KAJIAN KEBOLEHMESINAN KARANG LAUT BERLIANG SEBAGAI TULANG GANTIAN

(MACHINABILITY STUDY OF POROUS SEA CORAL MATERIAL FOR USE IN BONE GRAFTING)

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ABSTRAK

Penyelidikan terhadap karang laut sebagai tulang graf gentian telah dibuktikan melalui pelbagai kajian dan experiment. Ia telah terbukti mempunyai kesesuaian bio. Walaubagaimanapun aplikasi bahan tersebut mungkin menjadi terhad sekiranya ia tidak dapat diproses kepada bentuk yang diperlukan untuk menjalankan fungsi – fungsi tertentu. Oleh itu projek ini adalah bertujuan untuk menjalankan kajian kebolehmesinan karang laut dari spesis Porites. Eksperimen adalah berdasarkan kaedat *Taguchi orthogonal array* untuk pengoptimuman permukaan dengan mengkaji terhadap tiga parameter pemesinan utama iaitu kadar suapan, kedalaman serta halaju pusingan *spindle* disamping memberikan penenkanan terhadap kelusuhan mata alat dan pembentukan chip

ABSTRACT

Research of Sea coral as bone substitute has been reported in many experimental studies. It has been proven to be biocompatible. However the implementation of the material may be limited if the material cannot be processed into a shape required to perform its function. This project presents an investigation into machinability of Dead Sea coral from Porites sp. The experimental work is based on Taguchi orthogonal array for optimizing surface integrity by investigating three machining parameters feed rate, depth of cut and spindle speed besides the assessment on cutting too wear and chip fragment.

CHAPTER 1
INTRODUCTION

1.1 Problem overview

Current research on sea coral as bone substitute has been reported in many experimental studies. It has been proven biocompatible, biodegradable and has not been found to cause any inflammatory response. Previous study by HUSM had identified a species of sea coral from our own biodiversity that has similar characteristic to human bone. A problem arises because the machining processes are still the basic requirement to ensure dimension and geometrical accuracy. It is therefore important to understand the machinability of the material so as to be able to optimize the machining parameters. The application of machining techniques however, requires information and data on machinability. This project presents a study of the machinability of dead sea coral for bone grafting.

The experimental design based on Taguchi Method. The results of the Taguchi experiments are analyzed in a standard series of phases. First, the factorial effects (main effects) are evaluated and the influences of the factors are determined in qualitative terms. The optimum condition and the performance at the optimum condition are also determined from the factorial effects. In the next phase, analysis of variance (ANOVA) is performed on the result. ANOVA study identifies the relative influence of the factors in discrete terms. When the experiments include multiple runs and the results are measured in quantitative terms, Taguchi recommends signal to noise ratio (S/N) analysis. In S/N analysis, the multiple results of a trial condition are first transformed into S/N ratios and then analyzed.

1.2 Thesis Organization

The layout of this thesis is discussed in this section. Chapter one gives a general introduction to this report and the literature review literatures related literature reviews of machinability of material, coral material for bone grafting, ceramics milling machining and Taguchi method. Subsequently, the second chapter describes the methodology carried out in this study. Chapter three contains the details results and discussions for the report. Finally, chapter four concludes this report.

1.3 Literature Review

In order to study the machinability of the material, literature reviews of Dead Sea coral material, ceramic, machinability of material, milling machining and experiment design using Taguchi method carried out as follows:

1.3.1 Machinability of Materials

The term "machinability" refers to the ease or difficulty with which a given material (or group of materials) can be machined [3]. Several properties of the work material affect machinability; the most include the chemical composition, microstructure, mechanical properties (e.g. hardness, tensile strength and work hardening characteristic), and physical properties (e.g. thermal conductivity and diffusivity), However, machinability is not a work material property, but rather a property of the machining system which is affected by the work material, tool material, machine tool, part, fixture, cutting physical processes such as tool wear or surfaces generation which, as discussed below, are generally used as machinability criteria.

As a result, machinability must be assessed based on machining test, and the resulting, and the resulting rating depends on the test condition and the parameters measured to quantify the results. Machinability therefore cannot be uniquely define in quantitative term and may have varying or even contradictory meaning in different context. For example work piece materials from the same material family may require similar specific power to machine, but may yield different tool wear rates due to differences in the concentration of abrasive particles in the matrix. Using a machining power criterion, they would exhibit significant differences in machinability. When this fact is considered, the futility of trying to define a unique machinability rating or criterion applicable to all application of a specific becomes obvious, as does the qualitative rather than quantitative utility of machinability rating systems.

The term "machinability" is also used to describe accepted machining practice for a given material. Machinability data collected in handbooks of recommended cutting speed, feed rates and depths of cut for specific work materials. Separate values are normally given for different operations and tool material grades. Machinability data is generally gathered from production experience and summarizes machining condition which yield acceptable tool life and part quality under common operating condition. The recommended speed and feeds represent only initial starting condition which should be modified as needed to optimize machining performance in a give application.

(a) Machinability Criteria

The most commonly used criteria for assessing machinability are:

i. Tool life or tool wears rates.

This is the most meaningful and common machinability criterion. Tool wear affects both the quality and cost of the machined part. Machinability is said to increase when tool wear rates decrease (or tool life increase) under the machining conditions of interest.

ii. Chip form.

Materials which produce short chips which are easily managed and disposed of are more machinable than those which produce long, unbroken chips or small, powder-like chips. The chip form is particularly important for applications such as drilling for which chip breaking and disposal concerns may limit production rates.

iii. Achievable surface finish**.**

Generally, machinability increase as the surface finish achievable under a given set of cutting conditions improves. The average roughness is the most common parameter used to assess surface quality in machining tests. This criterion is must useful in ranking different classes of material. Although many factors affect the surface condition of a machined part, cutting parameters such as speed, feed and depth of cut have a significant influence on the surface roughness for a given machined tool and work piece setup.

iv. Surface integrity

Describes not only the topological (geometry) features of surfaces and their physical and chemical properties, but their mechanical, metallurgical properties and characteristic as well. Surfaces integrity is an important consideration in manufacturing operation because it influences properties, such as fatigue strength, resistance to corrosion and service life.

v. Surface texture.

The description of surfaces texture as a geometrical property is complex. However, certain guidelines have been established for identifying surface texture in terms of well define and measurable quantities. For example,

1. Flaws, or defects, are random irregularities such scathes, cracks, holes, depressions, seams, tears or inclusions.
2. Lay or directionality is the direction of the predominant surface pattern and is usually visible to the naked eye.
3. Roughness is defined as closely spaced, irregular deviation on a scale smaller than of waviness. Roughness may be superimposed on waviness. Roughness is expressed in terms of its height, its width and its distance on the surface along which it is measured.
4. Waviness is a recurrent deviation from a flat surface, much like waves on the surface of water. It is measured and described in terms of the space between adjacent crests of the waves (waviness width) and height between the crests valleys of the waves (waviness height). Waviness can be caused by (a) deflection of tools, dies or the work piece (b) forces or temperature sufficient to cause warping, (c) uneven lubrication (d) vibration or (e) any periodic mechanical or thermal variations in the system during manufacturing operations.

1.3.2 Ceramics

Ceramics consist of crystalline metallic oxides, carbides, nitrides and borides fused by the high temperature process known as sintering. They have following relative characteristics: brittleness; high strength; and hardness at elevated temperatures; high elastic modulus and low toughness, density, thermal expansion and thermal and electrical conductivity. However, because of the wide variety of ceramic-material compositions and grains sizes, the mechanical and physical properties of ceramics vary significantly. Because of their sensitivity to flaws, to defects and to surface or internal cracks, to the presence of different types and levels of impurities and to different methods of manufacturing, ceramics can have a wide range of properties.

(a) Mechanical and Physical properties

The tensile strength of polycrystalline ceramic parts increases with decreasing grain size and porosity. Thermal conductivity of ceramics, like of other materials, decrease with increasing temperature and porosity, because air is a poor thermal conductor. Thermal expansion and thermal conductivity induce stresses that can lead to thermal shock or to thermal fatigue. The tendency toward thermal cracking (called spalling when a piece or a layer from the surface breaks off) is lower with low thermal expansion and high thermal conductivity.

Because of their strength and inertness, ceramics are used as biomaterials (bioceramics) to replace joints in the human body, as prosthetic devices and in dental work. Furthermore, ceramic implants can be made porous; bone can grow into the porous structure (likewise with porous titanium implants) and develop a strong bond, having high structural integrity, between them. Commonly used bioceramics are aluminum oxide, silicon nitride and various compounds of silica. Another important group of ceramics comprises materials deriving from calcium. Such ceramics are composed of calcium sulphate, phosphate and carbonate derivates and their mixtures in dense, porous and granular forms. [6]

1.3.3 Sea Coral for bone grafting

Certain coral skeletons have been found to be excellent material for repairing localized damage to bones from injury or disease. Traditionally, bone was obtained from another part of the patient, an expensive and painful procedure. Numerous materials, including Animal bone and synthetic materials have also been used but coral skeletons appear to be one of the best. Why? The objective is to have the graft material replaced by real bone, a process called "remodeling" which our bones constantly undergo. Grafts made from coral are resorbed more quickly than other materials because coral is very porous and dissolves. The coral exoskeleton consists of (98%-99%) calcium carbonate ($CaCO_3$) in the form of aragonite crystals, the high pressure form of calcite. The crystal is 100µm long and is prismatic in shape (Guillemin et al. 1981, 1995). The remaining is composed of simple amino acids (Issahakian et al. 1987a, Ouhayoun et al. 1992) and has osteoconductive properties (Sautier et al. 1990).

The porosity of coral has been shown to be an important physical property for its behavior as an implant. Coral skeletons present with different size porosities. The volume of porosity affects the rates of alloplast resorption and bone formation. It exhibits an open porosity, as all the pores communicate with each other. The Porites porosity volume is 49.2% and their mean pore diameter is 250 µm (range 150–400 µm) , the smaller the porosity of the coral exoskeleton is, the greater the density per volume unit and the greater the compressive strength and modulus of elasticity become. The rate of coral resorption and bone deposition is faster with larger porosity volumes and smaller pore diameters both in pig and in sheep models (Guillemin et al. 1989). Coral skeletons of higher porosity volume allow larger cellular infiltrate and ion exchange promoting a faster resorption and bone apposition (Guillemin et al. 1989, Jammet et al. 1994).
The porous Porites is brittle and can be used on non loading sites. Brittleness is a measure of the relative susceptibility of a material to deformation and fracture [4] or in other words brittleness is the property of breaking without much permanent distortion. It may due to the brittleness of the grain boundaries or of the crystals themselves. 1979. The coral pore size is consistent and varies very little as shown by figure 1.1 below and figure 1.2 shows the optical microscopy of sea coral.

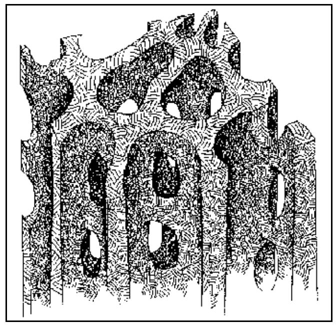

Figure 1.1 Drawing of a bone graft substitute replicate from Porites. Channels of osteonic diameter and channel wall fenestration mimic the interstitial matrix of cortical bone (Holmes 1988)

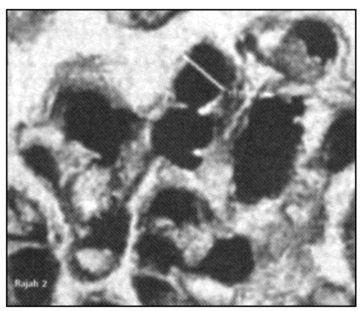

Figure 1.2 Micrograph of Porites coral shows the porosity of Porites

More than 2000 coral species have been described from the intertropical area and of these, fourteen Scleractian corals have been studied as possible bone substitutes. The following genera have already been used as bone grafts: Pocillopora, Acropora, Montipora, Porites, Goniopora, Fungia, Polyphyllia, Favites, Acanthastrea, Lobophyllia and Turbinaria. (ouchon et al. 1995). The most successful research was studied by HUSM had identified a species of Dead Sea coral from our own biodiversity is Porites [7] which is shown by figure 2.3 below.

Figure 1.3: Sea coral from biodiversity

1.3.4 Milling operations

Milling is the process of cutting away material by feeding a workpiece past a rotating multiple tooth cutter. The cutting action of the many teeth around the milling cutter provides a fast method of machining. The machined surface may be flat, angular, or curved. The surface may also be milled to any combination of shapes. The machine for holding the workpiece, rotating the cutter, and feeding it is known as the Milling machine.

Milling was carried out on CNC (computer numerical control) machining centre. These machine tools are versatile and are capable of milling operation with repetitive accuracy and reprogrammable. Therefore human error and time consume can be reduces.

A solid carbide end mill tool of 4 mm in diameter was chosen due to high wear resistance and hardness properties associated with it. Flat surfaces as well as various profiles can be produces by end milling. The cutter in end milling (end mill) is shown in figure. The cutter usually rotates on an axis perpendicular to the workpiece, although it can be tilted to machine-tapered surfaces.

(a) Surface Finish in Milling

The cutting edge all cut slightly different feed rates and depth of cut. Vibration due to the interrupted nature of the process and changes in cutter position caused by spindle and/or cutter run out and stability of part and fixture produce further variations in the effective feed rate and depth of cut of each cutting edge. The effective feed rate also varies with the angle of the cutting edge from the feed direction. As a result of all these effects, the surfaces finish in milling is less uniform than that in turning and boring, in which the machined surface is formed by a single cutting edge cutting at a comparatively constant feed rate and depth of cut.

(b) Measures of Roughness

Surfaces roughness is generally described using two methods: arithmetic mean value and root-mean-square average. A simple measure of roughness is the average area per unit length that is off the centre line (mean). We will call this the Centre Line Average (CLA), or Arithmetic Average (Ra), the units are μm. The arithmetic mean value Ra is defined as in the figure 2.4.

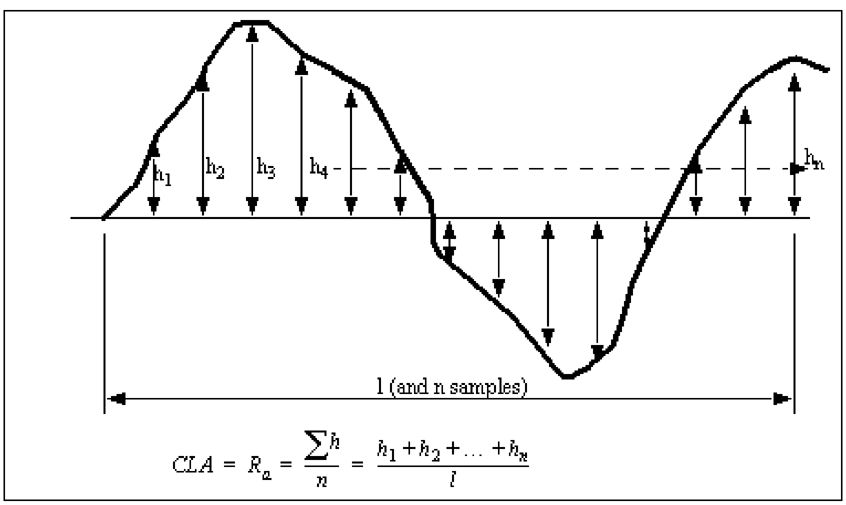

Figure 1.4: The arithmetic mean value Ra

The datum line AB in figure 2.4 is located so that the sum of the areas above the line is equal to the sum of the areas below the line.

(c) Stylus Measurements

The finish of machined surfaces measures with a stylus type profile meter or profilometer, an instrument similar to a phonograph which amplifies the vertical motion of a stylus as it is drawn across the surface. The output of the profilometer Is a two dimensional profile of the traced surface segment, amplified in the directions both normal and along the surface to accentuate surface contour and irregularities. On a gross scale, the surface profile of a nominally smooth surface gives an indication of the surface's shape, waviness and roughness

The distance that the stylus travels is called cutoff; it generally ranges from 0.08 mm to 25 mm. The rule of thumb is that the cutoff must be large enough to include to 10 to 15 roughness irregularities as all surface waviness. In order to highlight the roughness, profilometer traces are recorded on an exaggerated vertical scale, the magnitude of the scale is called gain on the recording instrument. Thus the recorded profile is significantly distorted and the surface appears to be much rougher that it actually is. The reading record instrument compensates for any surfaces waviness, it indicates only roughness, A record of the surface profile is made using mechanical and electronic instrument.
Because of the finite radius of the diamond stylus tip, the path of the stylus is less rough that the actual surface.

1.3.5 Introduction to Taguchi Method

There is a unique statistical experimental design method named Taguchi's robust design method. Parameter design by Taguchi method is off-line quality control method. Off line quality control methods are quality and cost control activities conducted at the product and process design stages to improve product manufacturability and reliability and to reduce product development and lifetime costs. Parameter design can be used to make a process robust against sources of variation and hence improve field performance. In view of Taguchi's concept, the product must be produced at optimal levels and with minimal variation in its functional characteristics.

Two factors affect the product's functional characteristics: control factors and noise (or uncontrolled) factors. Control factors can be easily controlled and on the other hand noise factors are nuisance variables that are difficult, impossible or expensive to control. Noise factors, in general, are responsible for causing a product's functional characteristic or process to deviate from target value. Controlling of noise factors is very costly or difficult, if not impossible.

In Taguchi's method, based on the experimental results, the optimal combination of factor levels that make the process less sensitive to the effects of noise factors (environmental variables, deterioration, and manufacturing variations) that are the causes of variation will be selected. Because parameter design reduces performance variation by reducing the influence of the sources of variations rather than by controlling the sources, it is a very cost effective technique to improve product quality. So factor levels should be made to make the product or process least sensitive to changes in the noise factors; that is, instead of finding and eliminating causes, as the causes are often noise factors, the impact of the causes should be reduced

This robust design method is in use in many areas of engineering . All of these showed that this robust design methodology offers simultaneous improvement of process, performance and cost, and engineering productivity. Its widespread use in industry will have a far-reaching economic impact because this methodology can be applied profitably in all engineering activities, including product design and manufacturing process design.

Different types of designs are needed in different experimental environments. Experimental design is a critically important tool for improving the performance of a manufacturing process. It also has extensive application in the development of new processes. The application of experimental design technique early in process development can improve yield and reduce variability.

The aim of a parameter design experiment is then to identify settings of the design parameters that maximize the chosen performance measure. The estimation of a prediction equation that is valid over a wide region of the parameter space is clearly not the goal. Taguchi recognizes the presence of interactions among design parameters, but he downplays their importance relative to the main effects in constructing the design matrix. According to Taguchi, when there are limits on the number of test runs, it is better to include many design parameters in the design matrix even until no degrees of freedom are left for estimating the residual error than to include only a few design parameters and allow for estimating interactions. This was the case that the test runs were very expensive and many. With the large number of design parameters, the number of test runs required to estimate all main effects and all pair interactions will be prohibitively large.

As a first order model involving only linear terms is often inadequate. Curvature effect is very important and this effect almost always occurs when either the test settings are chosen wide apart or the test settings are near a peak of the response variable. The problem is how to construct a second order design matrix that minimizes the number of test runs. If a good second order design matrix with manageable number of test runs is not available, how does one make the trade offs? The goal of a parameter design experiment is to identify optimal settings for all the design parameter, not to build the model fitting of process. Taguchi has achieved substantial payoffs just by conducting many main effects only experiments and by checking the results by confirmation experiments. While such design has been criticized due to no estimate of interactions, he is usually successful because main effects almost dominate interaction effects. In industrial aspect, the important main effects that were selected by Taguchi's method may be also strong effects at scale-up production stages. Thus, it is highly possible that the optimal conditions that were determined by Taguchi's method will be reproduced at practical production stages. Different types of designs are needed in different experimental environments. In this case it is economical to extensively study environmental variables to design a robust process, one that is insensitive to environmental disturbances.

The user needs to be confident that the products will work every time in its application and the producer needs to make sure that each batch of process is reproducible. The use of this statistical experimental design in this area can help the development of optimum reproducible production system.

Taguchi's parameter design method.

Objective of Taguchi's method: Taguchi's parameter design can be used to make a process robust against sources of variation and hence improve field performance. If we can design a process that has the robustness to noise factors that largely affects the variance of performance characteristics at a developing stage, it will very possible for the process to have robustness against other noise factors that could not be considered at the development stage. The aim of a parameter design experiment is, then, to identify settings of the design parameters that maximize the chosen performance measure and are insensitive to noise factors.

Orthogonal array: According to Taguchi, when there are limits on the number of test runs, it is better to include many design parameters in the design matrix even until no degrees of freedom are left for estimating the residual error than to include only a few design parameters and allow for estimating interactions. With large number of design parameters, the number of test runs required to estimate all main effects and all pair interaction can be prohibitively large. A first order model involving only linear terms is often inadequate. Curvature effect was very important and this effect almost always occurs when either the test settings are chosen wide apart or the test settings are near a peak of the response variable. The problem is how to construct second order design matrixes that minimize the number of test runs. If a good second order design matrix with manageable number of test runs is not available, how does one make the trade offs? The goal of a Taguchi's experimental design is to identify optimal settings for all the design parameter, not to build the model fitting of process. Taguchi has achieved substantial payoffs just by conducting many main-effect-only-experiments and checking the results by confirmation experiments. If it can be proved that the system could be described well by even only main effects, the optimal condition determined by only main effect analysis can be very efficient and simple method for optimization. Orthogonal array has been used to minimize the number of test runs while keeping the pairwise balancing property in Taguchi's method for that purpose. These basic principles serve as a screening filter which allows the examination of the effects of many process variables, identifying those factors which have a major effects on process characteristics using a single trial with a few reactions.

For example, optimization experiment would normally require each variable to be tested independently. Thus, a trial run investigating the effects and interactions of four reaction variables each at three concentration levels, would require an experiment with 81(i.e. 34) separate reactions. Using an orthogonal array, however, an estimate of the effect of each variable can be carried out using only nine experiments. Providing that three level are used for each variable tested, the number of experiments required (E) is calculated from the equation E= 2k +1, where k is the number of factors to be tested. If the calculated number is not a multiple of three, then the required number of variables to be tested is the next multiple. Hence, as the number of components to be tested is increased, the reduction in the number of experiments required becomes more marked; e.g. to test 9 factors would require 39 = 19683 experiments to analyze fully, whereas using Taguchi's methods this could be reduced to just 21(2 x 9 + 1 = 19, 19 is not a multiple of three and then next integer divisible by three is 21)

Taguchi's parameter design: Taguchi's method for identifying settings of design parameters that maximize performance characteristics (e.g. yield or productivity etc) is summarized below.

1. Identify the factors and their ranges
2. Construct the design and noise matrices, and plan the parameter design experiments.
3. Conduct the parameter design experiments and evaluate the performance statistic for each test run of the design matrix.
4. Use the values of the performance statistic to predict new settings of the design matrix (if needed).
5. Confirm that the new settings indeed improve the performance statistic.

The design will be planned to determine the control factor's level that is less sensitive to noise factors. An orthogonal array containing the control factors will be arranged in the inner array, while an orthogonal array containing noise factors will be arranged in the outer array. Taguchi suggested that parameter design using noises that are deliberately created was more effective than not, if noises can be created purposely. The reason is that if noise is not induced deliverately, many experiments must be performed to investigate the effects of noise factors diversely on process and it is very difficult to obtain reliable results under different noise conditions. If the experiments can be performed under various levels of noise i.e. with positive induction of noise to the design, we can obtain a realistic level of robustness. Therefore, a characteristic of Taguchi's parameter design is the deliberate creation of noise for the identification of control factor's level that is the least sensitive to the noises.

Taguchi's tolerance design: If among the noise factors, some affect the system largely and result in a large variances in performance characteristics, we cannot achieve the combination of control factor's level that is insensitive to all the noise factors. In this case, the noise factor that causes large variance must be controlled to the way of reducing the variance in order to obtain a lower variation, which is called tolerance design according to Taguchi's method. The first step in tolerance design is to determine the contribution of the noise factor to the variation; to know which noise factors was the cause of large variance. And then, the way of reducing the effect of the noise factor must be considered. Through the tolerance design, we make appropriate economic trade-offs between the increased cost of the product and the improved quality.

1.4 Objectives Of The Project

1. To test some basic machining condition in order to understanding the machinability of sea coral therefore the parameter can be optimized.
2. To get the optimum machining parameter

1.5 Scope of The Project

This project presents a study of the machinability of Porites a Dead Sea coral material. The experimental work is based on Taguchi Orthogonal array for optimizing surface integrity by investigating three machining parameters such as feed rate, depth of cut and spindle speed. Cutting tool wear and chip fragmentation are also studied at the end of experiment. The machined surface and tool wear were evaluated using non-destructive methods and theoretical understanding is used to explain the results.

CHAPTER 2

STUDY METHODOLOGY

2.1 Introduction

The purpose of this chapter is to present how the experiment was conducted. Experiment was based on the Taguchi method which discuss in detail in the section 2.2. The overview of the experiment study can be seen as figure 2.1 below.

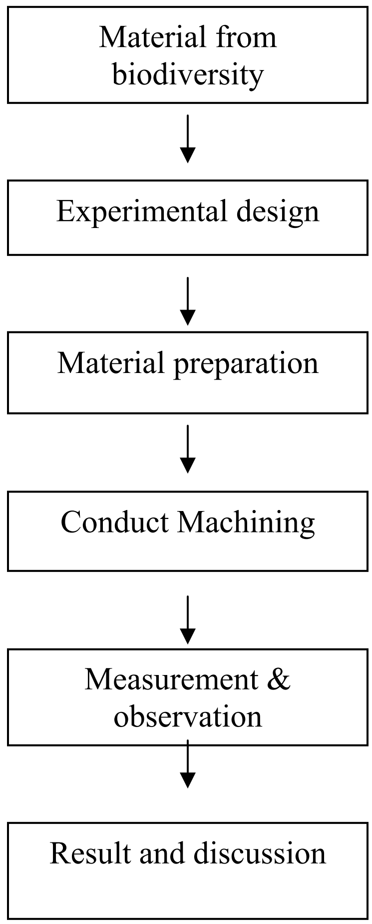

Figure 2.1 Flow of experiment