UNIVERSITI TEKNIKAL MALAYSIA MELAKA

INTELLIGENT AND INTEROPERABLE MANUFACTURING SYSTEM

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Manufacturing Process)

by

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the Degree in Bachelor of Manufacturing Engineering (Manufacturing Process). The members of the supervisory committee are as follow:

……

Principal Supervisor

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ABSTRAK

Kepintaran dalam terma kejuruteraan adalah kepintaran dari alat atau mesin dalam menghasilkan beberapa jenis produk yang memenuhi keperluan rekabentuk. Interoperasi bererti kemampuan dua atau lebih peranti atau mesin untuk bekerja sama antara satu sama lain. Penyelidikan ini terdiri daripada kajian tentang sistem pembuatan pintar dan kebolehan interoperasi yang akan merangkumi semua aspek antara kepintaran dan interoperasi, termasuk keperluan aspek-aspek dan sejauh mana manfaatnya dalam industri. Dalam rangka untuk menyiapkan kajian ini, elemen pencarian bermula dari objektif penyelidikan. Salah satu tujuan adalah untuk memantau sejauh mana aspek kepintaran dan interoperasi memberikan sumbangan dalam industri pada saat ini. Jika kita melihat secara umum, industri hari ini dilengkapi dengan mesin terkini yang berteknologi tinggi dan robotik tetapi kita tidak tahu seberapa jauh kepintaran dari peranti dalam membantu proses pengeluaran produk. Laporan ini juga akan membincangkan tentang skop kajian. Skop kajian ini adalah di Malaysia dan akan diperluaskan skopnya jika ada keperluan yang bersesuaian di rantau lain. Dalam skop projek juga menekankan pada aspek mesin dan pembuatan dalam topik yang dibincangkan. Dalam pendahuluan, kajian awal dan metodologi membincangkan tentang pernyataan masalah, fakta dan penemuan, dan penyelidikan yang sedia ada atau kajian topik yang dibincangkan. Untuk pelaksanaan kajian ini dibincangkan dalam Metodologi Projek. Keputusan dan perbincangan telah dibahaskan di dalam Bab 4 dan 5. Kesimpulan pula disimpulkan di Bab 6.

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ABSTRACT

Intelligent in term of engineering is the smartness of a tool or machine in develops some kind of product that meets the need of the design. Interoperability means that the ability of two or more device or machines to work together between each other. This research consists of a study of intelligent and interoperability manufacturing system that will cover the whole story between the intelligent and interoperability, including the need of these aspects and how far does it benefit in the industry. In order to complete this research, the elements of the finding start with the objectives of the research. One of the objectives was to monitor how far these intelligent and interoperability aspects contributes in our industry nowadays. If we seen generally, our industry was equipped with the latest high technology machines and robots but, we don't know how far was the intelligent of the devices in assisting the production processes. This report will also discuss on the scope of the research. The scope of this study was in Malaysia and will expand the scope if there is suitable need for other region. In the scope also emphasize on the machining and manufacturing aspect for the topic mention. In the introduction, literature review and research methodology section mention about the problem statement, facts and findings, and existing research or on going research of the topic discussed. For the execution of the research was discussed in the Project Methodology. The result and discussion was discussed in Chapter 4 and 5. The conclusion was concluded in Chapter 6.

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Wassalam.

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LIST OF ABBREVIATIONS

CAD	-	Computer Aided Design
CAM	-	Computer Aided Manufacturing
CAPP	-	Computer Aided Product Planning
CIM	-	Computer-Integrated Manufacturing
CL	-	Centre Location
CNC	-	Computer Numerical Control
DesignKNet	-	Design Knowledge Network
FKP	-	Fakulti Kejuruteraan Pembuatan
IGES	-	Initial Graphics Exchange Specification
ISO	-	International Organization of Standardization
LISP	-	One of Programming Language
NC	-	Numerical Control
SFPS	-	Shop-floor Programming System
STEP-NC	-	Standard for the Exchange of Product-Numerical Control
STL	-	StreoLithography
US	-	United State
UTeM	-	Universiti Teknikal Malaysia Melaka
VRML	-	Virtual Reality Modeling Language

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CHAPTER 1
INTRODUCTION

1.1 Project Background

Interoperable and intelligent are two different things that need comprehension to understand it. It is widely used in nowadays manufacturing environment. In manufacturing system, it is used to communicate each other in order to build a new manufacturing system that will make the manufacturing industry become more advanced and sophisticated. In this project, a new research will be develop regarding to this interoperable and intelligent aspect in manufacturing system. This research intends to give new suggestion or idea in how to develop a good manufacturing system that intelligent and interoperable for machining purpose.

Intelligent can be defined as having a high degree or level of understanding of a machine to do the job without manpower to handle. It is also smart technologies used in nowadays industries. This intelligent can also be defined as the capacity and taste for the higher forms of knowledge. In intelligent technologies, it uses of the computer-integrated manufacturing (CIM) system that relate the intelligent with the system and produce a good manufacturing system to be used. It is a knowledge-based system that has their own working knowledge that is LISP (one of programming language), knowledge representation such as production rules and semantic networks, knowledge-acquisition methods such as protocol analysis, and machine learning techniques.

Intelligent in manufacturing also can be understand as the brain of a machine and how smart the machine can interact with the command that given to do some task. It is also sometimes

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Interoperability is a property referring to the ability of diverse systems and organizations to work together (inter-operate) (Wikipedia, 2010). The term is often used in a technical systems engineering sense, or alternatively in a broad sense, taking into account social, political, and organizational factors that impact system to system performance (Wikipedia, 2010). Interoperable also can be defined as a property of a product or system, whose interfaces are completely understood, to work with other products or systems, presents or future, without any restricted access or implementation. Interoperable can also be define as the ability of two or more systems or components to exchange information and to use the information that has been exchanged.

1.2 Problem Statement

Analyzing the identified problems is a collection of information about all the existing and non existing research around the world. The main problem statements that had occurred in the real environment are listed as follow:

Some of the intelligent system cannot be communicate or exchange their data between a platform to other platform. This will make the problems of alteration of the data in order to suit the machine languages of other manufacturing system.

In some country or region, a new intelligent system was created for manufacturing purpose but it has their own codes that only can be used in their machine or systems. This will limit the ability of the machine to interoperate with other machine all around the world. This situation will also complicate other technologist to do their machining on different machines.

1.3 Objectives

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This research is intended to meet some objectives that have been recognized to improve the quality of interoperable and intelligent manufacturing system. The objectives are as follow:

i) To study on the intelligent and interoperable aspect of the manufacturing system.
ii) To investigate the manufacturing system how much does the interoperable and intelligent contribute in the industry itself.

1.4 Scope

The scope of this research consists of some elements that will guide throughout this study. The elements include the following:

- **Computer Numerical Control (CNC) machine tools**

For the ease of the study, it has been specified the elements to be study on the CNC machine tools that used in the industry today. This will help in the further research.

- **Milling machine**

This study also put the limitation on what machine has to be focus on and the milling machine was selected to be the main specimen of this study.

- **Area of study**

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The area of study has been specified only around Malaysia especially UTeM. There are also including other academic institution and industry in Malaysia that used this kind of technology.

1.5 Project Significance

Once this research complete, there will be a gain of benefits which can be summarized as follow:

- In other country, the application of this intelligent and interoperable machine has been widely commercialized.
- The specific research study was in FKP laboratory, UTeM and focusing on the milling machine.
- After this research also it will shown whether there are any country or organization that has been started on the research of this technology.
- The system that in current research are the futuristic and advanced technology.

1.6 Expected Output

In the end of the research, it is anticipated that the output of the research will offer as follow:

- Database to showcase the outcome of the study and investigation.
- Knowledge base to seek such an advanced system in the region.
- The data model that has been used in the current intelligent and interoperable manufacturing systems.
- Enhancing the current technology to be more advanced and smarter in future systems to be develop.

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1.7 Summary

The aim of this research is to expose more of the knowledge to the students and also make the manufacturing system and better. Other than that, this system will be a medium for CNC technologist and community to interact with each other and also with all around the world in order to increase the level of intelligentness of the system.

Once the scopes and objectives that are identified, this will bring to the next activity which in literature review that will be discussed in detail in next chapter.

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CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

In this chapter, it provides a brief overview of the concepts behind this research study and also includes some of the existing system review.

It is an important process in system development research which encompasses research and analysis on previous system, technique used and study on project domain. It enables the audience to read more on the subject relevant to the project and see how the others have approached to the proposed area. The research about interoperable and intelligent manufacturing system is complete and done through searching, collecting, studying and analyzing relevant resources from journals, articles, reference books and web pages.

2.2 Fact and finding

Some research has been done on the area of study. Each of fact of information about this manufacturing system is getting from the relevant sources such as journal, reference books and website to enhance the knowledge in commencing this study.

2.2.1 Existing System Research

2.2.1.1 Interoperable CNC System for Turning Operations

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ISO 14649 is referred to as STEP-NC due to its interaction with ISO 10303 (STEP) and was initiated to provide a data model for a new breed of intelligent CNC controller that is well-structured with work plans and working steps. ISO 14649 aims to model the complete information requirement that must exist in a controller to control a machine tool by defining "what-to-make" and plans "how-to-make". STEP-NC has been developed as a result of several research projects carried out by companies and academic institutions. In terms of international research and development into these standards, projects such as OPTIMAL (ESPRIT, 1997) largely overcame the legacy standards of ISO 6983 (Yusri *et al.*, 2009).

OPTIMAL is one of the earliest STEP-compliant systems and is based on feature information and machining strategies. The research does not stop there, because the researchers now focus on identifying and defining interoperable manufacturing and STEP-NC compliance in the context of concurrent engineering. In particular, information reviews of STEP-NC, manufacturing processes and manufacturing resources are also major foci in this research area. STEP-NC is aimed at overcoming the problems left from ISO 6983 which focuses on programming the path of the cutter centre location (CL) referred to the machine axes rather then machining tasks (Yusri *et al.*, 2009).

One approach to the problem is to exchange a high level of information between CAD/CAM systems and NC controllers. STEP-NC works by manufacturing features, operations and the working steps. The STEP-Compliant Data programming interface for numerical controls has been introduced and proposed for standardization by the International community, where its higher level of information aims to overcome the shortcomings of contemporary NC programming. The new NC programming data model purports to support a well structured hierarchical interface, and object-oriented and two way communication from the CAD environment down to the shop floor (Muller, 2000). STEP-NC is an improved interface between the CAD world and the manufacturing arena. It is recognized as such since it provides process information at the time and place of the manufacturing activity. The proposed STEP-NC data format supports accurate and timely adaptive control of the production equipment and provides feedback for information back to the planning activity (Yusri *et al.*, 2009).

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The current standard of programming NC namely G & M codes or ISO 6983 has had no significant change since the format of NC machines was developed at MIT in 1952 (Muller, 2000; Ahlquist, 2002; Allen, 2005; Xu, 2006) and the evolution of NC machines since using hardwired configurations to the current fully-integrated systems that can be found almost everywhere, from small job shops in rural communities to multi-national companies in large urban areas. During the pre-Computer-Numerical Control (CNC) epoch the program language had been modified by vendors and controller developers who added their own commands. Since the 1970's significant developments have been made towards more automatic and reliable computer numerically controlled machines with new machining processes (Yusri *et al.*, 2009).

Today's highly sophisticated Computer Numerically Controlled (CNC) machines utilize a variety of cutting technologies such as multi-turret and multi-spindle in complex axial configurations and this machine capability increases the level of flexibility and capability compared to the previous decade (Nassehi, 2006). A large number of Computer Aided Systems (CAx) have been developed and implemented in recent years to support all stages of product life by computer systems and many can simulate virtual CNC machining with the complete machine toolpath (Newman, 2004).

Since the first NC machine was introduced in 1952, various process plan packages have been developed and each system tried to interpret the part data format more reliably. Most of these systems are specialized to support certain applications, and are based on an information model that handles the application specific view of the product. These current trends are aimed at open systems but they are predominantly used in retrofitting applications for conventional NC machines. Some of the CAx systems do not share common databases for the product information due to the resistance from software and hardware vendors in terms of business strategy (Yusri *et al.*, 2009).

One of the aims for the next generation of CNC machines is to be interoperable and adaptable so that they can respond quickly to changes in market

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demand and the manufacturing needs of customized products (Xu *et al.*, 2006). As part of this, 2006 was a time when researchers were particularly focused on proposing a framework for turning. Most of the researchers proposed prototype systems to support data interoperability between the various CAx systems based on ISO standard 14649 that provided the first data exchange format used in the operation of NC machines as shown in Table 2.1 (Yusri *et al.*, 2009).

Among these systems, G2STEP is the latest system to cover the machine functioning from pre-processor to STEP-NC part program generation including part program verification (Shin *et al.*, 2007).

This development of a future manufacturing platform to enable different processes and capability such as milling applications, multi-axis and complex components as the basis of the integration of CAD/CAPP/CAM and CNC will be a major research task for years to come. For the time being many obstacles come from software/hardware vendors as the current approaches give them many opportunities to maintain their market, but the new standards can provide the platform for the future of global interoperable manufacturing (Newman *et al.*, 2007). The Shop-floor Programming System (SFPS) introduced by Suh is the first system fully compliant with ISO 14649 (Suh *et al.*, 2003) and to date, only this system has been patented (US patent references; 6400998, 65112961, 6556879, 6650960 and 6671571).

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Table 2.1: Review of STEP-Compliant Systems (Source: Interoperable CNC System for Turning Operations, 2009)

No	Systems	Input	Output	Domain
1	*SFPS (Milling) [14]*	*STEP AP203 & AP214*	*Part program physical file (text)*	*Prismatic*
2	*STEPTurn [15,16]*	*STEP AP203*	*Part program physical file (text)*	*Rotational*
3	*TurnSTEP [17,18]*	*STEP AP*	*ISO 14649 physical file and extensible mark-up language (XML)*	*Rotational*
4	*G-Code Free for lathe [19,20]*	*STEP AP203*	*Native CNC language program*	*Rotational*
5	*G2STEP (2-axis turning machining) [13]*	*G-codes*	*STEP-NC part program*	*Rotational*

There is no doubt, that so far none of the proposed systems are fully capable of machining turn/mill components. Work to date has focused on the separate parts of

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ISO 14649 using Part 11 for milling operations including drilling and Part 12 for turning. No significant work has been done on combining the two parts for turn/mill components. However, the authors and some researchers (Heusinger *et al.*, 2006) believe that this industrial requirement could be achieved through research and development involving collaboration by researchers, users, manufacturers, academia and the ISO committee (Yusri *et al.*, 2009).

If developers look from the business perspective, and academia focuses on theoretical aspects the objective of combination turning and milling machining compliance with the new standard (STEP-NC) can be realized. If we focus on turning operations, only three proposed systems are available, STEPTurn, TurnSTEP and G2STEP. But, if we scope for emanufacturing, STEPTurn leads in this aspect due to the capability of internet file transfer. TurnSTEP clearly defines the number of set-ups as either one set-up or two set-ups dependent on the independent machine format (Suh *et al.*, 2006).

TurnSTEP has some weaknesses such as threads cannot be automatically generated but need to be defined and the process plan graph edited by the user manually. The output of this system can be in text and XML file formats (Suh *et al.*, 2006). As reported TurnSTEP is at a prototype stage and the implementation of another part, which is intelligent and autonomous is still under development. In terms of implementation of bi-directional information flow, none of the systems show how it would work and do not make it clear how the functionality is supported in prototype systems. So far the test components used contain only simple turning operations with z and x axes and do not cover multi-axis machining. The authors strongly agrees with the suggestion by Heusinger and Rosso-Jr, for the STEP-NC compliant information structure to support the milling capability of the NC turning centre to meet industrial needs mapped by ISO 14649 Part 11 and 12 (milling and turning) (Heusinger *et al.*, 2006; Rosso-Jr *et al.*, 2004). The authors have noticed that all the proposed systems use a feature recognition approach and feature based techniques to allow the user to edit the part program. Xu has stressed that the commercial software, namely ST-Plan, can create STEP AP 224 machining features from CAD files (AP 203 or AP 214) (Xu and Newman, 2006). All the proposed systems comply with ISO 14649 and this is the first stage to develop the universal

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manufacturing platform for CNC machining as proposed by (Choi *et al.*, 2006; Newman *et al.*, 2007).

2.2.1.2 Enhancing CNC Manufacturing Interoperability with STEP-NC

Based on a STEP concept, STEP-NC objective is to significantly enhance the communication between CAD/CAM systems and NC controllers. It allows the use of modern NC functionalities and simplifies the programming (CAM, CAPP…) by a feature oriented description. The manufacturing stage is fully included in the whole product development process: the modifications made on the shop-floor stage can be saved and fed back to the design stage, as ISO 14649 is fully STEP-compliant. Another important aspect is that using STEP-NC means working with a unique NC formalism for any machine tool software, as no post-processing operation is needed (Figure 2.1). The communication language used by STEP-NC is a high level one; the data exchanged relate to the machining features rather than to simple axis coordinates control (Matthieu *et al.*, 2009).

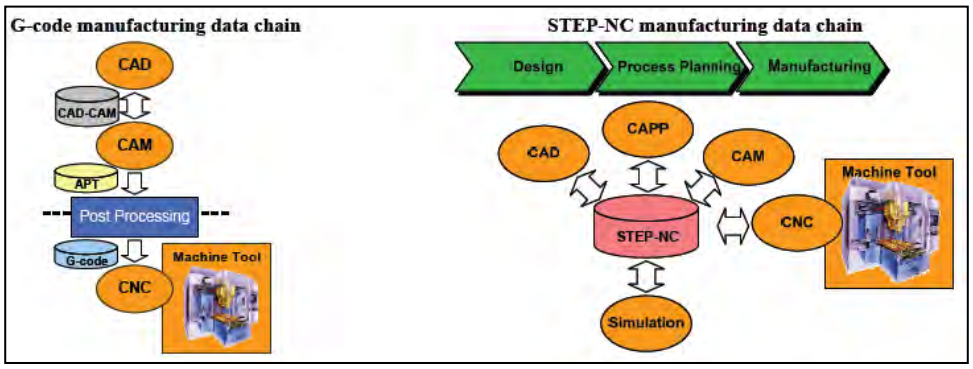

Figure 2.1: Manufacturing data chains with G-code and STEP-NC (Source: Matthieu *et al.*, 2009)

STEP-NC formalism consequently enhances the manufacturing equipment effectiveness by developing intelligent programming approaches and making these equipment and software tools more interoperable by exchanging seamlessly high level data all along the manufacturing data chain (Matthieu *et al.*, 2009).

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