UNIVERSITI TEKNIKAL MALAYSIA MELAKA

A STUDY ON GRAPHITE MACHINING

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

by

FATIMAHTUL ADNIN BINTI SULAIMAN

FACULTY OF MANUFACTURING ENGINEERING

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……………………………………………………..
DR.BAGAS WARDONO
Pensyarah,
Fakulti Kejuruteraan Pembuatan
Universiti Teknikal Malaysia Melaka(UTeM)
Karung berkunci 1200, Ayer Keroh,
75450, Melaka

DECLARATION

I hereby, declare that this report entitled **"A STUDY ON GRAPHITE MACHINING"** is the result of my own research except as cited in the references.

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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 of Bachelor of Manufacturing Engineering (Manufacturing Process) with Honours. The members of the supervisory committee are as follow:

…………………………………….

DR.BAGAS WARDONO

(Main Supervisor)

ABSTRACT

This project focuses on machining of Graphite material using a conventional lathe machine. The aim of this project is to study the significance of various variables and identify parameters that affect the machining of Graphite. The machining parameters considered in this project are cutting speed, feed rate, and depth of cut. The importance of the machining parameters will be determined in term of surface roughness. The material used in this project is Graphite with 200mm length and 50mm diameter. The cutting tool used in this project is diamond shape TiN coated carbide cutting tool. Upon completion of the machining process, the work piece is evaluated in terms of the surface roughness using portable surface roughness tester. For each run of the experiment, three measurements were taken and the average is used to represent the surface roughness of the corresponding run. Design of Experiment (DOE) is utilized in this project to find the significant machining parameters. The analysis from DOE shows that the feed rate is the most significant factor in surface roughness, while cutting speed and depth of cut do not show significant impact toward the resulting surface roughness.

ABSTRAK

Projek ini menumpukan kepada proses pemesinan Graphite dengan menggunakan mesin larik. Tujuan projek ini adalah untuk mengkaji kepentingan pelbagai pemboleh ubah dan mengenal pasti parameter-parameter yang memberi kesan kepada proses pemesinan Graphite. Parameter-parameter pemesinan yang diambil kira dalam projek ini adalah halaju potongan, kedalaman potongan, dan kadar pemakanan dalam satu pusingan. Kepentingan parameter-parameter pemesinan akan ditentukan melalui kekasaran permukaan. Bahan kerja yang digunakan dalam projek ini ialah Graphite dengan panjang 200 mm dan diameter 50 mm. Mata alat yang digunakan dalam projek ini ialah mata alat ’carbide’ yang telah dilapiskan dengan TiN. Selepas selesai proses pemesinan, bahan kerja dinilai berdasarkan kekasaran permukaan dengan menggunakan penguji kekasaran permukaan mudah alih. Untuk setiap proses pemesinan, tiga ukuran diambil pada bahagian yang berlainan dan purata digunakan sebagai mewakili kekasaran permukaan daripada proses pemesinan yang telah dilakukan. ’Design of Experiment’ (DOE) digunakan dalam projek ini untuk mengenal pasti dan mencari parameter-parameter pemesinan yang penting. Analisis daripada DOE menunjukkan bahawa kadar pemakanan dalam satu pusingan adalah faktor yang paling penting dalam kekasaran permukaan manakala halaju potongan dan kedalaman potongan tidak menunjukkan kesan yang penting dalam kekasaran permukaan.

DEDICATION

This work is dedicated to my beloved parents and friends

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LIST OF ABBREVIATIONS

AA	-	Arithmetic Average
Al_2O_3	-	Aluminum Oxide
ANOVA	-	Analysis of Variance
ASME	-	American Society of Mechanical Engineers
BUE	-	Built Up Edge
CLA	-	Center Line Average
CrN	-	Chromium Nitride
CVD	-	Chemical Vapor Deposition
DOE	-	Design of Experiment
EDM	-	Electrical Discharge Machining
HSM	-	High Speed Machining
H.S.S	-	High Speed Steel
Mg-C	-	Mag-Carbon
MMC	-	Metal Matrix Composites
PVD	-	Physical Vapor Deposition
Ra	-	Arithmetic average
Rq	-	Root mean square value
TiAlN	-	Titanium Aluminum Nitride
TiCN	-	Titanium Carbonitride
TiN	-	Titanium Nitride
TiC	-	Titanium Carbide
WC	-	Tungsten Carbide

CHAPTER 1
INTRODUCTION

1.1 BACKGROUND

Carbon-graphite offers the design engineer a unique family of mechanical materials. Manufactured entirely from carbon and including high temperature carbonaceous bonding, these materials combine the strength, hardness and wear resistance of carbon with the corrosion resistance and self lubricating properties of graphite. The precisely controlled inherent porosity of carbon-graphite can be filled with a variety of impregnates to enhance chemical, mechanical and tribological properties [11].

Machining of Graphite is different from machining of Metals. Metal exerts plastic deformation when a tool edge cuts it, producing a curl or chips. Machining of Graphite will separate small powder like particles from the work piece. This will result a brittle fracture caused by the stress and produced by the cutting tool edge. Machining graphite operation consumes much less energy and generates much less heat than in machining metals. Graphite is abrasive material causing fast wear of metallic uncoated cutting tools. Only diamond (preferable) or carbide tools may be used for cutting graphite [2]. Graphite and carbon are generally machined dry without using cutting fluids which also known as coolants. If coolants are used in some machining operations such as grinding, honing, and polishing the work piece should be dried at 150-200°C to remove liquids absorbed by the material.

Graphite as compared to metals is machined at higher cutting speed, feed rate of speed and depth of cut. Different operations of machining Graphite such as turning, milling, and drilling have different values of cutting parameters. Chipping or breakage of the material in the exit of a cutting pass may be avoided by limiting the depth of cut to a half of the insert length. Lowering feed rate in the exit of a pass also prevents chipping. Chamfer at the end of the work piece makes the tool entrance and exit easier and diminishes chipping. Machining graphite and carbon produces dust with particles size in the range 0.0004”-0.005” (10-130μm). The dust must be removed from the machining region by a dust extraction system providing a minimum air velocity of 6 ft/s (20 m/s).

Graphite is softer and relatively weak because of the crystalline order and closer spacing between the monoplanes and stacks. A graphite structure can be compared to a deck of cards with individual layers able to easily slide off the deck. This phenomenon gives the material a self lubricating ability which is matched by no other material. External lubricants are simply not necessary [11].

1.2 PROBLEM STATEMENT

The cutting tools and techniques used in graphite machining are different to those used in metal machining. The selection of tool geometry, tool material and cutting parameters require a modification because of the differences in hardness, strength, microstructure and friction characteristics. Graphite is considered to be easily machined due to its low mechanical strength. The abrasive behavior of graphite will lead to a shortened tool life for tools without coating. Graphite machining using common cutting parameters and basic cutting strategies and tool movements, can be made viable and does not present significant difficulties.

Graphite is also a brittle material, with brittle fracturing being a main characteristic when submitted to most of the machining processes. Graphite is machined under a process of polycrystalline structure fracturing instead of plastic deformation. High temperature or cutting forces are almost non-existent in graphite cutting process. Graphite powder generation and its impregnation at the most unexpected points of the machine-tool, is one of the problems encountered during machining. The graphite powder penetrates the small breaches and openings of the machine tool. Other than that, the powder is deposited over the beds and inside bearings, which causes damage to the clamping screws and slide bearings. Graphite is an electrical conductor and when these particles penetrate the computers and engine control cabinets, intermittent short circuits can occur, which lead to the destruction in the electronic parts.

1.3 OBJECTIVES OF PROJECT

The specific objectives for this project are:

1) To study the significant of various variables which are cutting speed, feed rate, and depth of cut that affects the machining of Graphite.

2) To identify the characteristics of Graphite machinability.

3) To identify parameters that affects the machining of Graphite.

4) To implement statistical tool namely Design of Experiment (DOE), in finding the significant parameters.

1.4 SCOPE OF PROJECT

Graphite is generally grayish black, opaque and has a lustrous black sheen. It is unique in that it has properties of both a metal and a non-metal. It is flexible but not elastic, has a high thermal and electrical conductivity, and is highly refractory and chemically inert. Graphite has a low adsorption of X-rays and neutrons making it a particularly useful material in nuclear applications. For this project, the experiment will involve the setting-up and running of machining trial using graphite and TiN coated carbide cutting tool followed by detailed examination of the material using portable surface roughness tester. The machining parameters involved in this project are cutting speed, depth of cut, and feed rate. A lathe machine will be used to run the machining trial and the machine is run in dry machining without using coolant. The surface roughness that will be obtained during machining trial are examined and their result is analyzed to relate with cutting parameters used in this machining trial. Design of Experiment (DOE) will be used in this project to determine the relationship among various factors affecting the process. From the results, better cutting parameters in machining graphite will be recommended. The results obtained will be important in helping the applications of graphite in manufacturing industry.

CHAPTER 2
LITERATURE REVIEW

This literature review discusses the information about the material and the cutting tool used in this project, namely graphite and cemented carbide. As for the cutting tool, two different types will be discussed which are coated and uncoated cutting tools. In addition, the machining parameters and types of machine used will also be discussed. At the end of the chapter, previous works related to Graphite machining are presented.

2.1 GRAPHITE

Graphite is a crystalline form of carbon having a layered structure with basal planes or sheets of closed-packed carbon atoms. Consequently, graphite is weak when sheared along the layers. This characteristic, in turn, gives graphite its low frictional properties as a solid lubricant. However, its frictional properties are low only in an environment of air or moisture; in a vacuum, graphite is abrasive and poor lubricant. Unlike in other materials, strength and stiffness of graphite increase with temperature. Amorphous graphite is known as lampblack (black soot) and is used as a pigment.

Although brittle, graphite has high electrical and thermal conductivity and good resistance to thermal shock and to high temperature (although its begins to oxidize at 500 ˚C). Therefore, graphite is an important material for applications such as electrodes, heating elements, brushes for motors, high-temperature fixtures and furnace parts, mold materials (such as crucible for the melting and casting of metals), and seals. A characteristic of graphite is its resistance to chemicals, cross-section and high scattering cross-section for thermal neutrons that makes graphite suitable for nuclear applications. Ordinary pencil “lead” is a mixture of graphite and clay.

Graphite is available commercially in square, rectangular, and round shape of various size and generally is graded in decreasing order of grain size; industrial, fine grain, and micro grain. As in ceramics, the mechanical properties of graphite improve with decreasing grain size. Micro grain graphite can be impregnated with copper. In this form, it is used for electrodes in electrical discharge machining and for furnace fixtures. Graphite usually is processed first by molding or forming, then by oven baking, and finally by machining to the final shape [15] (pp.232-233).

According to CERAM Research [1], there are two main classifications for graphite, which are natural and synthetic. Natural graphite is a mineral consisting of graphitic carbon. It varies considerably in crystalline. Most commercial (natural) graphite is mined and often contains other minerals. Subsequent to mining the graphite often requires a considerable amount of mineral processing such as froth flotation to concentrate the graphite. Natural graphite is an excellent conductor of heat and electricity. It is stable over a wide range of temperatures. Graphite is a highly refractory material with a high melting point (3650°C). Natural graphite is subdivided into three types of material that are Amorphous, Flake, and High crystalline.

Synthetic graphite can be produced from coke and pitch. It tends to be of higher purity though not as crystalline as natural graphite. There are essentially two types of synthetic graphite. The first is electro graphite, which is pure carbon produced from calcined petroleum coke and coal tar pitches in an electric furnace. The second type of synthetic graphite is produced by heating calcined petroleum pitch to 2800°C. On the whole, synthetic graphite tends to be of a lower density, higher porosity and higher electrical resistance. Its increased porosity makes it unsuitable for refractory applications. Synthetic graphite consists mainly of graphitic carbon that has been obtained by graphitization, heat treatment of non-graphitic carbon, or by chemical vapor deposition from hydrocarbons at temperatures above 2100K.

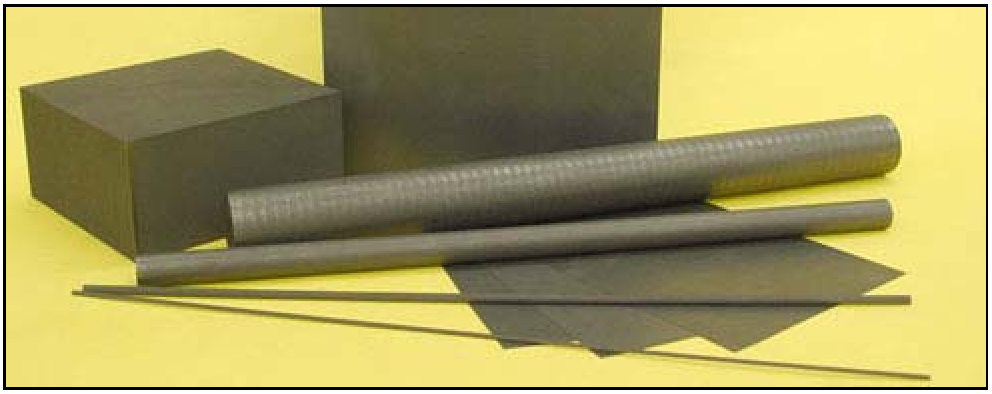

Figure 2.1: Various shapes and sizes of Graphite [2]

2.1.1 APPLICATIONS

Graphite has been used in many different types of applications. Several of them are discussed below [1]:

1) Refractory Material

Due to its high temperature stability and chemical inertness, graphite is a good candidate for a refractory material. It is used in the production of refractory bricks and in the production of "Mag-carbon" refractory bricks (Mg-C). Graphite is also used to manufacture crucibles, ladles and moulds for containing molten metals. Additionally graphite is one of the most common materials used in the production of functional refractory for the continuous casting of steel. In this application, graphite flake is mixed with alumina and zirconia and then isostatically pressed to form components such as stopper rods, subentry nozzles and ladle shrouds used in both regulating flow of molten steel and protecting against oxidation. This type of material may also be used as shielding for pyrometers. In the production of iron, graphite blocks are used to form part of the lining of the blast furnace. Its structural strength at temperature, thermal shock resistance, high thermal conductivity, low thermal expansion and good chemical resistance are of paramount importance in this application. The electrodes used in many electrical metallurgical furnaces are manufactured from graphite such as the electric arc furnaces used for processing steel.

2) Chemical Industry

There are many high temperature uses for graphite in the chemical industry such as in the production of phosphorus and calcium carbide in arc furnaces. Graphite is used as anodes in some aqueous electrolytic processes such as in the production of halogens (chlorine and fluorine).

3) Nuclear Industry

High purity electro graphite is used in large amounts for the production of moderator rods and reflector components in nuclear reactors. Their suitability arises from their low absorption of neutrons, high thermal conductivity and their high strength at temperature.

4) Electrical Applications

The main application for graphite as an electrical material is in the manufacture of carbon brushes in electric motors. In this application the performance and lifetime of the component is very dependent on grade and structure.

5) Mechanical Applications

Graphite is used widely as an engineering material over a variety of applications. Applications include piston rings, thrust bearings, journal bearings and vanes. Carbon based seals are used in the shafts and fuel pumps of many aircraft jet engines.

2.1.2 ADVANTAGES AND BENEFITS OF GRAPHITE

Particle size determines the grade of graphite whether it is a good grade or a poor grade. Particle size gives strength, machinability and greatly influences the metal removal rate, wear and the surface finish. Graphite is made up of carbon particles that are put through a graphitizing process to produce graphite. The smaller the particle size is, the better the graphite. Particle sizes in different grades of graphite can be 0.0006" for general-purpose use to 0.00004" for the extremely fine detail and superior surface finishes. Graphite can be purchased in big blocks, and then cut up to be machined or it can be ordered precut or ground into the size required.

Graphite can be machined very easily through the milling, grinding, turning, drilling, tapping, even filing to whatever shape that a manufacturer wants. Another advantage of graphite is that it doesn't burr. There is no deburring when finished machining the graphite into the complex shape and forms using the duplicating machine or high-speed mill [10].

2.1.3 LIMITATION OF GRAPHITE

Machining graphite will result in dust particles on the floor and in the nearby machines. However, the new high-speed mills that are sold today are specially designed to machine graphite. They are totally enclosed and have a vacuum system to remove all of the dust and there are some machines that can even cut square internal corners.

When manufacturing graphite for mold, there is an important point to keep in mind, which is the finishing on any electrode is the finishing that will be put in the mold. A lot of cutter or grinding marks on the electrode will reproduce in the mold. Normally, the finishing on the graphite should be as good the manufacturer needs in the mold [10].