be easily shared around the world. In user's side such as manufacture, to setup new technology took time and costly. CAM programmer will stay for STEP paradigm as CNC vendor and user don't want to apply STEP-NC because they do not aware of it benefits (Tan et al., 2009a). Besides that, there are multi-discipline of knowledge involve. Engineer or people on mechanical engineering background find it is difficult to understand the programming language. Express language becomes an obstacle which the language is very difficult to understand. To develop the software requires a skill of a few of programming language that necessary. Collaboration should be made between people who in engineering and software programming disciplinary where software development process is one of the methods to develop software to generate STEP-NC program and to understand EXPRESS language that model the STEP-NC data structure.

For the long run, STEP-NC give more benefit in term of data transfers. Users do not have to stick to one CNC vendor where native STEP-NC machine is standard. CAD data can be transferred directly without error. In fact, data can be transferred bi-directionally in CAD/CAM/CNC chain. Shop floor is no longer the isolated island in manufacturing process. STEP-NC gives more advantage for user's and profit is more convincing although to setup new technologies is highly in cost and time. Figure 2.5 visualize the possible of data transfer of STEP-NC.

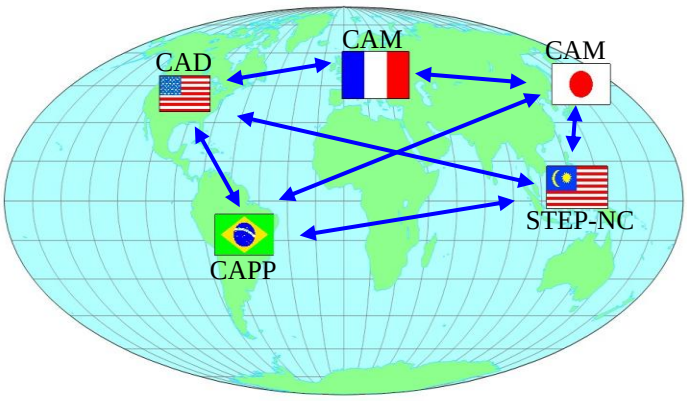


Figure 2.5: STEP-NC data transfer

It concludes the discovery of STEP-NC and here after G & M code will not be used as its weakness. As the technology of G & M code has been used in about 50 years, there are few controversy and breakthrough to implement the new standard. However, as it gain worldwide consensus, many researchers take part in this research field (Ibrahim, 2010; Minhat et al., 2009; Suh et al., 2002; Yusof et al., 2009). It is believe to be good possibilities and new step to bring this research field to the next advance level.

2.6 Researches around the world

After the code has been established, researchers struggled to make STEP-NC implementable to CNC system. Table 2.4 shows researches that have been established around the world. Countries such as Korea, USA, CANADA and UK have developed a STEP-NC generator, even STEP-NC prototype machine system (Shin et al., 2007; Kumar et al., 2008; Newman et al., 2002; Suh et al., 2002; Suh et al., 2006b; Suh et al., 2003; Xu, 2006; Yusof et al., 2009). They also made a collaboration to boost up the development of STEP-NC research. Without proper planning and study, in short term, manufacturing industries sees implementation of new technology as costly and hard to be implemented, as they have to set up new

machines and production process will be halted due to all the installation and testing done. However in the long term, STEP-NC will help manufacturers overcome the G & M code drawbacks and their data can be shared all over the world, as STEP-NC promised that its data can be transferred globally.

Table 2.4: Research around the world

No	Software	Country	Year	Paper
1	AB-CAM	UK	2002	CAD/CAM solutions for STEP Compliant CNC Manufacture (Newman et al., 2002)
2	PROSFP	KOREA	2003	Architecture and implementation of a shop floor programming system for STEP- Compliant CNC (Suh et al., 2003)
3	KOREA STEP-NC	KOREA	2002	Developing an Integrated STEP –Compliant CNC Prototype (Suh et al., 2002)
4	TurnSTEP	KOREA	2006	STEP-Compliant CNC system for Turning: Data model, architecture and implementation (Suh et al., 2006b)
5	STEPcNC	NEW ZEALAND	2006	Realization of STEP-NC enabled machining (Xu, 2006)
6	G2STEP	KOREA	2007	Reincarnation of G code based part programs into STEP-NC for Turning application (Shin et al., 2007)
7	STEP-READER	INDIA	2008	Automatic data extraction from ISO 10303-21 (STEP) for feature recognition (Kumar et al., 2008)
8	SCSTO	UNITED KINGDOM	2009	Interoperable CNC System for turning Application (Yusof et al., 2009)

From the review, there is no claim on combination of milling/turning technology yet. STEP-NC gives more benefit when all manufacture can “talk same language” where machine is standard from G & M code that include with the proprietary function.

2.7 Research in Malaysia

Research in Malaysia started a little bit late and although some academician have started they still hiding their research and insist not to share their knowledge. Looking for other researcher experience such ISO 14649 committee, they are big hearted to hold cooperation and reviewed their research progress to boost their current research. Table 2.5 simplified the number of research that available in Malaysia.

From the review, only few names have started but it is a good opportunity to promote STEP-NC and encourage more researcher and relevant industry to cooperate and makes new things in the research.

Table 2.5: Research in Malaysia

No	Title	Year	Organization	Author	Conference
1	Development Of Tool Path Milling Interface For Integrating *Step-nc* To Oapc-nc Milling (Ibrahim, 2010)	2010	USM	Dzullijah Binti Ibrahim	MYTO
2	Intelligent manufacturing system: STEP-NC (Tan et al., 2009a)	2009	UTHM	Zamri Tan NZ, Yusof Y[a], Hushim MF, Yusof Y[b]	ICADME 2009 ATCI 2009
3	Comparative Study between Physical File Part-21 STEP-NC and G & M Code ISO6983 (Hushim et al., 2009)	2009	UTHM	M.F. Hushim, Y. Y., N.Z. Zamri Tan, Y. Yusof	ICADME 2009
4	The development of method for intelligent manufacturing for STEP-NC compliant machine (Tan et al., 2009b)	2009	UTHM	Zamri Tan NZ, Yusof Y	CISAR 2009
5	Study and Implementation of STEP-NC Technology for Automated CNC Machining.	2008	UUM	Muhamad Nasir Murad	MUCET 2008

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