UNIVERSITI TEKNIKAL MALAYSIA MELAKA

THE EFFECT OF CUTTING PARAMETER TO THE HOLE DIAMETER ACCURACY OF AISI D2 TOOL STEEL IN DRILLING PROCESS

This report is submitted in accordance with requirement of UniversitiTeknikal Malaysia Melaka (UTeM) for the Bachelor of Manufacturing Engineering Technology(Process and Technology) with Honours

by

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TAJUK: **The Effect of Cutting Parameter to the Hole Diameter Accuracy of AISI D2 Tool Steel in Drilling Process**

SESI PENGAJIAN: **2015/16 Semester 1**

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APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the Bachelor of Manufacturing Engineering Technology (Process and Technology) with Honour. The member of the supervisory is as follow:

……………………………….

(MohdHairizal bin Osman)

ABSTRACT

Nowadays increasing of productivity and the quality of machined parts are the main challenges of metal cutting industry during drilling processes. Optimization methods for drilling process is really important for improvement of output quality in product and processes including in process parameters relationship and determination of optimal cutting conditions.This research is about the optimization method of selected cutting parameters which are feed rate, spindle speed and type of drill bit in drilling process on AISI D2 Tool Steel to achieve hole diameter accuracy. This project will be focus on drilling process using CNC Milling Machine with the present of coolant. The predetermined values for feed rate are 191 mm/min,381mm/min and 636 mm/min. While for spindle speed, the values are 955 RPM, 1273RPM and 1591 RPM. Lastly, types of the drilling tool were used are High Speed Steel (HSS) coated with Titanium Nitride (TiN), High Speed Steel (HSS) coated with Titanium Carbon Nitride (TiCN) and High Speed Steel (HSS) uncoated.The experimental layout was designed by Taguchi L9 (3^3) Orthogonal array technique. The value of hole diameter are measure by Coordinate Measuring Machine (CMM). The signal to noise (S/N) ratio and the analysis of variance (ANOVA) are employed in order to find out the optimal levels and analyse thehole diameter values. Confirmation tests were done using the optimal levels of parameter are carried out to measure the effectiveness of the Taguchi optimization method.

ABSTRAK

Padamasakinimeningkatkanproduktivitidankualitimesinadalahcabaranutamal ogamindustripemotongandalam proses penggerudian. Kaedahpengoptimumanuntuk proses penggerudianadalahbenar-benarpentinguntukpeningkatankualiti output dalamprodukdan proses tertentutermasukdalam parameter proses hubungandanpenentuankeadaanpemotongan yang optimum. Kajianiniadalahmengenaikaedahpengoptimuman parameter dariaspekkadarsuapan, kelajuangelendongdanjenismatagerudidalam proses penggerudianmemakan AISI D2 alatkeluliuntukmencapailubang diameter ketepatan. Projekiniakanmemberitumpuankepada proses penggerudianmenggunakan CNC Milling Machine denganmenggunakancecairpenyejuk. Nilaiuntukkadarsuapan 191 mm / min, 381 mm / min dan 636 mm / min. Untukkelajuangelendong, nilaiadalah 955 RPM, 1273RPM dan 1591 RPM. Akhirsekali, jenis-jenisalatpenggerudiandigunakanadalah Steel BerkelajuanTinggi (HSS) disalutdengan titanium nitrida (TiN), Speed Steel tinggi (HSS) disalutdengan titanium karbon Nitride (TiCN) dantinggiSpped Steel (HSS) uncoated.Susunatureksperimendirekaoleh Taguchi L9 (3^3) teknikpelbagaiortogon.Nilai diameter lubangadalahdiukurolehCoordinate Measuring Machine (CMM).Isyaratkepadanisbah (S / N) bunyidananalisisvarians (ANOVA) bekerjauntukmencaritahap optimum danmenganalisisnilai-nilai diameter lubang.Ujianpengesahantelahdilakukandenganmenggunakantahap optimum parameter dijalankanuntukmengukurkeberkesanankaedahpengoptimuman Taguchi.

DEDICATIONS

Especially dedicated to my beloved father, En Badrul Hisham bin MohdDahan and my beloved mother, PnRusnidabinti Mohamad who are very concern, understanding, patient, and supporting. Special thanks to my supervisor En Mohamad Hairizal bin Osman, for the constructive guidance, encouragement and patient in fulfilling my aspiration in completing this project. To my sister, brother and my entire friend, the work and success will never be achieved without all of you.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLE

CHAPTER 1
INTRODUCTION

1.0 Introduction

In this chapter, the flow of the project will be discussed from introduction, objectives and problem statement and follow by the scope of the work. The entire sub-topic relates with each other to ensure the readers of this report can understand on how the project process flow. This project will describe about optimization on the holes diameter accuracy. Several test will be conduct with different parameters, different types of drill tools and the material use to drill on is AISI D2 tool steel. Taguchi method will be used to analyse this project. By doing the analysis, the best parameter for the drilling process that produce the best holes diameter accuracy can be determine.

1.1 Project Background

In this modern age, there are many challenges in the manufacturing industry. The quality of the machined parts and increase the productivity are the examples of the main challenges in this industry(Khidir, 2011). Modern cutting tools such as drilling tool allow cutting process at high speed and increase the volume of the product produce. This project will be focus on the optimization parameter for drilling process with coolant for holes diameter accuracy based on the Taguchi method.

Drilling process is one of the most widely used and the oldest process use in machining. Drilling can be described as a process where a multi-point tool is used to remove unwanted materials to produce desired holes(Patel, 2014). There are many factors that can influence the quality of the drilled holes. The most obvious are the cutting parameters which are cutting speed and feed rate and also cutting configurations consist of tool diameter, material and geometry. For this project, spindle speed, feed rate, and type of drill bit had been choose as the parameters that need to be observe. The drilling process will be conducted by three axis CNC milling machine. Using this machine, it will be more precise and easier to set the value of the selected parameter. The types of the drilling tool use are High Speed Steel (HSS) coated with Titanium Nitride (TiN), HSS coated with Titanium Carbon Nitride (TiCN) and HSS uncoated. The diameter for each of the cutting tool is 10mm. There will be presence of coolant during the drilling process.Coolants generally perform three major functions: cooling, lubrication, cleaning and are usually oil orwater based. Oil based coolants are often said to offer superiorlubricity, longer fluid life, improved surface finish, higher stockremoval rate and extended tool life(Mohan, et al., 2008). The coolant type use in this project is Fuchs Lubricants ECOCOOL 6210 IT.

The drilling process will be done on AISI D2 Tool Steel. AISI D2 Tool Steel is a hard material and has extremely high wear resistance properties. AISI D2 is one of the most popular high-carbon and high chromium steels of this series and it is characterized by its high wear resistance and compressive strength, good through-hardening properties, high stability in hardening and good resistance to tempering back(Guillen, et al., 2013).

The Taguchi method will be used to analyse the collected data to get the best parameter for drilling process for hole diameter accuracy. Taguchi method is effective in focusing on quality improvement in product development process. It provides efficient and systematic approach to measure the performance, quality and cost. It uses a fractional factorial experiment design, called an orthogonal array to reduce the number of experiments under permissive permeability (Gu, et al., 2013).

1.2 Problem Statement

The main problem that needs to be focus for this project is that the material of AISI D2 Tool Steel has difficulty to machine. Due to composition of chemical in this type of steel, it is really hard to machine it. A duplex microstructure with coarse complex carbides provides the steel with high wear resistance and good toughness.Machinability of hard material through machining is hindered due to excessive wear of the cutting tools and differently in achieving desired quality of the machined surface.With high speed operation for AISI D2 Tool Steel, the cutting tools wear can be very much due to the mechanical stress and temperature increases.

1.3 Project Objective

The objectives for this project are:

1. To study the effects of cutting parameters to the holes diameter accuracy in drilling process.
2. To identify the optimum parameter for the drilling process of AISI D2 Tool Steel.

1.4 Project Scope

Several scopes have been outlined in order to achieve the objectives of this project. The following important elements that must be followed:

I. There are 3 different types of the drilling bit that have same diameter which is 10mm will be used in this project for the drilling process.

II. The size of the block will be used is 100mm x 100mm x 10mm. There will be 9 holes drilled on the block and each type of drill bit will produce 3 holes.

III. To measure the holes diameter accuracy, Coordinate Measuring Machine (CMM) will be used to determine the value of hole diameter after drilling process.

IV. During the drilling process, coolant must be used. The type of coolant use is Fuchs lubricants (ECOCOOL 6210 IT).

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

In this chapter, there will be some discussion of the research background related to the project. The overall result I the concept literature review framework shows that the link between research projects with the theory and concepts in the figure or an appropriate model about this project.

2.1 Tool steel

Tool steel is a variety of carbon and alloy steels combined to be made into tools as shown in Table 2.1. High hardness and resistance to abrasion and deformation make the tool steel suitable to use for shaping other materials. Tool steels are alloyed steel designed for high strength, impact toughness, and wear resistance at elevated temperature. (Kalpajikan, et al., 2010). Table 2.2 below show the value of the most three important properties of tool steels that always been highlighted.

Table 2.1: Basic type of Tool Steel

Type	AISI
High speed	M (molybdenum base) T (tungsten base)
Hot work	H1 to H19 (chromium base) H20 to H39 (tungsten base) H40 to H59 (molybdenum base)
Cold work	D (high carbon, high chromium) A (medium alloy, air hardening) O (oil hardening)
Shock resisting	S
Mold steels	P1 to P19 (low carbon) P20 to P39 (others)
Special purpose	L(low alloy) F (carbon tungsten)
Water hardening	W

Table 2.2: Relative values of the three most important properties of tool steels

Type	AISI	Wear resistance	Toughness	Hot hardness
Carbon (water hardening)	W1	4	7 (shallow hardened)	1
	(1095)	4	7 (through hardened)	1
Low alloy	L6	3	6	2
Shock resisting	S2	2	8	2
Die steels for cold working	O2	4	3	3
	A2	6	5	5
	D2	8	2	6
Die steels for hot working	H13	3	9	6
	H21	4	6	8
High speed	M2	7	3	8
	T1	7	3	8
	T15	9	1	9

2.2 AISI D2 tool steel

AISI stands for American Iron and Steel Institute.Its development was in response to the need iron and steel industry for collecting statistics and information, carrying on investigations, providing a forum to discuss problem and advancing the interests of the industry.AISI D2 is one of the most popular high-carbon and high-chromium steels of this series and it is characterized by its high wear resistance and compressive strength, good through-hardening properties, high stability in hardening and good resistance to tempering-back.(Guillen, et al., 2013). The blanking dies and punches for sheet in stainless steel, brass, copper, zinc and hard abrasive materials are the typical applications for AISI D2 Tool Steel. Table 2.3 below show the chemical composition of D2 Tool Steel.

Table 2.3: Chemical composition of D2 Tool Steel

Chemical Composition Element	Content (%)
Carbon (C)	1.40 – 1.60
Manganese (Mn)	0.60
Silicon (Si)	0.60
Cobalt (Co)	1.00
Chromium (Cr)	11.00 – 13.00
Molybdenum (Mo)	0.70 – 1.20
Vanadium (V)	1.10
Phosphorus (P)	0.03
Nickel (Ni)	0.30
Copper (Cu)	0.25
Sulphur (S)	0.03

2.3 Drilling process

Drilling is most efficient and economical method of cutting a hole in a solid metal. It broadly covers those methods used for producing cylindrical holes in the work piece. Hole making had long been recognized as the most prominent machining process, requiring specialized techniques to achieve optimum cutting condition. The drilling machines are highly used in an industry for metal removal operation. It is therefore; essential to optimize quality and productivity simultaneously. It has been reported that drilling accounts for nearly 40% of all the metal removal operation in the aerospace and automobile industries(Patel, 2014)

2.3.1 Drilling with coolant

Drilling process with coolant give a lot of advantages and benefits.The term drilling with coolant means there will be fluids that provide a layer of lubricants to act as a cushion between the work piece and the too in order to reduce the friction. Cooling and lubrication are important in reducing the severity of the contact processes at the cutting tool-work piece interfaces(Astakhov, 2000).The role of coolant is very sensitive in determine the cutting speed. Coolant play a significantly role in drilling operations and impact to the quality of work.Directing the coolant through the tool to the cutting edge improves lubricity and reduces the temperature at the point of contact. Depending on the application, the introduction of through the tool coolant may enable the operator to increase feeds and speeds as well as reducing or eliminating the retract cycle (peck drilling).

2.3.1.1 Application of coolant

Cutting fluids are widely used in industries for metal cutting operations in order to optimize the process of machining operations such as turning, drilling, grinding, milling, stamping, and sawing. Coolant and lubricants will make the finish part become more smooth and precise and widely used. There are many benefits when using the cutting fluid during machining process such as extended tool life, increased speeds and feeds, tighter tolerance capability, and improved finish depending on selection of cutting fluid. It has seen extensive use and have commonly been viewed as a required addition to high productivity and high quality machining operations.(Adler, et al., 2006).There are also can improve the machinability of the work piece, increase productivity and make the tool life is more longer by reducing tool wear.

2.3.2 Dry drilling

Many applications nowadays may desired to work without any lubricant because of the cost and maintenance of the lubricants, hazards from lubricant itself and difficulty to dispose it. In the last few years, concerning about environment have forced the usage of cutting fluids during machining operation become less, together with the search for machining methods that avoid or minimize their use (Kurt, et al., 2007).

2.4 Related Parameter in Drilling Process

There are many parameters that significantly affect the drilling process such as cutting speed, feed rate, and depth of cut, tool material, hot or cold worked and much more. Normally, these parameters are used for drilling optimization. Therefore, it is important to know which parameter will be used in order to achieve the desired results. Many drilling parameters affect the performance of the drilling process. When the parameters are not adjusted properly, they will make the drilling operation less economical(Hossain, 2015). Many previous investigations show the effect of machining parameter. According to(Ibrahim, et al., 2006) had investigate the effect of feed rate, spindle speed and type of drilling tool on holes diameter accuracyon mild steel. The results show that the type of drilling tool (51.19%) had the most effect on the hole diameter accuracy followed by feed rate (15.29%) and spindle speed (1.57%). Other than that, (Nalawade, 2015) had investigate the effect of cutting speed, feed rate, drilling depth and drilling tool on surface finish and hole accuracy in drilling of EN 31. The result show that the most significant parameter effects hole diameter accuracy is cutting speed with (73.53%) contribution followed by drilling depth (8.64%), feed rate (5.86%) and lastly drill tool(0.13%). Based on this research, the effectiveness of parameter for drilling process is depend on the type of sample want to be drill. Different sample of work piece determine which parameter will contribute the most to the desired result. The selection of parameter can be made only when all the other characteristics are been considered.

2.5 Various type of drilling tool

The selection of cutting tool materials is the most important factors in machining operations.There are many type of drilling tools can be found for example High Speed Steel (HSS), coated with other materials, carbon steels and many more. Different type of tools will have different characteristics that will influence the machining operations. A cutting tool must have the specificcharacteristics in order to produce good quality and economical parts(Kalpajikan, et al., 2010).

- Hot hardness – the hardness, strength, and wear resistance of the tool aremaintained at elevated temperatures encountered in machining operations.
- Toughness and impact strength – impact forces on the tool that encountered repeatedly in cutting operations or forces due to vibration and chatter during machining do not chip or fracture the tool.
- Thermal shock resistance – withstand rapid temperature cycling encountered in interrupted cutting.
- Wear resistance – an acceptable tool life is obtainable before replacement is necessary.
- Chemical stability – with respect to material want to be machine, to avoid or minimize any adverse reactions, and tool chip diffusion.

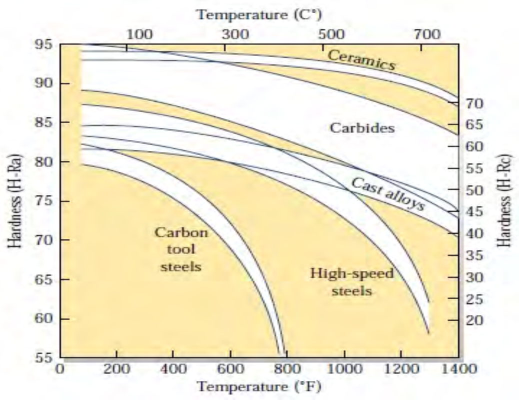

Figure 2.1: Hardness of various cutting tool materials

2.5.1 Coated drilling tool

New alloy and engineered materials are being developed for many purposes. These material have high toughness and hardness, but usually reactive with tool materials. The difficulties to machine these materials and performance during machining process have led to development of coated tools.There are many types of coating materials use to improve the tools performance during the machining process. The most common coating materials are titanium nitride (TiN), titanium carbide (TiC), titanium carbide (TiCN), and aluminum oxide (Al_2O_3) (Kalpajikan et al., 2010).

2.5.2 The influence of cutting tool material to the drilling process

Based on previous research, itshow thatdifferent cutting tool material had effect to the performance of the drilling process. According to(Ibrahim, 2006), type of drilling tool material is rank as number one and the most significant factor contribute to the hole diameter accuracy. In the study, Hss coated with Titanium Nitrate (TiN) has been highlighted as the best material of drilling tool in order to get hole diameter accuracy.

2.5.2.1 Titanium Nitride (Tin) coated cutting tool

Titanium nitride coatings have low friction coefficients, high hardness, resistance to high temperature, and good adhesion to the substrate. Consequently, they greatly improve the life of high speed steel tools, as well as the lives of carbide tools, drill bits, and cutters. TiN coated tools (gold in color) perform well at higher cutting speeds and feeds.(Kalpajikan, et al., 2010).Table below show the composition of Titanium Nitride coating.

Table 2.4: Chemical composition of Titanium Nitride coating

Chemical composition	
Element	Content (wt%)
Titanium (Ti)	77.0 min
Nitrogen (N)	20.0 min
Carbon (C)	0.10 max

2.5.2.2 Titanium Carbon Nitride (TiCN) coated cutting tool

Titanium carbo-nitride is an abrasion resistant ceramic coating formed by adding a small amount of carbon to the TiN coating during the deposition process. It high hardness gives maximum tool life. The carbon makes the coating harder and gives it a lower friction coefficient. TiCN is used extensively on tools which are used in more abrasive cutting and machining operations.(Group, 2015) It is also used in a wide variety of other applications. The table 3.3 below shows the chemical composition and grades of titanium carbon-nitride coating.

Table 2.5: Chemical composition and grades of Titanium Carbo-Nitride coating

Chemical composition			
TiCN 30:70 Grade		TiCN 50:50 Grade	
Element	Content (wt%)	Element	Content (wt%)
Total Carbon (C)	6.3	Total Carbon (C)	10.1
Free Carbon (C)	0.1	Free Carbon (C)	0.1
Iron (Fe)	0.1	Iron (Fe)	0.1
Oxygen (O2)	0.6	Oxygen (O2)	0.6
Nitrogen (N2)	14.2	Nitrogen (N2)	10.2

2.6 Process parameter optimization

2.6.1 Taguchi method

Taguchi method is a way to reduce variation in a process through the design of the experiment. The main objective of this method is to produce high production and high quality of the product at low cost. When the process is poor, it will not only affect the manufacturer but also to the society. This method shows the designing experiment to investigate how different parameter affects the mean and variance of a process performance characteristic and it performance.The experimental design proposed by Taguchi involves using orthogonal arrays to organize the parameters affecting the process and the levels at which they should be varied. The collection of the data is necessary to determine which factors most affect product quality with a minimum amount of experimentation, thus saving time and resources.(Panda, et al., 2013)

The use of Taguchi's parameter design involves the following steps (Foster, 2000)

a. Identify the main function and its side effects.

b. Identify the noise factors, testing condition and quality characteristics.

c. Identify the objective function to be optimized.

d. Identify the control factors and their levels.

e. Select a suitable Orthogonal Array and construct the Matrix

f. Conduct the Matrix experiment.

g. Examine the data; predict the optimum control factor levels and its performance.

h. Conduct the verification experiment.

In accordance with the steps that are involved in Taguchi's Method, a series of experiments are to be conducted.

CHAPTER 3
METHODOLOGY

3.0 Introduction

For this chapter, it will discuss about how this project will be design, how to run this project, type of software and hardware involved in this studies, method on how the data are collect in this project and overall related part for the completion of the project based on the requirement. The whole processes for this project will be covered, from the very start of the project to the last of it. The process begins with the squaring the received work piece D2 Tool Steel. The work piece goes squaring process using conventional milling machine until the dimension is 100mm x 100mm with 10mm thickness. Then, follow by the drilling process using CNC 3 axis machine with different parameter that had been selected. There will be 9 drill bit use for the drilling process which are three HSS uncoated, three Hss coated with TiN and three Hss coated with TiCN. Each drill bit will produce one hole. Lastly, holes diameter accuracy will be measured by Coordinate Measuring Machine (CMM**)**. The Figure 3.1 shows the flow chart of the process and procedure in conducting the project according to the sequence.

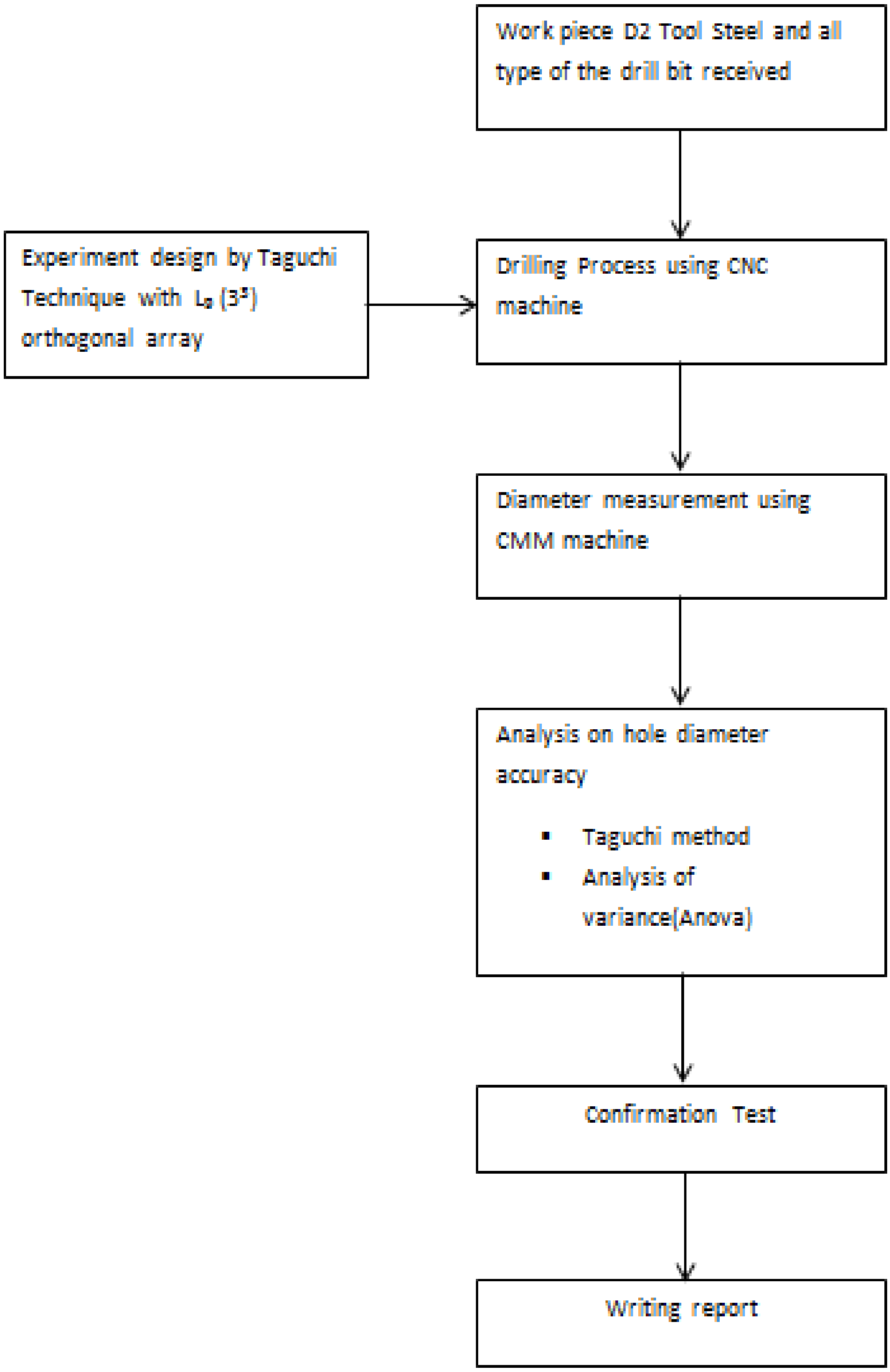

Figure 3.1: Flow chart of process carried out

3.1 Preparation of experiment

3.1.1 Workpiece

The type of workpiece material used was cold work tool steel, which AISI D2 tool steel as a work piece to be drilled. The size of the work piece is 100mm x 100mm with 10mm thickness. Figure 3.2 show the work piece AISI D2 tool steel. The composition of the material is shows in Table 3.1 below.

Table 3.1: Chemical compositon for D2 tool steel

Element	Content (%)
Carbon (C)	1.40-1.60
Manganese (Mn)	0.60
Silicon (Si)	0.60
Cobalt (Co)	1.00
Chromium (CR)	11.00-13.00
Molybdenum	0.70-1.20
Vanadium (V)	1.10
Phosphorus (P)	0.03
Nickel (Ni)	0.30
Copper (Cu)	0.25
Sulphur(S)	0.03

Figure 3.2: D2 tool steel with (100mm x 100mm x 10mm) dimension

3.1.2 Cutting tool

In this project, there will be three types of drill bit that will be used which are High Speed Steel (HSS) uncoated, High Speed Steel (HSS) coated with Titanium Nitride (TiN) and High Speed Steel (HSS) coated with Titanium Carbon-Nitride (TiCN) as shown in Figure 3.3, Figure 3.4, and Figure 3.5 below.

Figure 3.3: High Speed Steel cutting tool

Figure 3.4: High Speed Steel coated with Titanium Nitrate

Figure 3.5 : High Speed Steel coated with Titanium Carbon Nitrate

It is important to know characteristic of the cutting tool because one of the parameter that need to be observe is type of drill bit. The only different between cutting tools use in this experiment are only the type of coated used.Other dimensional properties are same. The dimensional properties of each cutting tools is show in Table 3.1 below.

Table 3.2: Dimensional properties of cutting tools

Drill	1	2	3
Tool diameter	10 mm	10 mm	10 mm
Coating	TiCN	TiN	Uncoated
Flute	2	2	2
Point angle	118	118	118
Helix angle	30	30	30
Shank type	cylindrical	cylindrical	cylindrical

3.2 Design of experiment

For the parameter, feed rate, cutting speed and types of drill bit have been choose as cutting parameter that need to be considered during conducting the experiment. All the characteristics for the cutting parameter have been decided as shown in Table 3.3 below. The reason the value of the parameters was chosen as a reference is based on the (Nalawade P.S, 2015) research. The reason the parameter was chosen is because the type of material want to be drill in the experiment, EN31 (HRC 56-63) has quite similarity value of hardness compare to the AISI D2 Tool Steel (HRC 55-63).

Table 3.3: The parameter study at the level choose

Factor		Unit	Level		
			1	2	3
A	Feed rate	mm/rev	0.20	0.25	0.30
B	Spindle speed	RPM	680	825	970
C	Types of dill bit		HSS+TiN	HSS+TiCN	HSS uncoated

The experiment layout will be design by using Taguchi method in Minitab software, The L9 of orthogonal array will be used because there are 3 factors and 3 levels need to be analyze. Figure 3.4 and Figure 3.5below show the orthogonal array design and with their level.

Table 3.4: The orthogonal array design

Trial number	Designation	Feed rate	Spindle speed	Types of dill bit
1	A1B1C1	1	1	1
2	A1B2C2	1	2	2
3	A1B3C3	1	3	3
4	A2B1C2	2	1	2
5	A2B2C3	2	2	3
6	A2B3C1	2	3	1
7	A3B1C3	3	1	3
8	A3B2C1	3	2	1
9	A3B3C2	3	3	2

Table 3.5: The orthogonal array design with their value

Trial number	Designation	Feed rate	Spindle speed	Types of dill bit
1	A1B1C1	191	955	HSS+TiN
2	A1B2C2	191	1273	HSS+TiCN
3	A1B3C3	191	1591	HSS uncoated
4	A2B1C2	381	955	HSS+TiCN
5	A2B2C3	381	1273	HSS uncoated
6	A2B3C1	381	1591	HSS+TiN
7	A3B1C3	636	955	HSS uncoated
8	A3B2C1	636	1273	HSS+TiN
9	A3B3C2	636	1591	HSS+TiCN

3.3 Drilling process preparation

The CNC machine model DMC 635 V Eco line will be used to conduct the drilling process for this experiment as shown in Figure 3.6 below. The programming use for the CNC machine in this experiment is Catia V5. First, the programming for the drilling process using Catia V5 software needs to be done. Set the type of drilling method use for drilling process to peck holes drilling. Figure 3.7 show the simulation result of the programming in Catia V5. Then post the finish program to NC code because the controller of the CNC Milling (Siemenes 810 D) only can read this type of coding. After that, clamp the work piece in the CNC machine as shown in Figure 3.8 below.There will be present of coolant during the drilling process.The type of coolant use is Fuchs Lubricants ECOCOOL 6210 IT.

Figure 3.6: CNC machine model DMC 635 V Eco line

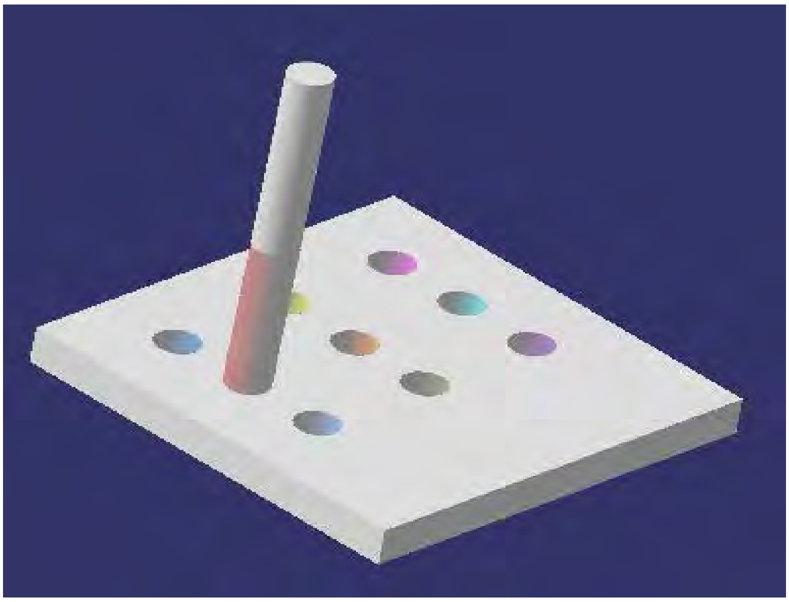

Figure 3.7: The simualtion result from Catia V5

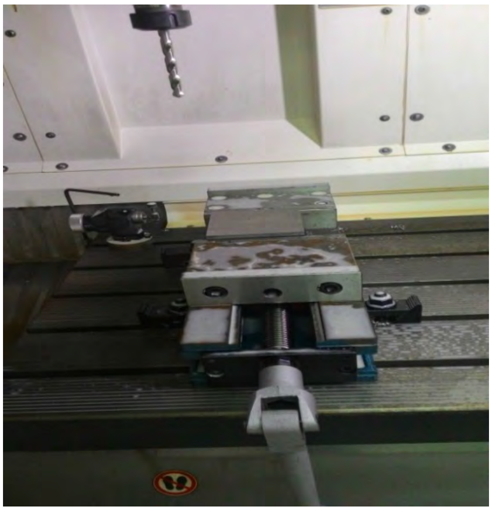

Figure 3.8: Position of workpiece after clamp in the CNC milling machine

3.4 Hole diameter analysis

In order to measure the hole diameter accuracy, a CMM machine will be used to take a good reading for each hole that has been drilled.All the readings that have been recorded will be analysed in order to identify the most optimum parameters for the drilling process as show. Table 3.6 and Figure 3.9 below shows the procedure of CMM and the position of work piece during the measuring process.

Table 3.6: Procedure of CMM

Step	Description
1	Setup the work piece on the measuring table.
2	Set the base alignment and clearance plane.
3	Set the probe at the center of the circle, using circle feature and four point circle macro strategy to measure the first hole diameter. Repeat the step for another two more reading at the same hole. Repeat the same step until finish for another hole.
4	Click Run Measurement Plan and click OK to start the CNC run. The program will run auto to take all the hole diameter reading.
5	Generate the result of hole diameter.

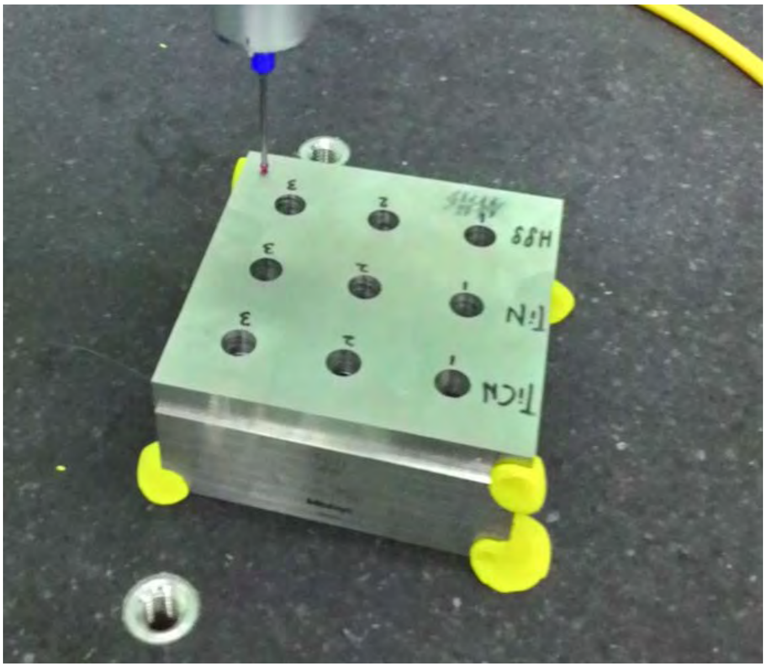

Figure 3.9: Setup of work piece on the measuring table.

3.5 Data collection

The data from the testing were recorded in table form as shown in Table 3.6 below for the holes diameter accuracy values. Each hole will be measure three times and the mean will be calculated.

Table 3.7: Table form for hole diameter accuracy

Parameter			Holes diameter accuracy (mm)			
Feed rate (Mm/min)	Spindle speed (RPM)	Type drill bit	X_1	X_2	X_3	Mean
191	1591	HSS				
381	1273	HSS				
636	955	HSS				
191	955	HSS+TiN				
381	1591	HSS+TiN				
636	1273	HSS+TiN				
191	1273	HSS+TiCN				
381	955	HSS+TiCN				
636	1591	HSS+TiCN				

3.6 Statistical analysis tool

Statistical analysis is the science of collecting, exploring and presenting largeamounts of data to discover underlying patterns and trends. The purpose of the analysis is to become more scientific about decisions that need to be made.

The software that be used to analyse the results of hole diameter accuracy of both techniques is Minitab 17. This software is suitable to be used when analysed multiples different samples of unknown normal distribution. The calculation of signal to noise ratio, SN ratio and means was carried out by Minitab 17 to determine which combination of parameters is the best and significantly affect the drilling process. Analysis

CHAPTER 4
RESULT AND DISCUSSION

4.0 Introduction

This chapter will discuss about the optimization of parameter for hole diameter accuracy and the relationship of the parameter which can be seen by focusing on three different parameters which are feed rate, spindle speed and type of drill bit use. Besides, the relevant figure and tables been added up to illustrate the description for this project flow. In other word, this chapter is a continuation of the previous chapter. Discussion of the experimental results will also be included in this chapter.

4.1 Experimental Results

From experiment in previous chapter, the relationship between feed rate, spindle speed and type of drill bit is important information that can help to do parametric optimization to determine hole diameter accuracy. This experiment is conducted to gainresultsthat can be analyse to find out which combination between the factors is the best in order to produce hole with high accuracy.

4.1.1 Holes diameter accuracy

The table 4.1 below shows the result for holes diameter accuracy corresponding to the parameter combination between the values of feed rate, spindle speed and type of drill bit.

Table 4.1:Response table for hole diameter accuracy reading and mean

Parameter			Holes diameter accuracy (mm)			
Feed rate (Mm/min)	Spindle speed (RPM)	Type drill bit	X_1	X_2	X_3	Mean
191	1591	HSS	10.1363	10.1305	10.1025	10.1231
381	1273	HSS	10.0466	10.0439	10.0464	10.0836
636	955	HSS	10.0103	10.0121	10.0113	10.0496
191	955	HSS+TiN	10.0836	10.0874	10.0840	10.1062
381	1591	HSS+TiN	10.0260	10.0236	10.0261	10.0457
636	1273	HSS+TiN	10.0288	10.0230	10.0314	10.0253
191	1273	HSS+TiCN	10.0383	10.0476	10.0626	10.0278
381	955	HSS+TiCN	10.1193	10.1011	10.0981	10.0133
636	1591	HSS+TiCN	10.0579	10.0496	10.0451	10.0509

4.2 Result and Discussion

The experimentalresults from Table 4.1 were analysed and calculated by using Minitab Software to determine the main effects or contribution for the mean and S/N ratio. Besides, the software also used to identify the factors significantly affecting the performance measure. Using the S/N ratio, the best value for each parameter can be determined and the best parametric combination use to achieve good result for hole diameter accuracy.

4.2.1 Taguchi Analysis

The characteristic choose to analyse the Taguchi design is ‘smaller is better’ to identify the best parametric combination. Figure 4.2 below shows the results for Taguchi Analysis in the Minitab Software.

Response Table for Signal to Noise Ratios
Smaller is better

Level	Feed rate	spindle speed	Drill bit
1	-20.07	-20.05	-20.07
2	-20.04	-20.04	-20.03
3	-20.04	-20.07	-20.05
Delta	0.04	0.03	0.05
Rank	2	3	1

Response Table for Means

Level	Feed rate	spindle speed	Drill bit
1	10.09	10.06	10.09
2	10.05	10.05	10.03
3	10.04	10.08	10.06
Delta	0.04	0.03	0.05
Rank	2	3	1

Figure 4.1: Taguchi analysis in Minitab and for signal to noise ratios and means

Based on the data produce by Minitab,from the data gain by the analysis made in Minitab, the value for signal to noise ratio is in negative value. The negative value of S/N ratio indicates that the characteristics for the data is for ‘smaller is better’ analysis. The best S/N ratio for ‘smaller the better’ analysis can be determine by the data approaching to zero value. (Sharma and cudney)

From the Taguchi Analysis in Minitab, the most significant parameter affects or influence the value of hole diameter accuracy can be determine. Using the Taguchi analysis in Minitab software, the rank will be calculated. For this experiment, the most significant parameter written as ranking number one which is the value of the type of drill bit. Second is the value of feed rate and lastly is spindle speed. The rank represents the delta value, change between the S/N ratios for different level.

In addition, the Minitab S/N ratio given rank can be assume is true because the rank also can be determine the by analyse significance value from the slope of graph that plotted using mean and S/N ratio value. Figure 4.2 and 4.3 below shows the main effects plot for means and S/N ratio. The plots show the variation of response according to the three parameters; feed rate, spindle speed and type of drill bit separately. In the graph, the x-axis indicates the value of parameter at three levels and y-axis indicates response value.

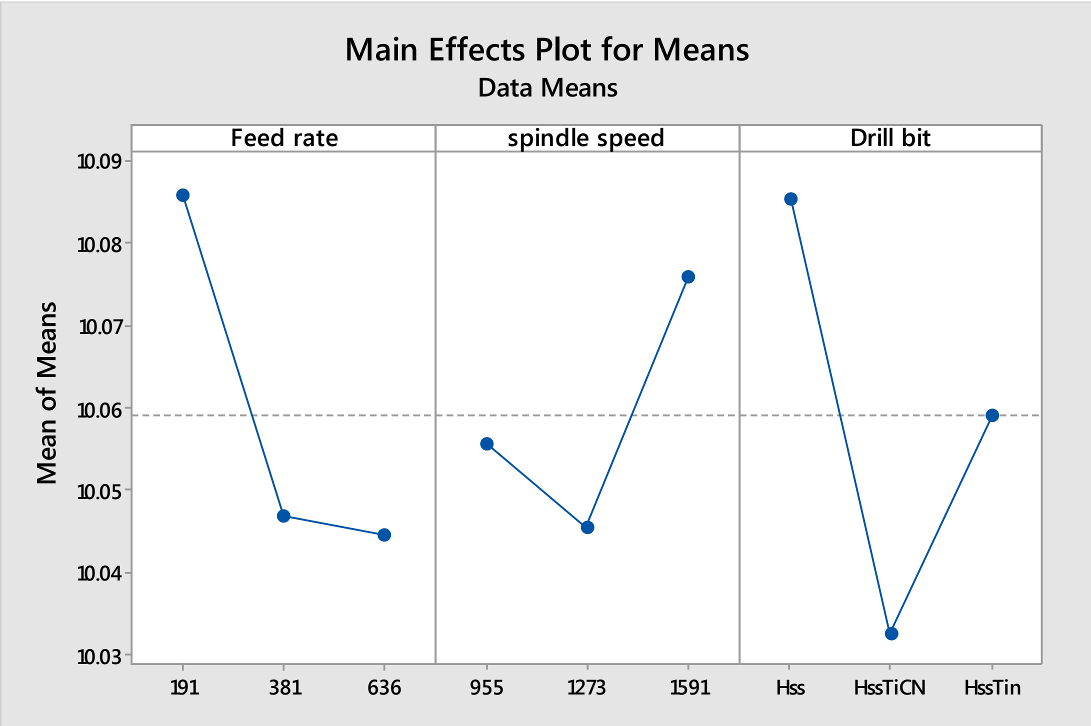

Figure 4.2: Main effects plot for Means

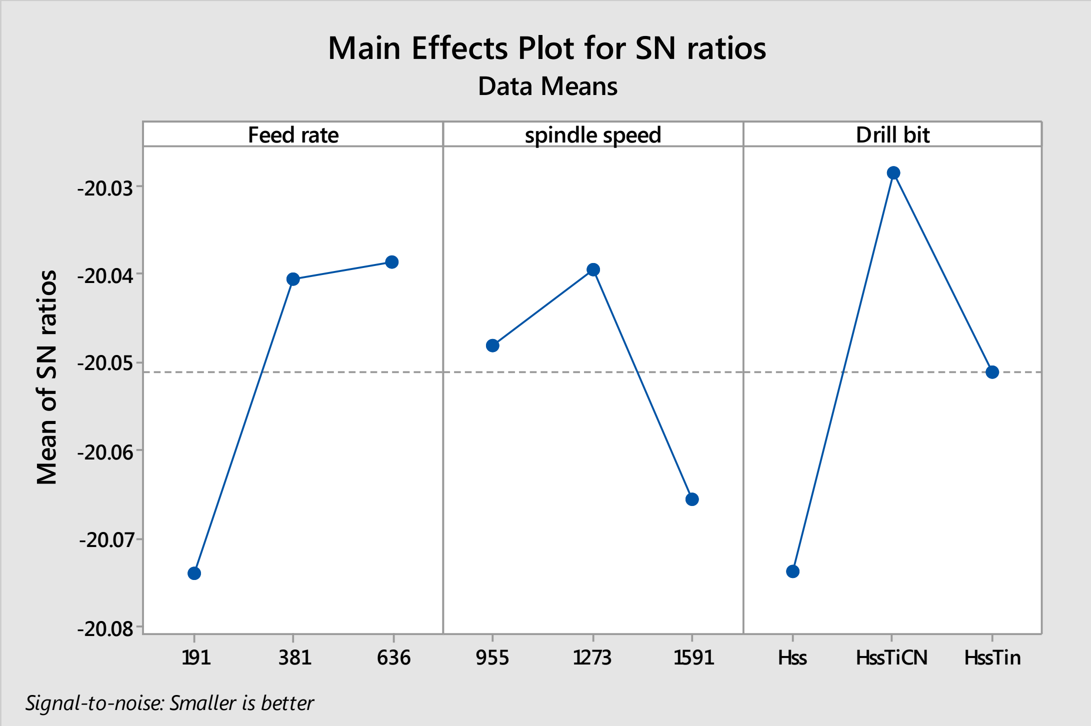

Figure 4.3: Main effects plot for S/N ratios

The graph main effect plot for means is based on the mean value of holes diameter accuracy and for S/N ratio,the graph plot is based on the S/N ratio value get from Taguchi analysis by Minitab software. From the graph, we can determine the best combination of parameter by observing graph from the S/N ratio. The highest for the S/N ratio respective to each parameter shows the optimal parameter in order to achieve the best hole diameter accuracy. After analyse which value for each parameter has high S/N ratio, the best combination of parameter can be determine.

From S/N ratio main effect graph, for the factor feed rate, the plot for 636(mm/min) is the highest plot, for the factor spindle speed, the plot for 1273(RPM) is highest and lastly for the factor type of drill bit, (Hss+TiCN) has the highest plot. Therefore, it can be concluded that the combination of 636mm/minfeed rate, 1273RPM spindle speed and drill bit (Hss+TiCN) is the suggested parametric combination in order to gain the best hole diameter accuracy value. This combination can later be used for Taguchi design prediction and for confirmation test

4.2.2 Analysis of variance (ANOVA)

The experimental results from Figure 4.1 were analysed with analysis of variance (ANOVA), which use to identify the factors significantly affecting the performance measure.ANOVA also establishes the relative significance of factors in terms of their percentage contribution to the response. This analysis is performed on S/N ratios to obtain the contribution of each of the factors. The result of ANOVA with S/N ratio is shown in Table 4.2 respectively. The last column in Table 4.2 showsthe percentage of contribution for each parameter that influences the value of the result.

Table 4.2: Analysis of variance for S/N ratio

Source	DF	Seq SS	Adj MS	F	P	Contribution %
Feed rate	2	0.002378	0.002378	1.14	0.467	27.53
Spindle speed	2	0.001069	0.001069	0.51	0.661	12.38
Type of drill bit	2	0.003109	0.003109	1.49	0.401	36.19
Residual error	2	0.002081	0.002081			23.9
Total	8	0.008637				100

Percent (%) is defined as the significance rate of the process parameters on the hole diameter accuracy. The percent numbers depict that the type of drill bit, feed rate and spindle speed have significant effects on the hole diameter accuracy. Based on the Table 4.2, type of drill bit (39.19%) is the most significant cutting parameter followed by feed rate (27.53%). However, spindle speed has least effect (12.39%) in controlling the hole diameter accuracy which is not statically significant. This also shows the resultsfrom ANOVA are same with the rank result in previous section based on which one has the highest and least contribution to the performance measure

4.2.3 Taguchi Analysis Prediction

In Minitab 17 software, the best S/N ratio, mean and the combination of parameter of hole diameter accuracy can be obtained based on the Taguchi analysis. Select the 'Predict Taguchi Design' features and set the levelbase on the analysis on the main effects plot for S/N ratioswhich are feed rate 636mm/min, spindle speed 1273rpm and drilling tool is HSS+TiCN. Figure 4.4 below show the result of predicted value in the Minitab software.

Predicted values

```
S/N Ratio     Mean
 -20.0042  10.0047


Factor levels for predictions

Feed  spindle
rate    speed  Drill bit
 636     1273  HssTiCN
```

Figure 4.4: Prediction parameter and value of S/N Ratio and Mean

From these predicted values of S/N ratio, mean and the combination of parameter, an optimal level has obtained. The study found 'A3B2C2' is the prediction parameter as an optimal level. 'A' is refer to feed rate, 'B' is spindle speed, 'C' is type of drill bit and the number show the level of the parameter.Using this optimal level result, confirmation test can be conduct to determine the error percentage of actual result and the predicted result of the Taguchi's design.

4.3 Confirmation Test

The confirmation test is a step after the prediction analysis in order to verify the results drawn based on Taguchi's design approach. The confirmation experiment is highly recommended by Taguchi method to verify the experimental results.A selected number of experiments are 2 which under specified cutting conditions based on the optimal level in the prediction analysis.The result from the confirmation experiment is compared with the predicted value based on the parameters and levels tested. In this study, a confirmation experiment was conducted by utilizing the levels of the optimal process parameters (A3B2C2) for the hole diameter accuracy value. Table 4.3 shows the result for the confirmation test.

Table 4.3: Confirmation test results

Result	Optimal machining parameter	
	Prediction	Confirmation test result
Mean	10.0047	10.0081
Level	A3B2C2	A3B2C2

4.3.1 Comparison of the result

Based on the Table 4.3, there are not too much different between the mean of predicted parameter with the mean of confirmation result. The result of confirmation test show the lowest reading compare to other hole diameter result in Table 4.1 above. The analysis of confirmation experiments has shown the Taguchi parameter design can successfully verify the optimum cutting parameter 'A3B2C2' which are feed rate = 636(mm/min), spindle speed = 1273(RPM) and type of drill bit = (Hss+TiCN).

CHAPTER 5

CONCLUSION

5.0 Conclusion

The influences of feed rate, spindle speed and type of drill bit on holes diameter accuracy in drilling operation under present of coolant was examined. The experiment that had been conducted successfully achieved and conclusion based on the findings are obtained even though there were obstacles during completed this project. The drilling process under present of coolant and different parameter variation was performed on D2 tool steel and obtained data has been analysing by using Taguchi technique.This project has use the Taguchi design to determine the design of experiment in order observe the relationship between hole diameter accuracy against the parameters. The Taguchi design was conducted by the help of Minitab 17 software that have the DOE Taguchi feature and also for the confirmation trial in order to prove the predicted value. It was observed that, Taguchi orthogonal array provides a large amount of information in a small amount of experimentation. Besides that, it creates an efficient and concise test set with fewer many fewer cases than testing all combinations of all variables. So, the overall cost needed to conduct this experiment can be reducing because the number of experiments is less. This software also used to conduct the analysis of variance to obtain the contribution of each of the factors to the hole diameter accuracy in term of percentage.

As a conclusion, the different parameters have influence to the hole diameter accuracy.The optimal combination of drilling parameters and their level for hole diameter accuracy of drilling process with present of coolant are A3B2C2. The value for feed rate is 636mm/min, spindle speed is 1273rpm and type of drilling tool is HSS+TiCN. The confirmation tests were conducted to verify the optimal cutting parameters. The percentage contributions of feed rate, spindle speed and type of drilling tool are 27.53%, 12.39%, 39.19%.

5.1 Recommendation

In order to further investigation on this experiment, the following are recommended to improve the study and experimental model of the process

- Type of drilling process use must be change from peck drill to deep hole drilling.
- Different type of material to be studied
- Use different type of coating material for the case study

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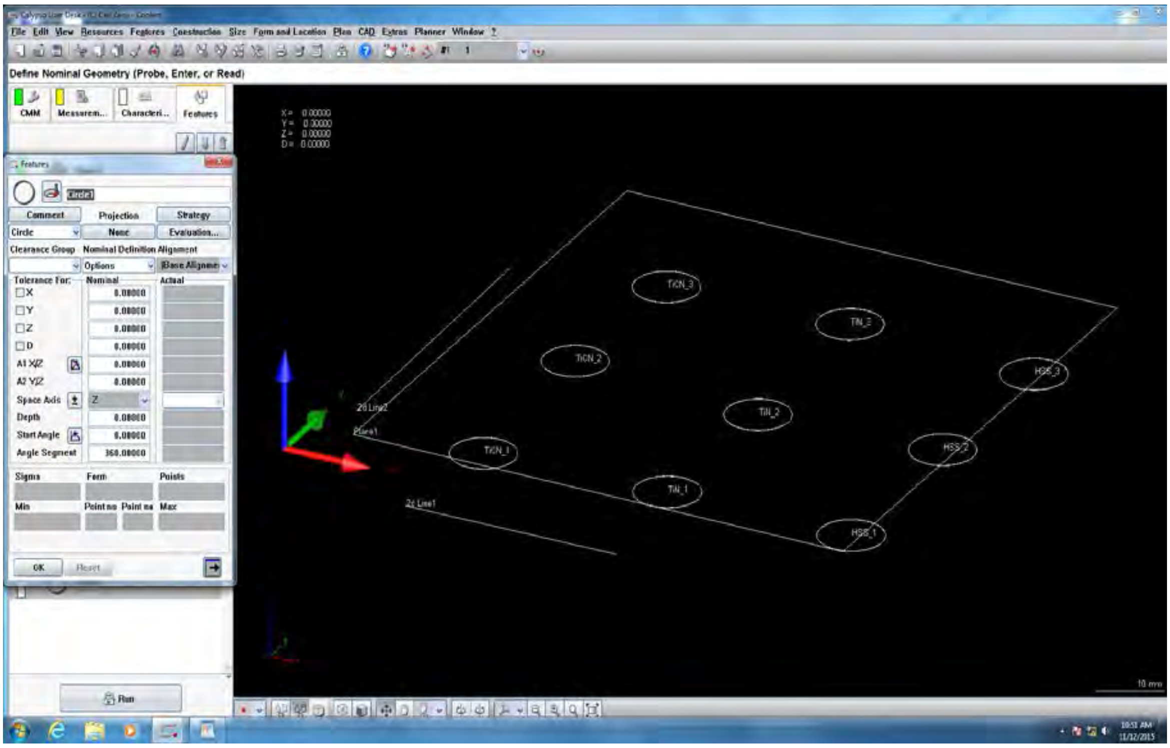
APPENDICES

Appendix A – Coordinate measuring machine software (4 point technique)

APPENDIX A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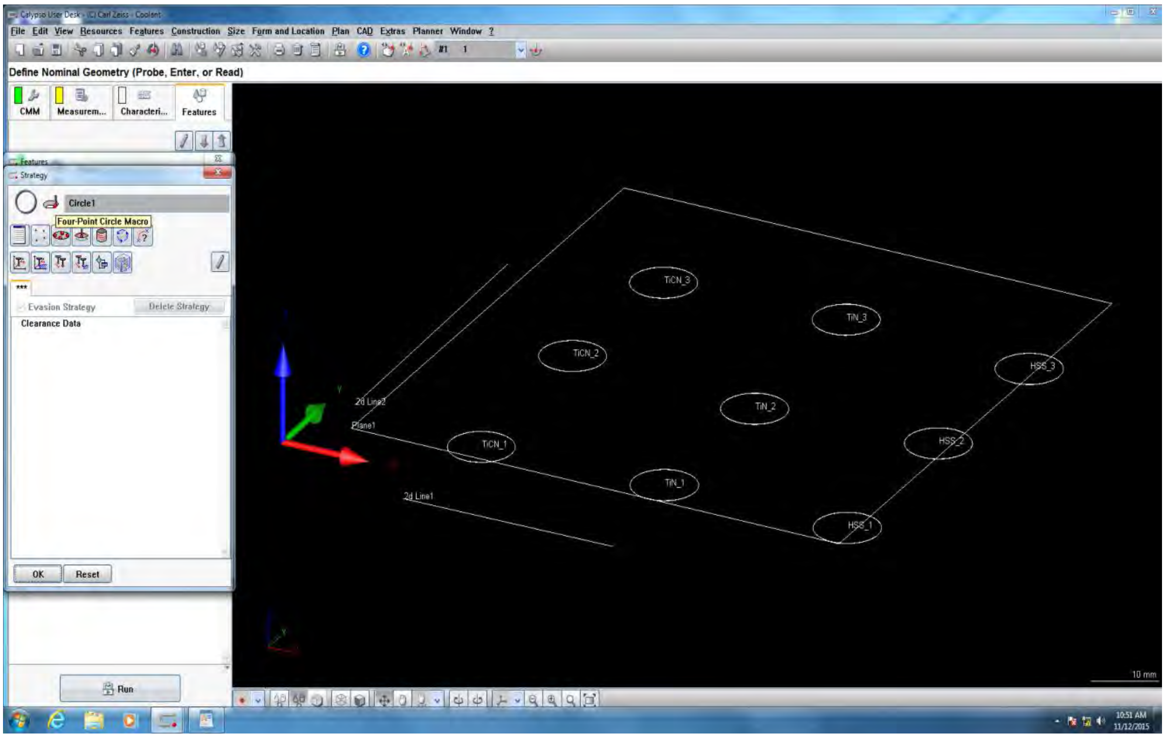
Features
Circle1
Comment
Projection
Strategy
Tolerance For:
Nominal
Actual
OK
TiCN_3
TiN_3
TiCN_2
HSS_3
TiN_2
TiCN_1
HSS_2
TiN_1
HSS_1
Run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CMM
Features
Strategy
Circle1
Four-Point Circle Macro
Evasion Strategy
Delete Strategy
Clearance Data
OK
Reset
TiCN_3
TiN_3
TiCN_2
HSS_3
TiN_2
TiCN_1
HSS_2
TiN_1
HSS_1
Run