DEVELOPMENT OF RESISTIVE SINTERING FURNACE FOR SINTERING PROCESS

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

by

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirement for Degree of Manufacturing Engineering (Hons). The member of the supervisory committee is as follow:

…….....

(Mr. Mahasan bin Mat Ali)

ABSTRAK

Tujuan utama projek ini adalah untuk menghasilkan sebuah mesin yang boleh ‘sinter’ dan mengubah sifat sesuatu specimen yang boleh digunakan untuk mata alat. Berdasarkan konsep ‘resistance welding’, ideanya ialah untuk menghasilkan sebuah mesin ‘resistive sintering furnace’ untuk proses ‘sintering’. Komponen utama untuk mesin ini adalah pengubah. Pengubah toroidal akan digunakan untuk menghasilkan voltan rendah arus tinggi dengan beberapa pengubahsuaian pada pengubah tersebut. Gegelung sekunder akan ditukar kepada diameter wayar yang lebih besar dan mengurangkan bilangan lilitan. Untuk konsep rekabentuk adalah berdasarkan kriteria rekabentuk mesin dan lukisan teknik rekabentuk terperinci akan dibuat dengan menggunakan perisian CATIA. Pemilihan bahan untuk komponen ‘Resistive Sintering Furnace’ berdasarkan perisian CES EduPack untuk memilih bahan yang sesuai untuk setiap fungsi. Pembuatan mesin ini terdiri dari beberapa jenis proses pembuatan yang merupakan proses pemotongan, proses penggerudian, proses kimpalan dan juga proses pengubahan. Semua proses akan dijalankan di makmal Fakulti Kejuruteraan Pembuatan.

ABSTRACT

The purpose of this project is to develop a machine that can sinter and change the properties of a specimen that can be used for cutting tool. Based on the concept of resistance welding, the ideas created to develop resistive sintering furnace machine for sintering process. The main component for this machine is transformer. Microwave transformer will be used to produce low voltage high ampere of current with some modification on the transformer. The secondary coil will change to bigger diameter of wire and reduces the number of turn. For The design concept are based on the design criteria of the machine and the technical drawing of detail design will be created by using CATIA software. The selection of material for the component of Resistive Sintering Furnace are based on CES EduPack software to select the suitable material for each function. The fabrication of this machine consist of several types of manufacturing process which are cutting process, drilling process, welding process and also turning process. All of the process will be conducted at Faculty of Manufacturing Engineering's lab.

DEDICATION

My special thanks to my family is my father, Saidin bin Saman

my mother, Salina binti Jaman

my brothers, my sisters, my friends

my supervisor, Encik Mahasan bin Mat Ali

for all kind of tutoring, patience and unwavering support.

Without all of you, I will not be able to complete this project until I graduate.

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First of all, I praise Allah the All-Powerful, the Greatest of all on whom we ultimately rely for support and guidance. I would like to thank Allah for giving me strength to complete this research even though having difficulty during completing this project.

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Besides, I would not forget to give my special thanks to my parent and family that give motivation, inspiration and strength that make me to be here and they help me at every stage of my study in many aspect. In addition, special thanks to all my beloved friend because always there to help and give moral support throughout my study.

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$\mathbf{Q = \ mc\theta 2 - \theta 1 + mL}$ ..... Equation 1 20

$\boldsymbol{d = \ 30.406I2\ \delta\ K}$ ..... Equation 2 22

$\boldsymbol{I = \ Pap\ 103Vmax\sqrt[3]{3}}$ ..... Equation 3 22

CHAPTER 1

INTRODUCTION

This chapter will discuss about the background of the project of development of resistive sintering furnace for sintering process which is consist of several component that that will be describe and explained on Chapter 2.

1.1 Background of Study

Figure 1. 1: Conventional Heat Treatment Furnace Machine

Furnace is a device to heat the product for heat treatment or sintering. The source of heating obtained are from electrical or gas energy. However, this study will focus on the development of sintering furnace innovated from the idea or resistance welding. During resistance welding two steel plates that placed between two electrodes will joined when the

high electric conducted through the electrodes. In this study, similar concept of resistance welding will be applied. However, the component of steel plates will be change with specimen like cutting tool that can conduct electricity. As electrical current conducted through specimen, the heat will be generate inside specimen due to resistance between specimen particles. Higher heat will facilitate sintering process of specimen to be compacts and change their properties.

1.2 Problem Statement

In manufacturing industry, normally use the normal sintering furnace machine to do a sintering process for compact ceramic. The heating element didn't contact the specimen, so it took a lot of energy consumption and produce waste. The heating element took a longer time to achieve the constant temperature. After achieve the constant temperature, the specimen will be put inside the oven and the usually the material will took a time for a heat to fully contact. The whole sintering process took almost 9 to 12 hours to complete.

No suitable machine that can perform a sintering for small and single specimen. This is because the normal sintering machine built for a large size and usually used for mass production. This will cause wasting energy and time loss to the manufacturer.

A normal sintering furnace machine is highly price and its cost almost RM100 000.00 for a single machine. So, to perform a sintering process for a small and single specimen it using a highly cost machine quite extravagant and its can cause a lot of loss to the manufacturer. As the alternative way is to develop a new resistive sintering furnace for sintering ceramic.

1.3 Objective

The aim of this project is to develop resistive sintering furnace machine and in order to achieve this aims, three objective have been constructed. My objective described below:

1. To design the resistive sintering furnace machine that used low energy consumption and shorter processing time.
2. To fabricate the resistive sintering furnace machine based on the design determined.
3. To test the performance and the limitation of resistive sintering furnace machine for sintering

1.4 Project Scope

1. The machine is used for small industry that need to perform sintering on their specimen but only in small scale.
2. Mainly target on industry that produced cutting tool in small scale manufacturing process.
3. Improve sintering process in term of costing, time, effectiveness and result from the current furnace type machine.

1.5 Thesis Review

Chapter 1 has been described according to the background study of this project which is the main topic of any project. In this chapter also explained about the problem statement, objective and scope of this project that required to complete this project within the time given. The objective and scope will be used as references to selecting the correct journal or article for literature review that to be used for searching the information that related to this project. Chapter 2 will describe about the literature review and Chapter 3 will describe about the methodology.

CHAPTER 2

LITERATURE REVIEW

In this chapter basically will describe about the summary of literature review based on the selected articles and journals that related to the concept, material, method and manufacturing process of developing the resistive sintering furnace. This section is important because it is closely related to the results of the research conducted by various people directly involve in engineering.

2.1 Resistive Sintering

Resistive sintering is a method that generated heat through the conduction of current that pass through the resistance (workpiece) that will generated heat and sinter the material at the certain time for the material need to change their microstructure and properties. According to Lagos et al. (2017), Electric current assisted sintering (ECAS) gathers a family of consolidation methods in which mechanical pressure is combined with electric and thermal fields to enhance particle bonding and densification.

According to Lenel (2017), resistive sintering is a process which is a powder is compacted to pressure and simultaneously heated by passing a low voltage high ampere current throughout the process. The normal sequence of operation for sintering is to compact the powder in a die at room temperature and sinter the material in sintering furnace. During pressing the material, the heat will generated through the material which is the electrode producing high ampere of current while the work piece has that sinter has very higher electrical resistance and low thermal conductivity. The advantage using this concept of

resistive sintering the material are the duration for the sintering process quite short compare to normal method which sinter the material in a furnace.

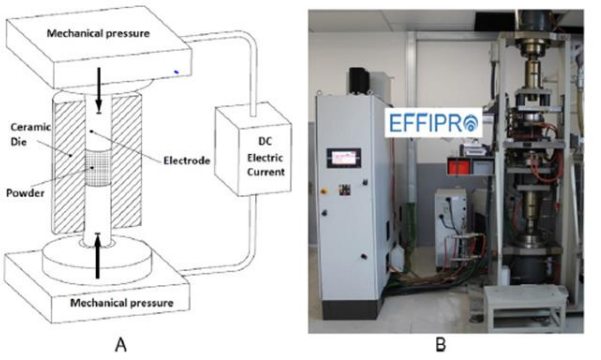

Figure 2. 1: Resistance sintering prototype developed by EFFIPRO project. (Lagos et al., 2017)

For the resistive sintering machine, the electrode that used usually copper electrode. The electrodes will generate electric and press the alumina based ceramic in a ceramic die. The pressure that applied is by using 15 tonnes electric press. According to Orrù, Licheri, Locci, Cincotti, & Cao (2009), say that the conducting material are heated by Joule effect and heat transfer by container and electrode while no-conducting material are heated by latter way. The process is quite similar with hot pressing process, the resistive sintering process is characterized by the application of electric current through a power supply, that make it can produce very rapid and efficient heating.

By using conventional heat treatment technique, the process normally heated up by using radiation from enclosed furnace. The material or powder that heated up in the furnace using through convection of gases and external heating element involve. There is no contact between the material and heating element, that may cause the heating rate typically slow and the process can last about more than 1 hour. Compare to resistive sintering technique, the heating element which is copper electrode is having contact with the material, which mean the heating process directly occur by conduction of current through resistance can cause the material can heated up to certain temperature only in few minutes.

According to (Orrù et al., 2009), resistive sintering process are characterized by the efficient use of heat input, particularly when the electrically insulating container is used and

the electric current is applied for extremely short duration. The resistive sintering technology is the very short processing time with regards to conventional processing. In conventional sintering, the duration of heat treatment may take several hours, but in resistive sintering, the duration range is in between 20-30 minutes (Lagos et al., 2017).

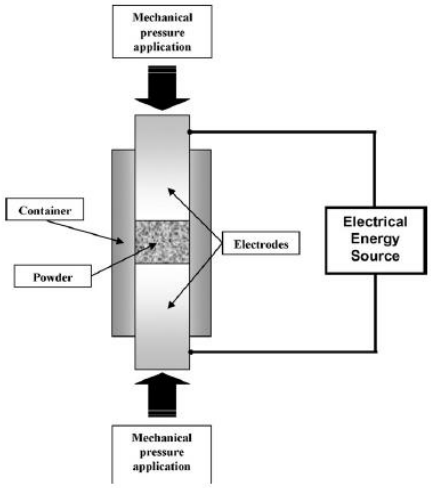

Figure 2. 2: Resistive sintering process that involve current and resistance.

2.2 Microwave Sintering

In microwave sintering, heat is generated internally through the interaction of the microwaves with the atoms, ions, and molecules of the material, which produces an inverse heating profile. The microwave heating process is more volumetric, thus allowing higher heating rates. However, most research to date is based on conventional low- frequency (2.45 GHz) microwave applicators, and at this frequency, many ceramics present poor microwave absorption characteristics (Menezes, Souto, & Kiminami, 2012).

In fast firing, the objective is to enhance the densification rate in detriment to the coarsening rate by a rapidly approaching to the sintering temperature. Because coarsening mechanisms as example for surface diffusion and vapour transport normally prevail over densification mechanisms at lower temperatures, it has been suggested that rapid heating to higher temperatures can be beneficial to achieve high density allied to fine grain size. In this case, the shorter time spent at lower temperatures serves to reduce the extent of coarsening,

while the driving force for densification is not decreased significantly (Menezes et al., 2012), resulting in high densification and fine microstructures, which is a factor of paramount importance in the sintering of nanostructured ceramic and composite materials.

2.3 Concept of Resistive Sintering from Resistance Spot Welding

The concept of resistive sintering is based on electrical resistance spot welding. Machine that will build for sintering the alumina based ceramic are very similar concept that used in spot welding machine. Resistive welding is a process used to permanently join metals such as steel sheet or other stock by typically pressing the stock together between pair of electrodes and then passing an electrical current from one electrode to through the metal stock and into the other electrode (Bush et al., 1991). The machine consist of two electrode which one above and another at bottom. Each of the electrode can move separately. The electrode carry low voltage high current that supply from the transformer. The electrode force produces a local deformation at the common interface to seat the work piece properly and to establish good electrical contact before current flow (Nied, 1984).

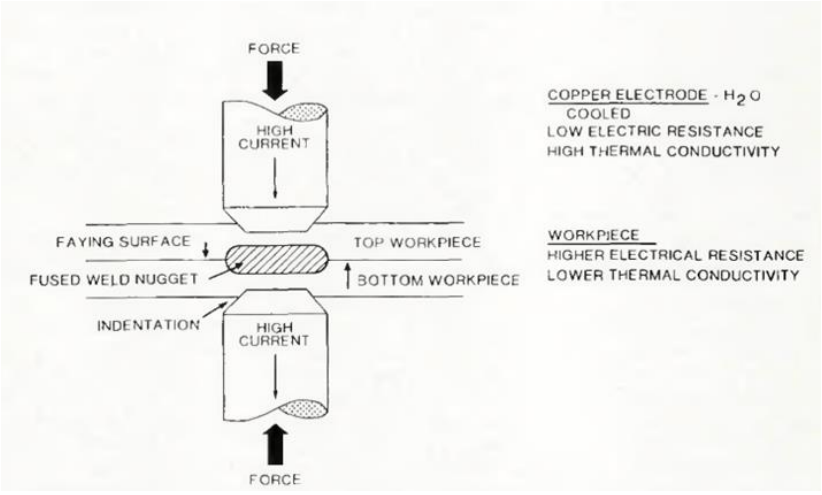

Figure 2. 3: Concept of resistance welding that used high current and low voltage

According to (Oliveira, Ponder, Brizes, Abke, & Ramirez, 2019) , the generation of amount of heating during the process by using electrical conductivity are usually limited because of lower electrical conductivity enabling the generation of more heat. The cooling rate experienced by the welded joint will depend on the material thickness and it can be range from 100 degree celcius per second to 3000 degree celcius per second, with a potential increase due to the use of water-cooled electrodes.

2.4 Resistance Welding Working Principle

Resistance welding is heat generated at interface of the part to be join using electric current with pressure which is the process is called thermos-electric process. The electrical resistance spot welding process for joining two materials at their common interface is a complicated inter-action of electrical, thermal, mechanical, metallurgical, and surface phenomena (Nied, 1984). The presence of resistance in current will generate heat that weld and join the workpiece. The pass of current through resistance will generate heat. The advantages using this technique or principle is the time for this process is very short. Furthermore, this concept does not consumables. This technique also environmentally friendly because the smoke or gases that produce is less compare to other welding method such as arc welding and MIG welding.

The surface of contact resistance also important. Surface condition such as surface roughness, cleanliness, oxidation and plating will influenced the contact resistance. The heat generation formula for this concept were use the modification of Ohm's Law when the watt and heat are considered synonymous. The basic formula of heat generation is:

$$H = I^2 RTK$$

Where the "I" is the weld current, "R" is the resistance, "T" is the time and "K" is heat losses. The weld current and duration of current were control by the power supply. The more the current were supply, the shorter the duration for weld. Welding heat transfer efficiency based on arc power calculated as the product of average current and voltage was too high (averaging 82%), while that calculated using the product of the root mean square (RMS) of the average current and voltage was too low (averaging 61%) (A. Joseph et al., 2003).

During the process of resistance welding, the part that heat generated will loss to surrounding by conduction, convection and radiation. The heat balance a function of part material and geometry, electrode material and geometry, polarity and weld schedule. Improving heat balance by such varied methods is unique to resistance welding and perhaps the reason for popularity of resistance welding as a method of choice in industry and the method can be combined to suit the needs of particular weld application (Technologies, n.d.). The good heat generated will produce a good resistance welding. To produce sufficient energy to overcome the resistance required highest heat assuming from resistance welding power supply.

2.5 Resistive Sintering versus Hot Pressing

According to Vasilos and Spring (1967), hot pressing is a densification process which is pressure and temperature are applied simultaneously. The application of the pressure will increase the contact stress between the powder particles, the powder particles will rearrange, sinter and flow due to high temperature.

The resistive sintering technique applied the same punch system concept as hot pressing. The electrode of the resistive sintering machine will pressed the powder and the current will flow and generated heat through the powder. As the hot pressing working principle, the punch will pressed the powder and the heating element at outside the die will generate the heat through the powder.

The concept of resistive sintering and hot pressing quite similar but have different significantly in heating mode. In hot pressing, an array of heating indirectly heats the punch/powder/die assembly by radiation and eventually by convection and/or conduction, while the resistive sintering, the punches transfer the electricity and Joule heat directly to the powder (Grasso, Sakka, & Maizza, 2009).