ELECTROSTATIC CHAMBER DEVELOPMENT FOR DUST COLLECTOR

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“I hereby declare that I have read through this report entitle “Electrostatic Chamber Development for Dust Collector” and found that it has been comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)”.

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ABSTRACT

Electrostatic dust collector is a chamber that function to trap dust or particle. The operation is based on electrostatic precipitator(ESP) which is widely used in industry as an important equipment for environmental protection. Electrostatic dust collector is designed to be used as indoor air filter. In this project, principles of electrostatic precipitation such as particle charging, electric field strength and collection efficiency are reviewed. Particulate matter with dimension less than 2.5µm (PM 2.5) can penetrate deep into the human respiratory system. Air filter can help to remove airborne bacteria from operating room air to help prevent postoperative infection. ESP can also remove dusts and gaseous pollutants. These new advancements will widen the field of application of electrostatic precipitator. In this project, the electrostatic dust collector was developed in an acrylic box with a copper wire as a discharge electrode, placed between two plate collecting electrodes which is aluminium plate. The negative DC voltage was applied to the wire electrode. The factor that affected collection efficiency such as size of particle, type of dust and supply voltage will be discussed in this report.

ABSTRAK

Penangkap habuk elektrostatik adalah sejenis bekas yang berfungsi untuk memerangkap habuk atau zarah. Fungsinya adalah berdasarkan *Electrostatic Precipitator(ESP)* yang mana digunakan secara meluas dalam industry sebagai alat yang penting untuk melindungi alam sekitar. Penangkap habuk elektrostatik direkauntuk digunakan sebagai penapis udara untuk kawasan tertutup. Dalam projek ini, prinsip ESP seperti mengecas zarah, kekuatan medan elektrik dan kecekapan memerangkap dikajisemula. Bahan zarah dengan dimensi kurang dari 2.5µm (PM 2.5) mampu menembusi ke dalam system pernafasan manusia. Penapis udara dapat membantu untuk menghapuskan bakteria yang dibawa oleh udara dari bilik pembedahan untuk mengelakkan jangkitan kuman. ESP juga boleh mengasingkan habuk dan gas yang tercemar. Penambahbaikan ini akan meluaskan penggunaan ESP. Dalam projek ini, penagkap habuk elektrostatik dibina dalam kotak akrilik dengan menggunakan wayar sebagai elektrod penyah-cas, diletakkan di antara dua plat pengumpul yang merupakan plat alumina. Voltan DC negative disambungkan kepada elektrod wayar. Faktor yang mempengaruhi kecekapan mengumpul seperti saiz zarah, jenis habuk dan voltan yang dibekalkan akan dibincangkan dalam laporan ini.

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INTRODUCTION

1.1 Motivation

In order to prevent air pollution due to industrial activity, engineers had developed a device to control air pollution known as electrostatic precipitator. This device very helpful to increase air quality and fulfil the requirement for air quality index. In an electrostatic precipitator, a static charge attracts contamination particles to electrified plates of metal, similar to how static electricity in clothing attracts bits of lint. This method works very well for power plant area, cement factory and dusty area.

Furthermore, quality of air nowadays also affected by the pollution of vehicles and haze. Thus, indoor air quality also polluted. Polluted air is harmful to health such as lung problem. In order to keep the indoor air quality clean, the development of chamber for dust particles based on electrostatic concept which has same principle as electrostatic precipitator is done in this project.

1.2 Project Background

Electrostatic dust collector is a chamber that use the electric field concept to trap the dust and particle to produce clean air. The concept of electrostatic dust collector is similar as Electrostatic Precipitator which is widely used in industry. By using this device, the pollution of air can be controlled. Figure 1.1 shows one of the type of electrostatic precipitator used in industry especially at the coal-fired power plant and factory such as cement manufacturer factory.

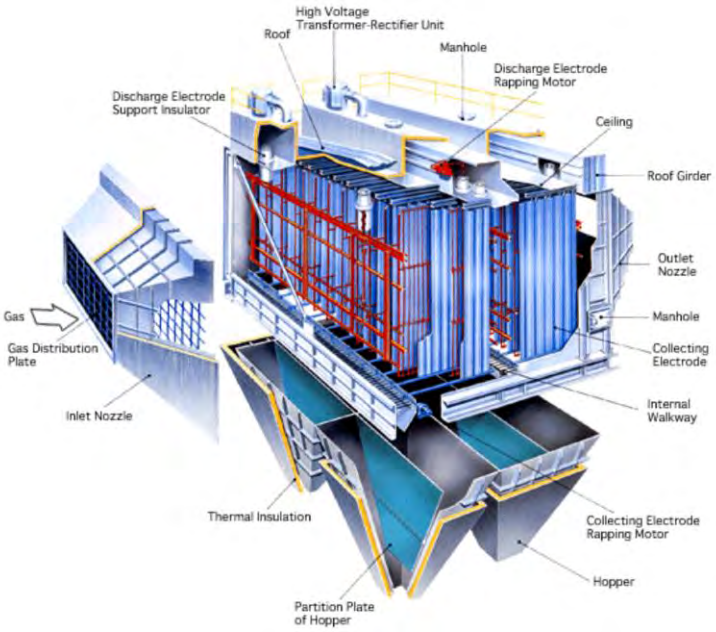


Figure 1.1: Electrostatic Precipitator

Basic principle of this device is, when dc high voltage is supply to the electrode, corona effect will ionize the surrounding atmosphere. Particles that enter the chamber will collide with the free electrons and form charged particles (ions). This charged particles move toward the collecting plate due to electrostatic force.

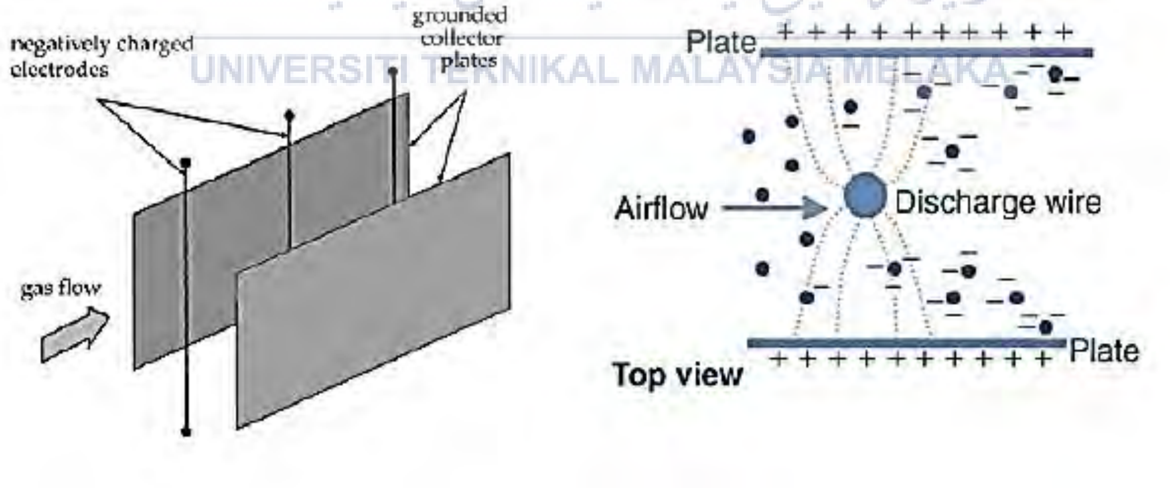


Figure 1.2: Basic Concept of Electrostatic Dust Collector

Clean air can be defined as dry air that are free from air pollution. Generally, the lower the concentration of airborne pollutants, the better the air quality. Sometimes, there are toxic metal found in air especially for the area which is near to the coal-fired power plants. Example of toxic metals are Arsenic(As), Nickel(Ni), Mercury(Hg), Strontium(Sr), Selenium(Se) and Beryllium(Be)[1].

It is important to have a good air quality especially in office or home where the human being spend time mostly. Polluted air can cause a lot of disease to people such as lung cancer, asthma and lung dysfunctions. Thus, the indoor air quality need to be concern. Electrostatic dust collector can help us to improve indoor air quality.

1.3 Problem Statement

Clean air is important for human being to ensure the healthy life. Dust will make the quality of air decreases. Small particle in air cannot be seen with our eyes due the size which is very small and light. Building and road construction near to our living area cause a lot of dust. Residential area which are located near to the industrial area also face the air pollution problem. Therefore, a lot of research have been done to produce a product which can collect dust and small particle in air. One of the solution is by using electrostatic concept. Electrostatic dust collector can trap particle which is smaller than 5 µm compare to the other air filter. Thus, the research about this concept will be conducted and the best design will be suggested as a product for control indoor air quality.

1.4 Objectives

The objectives of this project are:

i. To design and develop dust or particle collector chamber based on electrostatic concept
ii. to analyse the effect of size and type of dust to the efficiency of electrostatic dust collector
iii. To investigate the effect of size of cables to the efficiency of electrostatic dust collector
iv. To compare the effect of different supply voltage to the efficiency of electrostatic dust collector.

1.5 Scope

The focus of this project is to increase the indoor air quality. The scope of this project is to design electrostatic chamber to collect dust or ultrafine particle. This project consists of discharge electrode and collecting plate. The space between the electrode and collecting plate are important to study to prevent breakdown. Spacing 5 cm is tested in this project. Different size of cables is tested to see the effect to the collection efficiency. Size of cable used are 1.0, 2.5, 4.0, 6.0 and 10 mm^2. Two type of dust, sawdust and ash with different size will be tested is in range 1.0 µm to 5.0 µm (fine and finest). This project need high voltage supply (0-30 kV) in order to ionize the particle or dust.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Rigorous new regulations in dust emission by power plants and industrial processes have brought new requests for dust control devices. These new regulations will require most extreme molecule outflows on the level of 10–50 mg/Nm^3 and confinements to the discharge of fine particles smaller than 2.5 mm. To meet these necessities, new techniques for gas cleaning with collection efficiency higher than 99% have been designed and tested [2]. Table 2.1 show the air quality guideline by the World Health Organization (WHO) [3].

Table 2.1: Guideline by WHO

Type of Ash	**Guideline**
Particulate Matter smaller than 2.5 µm ($PM_{2.5}$)	10 µg/m^3 annual mean 25 µg/m^3 24-hour mean
Particulate Matter between 2.5 µm and 10 µm (PM_{10})	20 µg/m^3 annual mean 50 µg/m^3 24-hour mean
Ozone (O_3)	100 µg/m^3 8-hour mean
Nitrogen Dioxide (NO_2)	40 µg/m^3 annual mean 200 µg/m^3 1-hour mean
Sulphur Dioxide (SO_2)	20 µg/m^3 24-hour mean 500 µg/m^3 10-minute mean

A conventional electrostatic precipitator generally comprises of a series of high voltage and relating collector plates. There are many shapes of electrodes used in electrostatic precipitators such as plate, wire, flat plate and tubular. The high voltage electrodes are ordinarily wires. Particles are charged and subsequently isolated from the gas stream affected by the electric field created between the terminals. In a single-stage electrostatic precipitator, the electric field, used to produce the corona discharge is mainly used to attract and subsequently expel the charged particles [4]. In a two-stage precipitator, charging and expulsion of particles occurs in independent electric fields [2][4].

ESP is utilized to remove contaminations from large gas flow (hundreds of thousands m^3/h). The efficiency of ESP's relies upon voltages waveform and amplitude, type of power supply, current control, geometry of electrostatic precipitators, type of discharge wires, gas composition, particles distribution, gas flow, temperature, gas pressure and particles velocities distribution [5].

The basic operation of the ESP is that the gas particle will passes through an electric field and will be ionized. Then, the charged particle will diverted over the electric field to relocate and be deposited on the collecting plate [6].

2.2 Ionization Process

Ionization is one of the important process in Electrostatic Precipitator. The particle that enter ESP will be charged and produced ion. Generally, the particle that enter ESP will pass through strong electric field and accelerated rapidly and attains a high velocity. When this particle collides with stray electron from any variety of sources, it has enough energy to knock one or more electron loose from its shell, so the particle (gas molecule) will ionize [7].

Ionization is a process of freeing an electron from a gas atom with the simultaneous production of a positive ion. Mechanism of ionization can be categorised to ionization by collision, photo-ionization, secondary ionization process. Gas becomes a conductor when a high-voltage is applied between the two electrodes immersed in a gaseous medium and an electrical breakdown occurs [8].

2.2.1 Ionization by Collision

During the ionization by collision, number of new electron and positive ion increasing when a free electron collides with a neutral gas atom.

Based on Figure 2.1, when electric field E is applied across two plane parallel electrodes (consider a low-pressure gas column), any electron starting at the cathode will be accelerated more and more between collisions with different gas particles during its travel towards the anode [8]. The ionization will take place when the energy (ε) gained during this travel between collisions greater than the ionization potential, V_i. That is the energy required to release an electron from its atomic shell. The expression below explained this process:

$$e^- + A \xrightarrow{\varepsilon > Vi} e^- + A^+ + e^- \tag{2.1}$$

where, A is the Atom, A^+ is the positive ion and e^- is the electron.

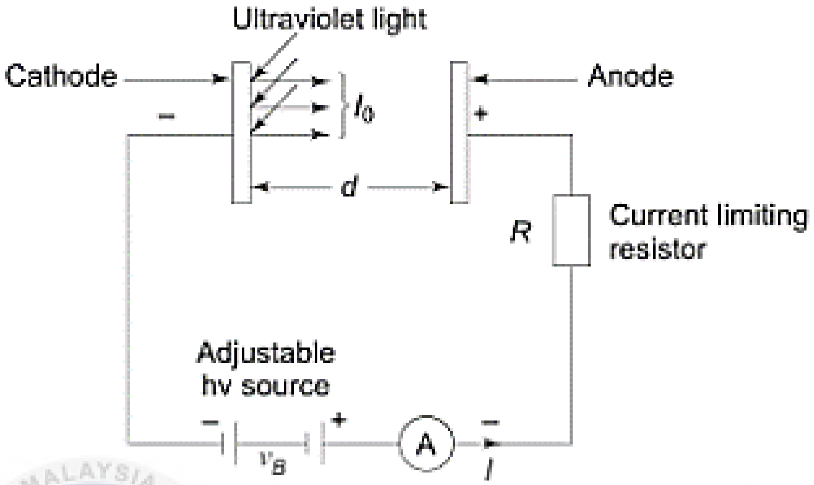


Figure 2.1: Arrangement for study of a Townsend discharge

A few of electrons produced at the cathode by some external means ionize neutral gas particles and producing positive ions and more free electrons. The electron then makes ionizing collision themselves thus increasing the number of electrons. Then, the process will repeat itself.

2.2.2 Photo-ionization

Photo-ionization happen when the amount of radiation energy consumed by an atom surpasses the ionization potential [8]. Process which radiation can be consumed by atom or molecule are:

a) excitation of the molecule to a higher energy state
b) continuous absorption by direct excitation of the particle or separation of diatomic molecule or direct ionization.

Similarly, as an energized molecule discharges radiation when the electron returns to the lower state or to the ground state, the reverse process occurs when an atom absorbs radiation. The reversible process can be represented as:

$$hv + A \leftrightarrow A^* \tag{2.2}$$

Ionization occurs when

$$\lambda \leq c \cdot \frac{h}{V_i} \tag{2.3}$$

where;

h = Planck's constant

c = velocity of light

λ = the wavelength of the incident radiation

V_i = ionization energy of molecule

Based on the equation, the greater ionization energy, the shorter the wavelength of the radiation capable of causing ionization. It was shown experimentally that a radiation having a wavelength of 1250A is equipped for creating photo-ionization of practically gasses.

2.2.3 Secondary Ionization Process

Secondary ionization process is the process of producing secondary ionization which sustain a discharge due ionization by collision and photo-ionization. It can be classified into three section.

a) Electron Emission due to Positive Ion Impact

Positive ion is formed due to ionization by collision or photo-ionization. Emission of electron from the cathode causes by approaching of the positive ion to a metallic cathode by giving up its kinetic energy on impact. If the total of kinetic energy plus with ionization energy is greater than twice the work function of metal, an electron will be ejected and the ion will be neutralised by the second electron. This probability depends on the material of electrode and kind of gas used.

b) Electron Emission due to Photons

In order to release an electron from metal (its atomic structure), enough energy is needed. Photon of ultraviolet light also can supply the energy. Electron emission happen at the critical condition:

$$h \cdot v \geq \varphi \tag{2.4}$$

where

φ = the work function of the metallic electrode

The relationship of the frequency (v) known as threshold frequency is expressed by:

$$v = \frac{\varphi}{h} \tag{2.5}$$

If the incident radiation has a greater frequency than the threshold frequency, then the excess energy goes partly as the kinetic energy of the emitted electron and partly to heat the surface of electrode.

c) Electron Emission due to Metastable and Neutral Atoms

Metastable atom is the particle have longer lifetime (10^{-3} s) than ordinary particle (10^{-8} s). Impact of excited (metastable) atoms will eject electron from the metal surface by provided energy that sufficient to overcome work function. The most easily method to observe this process is with metastable atom due to its lifetime. In the ground state, neutral atoms give rise to secondary electron emission if their kinetic energy is high (≈ 1000 eV).

2.2.4 Electron Attachment Process

Electron attachment process is the process that form negative ion by the collision which electron will attached to atom. The energy of the electron and the nature of the gas is the important factor for this process. All the insulation gases such as O_2, CO_2, Cl_2, F_2, C_2F_6, C_3F_8, C_4F_{10}, CCl_2F_2 and SF_6 have this property. Electron attachment process can be presented as:

$$Atom + e^- + k \rightarrow negative\ \text{atomicion} + (E_a + \text{K}) \tag{2.6}$$

E_a = Electron affinity

K = Kinetic energy

Insulation gases have the vacancies in their outermost shells so they have an affinity for electron. The attachment process plays a very important role in the removal free electron from an ionized gas when arc interruption occurs in gas-insulated switchgear.

2.3 Corona Discharge

Corona discharge is a discharge in the gas to appear at points with highest electric field intensity, namely at sharp points or where the electrodes are curved or on transmission lines when there is increase in voltage in non-uniform electric field. This type of discharge will ensure production of electron in ESPs so that ionization process occur.

In ESPs, generation of corona occur between the parallel electrode, which is connected to a dc high-voltage supply, and the grounded outer electrode [9]. Ions produced in the discharge will charging the particle are subsequently accelerated by the electric field forces toward the outer electrode. The process of electrostatic precipitation relies on upon this movement of the charged particles toward the collector electrode.

Non- uniform electrical field is required to produce corona discharge generation in the air at atmospheric conditions, which can be achieved by using a small diameter wire electrode, energized from a high-voltage supply, and a metallic plate or cylinder, connected to the ground, which is designated as collecting electrode. In order to improve the air quality and to reduce the emissions of smoke, fumes, and dust, industrial ESPs are used [6].

The voltage-current characteristics of a corona discharge [10] normally presented as

$$I = AV\,(V - V_c) \tag{2.7}$$

Where:

A is a constant,

V = the corona starting voltage

I = the electric current

V = the applied voltage

The flashover voltage of negative corona at an electrode separation, d greater than 5 cm, is ~15d kV, and that of the positive corona is about half that of the negative corona. Generally, the negative polarity is utilized due to the higher flashover voltages of negative corona, giving a larger margin of operating voltages. For indoor air cleaning, the positive polarity is utilized because of lower ozone generation.

Ahmed Kasdi[11] had been conducted an experiment about “Computation and measurement of corona current density and V-I characteristics in wires-to-plates electrostatic precipitator”. The researcher used different configuration of electrode in order to test electrostatic precipitator performance. From this experiment, few results were obtained. For the same applied voltage, as the quantity of wire used increases the collected current increases too. This is due to increasing of discharge electrode. For the same voltage, the corona discharged current increases significantly with the augmentation of the wire-to-wire spacing. This is due to the shielding effect exerted by each wire on the other.

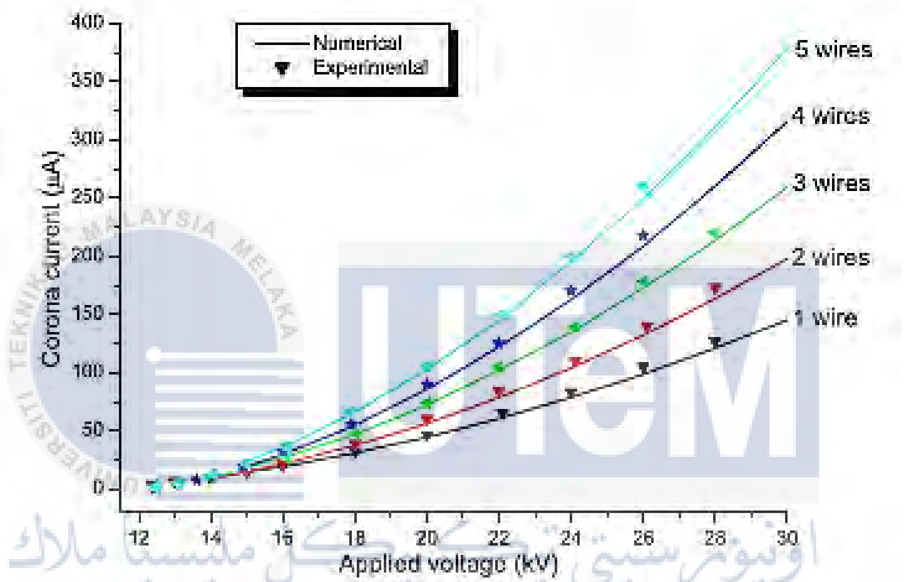


Figure 2.2: Current-Voltage characteristics for different number of wires

2.4 Operational Properties of ESP

Electrical energy is required for particle charging, gas ionization, particle coagulation or vapour condensation [2]. The overall collection efficiency of any cleaning device can be determined from the formula:

$$\eta = \frac{m_{out}}{m_{in}} \qquad (2.8)$$

Where m_{out} and m_{in} are the concentration of the particle mass at the outlet and the inlet of the device. ESP is a device which use electrostatic concept to collect dust. It has various shape of electrode, sharp electrode or thin wire stretched along the axis of a cylinder.

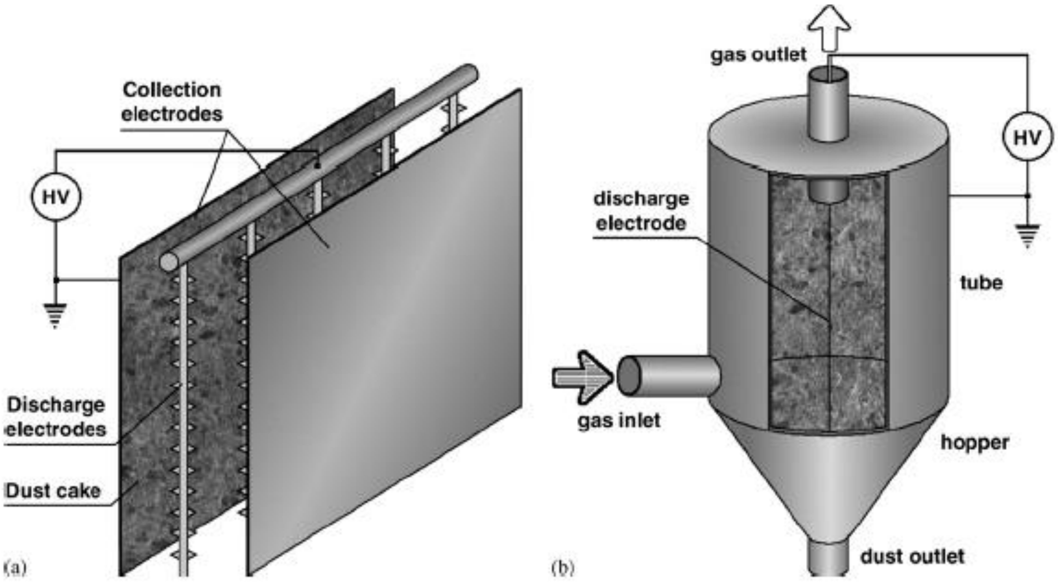


Figure 2.3: Two types of ESP (a)Parallel plate (b) Tubular

The charging particles mechanism which are most important consist of:

a) **Field charging**. Ions are headed to the molecule because of electrostatic force caused by an external electric field. This force is adjusted by the repulsive force of the charge granted to the particle.

b) **Diffusion charging**. This is because of the kinetic energy of gaseous ions that bombard the molecule independently of the electric field.

Field charging is the dominant mechanism for particle larger than 1μm while the ion diffusion is dominant for particle smaller than 0.1μm.

The current density on the collection electrode is usually in range of 0.1-1mA/m^2 and the energy consumption is usually the order of 0.3-108MW/1000 N m^3 [2].The collection efficiency of an ESP can be estimated from the Deustch formula:

$$\eta = 1 - e^{-V_m{}^{A/V}} \qquad (2.9)$$

v_m = the mean migration velocity of the particle across the precipitator

A = the cross-sectional area of the precipitator channel

V = the gas flow rate

From this formula, the migration velocity or cross-sectional area will increase by increasing the distance between the plates or decreasing the gas flow rate.

2.5 Gap between Plate of ESP

Theoretically, the smaller spacing between the parallel plate, the higher the current density at the same operational voltage. There is no exact relationship between the current density at collecting plate and efficiency of ESP was found [12]. The wider space between plate is used to increase overall collection efficiency. The optimum electrode spacing is between 400 to 600mm. on the other hand, there was no strong evidence for that assumption [2]. The upper limit of this distance is difficult to predict. Table 2.2 explained about the plate spacing can be divided.

Table 2.2: Comparison of Plate Spacing

Reference	**Gap Distance/mm**	**Comment**
Anatol Jaworek[2]	300	This distance is better for collecting dust of low resistivity
	400	Optimal for the collection of high resistivity dust
	450	Suitable for particle larger than 1µm. This spacing will be obtained maximum collection efficiency and optimal energy consumption. But for smaller particles, no significant effect was noticed.

A large distance between electrodes allows the applied voltage to be higher and electric fields at the collection electrode can also be higher due to decrease space charge effects.

2.6 Design of Electrode

There is various shape electrode used in ESP. Maria Jedrusik[13], had conducted an experiment by using four different shape of discharge electrodes that are barbed plate, wire, barbed tube and spiked band. One type of fly ash with different diameters is used and for given supply voltages and a constant inlet gas velocity. DC voltage supply is within range 0-45kV. From the experimental result of migration velocity and electrode geometries, the highest values of the velocity are obtained for the wire and barbed plate. The most effective and useful corona electrode in respect of effective transport of solid particles towards collecting plate is barbed tube.

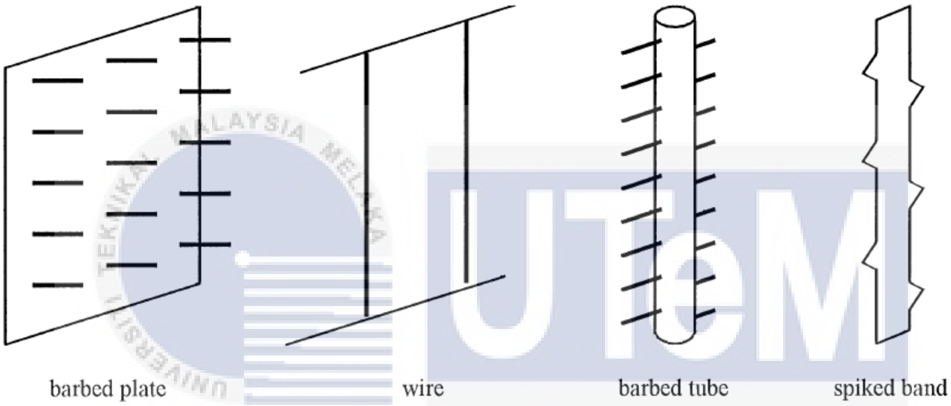
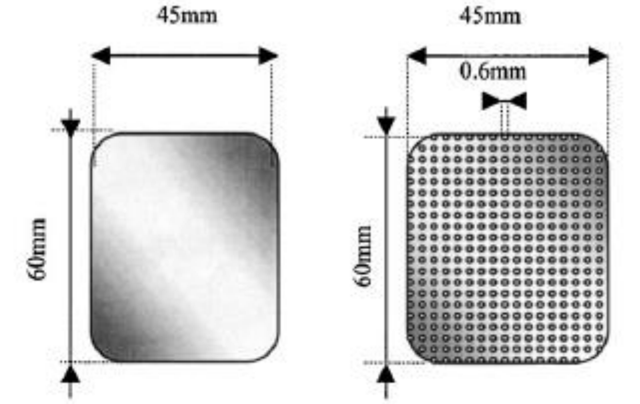
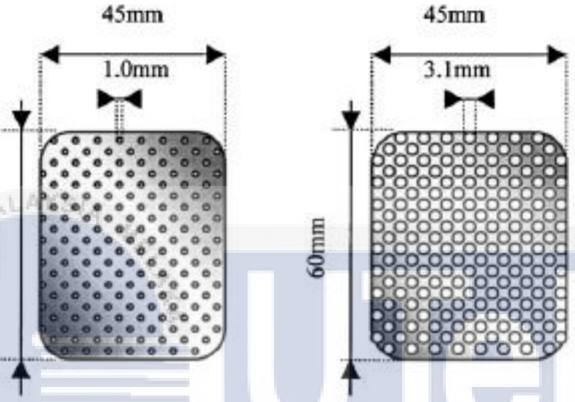


Figure 2.4: Shape of electrodes

Yosuke Kuroda [14] had conducted an experiment about effect of electrode shape on discharge current. The objective is to study the influence of electrode shape of ESP on the collection efficiency. Four plate with different diameter of hole are used as discharge electrode that are 0.0mm, 0.6mm, 1.0mm and 3.1 mm. Results obtained from this experiment showed that the highest collection efficiency is the electrode with hole size 3.1mm. Kuroda conclude that the electrodes with holes has the higher collection efficiency and discharge current compare to the plane electrode.



(a) electrode with no hole (b) electrode with holes of 0.6mm in diameter



(c) electrode with holes of 1.0mm in diameter (d) electrode with holes of 3.1mm in diameter

Figure 2.5: Electrode shape

2.7 Dielectric and Electrical Properties

Previous studies shows that the dielectric and electrical properties influence the rate charging particles [15]. Electric field affected the major parameter of ESP such as total charge, collection efficiency and migration velocities. Poisson's equation would help to determine the field within the electrostatic precipitator. The Poisson's equation is [16]

$$\nabla E = -\frac{\rho}{\varepsilon_o \varepsilon_r} \tag{2.10}$$

E = the electric field

ρ = the space charge

ε_o= the permittivity of free space

ε_r= the relative permittivity of medium

The rate of charging of dust particles in the transport zone of the electrostatic precipitator (the zone between the ionization area and the grounded electrode) depends on the permittivity and conductivity of the particle, as well as the conductivity of the external medium.

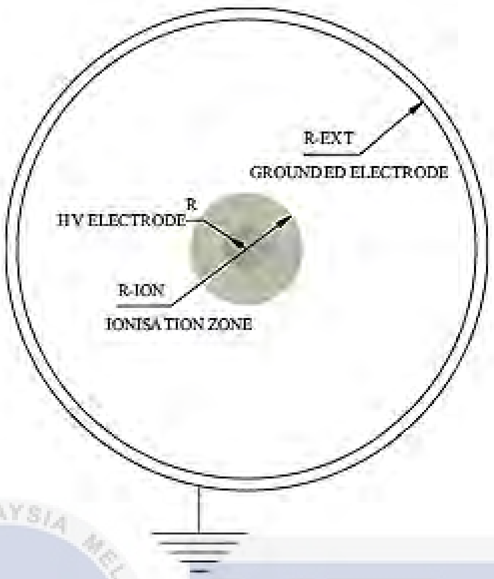


Figure 2.6: Cross-section of the coaxial corona reactor

CHAPTER 3

METHODOLOGY

3.1 Project Implementation

Overview of Electrostatic Dust Collector project is presented in Figure 3.1. At the beginning of this project, review on previous publication such as electrostatic precipitator had been conducted. Literature review of the research was written to summarize the information. After that, the chamber is developed by refer to the past research. Then, the testing of dust is conducted. After that, the result obtained is analysed.

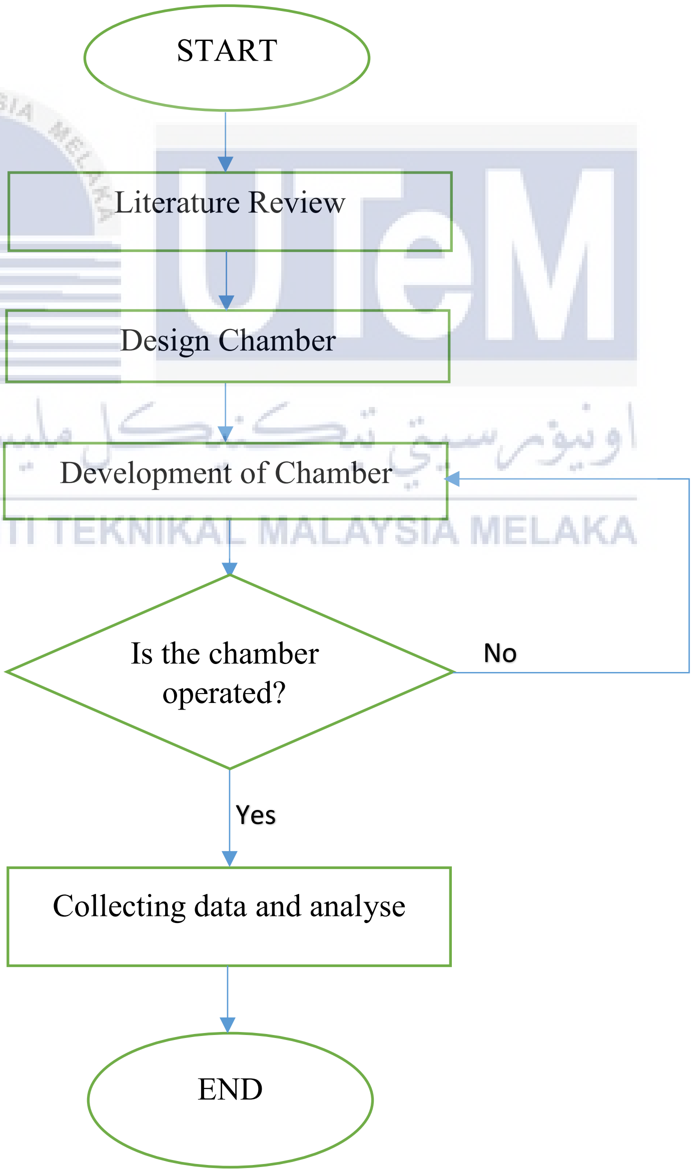


Figure 3.1: Flowchart of project

3.2 Design of Chamber

The chamber is design by using Catia software. The chamber is design with size: length of 40cm, height of 10 cm and width of 20 cm. different size of wire electrode are used. Size of collecting plate is 38cm length and width 18 cm with thickness 1mm. The gap between wire and plate is about 5 cm and space between wire and wire is 8cm.

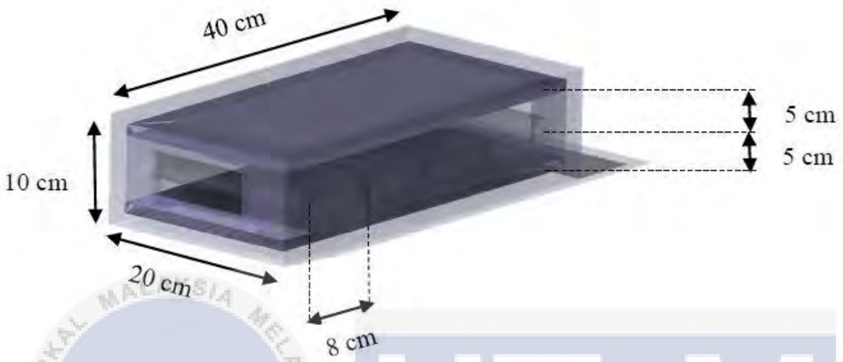


Figure 3.2: Design of the chamber

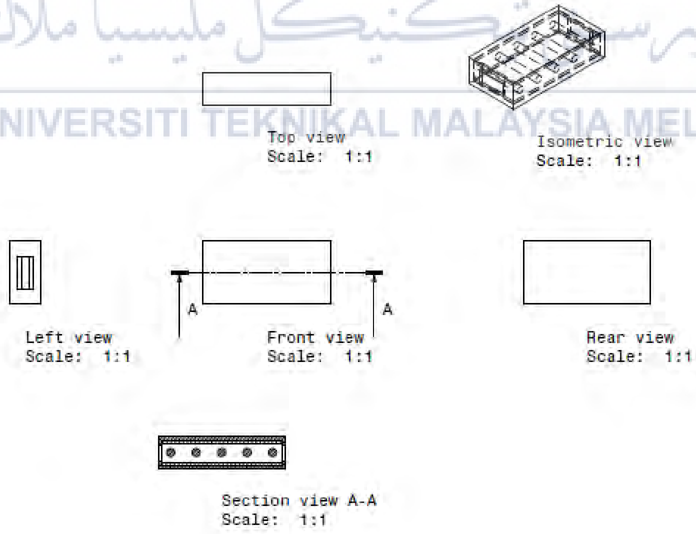


Figure 3.3: View from each side of the prototype

3.3 Development of Chamber

The chamber is developed by using acrylic box. The parallel plate used is aluminium plate and the space between plate and discharge wire is 5cm. Different size of wire are used to test the efficiency. The voltage used as a supply is in range 0-30 kV.

3.3.1 Wire

There are five different sizes of wire are used in this prototype. The size is 1, 2.5, 4, 6 and 10 mm^2. The material of the wire is copper wire. Wire is one of the best discharge electrode which can give high collection efficiency.

Figure 3.4: Different sizes of cable

3.3.2 Aluminium Plate

Aluminium plate will be used as the collecting plate. Aluminium is chosen because the price is cheaper than other plate and it also a good conductor. It is also easy to be cut and the light so it can be easily hold. The thick of aluminium plate used is 1 mm.

Figure 3.5: Aluminium plate

3.3.3 Type of Dust

Two type of dust are selected to be tested. It was sawdust and paper ash. The dust is then sieved to make it as ultrafine particles.

Figure 3.6: Two types of dust that are sawdust and ash

3.3.5 Acrylic Box

Acrylic box is selected as a chamber because it is transparent so we can see the condition inside the chamber. It is expensive but suitable for this prototype. The thick of the acrylic used is 3 mm.

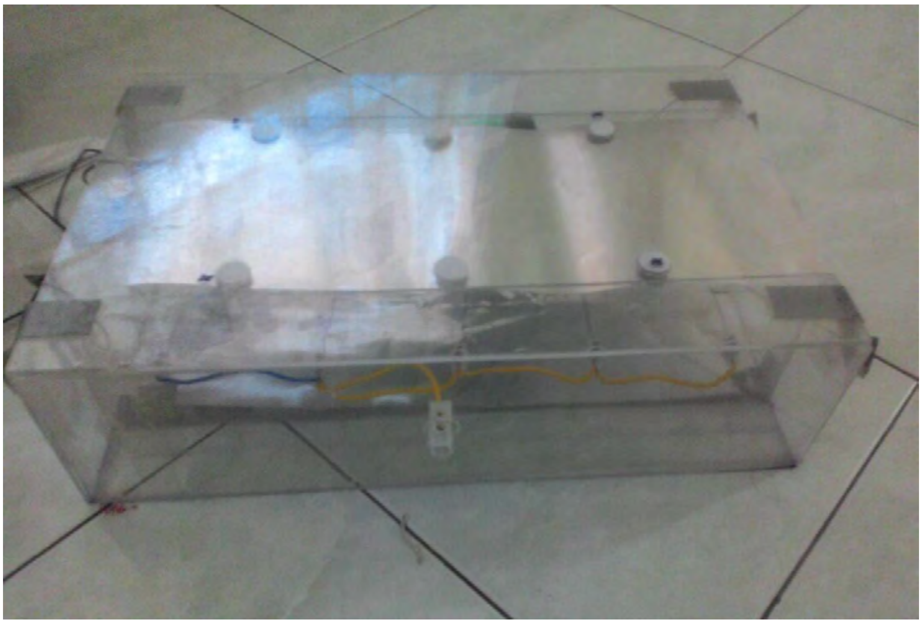


Figure 3.7: Acrylic box

3.3.6 Trek Model P0621N

This is one model of high voltage amplifier. The ratio of this device is 1V to 3kV. That's mean, if we supply 1V dc, it will give output 3kVdc. It is configured as a noninverting amplifier with a variable DC gain. Configuration of an inverting amplifier is also available. Table 3.1 shows the specification of the amplifier.

Table 3.1: Specification of Trek Model P0621N

Voltage Ratio	1:3000 of the HV output signal
DC Accuracy	Better than 0.1% of full scale
Output Voltage Range	0 to -30 kV DC or peak AC
Output Current Range	0 to ±20 mA DC or peak AC
Input Voltage Range	0 to -10 V DC or peak AC
DC Voltage Gain	3000V/V
Large Signal Bandwidth	DC to greater than 3.5 kHz (1% distortion)
Small Signal Bandwidth	DC to greater than 25kHz (-3dB)

Figure 3.8: High Voltage Amplifier Trek

3.3.7 DC Power Supply

DC power supply is used as a supply for this electrostatic chamber. This power supply used to give dc sources to Trek High Voltage amplifier. There are few precautions to use this equipment. Make sure it is grounded. To avoid electric shock, connect only to a grounded mating outlet. Other precaution is to properly connect or disconnect. Do not connect or disconnect the probe when it is connected to the supply.

Figure 3.9: DC Power Supply

3.4 Collecting Data

There are two type of dust that will be tested that are sawdust and sand. The size of particle that had been tested for both particle is fine and finest. The collection efficiency of the dust collector will be analysed by weighing the mass of particle that enter the chamber and the mass of the particle admit from the chamber. 0.1g of particle will be tested of each size of particle. Equation 3.1 is used to calculate the efficiency.

$$\text{Efficiency} = [(\text{original mass} - \text{mass outlet})/\ \text{mass original}] \times 100\% \qquad (3.1)$$

Figure 3.10 shows the set-up of the experiment. The procedure to conduct the experiment and collecting the data is shown in Figure 3.11. Before start the experiment, the connectivity of all cable in the chamber was checked. The connectivity of ground plate would also be checked by using multimeter. After checked the connectivity and ensure the connection is good, the chamber was connected to the supply and ground. Then, approximately 0.1g of dust was weighed. Permission from the technician must be asked before switch on the supply. After switched on the supply, the dust was inserted into the chamber and the result was observed. Then, the dust that that emitted through the outlet of chamber was weighed. All the result obtained were recorded. The procedure was repeated with different type and size of dust and different supply voltage. The collection efficiency was then calculated. All the results are recorded in table shown in Appendix A.

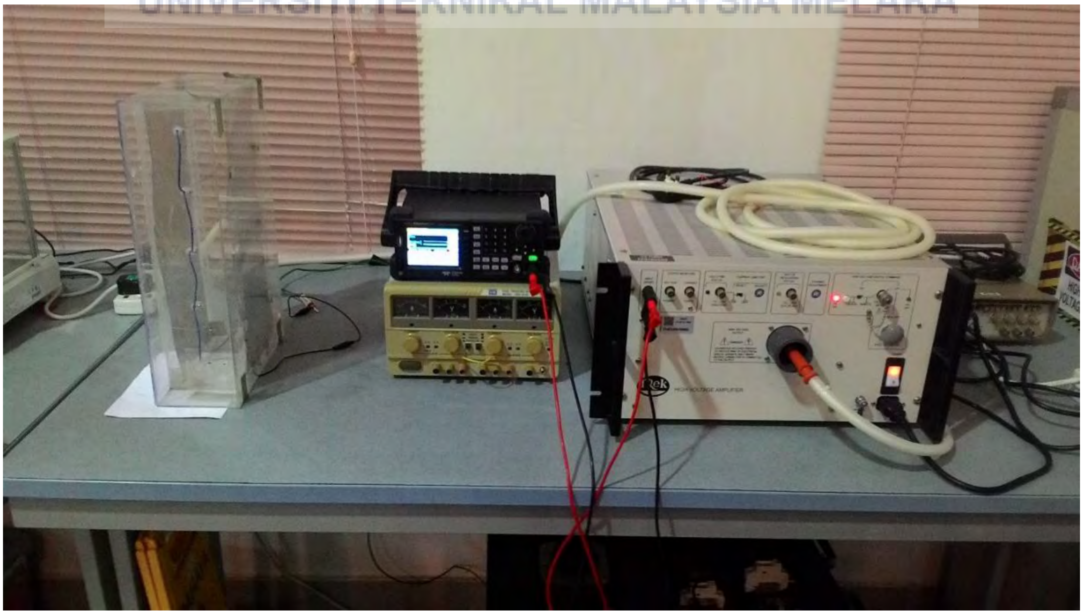


Figure 3.10: Set-up of the experiment

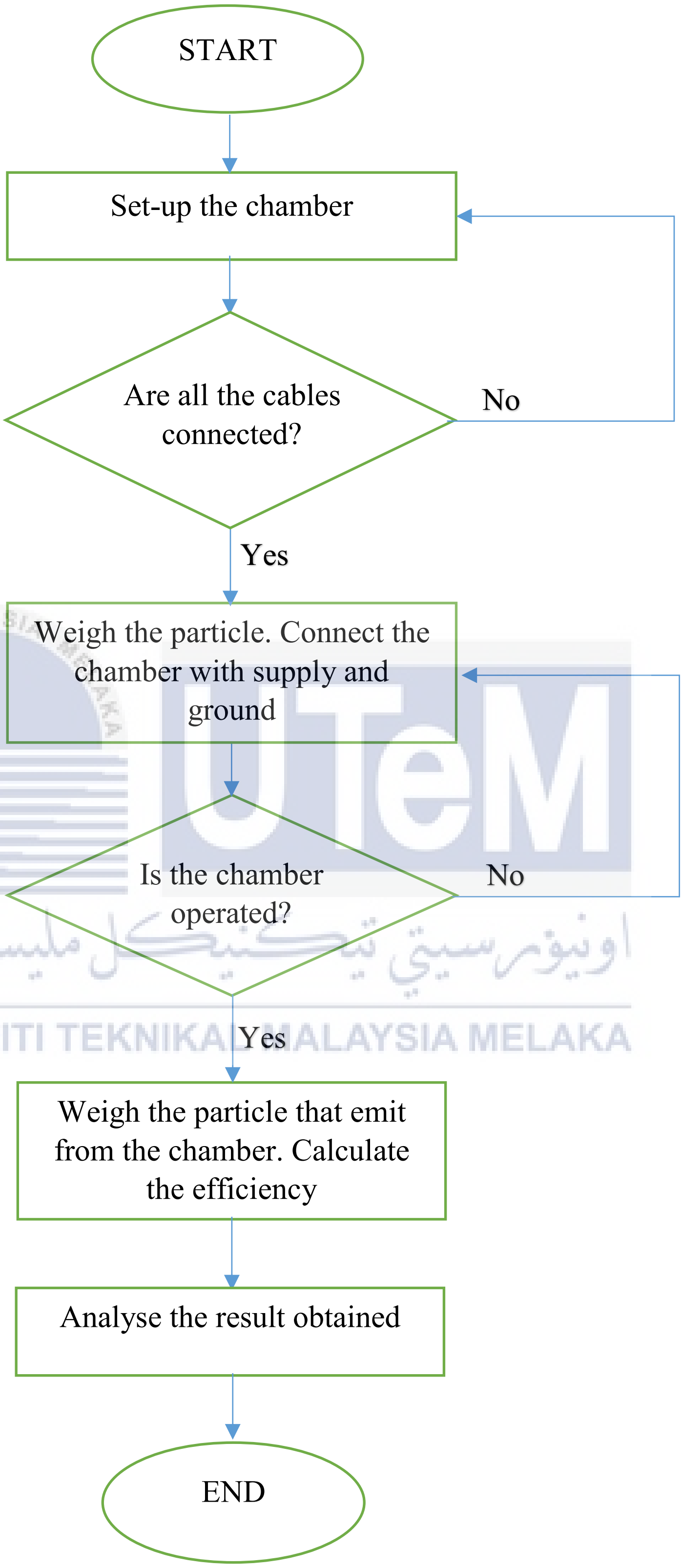


Figure 3.11: Process to collect the data

CHAPTER 4

RESULT AND DISCUSSION

An electrostatic chamber for dust collector was developed with a wire as discharge electrode and parallel aluminium plate as collecting plate. The efficiency of the chamber was tested by using different size of cables, two type of dust, two sizes of dust and different voltages. The collection efficiency is calculated by measure the weight of the dust. Equation 4.1 is used to calculate the efficiency.

$$\text{Efficiency} = [(\text{original mass} - \text{mass outlet}) / \text{mass original}] \times 100\% \qquad (4.1)$$

This chapter is focused on the results and discussion of the project. The analysis of the result will be explained for different size of cable, particle size, type of particle and voltage supply. All the tables that related to the graph in this chapter are shown in Appendix B.

4.1 Size of Cable

Different size of cable is being used to see the effect of collection efficiency of the electrostatic chamber. Figure 4.1 show the result of the collection efficiency when different size of cables was used. It can be seen from the graph below that size of cable does not effects the collection efficiency very much. From the result obtained, the most efficient is for the cable size 2.5 mm^2 with collection efficiency of 99.50%. The less efficient which have collection efficiency about 97.80% are for the cable size 4 mm^2, 6 mm^2 and 10 mm^2 for the fine sawdust. The difference between most efficient and less efficient just around 2 %.

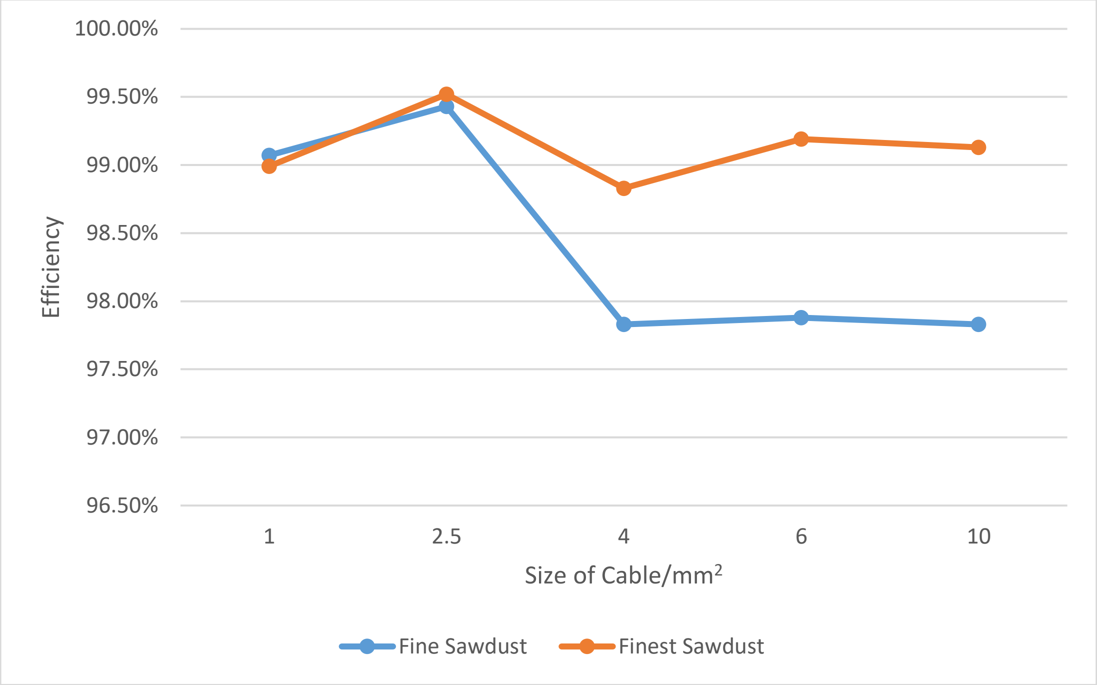


Figure 4.1: The collection efficiency of sawdust with different size of cable

Size of cable does not affect performance of electrostatic chamber may due to the small difference between the smallest and biggest size of cable. The smallest size of cable used in this testing is 1 mm^2 and the biggest size is 10 mm^2. The difference is only 9 mm^2. Thus, it does not show the major effect when different size of cable was tested.

4.2 Size and Type of Particle

Two size of particle had been tested to determine the collection efficiency of dust collector. Figure 4.2 shows the collection efficiency of two different sizes of sawdust and ash with supply 3 kV. Finest is the particle with size less than 1µm while fine is the particle with size between 1 µm and 5 µm. From the graph, analysis by comparing type of dust and size of dust had been done.

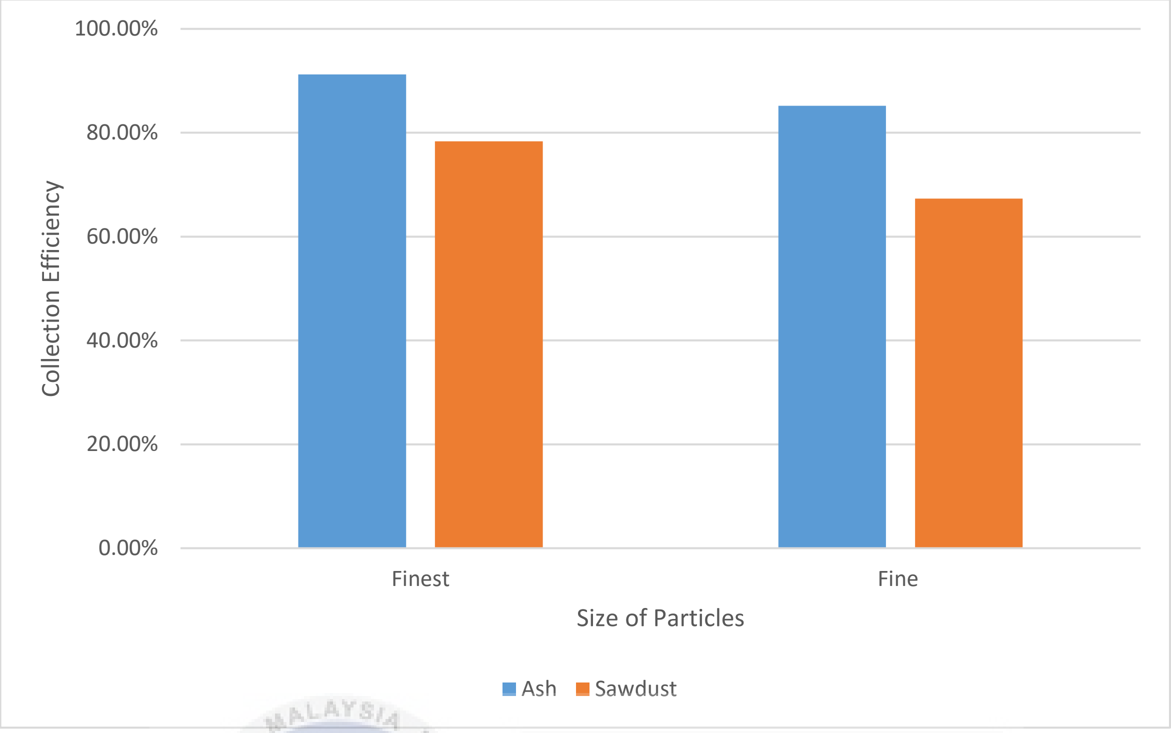


Figure 4.2: Collection efficiency of different size of particle

Firstly, different collection efficiency for both sizes of dust is observed. Collection efficiency of the finest particle is higher than the fine particle. The different for the collection efficiency for finest and fine ash is 6.00% while the different between finest and fine sawdust is 11.01%. This shows that size of particle will be effected the collection efficiency of dust. The higher the size of the particle, the higher energy needed to polarize the particle.

From this graph, the result also can be compare due to the type of dust used. The difference of collection efficiency between these two type of dust can be seen clearly. The collection efficiency of ash is higher than sawdust. The highest efficiency recorded in the graph is the finest ash which is 91.20% while the lowest efficiency is fine sawdust with efficiency 67.33%. The different collection efficiency between these two type of dust also can be seen clearly for fine particle size. The collection efficiency of ash remains higher compare to the sawdust.

The collection efficiency of ash was higher due to the conductivity of ash is better than sawdust. Ash contain carbon element which is placed in group 14 in periodic table. Figure 4.3 shows the carbon family in periodic table. Element in group 14 gain metallicity when moving down the group. This showed that type of dust is also affected the collection efficiency of the electrostatic chamber.

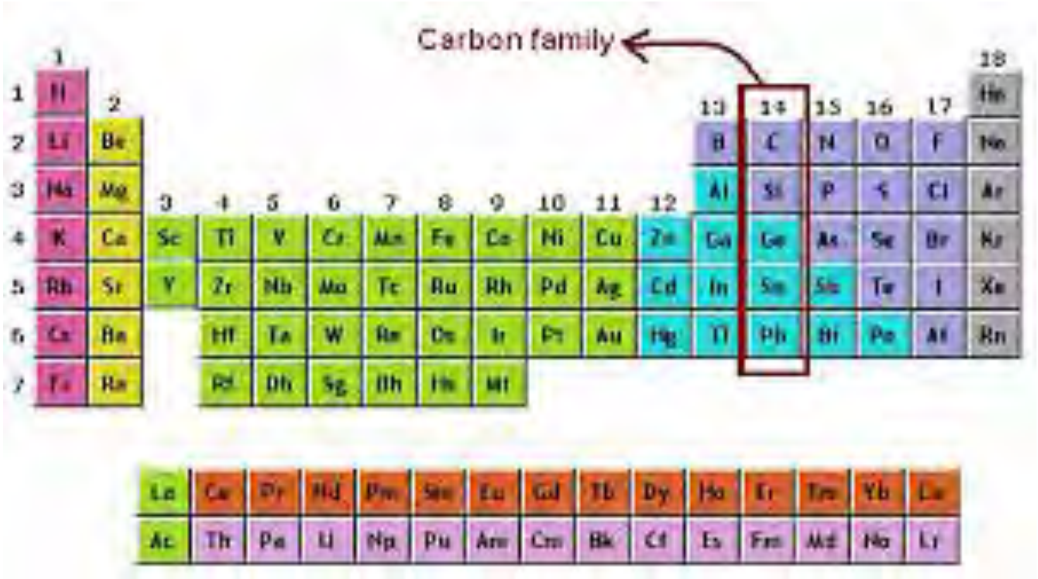


Figure 4.3: Periodic Table

4.3 Supply Voltage

Three supply voltage are used to test the collection efficiency of dust. The voltages are 30kV, 10kV and 3kV. Figure 4.3 shows the result obtained. From this graph, we can see that supply voltages are very affected the collection efficiency. The collection efficiency for 30kV supply is the highest for both type of dust that had been tested which is more than 99%. The collection efficiency for 10kV supply slightly decrease with efficiency about 98.66% for ash and 95.13 % for sawdust. The lowest collection efficiency is the supply voltage 3kV which is 91.20% for ash and 78.34% for sawdust.

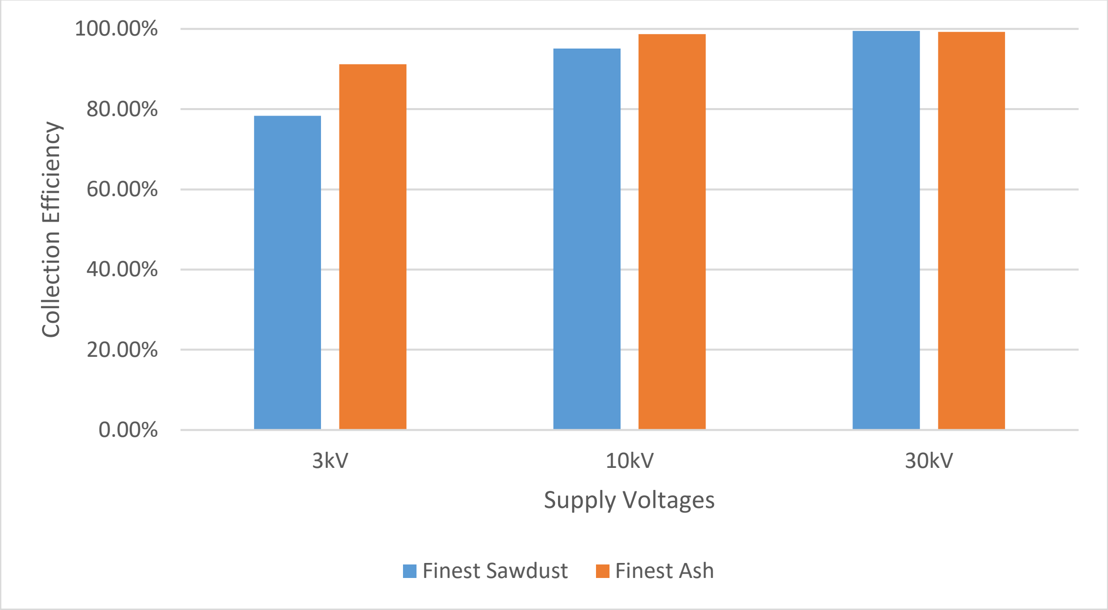


Figure 4.4: Collection efficiency with different supply voltages

The supply voltage effect to the efficiency of the chamber can be explain by the electric field between electrode and collecting plate. The electric field strength is different when the supply voltage was changing. Electric field strength can be calculated by using following formula:

$$E = \frac{Voltage}{distance} \tag{4.2}$$

From this formula, the electric field for each supply voltage can be calculated. Table 4.1 shows the electric field strength of each supply voltage. Distance between discharge electrode and grounded plate is 5 cm.

Table 4.1:Electric field strength for each supply voltage

Supply Voltage	Electric Field Strength
3 kV	0.6 kV/cm
10 kV	2.0 kV/cm
30 kV	6.0 kV/cm

The greater electric field strength, the higher ionization energy that will break the bond between molecule. Thus, the molecule will easily ionised. From this result, it can be concluded that supply voltage is one of the most important factor that will influence the collection efficiency of dust.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Electrostatic dust collector is a chamber that is used to trap particle or dust by the concept of electrostatic. The discharge electrode will produce corona effect when the DC high voltage is supplied and ionised surrounding atmosphere. Then the particle that enter the chamber will be ionised and move to the collecting plate by the electrostatic force. There are a lot of important thing that must be noted in order to develop the chamber.

One of the important thing is supply voltage to the discharge electrode. This supply voltage will determine the electric field strength in the chamber. Based on the previous study, the electric field strength will be affected the polarization of the particle. Result of this project shows that the collection efficiency increased when the supply voltage increased.

One of the factor that also affect the collection efficiency is the type and size of the dust used. Two type of dust are tested with two different size for each dust. collection efficiency of ash is higher compare to the sawdust. If the size is compared, the finest dust show the higher collection efficiency compare to the fine dust for both type of dust. This shows that type and size of dust are also affected the collection efficiency.

As a conclusion, all the objectives of this project were achieved. This project can help to increase the quality of air. Further study of this project can increase the possibility to produce the new devices for control indoor air quality. By reducing the dust particle which is not good for health, we can keep the quality of air clean.

5.2 Recommendation

This project has a lot of interesting part that need to be explored. It is not impossible that electrostatic dust collector for home usage will be developed. In future, maybe this project can be scale down so that the voltage used can be reduced so it is safe and suitable as home appliances. By reducing the space between collecting plate and electrode, the voltage also can be reduced with the same electric field strength. Study about type of the dust that can be trap by this project will also helped to increase the quality of this project.

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APPENDIX

Appendix A

Appendix A: Table for Record the Result Obtained

Voltage:		
	Efficiency (%)	
	Fine Ash	Finest Ash
1.0 mm^2		
2.5 mm^2		
4.0 mm^2		
6.0 mm^2		
10 mm^2		
	Fine Sawdust	Finest Sawdust
1.0 mm^2		
2.5 mm^2		
4.0 mm^2		
6.0 mm^2		
10 mm^2		

Appendix A: Checking the Connectivity of Cables

Appendix A: Dust Trapped in The Chamber

Appendix B

Appendix B: Data for Figure 4.1

Size of Dust / Size of Cables	**Efficiency (%)**	
	Fine Sawdust	Finest Sawdust
1.0 mm^2	99.07 %	98.99 %
2.5 mm^2	99.43 %	99.52 %
4.0 mm^2	97.83%	98.83 %
6.0 mm^2	97.88 %	99.19 %
10 mm^2	97.83 %	99.13 %

Appendix B: Data for Figure 4.2

Type of Dust / Size of Dust	**Efficiency (%)**	
	Ash	Sawdust
Finest	91.20 %	78.34 %
Fine	85.20 %	67.33 %

Appendix B: Data for Figure 4.4

Type of Dust / Supply Voltage	**Efficiency (%)**	
	Finest Sawdust	Finest Ash
3 kV	78.34 %	91.20 %
10 kV	95.13 %	98.66 %
30 kV	99.52 %	99.26 %