



UNIVERSITI TEKNIKAL MALAYSIA MELAKA

**OPTIMIZATION OF DRILLING PARAMETERS ON SURFACE
ROUGHNESS IN DRY DRILLING PROCESS OF AISI D2
TOOL STEEL**

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

by

NUR AMIRA BINTI SHUHAIMI

B071310817

910906-07-5918

FACULTY OF ENGINEERING TECHNOLOGY

2016

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

TAJUK: Optimization of Drilling Parameter on Surface Roughness in Dry Drilling Process of AISI D2 Tool Steel

SESI PENGAJIAN: 2016/17 Semester 1

Saya **NUR AMIRA BINTI SHUHAIMI**

mengaku membenarkan Laporan PSM ini disimpan di Perpustakaan Universiti Teknikal Malaysia Melaka (UTeM) dengan syarat-syarat kegunaan seperti berikut:

1. Laporan PSM adalah hak milik Universiti Teknikal Malaysia Melaka dan penulis.
2. Perpustakaan Universiti Teknikal Malaysia Melaka dibenarkan membuat salinan untuk tujuan pengajian sahaja dengan izin penulis.
3. Perpustakaan dibenarkan membuat salinan laporan PSM ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. ****Sila tandakan (✓)**

- SULIT** (Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia sebagaimana yang termaktub dalam AKTA RAHSIA RASMI 1972)
- TERHAD** (Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)
- TIDAK TERHAD**

Disahkan oleh:

Alamat Tetap:

Plot 109 Kampung Tersusun

Sungai Ara, 11900 Bayan Lepas,

Pulau Pinang

Tarikh: _____

Cop Rasmi:

Tarikh: _____

** Jika Laporan PSM ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh laporan PSM ini perlu dikelaskan sebagai SULIT atau TERHAD.

DECLARATION

I hereby, declared this report entitled “Optimization of Drilling Parameters on Surface Roughness in Dry Drilling Process of AISI D2 Tool Steel.” is the results of my own research except as cited in references.

Signature :

Author’s Name :

Date :

APPROVAL

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

.....

(Mr. Mohd Hairizal Bin Osman)

ABSTRAK

AISI D2 alat keluli adalah bahan yang digunakan secara meluas dalam industri pembuatan. Kajian ini adalah tentang kaedah pengoptimuman parameter penggerudian dalam penggerudian kering ke atas AISI D2 keluli yang digunakan untuk mencapai parameter yang minimum pada kekasaran permukaan. Parameter penggerudian yang digunakan adalah kadar suapan, kelajuan pengumpar dan jenis bahan alat penggerudian. Beberapa eksperimen akan dijalankan berdasarkan teknik tatasusun Taguchi L₉ Ortogon pada mesin pengisar CNC. Hasilnya akan dikumpulkan dan dibandingkan dengan hasil yang perolehi daripada perisian MINITAB 17. Analisis varians (ANOVA) digunakan untuk menentukan faktor-faktor kawalan yang paling penting yang memberi kesan kekasaran permukaan.

ABSTRACT

AISI D2 Tool Steel is a material that widely used in manufacturing industries. This paper is about an optimization method of the drilling parameters in dry drilling of AISI D2 steel that use in order to achieve minimum parameter on surface roughness. The parameter of drilling that use is feed rate, spindle speed and type of drilling tools material. A number of experiments will be conducted based on the Taguchi's L₉ Orthogonal Array technique on CNC milling machine. The result will be collected and compared to the result that obtain from MINITAB 17 software. Analysis of Variance (ANOVA) is used to determine the most significant control factors affecting the surface roughness.

DEDICATION

As a token of appreciation, I dedicate this thesis to both of my parents, Mr. Shuhaimi Bin Aziz and Mrs. Noorhayati Binti Hashim.

ACKNOWLEDGEMENT

Alhamdulillah. Firstly, I would like to thanks to Allah S.W.T for His blessing to enable me in completing this thesis in time. Special appreciation to my supervisor, Mr. Mohd Hairizal Bin Osman for guiding and giving advice to me throughout this thesis carried out.

I also would like to express my gratitude to Mr Shahrul Azman Bin Sundi @ Sundi, Mr Salleh Bin Abu Hassan and all the technicians who help me in completing this thesis successfully. Lastly, I would like express my sincere thanks to my beloved family and friends for their help and moral support that give me strength . And not forgotten to those who directly or indirectly contributed in this research, thank you so much.

TABLE OF CONTENT

Abstrak	vi
Abstract	vii
Dedication	viii
Acknowledgement	ix
Table of Content	x
List of Tables	xiii
List of Figures	xiv
List Abbreviations, Symbols and Nomenclatures	xvi
CHAPTER 1: INTRODUCTION	1
1.1 Project Background	1
1.2 Problem Statement	3
1.3 Objectives	4
1.4 Work Scope	4
CHAPTER 2: LITERATURE REVIEW	5
2.1 Drilling	5
2.1.1 Dry drilling	13
2.2 Cutting Tool Material	14
2.2.1 High Speed Steel (HSS)	15
2.3 Coated Tools	16
2.3.1 PVD Coating	17
2.3.1.1 TiN coating	21
2.3.1.2 TiCN coating	22
2.3.1.3 TiAlN coating	23
2.4 Material	24
2.4.1 AISI D2 Tool Steel	24
2.5 Surface Roughness	26
2.6 Taguchi Method	28

2.7	Analysis of Variance (ANOVA)	35
CHAPTER 3: METHODOLOGY		45
3.1	Flow Chart of Research	46
3.2	AISI D2 Tool Steel	48
3.3	Drilling Tools (Drill Bit)	49
3.4	Machining Parameter	52
3.5	Taguchi Method	53
3.6	Experiment Procedure	57
	3.6.1 Machining Process	58
	3.6.1.1 Surface Grinding	58
	3.6.2 Drilling Program	60
	3.6.3 Drilling Process	66
3.7	Experimental Analysis	69
CHAPTER 4: RESULT & DISCUSSION		74
4.1	Finding and Results	74
4.2	Surface Roughness Analysis	80
	4.2.1 The Mean Result and S/N Ratio of Surface Roughness	80
	4.2.2 The Main Effects Plot for Means and S/N Ratio	81
	4.2.3 Response Table for Means and S/N ratios	85
4.3	Analysis of Variance (ANOVA)	88
4.4	Taguchi Analysis Predicted	92
4.5	Confirmation Test	94
CHAPTER 5: CONCLUSION & FUTURE WORK		95
5.1	Summary of Research	95
5.2	Achievement of Research Objectives	96
5.3	Significance of Research	96
5.4	Problems Faced During Research	97
5.5	Suggestion for Future Work	98

REFERENCES	99
APPENDICES	112
APPENDIX 1	114
APPENDIX 2	115
APPENDIX 3	116
APPENDIX 4	117
APPENDIX 5	118
APPENDIX 6	119
APPENDIX 7	120
APPENDIX 8	121
APPENDIX 9	122
APPENDIX 10	123
APPENDIX 11	124
APPENDIX 12	125
APPENDIX 13	126
APPENDIX 14	127
APPENDIX 15	128

LIST OF TABLES

2.1	The Processing and Characteristic of AISI D2 Tool Steel	25
2.2	Example of $L_4 (2^3)$ Array	30
2.3	Examples of Noise Factor	32
2.4	Formula for ANOVA	40
3.1	The Levels of Machining Parameter	52
3.2	The Parameter for Three Factor and Level.	53
3.3	The Experimental Design by Using L_9 Orthogonal Array	55
3.4	Specification of DMC 365 Veroline	67
3.5	Specification of Surface Roughness Tester	70
4.1	Taguchi L_9 Orthogonal Array Design in Minitab Software	75
4.2	The Result For Arithemitical Mean Deviation of Ra and Average	76
4.3	Calculation of Find The Average of Hole	77
4.4	The Experimental Result	79
4.5	The Result of the Mean and Signal to Noise Ratio for The Surface Roughness	81
4.6	The Response Table for Means	85
4.7	The Response Table for SN ratios	86
4.8	The Calculation of The Mean And S/N Ratio	86
4.9	ANOVA Results of Analysis	88
4.10	Calculation for Mean of Square	89
4.11	Calculation for F-test	90
4.12	Calculation for Percentage of Contribution	91
4.13	The Result of Confirmation Test	94

LIST OF FIGURES

2.1	Two Common Types of Drills	7
2.2	Drilling a workpiece	8
2.3	Types of Drilling	8
2.4	Exemplification of Physical Vapor Deposition Process	19
2.5	Exemplification for Sputtering Process	19
2.6	Exemplification for Ion-Plating Apparatus	20
3.1	Project Flow Chart	46
3.2	Flow Chart Process	47
3.3	AISI D2 Tool Steel	49
3.4	High speed steel (HSS) drill bit	50
3.5	HSS + TiN Coated	50
3.6	HSS + TiCN Coated	51
3.7	HSS + TiAlN Coated	51
3.8	The Parameter for Three Factor in Taguchi Design	54
3.9	The Experimental Design by Using L ₉ Orthogonal Array in Taguchi Design	56
3.10	Experimental Process	57
3.11	Exemplification of surface grinding operation	58
3.12	Surface Grinding Machine (JTKP Laboratory)	59
3.13	D2 Tool Steel after Surface Grinding Process	60
3.14	All 54 Holes Marked by Spot Drill	61
3.15	TiN Coated Drill Bit with Feed Rate = 68mm/min and Spindle Speed = 627rpm	61
3.16	TiCN Coated Drill Bit With Feed Rate = 103mm/min and Spindle Speed = 627rpm	62
3.17	TiAlN Coated Drill Bit With Feed Rate = 146mm/min and Spindle Speed = 627rpm	62
3.18	Second TiN Coated Drill Bit With Feed Rate = 68mm/min and	63

	Spindle Speed = 482rpm	
3.19	Second TiCN Coated Drill Bit With Feed Rate = 103mm/min and Spindle Speed = 482rpm	63
3.20	Second TiAlN Coated Drill Bit With Feed Rate = 146mm/min and Spindle Speed = 482rpm	64
3.21	Third TiN Coated Drill Bit With Feed Rate = 68mm/min and Spindle Speed = 550rpm	64
3.22	Third TiCN Coated Drill Bit With Feed Rate = 103mm/min and Spindle Speed = 550rpm	65
3.23	Third TiAlN Coated Drill Bit With Feed Rate = 146mm/min and Spindle Speed = 550rpm.	65
3.24	DMC 365 V ecoline (JTKP Laboratory)	66
3.25	The Dry Drilling Process take place	67
3.26	D2 Tool Steel after Dry Drilling Process	68
3.27	Surface Roughness Tester SJ-410	69
3.28	AISI D2 Tool Steel on Table	71
3.29	The Probe in D2 Tool Steel's Hole	71
3.30	The Green Colour Bar on the Screen	72
3.31	The Graph of Surface Roughness	72
3.32	Data of Surface Roughness has been Printed Out	73
4.1	The Equation of 'Smaller is Better'	80
4.2	The Main Effects Plot for Means	82
4.3	The Main Effects Plot for SN Ratios	82
4.4	The Predicted Result for The Mean and S/N Ratio for the surface roughness	92
4.5	Calculation of Prediction Mean and S/N Values	92
4.6	Hole for New Parameter.	93
4.7	The Calculation of Percentage Error	94

LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

AISI	-	American Iron and Steel Institute
Al	-	Aluminium
ANOVA	-	Analysis of Variance
C	-	Carbon
°C	-	Degree Celcius
CNC	-	Computer Numerical Control
Co	-	Cobalt
Cu	-	Copper
Cr	-	Chromium
CVD	-	Chemical Vapour Deposition
DOE	-	Design of Experiments
Fe	-	Ferum
HSS	-	High Speed Steel
JTKP	-	Jabatan Teknologi Kejuruteraan Pembuatan
min	-	minit
mm	-	millimeter
Mn	-	Manganese
Mo	-	Molybdeum
N	-	Nitride
Ni	-	Nickel
OA	-	Orthogonal Array
P	-	Phosphorus
PVD	-	Physical Vapour Deposition
Ra	-	Mean Roughness
Ry	-	Maximum Peak f Roughness
Rt	-	Maximum Peak-to-Valley Roughness
Rz	-	Ten Point of Mean Roughness
RPM	-	Revolution per Minutes
S	-	Sulphur
S/N	-	Signal to Noise

Si	-	Silicon
Ti	-	Titanium
TiN	-	Titanium Nitride
TiCN	-	Titanium Carbon Nitride
TiAlN	-	Titanium Aluminium Nitride
V	-	Vanadium

CHAPTER 1

INTRODUCTION

1.0 Introduction

Inside this chapter one is an explanation about the introductions of the project. It consists of the project background, problem statement, objectives and project scope.

1.1 Project Background

Industry is a sector of production that produces goods or services that will generate the national growth. One of industry that generates growth is manufacturing industry. These industries have become a key sector for production and labour during industrial revolution. For industrial production, the raw material will be changed into finished goods on large scale which will make a lot of profit for the country.

Drilling is one of cutting operations that widely applied in manufacture industries. These processes use a drill bit or known as cutting tools to cut or broaden a hole of circular in substantial materials. Drilling can be assumed as a complex operation because the cutting velocity needs to be zero at the midpoint of the drill and the removal of material happen around the chisel edge that occurs by extrusion which makes the material move radially away from centre. The material removal on the cutting edge occurs by shear in the same way as turning and milling tools with the cutting speed and distance from the drill centre. (Staff, 2010) This drilling process is either in dry or wet condition.

During a dry drilling condition, the cutting fluid won't be used at all whereas wet condition, cutting fluid will be used. Types of cutting fluid or medium cooling that always used are coolant, oil/grease, or both. Nowadays, there is increasing interest in performing machine processes in dry conditions. This is because to reduces the cost to produce a lot of products, ease of chip to remove, able to recyclability and prevent from pollute the environment. (Tasdelen, Wikblom, and Ekered, 2008).

As for this project, dry drilling process will be used with drill bit (High Speed Steel) that coated with TiN (Titanium Nitride), TiCN (Titanium Carbon Nitride) and TiAlN (Titanium Aluminium Nitride). As for the material, AISI D2 Tool Steel is used. D2 is a high Carbon and high Chromium alloy which has outstanding strength, wear and corrosion resistance, and deep hardening characteristics which is ideal for maximum production runs. Besides, this material is widely used in manufacturing industries for cutting, punching, stamping tools, shear blades, thread rolling dies, cold extrusion dies, drawing and bending tools, flanging and straightening rolls, fine cutting tools, deep drawing tools, plastic moulds for abrasive polymers and much more. The elements that contain inside AISI D2 Tool Steel like C=1.6%, Si=0.34%, Mn=0.39%, Cr=11.55%, Mo=0.81%, V=0.84%, P=0.025% and S=0.01%. (*Tool Steel*, 2014)

This project will come out with an optimization procedure of drilling parameters (feed rate, spindle speed and type of drilling tools material) in dry drilling process for AISI D2 Tool Steel in order to obtain the minimum parameter on surface roughness. The layout of this experimental will be layed out by Taguchi's L₉ Orthogonal Array technique and also ANOVA (Analysis of Variance).

1.2 Problem Statement

AISI D2 Tool Steel is well known with high Chromium and high Carbon Steels of D series that widely used in manufacturing and machining operations. This is because of its outstanding strength and wear resistance, excellent hardening properties, great for stability in hardening and great resistance to tempering-back is better than other tool steel make it hard to cut or machining and the effect on the surface roughness after the machining process is done on it. Due to their capability to maintain their mechanical ability over a range of temperatures makes them become demanding materials for modern industrial such as punches, piercing and blanking dies, spinning tools, shear blades, slitting cutters as well as higher end wood working tools.

Drilling process usually used coolant as a medium cooling that prevent the device from overheating. But, now the interest in performing operations in dry machining is increasing due to its advantage in producing a higher productivity in a lesser time along with quality or feature improvement beside of improving the cutting that conducts on the product. (Orra and Choudhury, 2016). Besides that, this dry processes also can reduce the cost of production, recyclability, and prevent from polluting the environment that can cause an environmental hazard and contaminate the health of people around there. (Kalpakjian, Technology, and Schmid, 2013).

1.3 Objectives

This project is a study on cutting parameter in dry drilling conditions using Computer Numerical Control (CNC) machine. Here are objectives of this research:

- i. To study the significant factor of surface roughness of AISI D2 tool steel in drilling process.
- ii. To find the optimum parameter in dry drilling process on AISI D2 tool steel.

1.4 Work Scope

- i. To evaluate the parameter set up which is feed rate, spindle speed and type of drilling tools material on a surface roughness, by using a dry drilling process.
- ii. Three type of HSS coated drill bit with diameter of 11mm that used for this project is TiN, TiCN and TiAlN.
- iii. Material that used is AISI D2 Tool Steel with the dimension of 200mmx 200mmx13mm.
- iv. Design layout using Taguchi's L₉ Orthogonal Array Technique and ANOVA (Analysis of Variance).
- v. Each one of coated drill bit is used to drill for 6 holes in the same 3 levels of parameter.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

In chapter two, literature review is a text of the works of others people which can pave the way for a better research. It really helps in giving a relevance research for a particular topic. So, this chapter is consist of drilling process, cutting tools for drilling process, D2 tool steel, surface roughness and statistical analysis.

2.1 Drilling

Drilling is one of the traditional machining processes that up to now still consider as the most important metal cutting operations which involve with 33% of all cutting operations. Even the modern cutting process excessively upgrades, the traditional drilling method still be used as one of the universal processes. (Garg et al., 2015) This process is used to cut or broaden the size of circular cross section of the holes in materials. The drill bit will be urged on the work piece and will rotate at rates of hundreds to thousands of revolution per minute (rpm). (Patel and Verma, 2015)

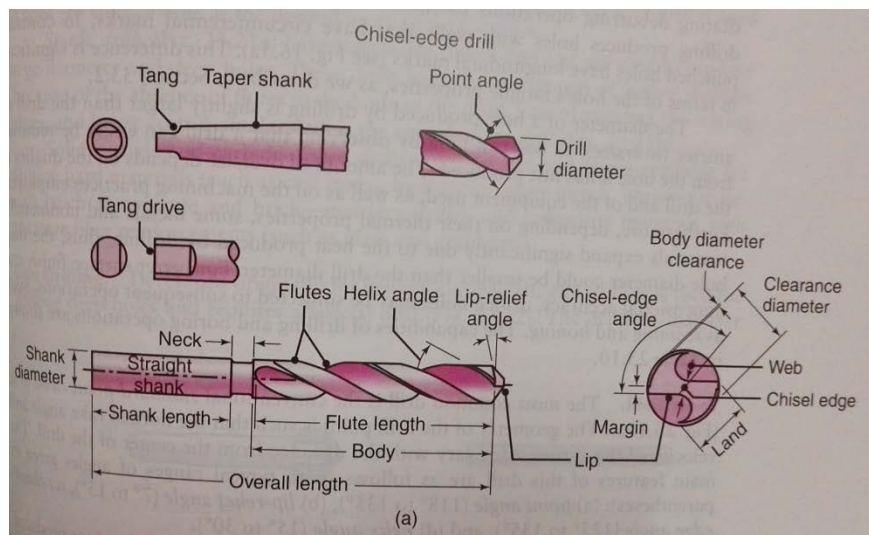
However, it also known as complex cutting processes that can simulate the action of a two twist drill with two dimensional models need to be considered because it can influence the feed velocity on the cutting geometry at the drill point. The simulation action of the drill point can develop the chip formation and indentation model. From the work material, the total torque and thrust can be predict include cutting condition, drill geometry and an empirical factor for the process.

This process is mostly used for the final step in the manufacturing of mechanical parts and it considered as economic importance (Li, Hegde, and Shih, 2007) and (Sharman, Amarasinghe, and Ridgway, 2008). Several literatures and studies show that drilling is one of the most times consuming metal removal process (36% of all machine hours) when compared to turning and milling which accounts for 25% and 26% machining hours respectively. When compared to other machining processes like turning and milling, the cutting tool in drilling process have to perform under severe conditions as the machining region is situated deep within the workpiece and hence it is still viewed as one of the challenging machining processes in spite of the widespread research work carried out. (Mathew and L., 2016)

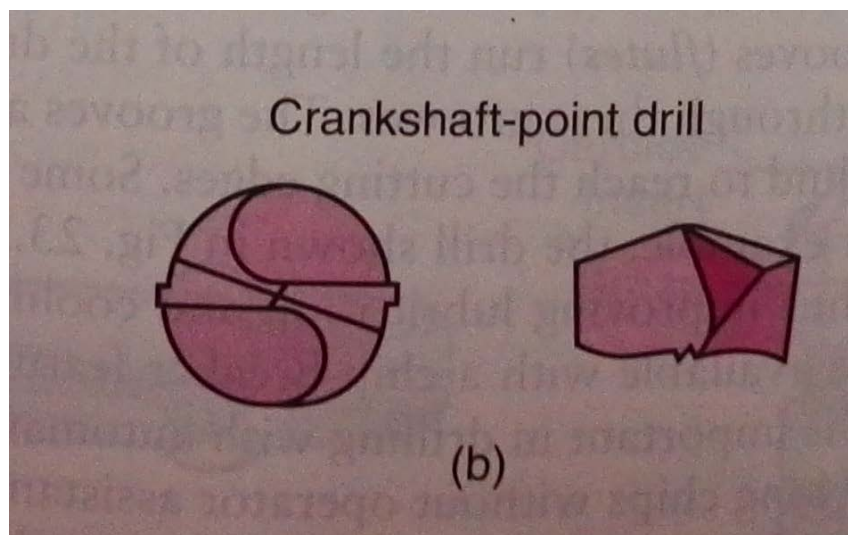
Nowadays, the drilling process is very important especially in making small hole. This small drilling hole is widely used in industries especially in producing precision products spanning from the manufacturing of fuel injection nozzles, printed circuit boards, Micro Electro-Mechanical System (MEMS) packaging, orifices in air bearings, and vent holes. Besides that, this process also used in aerospace industries in order to make a condenser tubes in turbines and holes in turbine blades. (Prasanna et al. 2014) It commonly use up to 50% in machining operations due to its new control systems where it has many advantages like reduce the cycle time, device breakage and cost, and also product quality improvements. (Sheng & Tomizuka 2006; Haber et al. 2010). According to Authors, the drilling performance such as metal removal rate, thrust force, torque and tool life can be forecast based on the process parameters like drill diameter, cutting speed and feed rate.

The cutting tool is very importance for the drilling process. This is because the failure to choose the suitable drill types can cause to uncontrollable vibrations and raised the cutting force which at the end will resulting in nasty outcomes like rapid tool wear, poor quality surface, inability to get the required dimensional accuracy, unwanted burr formation at the front and back of holes, and excessive noise. (Ekici, Motorcu, and Uzun, 2017). As the twist drill rotates and penetrates into the workpiece, it produces both thrust force and torque. The cutting action by the lips and the web as well as the extrusion action of the web contributes to the thrust force. (Mathew and L., 2016). Therefore, the various angles have been accomplished on the

drill in order to make accurate holes, lessen the force and torque of drilling and increase the tool life. (Kalpakjian, Technology, and Schmid, 2013)



(a) Chisel-Edge Drill



(b) Crankshaft Drill

Figure 2.1: Two Common Types of Drills. (a) Chisel-edge drill. The function of the pair of margins is to provide a bearing surface for the drill against walls of the hole as it penetrates into the workpiece. (b) Crankshaft drill. These drill have good centering ability, and because chips tend to break up easily, this drills suitable for producing deep holes.

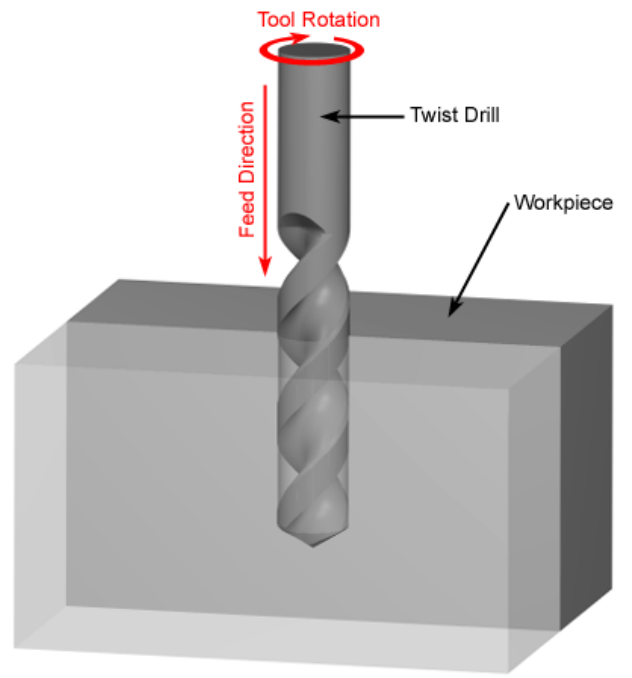


Figure 2.2 Drilling a workpiece

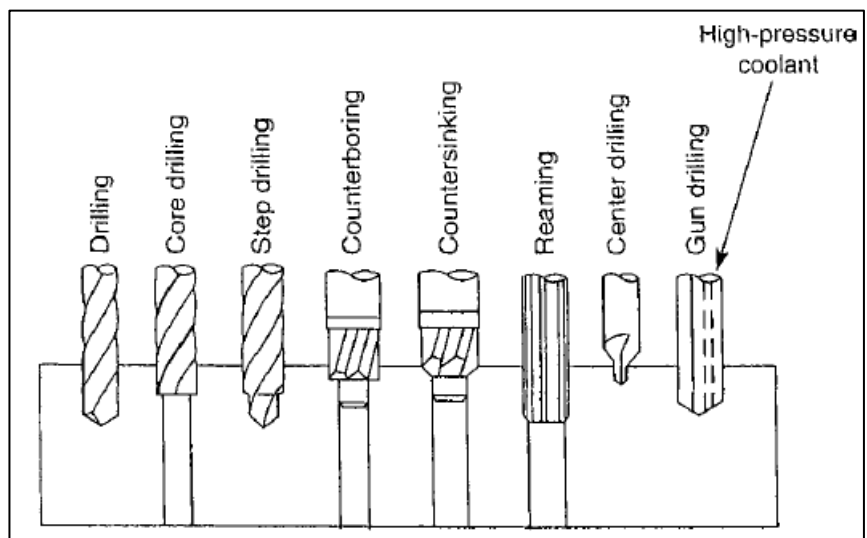


Figure 2.3: Another Types of Drilling

In Figure 2.2 shows the drilling process on a workpiece. As for Figure 2.3, it show types of drilling that used for machining.