EFFICIENCY OF WOOD DUST FILTRATION
BY WOOD DUST MEDIA FILTER

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Thesis
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ABSTRACT

This study was an experimental study. Objectives of the study were to investigate the relationship between; dust weight and collection efficiency, static pressure drop and collection efficiency of a wood dust filter. The wood dust in this study was from the wood processing industry. The wood dust panel filter was made by using coarse wood dust retained on a 1.50 mm sieve and filled into a 1.0x1.0x0.1 m. panel. The filtration efficiency was determined by the amount of small wood dust in the air sample before and after filtrating. The static pressure of the wood dust panel filter was measured during the experiment.

The results of study were found that the collection efficiency was 99.5% and reduced to 77.9% with increasing amounts of small wood dust. The relation between the small wood dust load and collection efficiency showed a high negative relationship ($r<-0.913$ to -0.953) and was significant at 0.01. The static pressure of the panel filter increased due to the increasing amounts of small wood dust. The wood dust load had a high positive relationship ($r<0.962$) with a static pressure panel filter and was significant at 0.01. Additionally, this study presented two predicted equations of collection efficiency from the wood dust load and static pressure drop of the panel filter. These were (1) Collection efficiency (%) = 105.269 - 2.613 Wt (wood dust load) and (2) Collection efficiency (%) = 106.745 - 0.117 Pa (static pressure drop).

KEY WORDS: FILTRATION EFFICIENCY / WOOD DUST FILTER / STATIC PRESSURE DROP

47 pages

ประสิทธิภาพการกรองฝุ่นไม้ด้วยชั้นกรองชนิดตัวกลางฝุ่นไม้

EFFICIENCY OF WOOD DUST FILTRATION BY WOOD DUST MEDIA FILTER

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บทคัดย่อ

การวิจัยครั้งนี้เป็นการศึกษาเชิงทดลอง มีวัตถุประสงค์เพื่อศึกษาความสัมพันธ์ระหว่างปริมาณฝุ่นที่ปล่อยเข้าชุดกรองกับประสิทธิภาพการกรองฝุ่นไม้ และศึกษาความสัมพันธ์ระหว่างความดันสถิตของชุดกรองฝุ่นกับประสิทธิภาพการกรอง โดยใช้ฝุ่นไม้จากอุตสาหกรรมผลิตภัณฑ์จากไม้ นำฝุ่นไม้นี้ไปร่อนผ่านตะแกรงขนาด 1.50 มม. ใช้ฝุ่นที่ไม่ผ่านตะแกรงใส่ในชุดกรองฝุ่นขนาด 1.0x1.0x0.1 ม. นำฝุ่นขนาดเล็กที่ผ่านชั้นกรองมาป้อนเข้าฮูดของระบบระบายอากาศที่จะถูกดูดต่อไปยังชั้นกรองฝุ่น ศึกษาประสิทธิภาพการกรองฝุ่นโดยการชักตัวอย่างฝุ่นที่ด้านหน้าและหลังชั้นกรองฝุ่นด้วยปั๊มเก็บตัวอย่างผ่านกระดาษกรองไฟเบอร์กล๊าส ตลอดการทดลองทำการวัดค่าความดันสถิตภายในท่อด้านหน้าและหลังชั้นกรองเพื่อศึกษาความดันที่เปลี่ยนแปลงในขณะกรองฝุ่น

ผลการทดลองพบว่าประสิทธิภาพการกรองฝุ่นมีค่าร้อยละ 99.5 และลดลงเหลือร้อยละ 77.9 เมื่อปริมาณฝุ่นที่ปล่อยเข้าชุดกรองมากขึ้น มีความสัมพันธ์ทางลบ (r<-0.913 ถึง -0.953) อย่างมีนัยสำคัญทางสถิติที่ระดับ 0.01 ซึ่งอาจมาจากฝุ่นขนาดเล็กมีการเคลื่อนที่ทะลุผ่านชุดกรอง สำหรับค่าความดันสถิตมีค่าสูงขึ้นเมื่อปริมาณฝุ่นที่ปล่อยเข้าด้านหน้าชั้นกรองฝุ่นมากขึ้น โดยมีความสัมพันธ์ทางบวก (r<0.962) อย่างมีนัยสำคัญทางสถิติที่ระดับ 0.01 นอกจากนี้การศึกษาครั้งนี้ได้นำเสนอสมการประสิทธิภาพการกรองสองสมการที่มีความสัมพันธ์กับน้ำหนักของฝุ่นที่ปล่อยเข้าชุดกรองและความดันสถิตของชุดกรอง ดังสมการที่ 1 ประสิทธิภาพการกรอง = 105.269-2.613x น้ำหนักฝุ่นที่ปล่อยเข้าชุดกรอง และสมการที่ 2 ประสิทธิภาพการกรอง = 106.745 - 0.117xความดันสถิตของชุดกรอง

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INTRODUCTION

1.1 Rational and Background

In industrial process, dust from manufacturing process and surrounding communities. Generally, dust occurs from cutting, planning, sanding and grinding. These processes produce small solid particle dispersing through ambience air. Without good control measure, small dust particle can enter to respiratory system and effect worker's health. In wood processing industry, wood dust occurring from cutting, trimming, and sanding process has difference sizes of particle. Accordingly, dust collection in wood processing industry, therefore, has also small dust particulate collection device called "Single-Stage" using suction and separation mechanism of dust from air and send to collection bag and another of coarse dust collection of equipment called "Dual Stage" using separation mechanism of coarse dust from small dust prior to collection bag, for example; using Cyclone to separate coarse dust from small dust with clean outlet air. High efficiency dust collection devices have various mechanisms and have a large size of system, as well as spend high expenditures for installation, maintenance and frequent collection filter bag replacement.

Data of registered industrial establishment by type of industry from Department of Industrial Work, Ministry of Industry on March 21st, 2013 reported that there were 7,964 wood related industries or wood product establishment with 184,184 workers(1), If there is no effective preventive and control measure, this would be effected to workers health. Since preservative chemicals and fungus from manufactured wood may produce wood dust that will irritate workers' skin and respiratory system, and will contribute to rhinitis or even to pneumonia. The allergic workers usually be unable to continue their work no matter what concentration level of the wood dust.

This study is designed by using coarse wood dust as a filter of air cleaning equipment with air ventilation mechanism, this will separate coarse wood dust from small wood dust then air with small wood dust will be filtrate through a filter made from the prepared coarse wood dust layer. This coarse wood dust filter using for a period of time is overload, then this has been designed to move into a dust collection equipment continuously, This study is not only a new designed technology for air collection equipment, but also reduces the bag filter replacement expenditures.

1.2 Objectives of the study

General Objective:

To investigate collection efficiency of wood dust collection system.

Specific Objective:

1. To investigate relation between inlet dust load and collection efficiency.
2. To investigate relation between pressure drop and collection efficiency.

1.3 Related Variables

Interested variables in this study are:

1.3.1 Independent variables are :

- Static pressure drop
- Dust weight

1.3.2 Dependent variable is :

- Amount of wood dust from dust collection filter equipment

1.3.3 Control variable is :

- Filtration velocity

1.4 Scope of the study

1.4.1 This research is to study wood dust collection efficiency of the dust collection equipment that uses 1 m. x 1 m. x 0.10 m. wood dust panel filter. Wood dust in this study is from wood manufucturing industry.

1.4.2 This research is to study wood dust collection efficiency with air filtration velocity at 0.20 metre per second (m/s)

1.4.3 This research uses weight of dust for generation between 1 – 9 Kg.

1.5 Expected outcomes

Dust collection system with less maintenance expenditmes for wood manufactuning industry.

1.6 Conceptual framework of the study

Static pressure drop

Dust weight

→ Collection efficiency

Filtration velocity

1.7 Terms and definitions

Filtration velocity : air flow rate per filter area, metre per second

Static pressure drop : Increased static pressure due to resistance of filter to air flow. This is a resistance from dust collection equipment, the higher pressure drop, the higher resistance. Static pressure drop can define from difference pressure of filter at inlet and outlet.

Collection efficiency : Capabity of dust cleaning equipment on removing of dust from air stream flowing through the system. This final result will be percentage of collection efficiency.

Dust concentration : Weight of dust per a unit of air volume.

CHAPTER II
LITERATURE REVIEW

2.1 Particulate collection equipments

Particulate collection equipment are dust collection equipment that separate dust from air stream in order to eliminate dust from manufacturing process as decontamination process of air for working and surrounding environments There are various types of particulate collection equipment depending on size of particles;

1.1 Precipitation chamber is a dust collection equipment that removes dust from reduced velocity air stream by using gravity force. Therefore, large size dust particle will be dropped in the chamber.

1.2 Cyclone is a dust collection equipment that removes dust from air stream by using centrifugal force. Large size dust particle will be centrifuged to impact the equipment's wall and drop down to the basement, the clean air vortex will be moved upward to outside ambience.

1.3 Scrubber is a dust collection equipment that using fluid to catch up dust particle. Dust will be removed from air stream by fluid.

1.4 Bag filter is a dust collection equipment that using inertial impaction, interception force, and Brownian's diffusion principle to remove dust from air. Dust with diameter larger than bag's fiber pore size will not be passed through bag's fiber gap. With this mechanism, particle will be catched up by bag's fiber.

1.5 Electrostatic precipitation is a dust collection equipment that using electrostatic force to remove dust in air stream. Dust will be catched up with negative electrode.

2.2 Particulate filtration mechanism

Dust collection equipments use various particle filtration mechanisms to remove dust from air stream;

2.1 Inertial Impaction

Inertial impaction is mechanism that dust and air flow in the same direction, when facing the filter, air will be bended. However, dust with diameter larger than 1 micrometer cannot be abruptly moved due to its inertial force, therefore, making impact to filter. Dust particle, finally, will be eliminated from air stream due to inertial impaction as shown in Figure 1

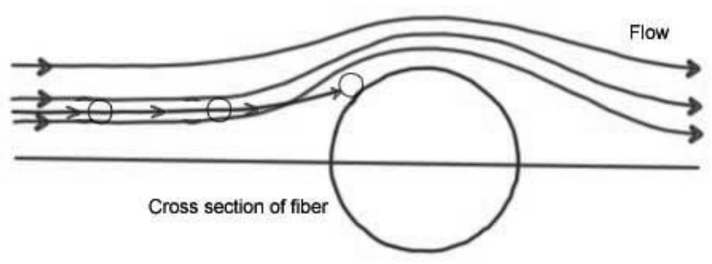


Figure 2.1 Inertial impaction mechanism

Dust collection using inertial impaction mechanism uses stokes number, which is ration of and fiber diameter, as parameter for calculation of this mechanism's efficiency.

$$Stk = \frac{\rho_p d_p^2 C_c V}{18\mu D_f} \quad (2.1)$$

Where	Stk	=	Stokes number
	ρp	=	particle density (g/cm^3)
	d_p	=	dust particulate diameter (cm)
	C_c	=	slip correction
	V	=	air flow velocity approaching the filter (face velocity)
	μ	=	air viscosity; (g/cm-s)
	D_f	=	fiber diameter; (cm)

Increasing of air velocity will increase inertial impaction and decreasing of fiber will increase efficiency.

Efficiency of inertial impaction (E_I) can be calculation from Yeh and Liu's formula (1974) (3) as follow:

$$E_I = \frac{(Stk)J}{2K_u^2} \quad (2.2)$$

Where: E_I = single fiber efficiency due to inertial impaction only

Stk = Stokes number

J = function in the expression of E_I

K_u = Kuwabara hydrodynamic factor

2.2 Interception

Interception is mechanism that air streamline has changed when breaking through filter. Dust with less inert force will flow in the same direction with air flow and approaching to face of the filter in the lesser distance than dust diameter and then has been catched up. The smaller dust diameter the lesser efficiency. This mechanism can be shown in Figure 2.2

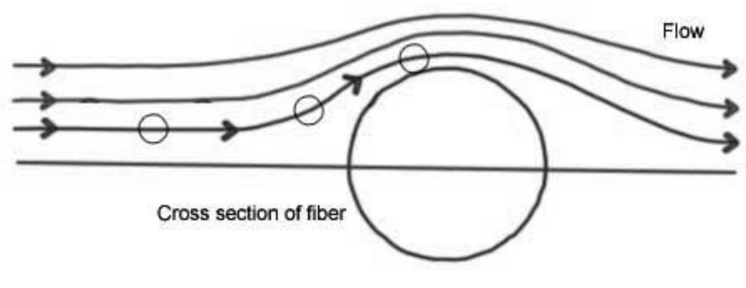


Figure 2.2 Interception mechanism

Efficiency of interception mechanism depends on parameter R ($R = d_p / D_f$) which is ratio of dust particulate diameter and fiber diameter.

Efficiency of interception mechanism of single fiber (E_R) can be calculated from Lee and Ramamuthi's formula (1993)[(4)] as follow:

$$E_R = \frac{(1-\alpha)R^2}{K_u(1+R)} \quad (2.3)$$

Where: E_R = single fiber efficiency due to interception only

α = solid fraction in the filter or solidity

K_u = Kuwabara hydrodynamic factor

2.3 Brownian diffusion

Brownian diffusion is mechanism that dust particulate diameter lesser than 0.3 micrometer moving with Brownian diffusion in air streamline hits to air molecule and transfer kinetic energy. The dust particulate then making import to filter and has been catched up. The larger dust particulate diameter, the lesser Brownian diffusion movement. This mechanism can be shown in Figure 2.3

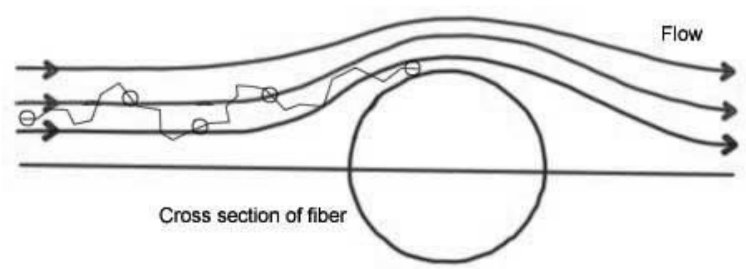


Figure 2.3 Diffusion mechanism

Efficiency of this mechanism depends on Peclet number

$$Pe = \frac{3D_f V\mu d_p}{kTC_C} \quad (2.4)$$

Where: P_e = Peclet number
D_f = fiber diameter; (cm)
V = air flow velocity approaching the filter (face velocity)
μ = air viscosity; (g/cm-s)
d_p = dust particulate diameter (cm)
k = Boltzman's constant
T = temperature
C_c = slip correction

Efficiency of diffusion mechanism of single fiber (E_D) can be calculated from Krisch and Fuchs' formula (1968)[(5)]

$$E_D = 2Pe^{-2/3} \tag{2.5}$$

The lesser Peclet number and dust particulate diameter, the more efficiency of diffusion mechanism

Total dust collection efficiency

Dusts collection efficiency of a dust collection equipment can be calculated by measuring air inlet and outlet and calculating the total efficiency; E_T by this following formula:

$$E_T = 1 - \frac{N}{N_0} \tag{2.6}$$

Where: E_T = total efficiency
N = particulate concentration down-stream of filter
N_0 = particulate concentration up-stream of filter

2.3 Dust flow rate measurement

Determination of dust flow rate measurement point should be selected at point with the regular and laminar air flow. Measuring point should be far from point of turbulence air flow e.g. elbow, tri-angle at least 6 – 8 time of duct diameter and for the most accuracy air flow should be measured from various point of measurement so called “Pitot Traverse”.

Determination of duct flow rate measurement point due to duct diameter shown in table 2.1 or calculated from this following formula:

$$r = D\sqrt{\frac{2n-1}{4N}} \quad \text{m} \qquad (2.7)$$

Where: r = radius of point n from the centre

n = number of the point counted outward from the centre

D = diameter of the duct (m)

N = number of point across the diameter

Table 2.1 Pitot-Static Traverse Measurement Location for Round Duct using the Log-Linear Rule

Number of Points per Diameter	**Distance from Wall in Duct Diameter**									
						centre				
6			0.032	0.135	0.321	0.679	0.865	0.968		
8		0.021	0.117	0.184	0.345	0.665	0.816	0.883	0.979	

2.4 Volumetric flow rate

Volumetric flow rate is volume of air passing through a point of measurement at a unit of time. The relation between average air flow and cross-sectional area at the point of air flow can be shown with the following formula.

$$Q = AV \qquad (2.8)$$

Where: Q = Air flow rate (m^3/s)

A = Cross-sectional area (m^2)

V = Air volume (m/s)

2.5 Filtration velocity

Filtration velocity can be identified by a ratio of air velocity per filter material. This ratio is a rate of air flow approaching to the filter[6] or so called "face velocity" which is average air velocity passing through the filter in unit of meter per second.

Face velocity is one of factors for calculation of filter area in order to select a dust collection equipment appropriated with size and collection dust concentration.

2.6 Relation between air velocity and velocity pressure

Relation between air velocity and velocity pressure. Can be calculate by this following formula:

$$V = 1.29\sqrt{VP} \qquad (2.9)$$

Where: V = air velocity; m/s

VP = Velocity Pressure; Pascal

2.7 Relate literatures

Chan and Hsian (2008) studied on “Cake Formation and Growth in Cake Filtration” Samples of study were dust composing with SiO_2, Al_2O_3, CaO and Fe_2O_3, with size between 0.55-18.17 µm. The study simulated filtration system using filter chamber installing with dust cake thickness measurement equipment and pressure sensor. The study was designed to use dust concentration at 200 g/m^3 and filtration velocity at 17, 20, 25, 28 and 32 cm/s. Measurement of cake formation and thickness of dust cake was done at various pressure drop by sampling technic for 16 points of measurement. The results of study were found that the higher thickness of dust cake, the lesser cake porosity, and the higher pressure drop. Decreasing of dust cake thickness contributed to reduction of pressure drop and efficiency of dust collection. From the equation of pressure drop $\Delta p_t = k_v \mu U + k_i \rho_g U^2$, a higher filtration velocity (U) resulted in a higher degree of compaction in dust cake and thus a higher cake resistance. The highest filtration velocity, the highest cake resistance and the highest pressure drop. The relation between average thickness of cake and filtration velocity was non-linear relation. The higher filtration velocity, the higher collection efficiency of dust cake, and the higher of stoke number and Peclet number which indicated the higher dust collection efficiency both from inertial impaction and Brownian diffusion; The study found that at the highest pressure drop, the higher average thickness of dust cake did not resulted in the higher of dust collection efficiency, and higher pressure drop resulted in higher cake resistance, however, higher thickness of dust cake did not resulted in cake resistance. Filtration velocity resulted in cake resistance significantly.

Subanda V. et al. (2001) studied on “Particle Separation from Gases using Cross-Flow Filtration” by using cross-flow filter made from ceramic tube with 4 cm. inside diameter and variable length adjustable from 200 mm. to 400 mm. The aerosol of line stone dust particle, diameter 5 µm. concentration of 9.8 g/m^3 was used as sample of the study. Consistent of air flow at 90 l/min. with filtration velocity at 6.0 cm/s, relative humidity at 15%, and 6 levels of cross-flow ratio ($\phi = \frac{Q_f}{Q_T}$) at 0.1, 0.2, 0.3, 0.5, 0.6 and 1 was used in the study. The aerosol of line stone dust particle was designed to enter cross-flow filter to a single-stage cyclone. An electron microscope was use for scanning of dust agglomeration. Dust from cross-flow filter was collected for 10 seconds. Total mass of particle entering the filter (M_t) was a calculation from mass of particles collected on the filter (M_f) and mass of particles collected in the cyclone (M_c). Calculation of cyclone's efficiency was done by using equation: $\eta_c = \frac{M_c}{M_T - M_f} x100\%$ Calculation of total efficiency of filter and cyclone was done by using equation $\eta_{fc} = \frac{M_c + M_f}{M_T} x100\%$. Results of the study showed that at cross-flow ration (Φ) at 0.1, 0.2, and 0.3, resulted in the lowest filtration rate, and also found that at the similar cross-flow ratio, filter length 400 millimeters acquired half filtration velocity of filter length 200 millimeters.

Sira Sriniwes et. al. (2005) studied on "Investigation of Dust Filtration Efficiency of Rice Husk Bed". The study used calcium carbonate particles instead of dust with average diameter of 1.6 micrometer, 3 levels of rice husk bed at: 0.125, 0.25, and 0.5 meters, and filtration velocity at: 0.22, 0.48 and 0.81 m/s. Dust was designed to enter the filter with laden air. The results were found that at the similar filtration velocity, the 0.5 meters thickness of rice husk bed obtained the higher collection efficiency than the 0.125 meter thickness of rice husk bed.

Jungmin Seak, Kwang Min Chun, Soonho Song, and Seyong Lee studied on "Study on the Filtration Behavior of a Metal Fiber Filter as a Function of Filter Pore Size and Fiber Diameter". This study investigated on pressure drop, mass, and filtration efficiency. Samples of the study were soot particles generated from soot generation that could adjust the soot particle sizes and concentrations. Pressure drop, and deposition temperature before and after filtration collector had been recorded continuously. Additionally, particle counter and soot diameter scanner were equipped for calculation of particle numbers and soot diameter in order to calculate the collection efficiency. The results were found that pressure drop and deposited mass on filter did not depending on types of collection materials, but depending on filter pore size and filter diameter. The pressure drop slope of all types of studied filters increased steeply, however, average filter pore size decreased. The lower the average pore size of filter, the higher extreme increasing of pressure drop over the time, the higher deposited mass on the filter.

Jin-Do Chung, Tae-Won Hwang, So-Jin Park studied on “Filtration and Dust Cake Experiment by Ceramic Candle Filter in High Temperature Conditions” to investigate the efficiency of ceramic filter, and stability of material against high temperature and long-term operation conditions by applying fly ash on the surface of the filter and relation of pressure drop and dust cake thickness under experimental conditions at 450^{o}C, 650^{o}C and 850^{o}C along 50 hour of the study. The results showed that pressure drop had relation with dust cake thickness.

Toshiaki Hayashi, Tai Gyu Lee, Melynda Hazelwood, Elizabeth Hedrick and Pratim Biswas studied on “Characterization of Activated Carbon Fiber Filters for Pressure Drop, Submicrometer Particulate Collection, and Mercury Capture” to investigate the relation between clean ACF filter pressure drop and air flow rate; pressure drop and dust loading; filtration efficiency and agglomerated dust on ACF filter; mercury (Hg) capture and filter breakthrough. The study used spherical particle (NaCl), agglomerated particle (SiO_2) and mercury (Hg) as samples of the study and examine these samples behavior in 3 experiments; 1) the first system consisted of clean ACF filter with air velocity at 0.4 - 30 cm/sec, measuring pressure drop to examine relation of pressure drop, collection efficiency and air flow rate; 2) examine relation between pressure drop and dust in consistent velocity at 5 cm/sec and recording dust load continuously; 3) examine relation between collection efficiency and particle size, particle size measured by DMA-CPC (Differential Mobility Analysis-Condensation Particle Counter) prior to and out of filter. The second system examined mercury capture of ACF filter using air flow rate at 0.1 L/min passing through bubbles in 4 installed impinger; the 1st impinger contained 0.1 M. HNO_3 solution, the 2nd to the 4th impinger contained 0.4 M. $KMnO_4$ and 1.0 H_2SO_4 solution, then measured Hg in the solution with CVAA (Cold Vapor Atomic Absorption). The third system examined ACF filter breakthrough by measuring Hg concentration prior to and out of the filter. The results of this study were found that clean ACF pressure drop correlation with face velocity. The higher face velocity, the higher pressure drop. The ACF pressure drop related with agglomerated dust loading. When dust cake was formulated, the increasing rate of ACF pressure drop correlated with increasing of dust loading. The larger particle size formed dust cake faster than the smaller particle size at the similar dust load. The smaller particles had higher breakthrough than the larger particles at the similar dust load. This finding was consistent with the dust collection type of cake filtration as the function of $\Delta P - \Delta P_0 = K_{2C} \frac{VM}{A}$

CHAPTER III
RESEARCH METHODOLOGY

3.1 Research Design

The study was designed as an experimental study consisting with three following step;

3.1.1 develop a dust collection system containing with dust panel filter size 1.0 m. x 1.0 m. 0.10 m. for investigation of collection efficiency

3.1.2 investigate filtration velocity by using average velocity pressure and calculeate duct velocity from equation $V = 1.29\sqrt{vp}$

3.1.3 determine collection efficiency by collection of dust samples both before and after panel filter including measuring of static pressure drop at every one kilogram of dust load to nine kilograms.

3.2 Research instruments

Research instruments of this study consisted of;

3.2.1 Dust collection from wood manufacturing process e.g. cutting, planing, and sanding without humidiating to dust, using a screen with 1.5 mm. pore size to screen coarse wood dust from small wood dust. The coarse wood dust was used as a media filter in panel filter and the small wood dust was used for dust generating to investigate the filter collection efficiency.

3.2.2 Magnehelic pressure gauge manufactured by Dwger Instrunments, Inc.

3.2.3 Air velocity, temperature, and humidity meter detector; Velocicale Plus Model 8386 A-M-GB manufactured by TSI, Inc.

3.2.4 Air sampling pump, Model Quick Take 30, manufactured by SKC, Inc.

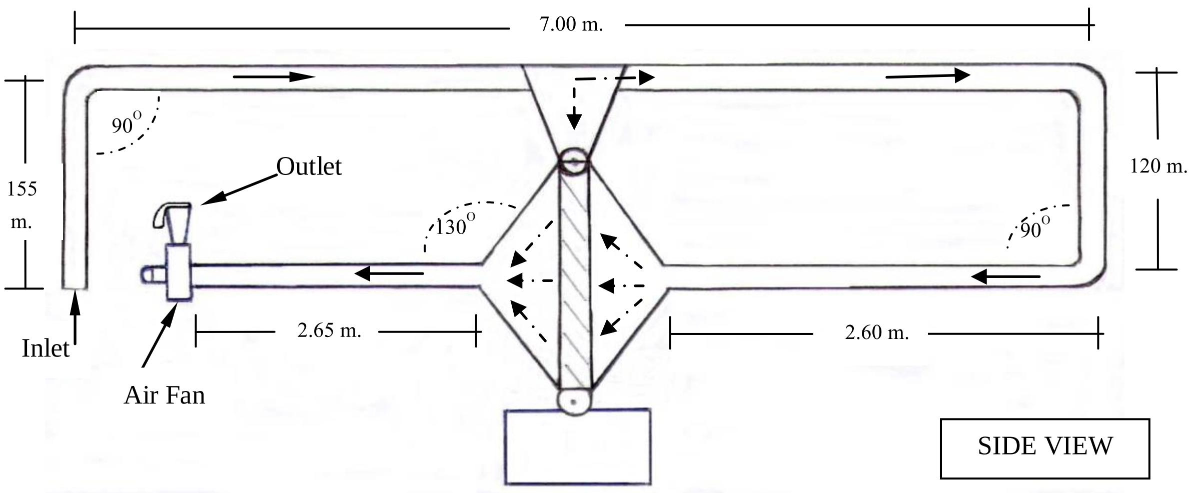
3.2.5 A balance with an accuracy of 0.01 g, manufactured by Mettler Toledo Co, Ltd.

3.3 Experimental Method

3.3.1 Design the dust collection system for investigation of filter collection efficiency; the system consisted of 4 main components;

1. Air duct made from steel, with duct diameter 0.2 m.
2. Dust separation unit designed for separating coarse dust particles from small dust particles by using gravity force.
3. Panel filter size 1.0 m. x 1.0 m. 0.10 m. used for receiving dust from dust separation unit.
4. Blower with 3-horse-power, 220 volts, with maximum speed at 1,500 rpm.

The components of the ventilation system is shown in Figure 3.1



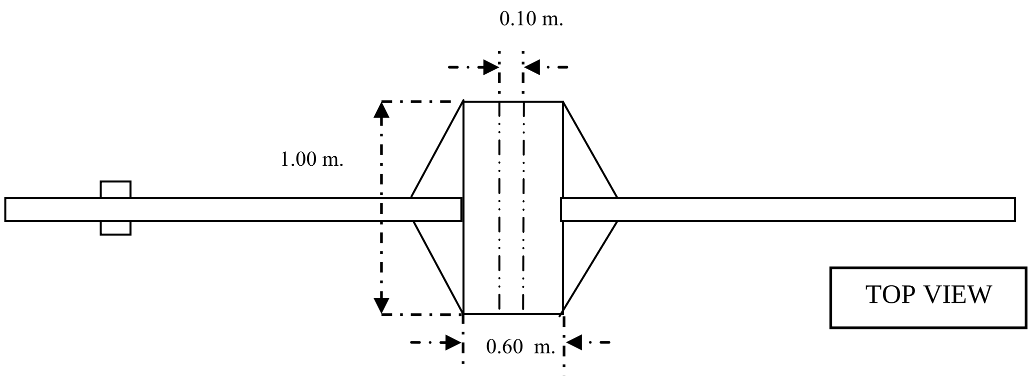


Figure 3.1 Demonstration of dust filtration equipment from side view and top view perspective.

3.3.2 Measure air duct velocity approaching to the filter by determination of an average air velocity in duct with these following steps;

3.3.2.1 Divide cross-sectional area of duct diameter 0.2 m. into 6 spots and marking on the air velocity measurement probe at the distance of 0.62, 2.63, 6.25, 13.24, 16.86, 18.87 cm. from duct inner surface as shown in Fig. 3.2

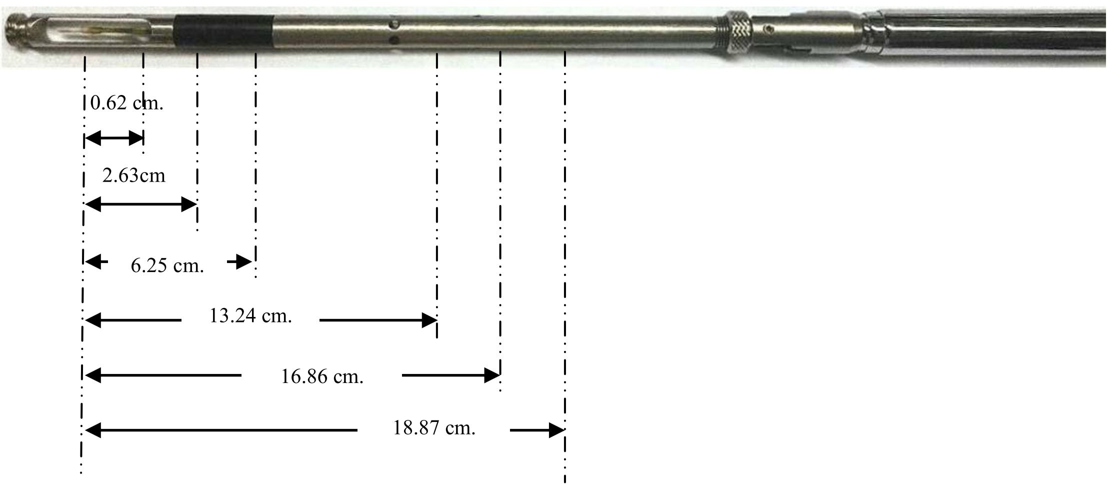


Figure 3.2 Demonstration of air sampling spot marked on air velocity measurement probe.

3.3.2.2 Place the probe connected with air velocity measurement device into the sampling port of duct and completely tightened the port. Then, turn-on the blower and measure the air velocity (m/s) at the 1st mark as starting point, record the air velocity with one decimal number, and then move to the next mark no. 2 to 6 and record the air duct velocity.

3.3.2.3 Repeat in 3.3.2.2 once again.

3.3.3 Investigation of the filter collection efficiency

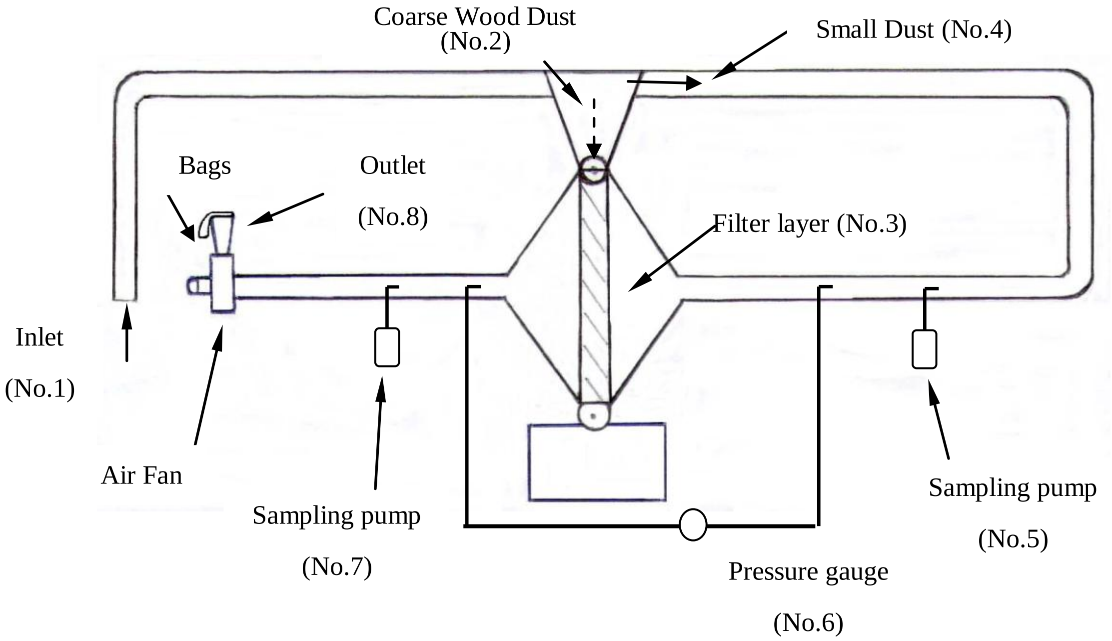


Figure 3-3 Demonstration of air ventilation, sampling equipment installation and pressure gauge.

3.3.3.1 Turn-on the blower motor and control the air duct velocity at 5 m/s and filtration velocity at 0.2 m/s

3.3.3.2 Load coarse wood dust into the collection system (No.1) as shown in Fig.3.3, coarse wood dust distributes (No.2) into panel filter (No.3) by gravity until full without compression.

3.3.3.3 Generate small wood dust weight one kilogram in front of the hood. The dust concentration in the duct become about 0.2-1.0 kg/m^3 of air.

3.3.3.4 Turn-on dust sampling pump which the sampling probes are installed in front of the panel filter (No.5) and after the panel filter (No.7). The dust samplers are replaced for every one kilogram of small wood dust generation, repeat for nine times. It means that totally nine kilograms of small dust are generated in front of the hood. The dust samplers and the pressure drop (No.6) of panel filter are recorded for every one kilogram of small dust generation.

3.3.3.5 Turn off the blower after finishing nine kilograms of dust generation.

3.3.3.6 Empty the panel filter.

3.3.3.7 Repeat the step 3.3.3.1 – 3.3.3.6 for 3 times.

3.3.3.8 Record temperature and humidity of air.

3.4 Data analysis and statistics

3.4.1 Analysis of samples in Laboratory

Weigh the filter samplers before and after sampling, then calculate dust load to determine the dust collection efficiency of panel filter.

3.4.2 Statistical analysis of data

Analyze the average pressure drop, relation between pressure drop and collection efficiency using ANOVA, correlation and multiple linear regressions.

CHAPTER IV
RESULTS

Experiment on dust collection efficiency using wood dust panel filter size 1m.x1m.x0.1m. was conducted based on the hypothesis assumption to investigate the collection efficiency related to dust load and static pressure panel filter. The research results are in 3 parts;

Part 1 Calculation results of air duct velocity.

Part 2 Testing results of collection efficiency.

Part 3 Statistical results of collection efficiency.

Part 1 Calculation results air duct velocity.

Table 4.1 shows the average air duct velocity. The duct velocity at cross-sectional area of duct was recorded. The average air velocity was 5.01 meter per second.

Table 4.1 Average air velocity in 0.2 m duct diameter

No.	**Distant from wall surface of 0.2 m duct diameter (cm.)**						**Average air velocity (m/s)**
	0.62	**2.63**	**6.25**	**13.24**	**16.84**	**18.87**	
1	4.97	5.10	5.13	5.30	5.27	5.17	5.16
2	4.07	4.60	4.93	5.33	5.13	5.07	4.79
Average air velocity (m/s)	4.52	4.85	5.03	5.32	5.20	5.12	5.01

Part 2 Testing results of collection efficiency.

Coarse wood dust 15 kilograms was loaded into the panel filter size 1m.x1m.x0.1m. The bulk density from the calculation was 150 Kg/m^3. The results of the experiments are shown as followings.

Figure 4.1 indicates relation between static pressure drop and dust weight. The figure shows the similar increasing of static pressure drop and dust weight loading into the collection system. When the static pressure drop increased until its maximum value at 8 kg of dust load, then the static pressure drop decreased at 9 kg of dust load.

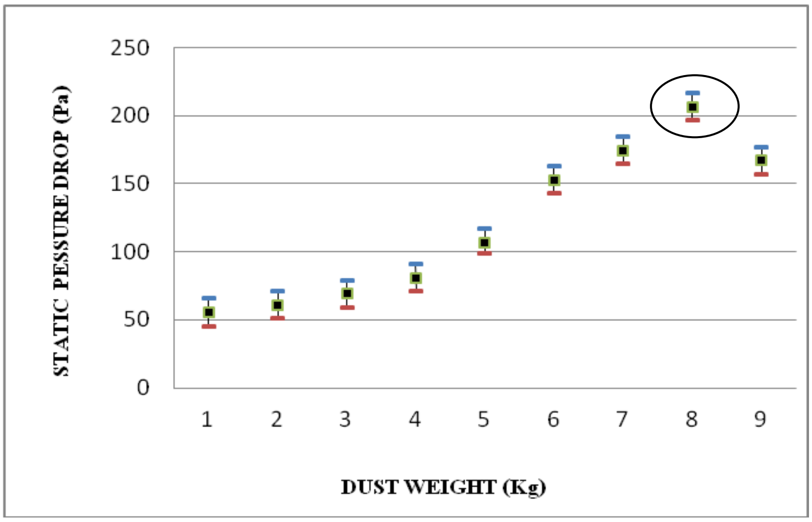


Figure 4.1 Relation between static pressure drop and dust weight.

Figure 4.2 indicates relation between collection efficiency and dust weight. It shows that collection efficiency decreased in contrary with dust weight loading into the collection system. The collection efficiency decreased obviously at dust weight of 5 kg.

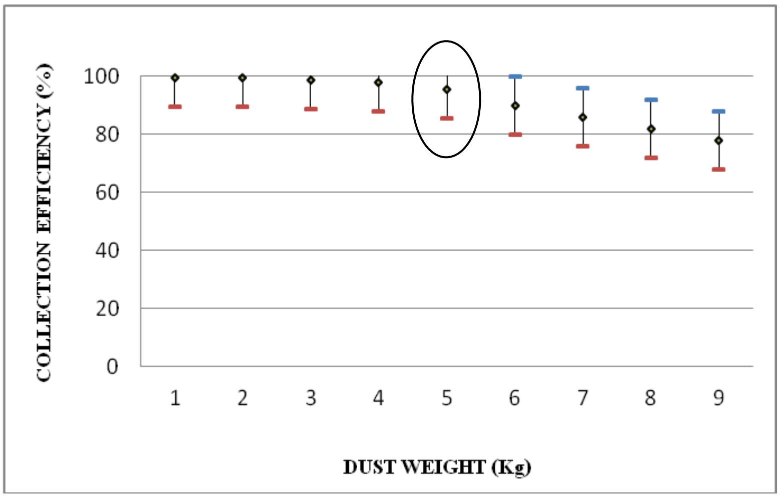


Figure 4.2 Relation between collection efficiency and dust weight.

Table 4.2 indicates average collection efficiency at dust weight 3, 6, 8, and 9 kg. Comparison of collection efficiency at every 1 kg dust weight found decreasing of collection efficiency at 1.02%, 9.80% and 17.79% respectively. Contrary, static pressure drop was increased.

Table 4.2 Comparison between average collection efficiency and difference of dust weight at each 1 kg.

Dust Weight (Kg.)	Static pressure drop (Pascal)	Average Collection Efficiency (%)	Difference of Collection Efficiency (%)
1	55	99.52	0.00
2	60	99.28	0.24
3	70	98.50	1.02
4	80	97.92	1.60
5	105	95.35	4.17
6	150	89.77	9.80
7	168	85.91	13.61
8	213	81.82	17.79

Part 3 Statistical results of collection efficiency.

The researcher used data of dust weight, static pressure drop, and collection efficiency to develop scatter plots in order to examine linear regression relation between dependent variables; dust weight, static pressure drop and independent variables: collection efficiency. The results are shown in figure 4.3 and 4.4.

Figure 4.3 indicates relation between static pressure drop and collection efficiency. These two variables had high significant relation. The scatter plots were in linear relation and unscattered, except only dust weight at 9 kg. The static pressure drop was decreased at 9 kg of dust load and the collection efficiency was also lower. The scatter plots at 9 kg of dust load were out of linear relation. Relation between static pressure drop and collection efficiency was found in contrary direction which means the higher static pressure drop, the lower collection efficiency.

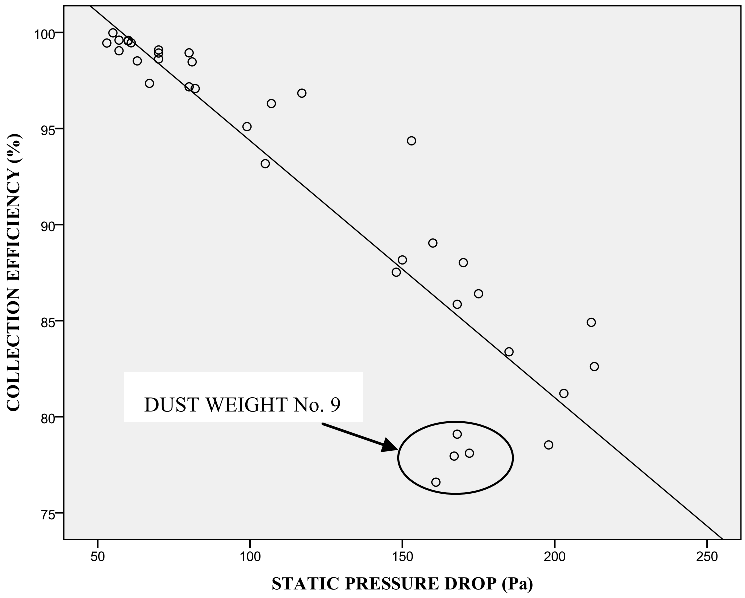


Figure 4.3 Relation between static pressure drop and collection efficiency.

Figure 4.4 indicates relation between dust weight and collection efficiency. These two variables had high significant relation. The scatter plots were in linear relation and unscattered, They have negative relation which means the higher dust weight, the lower collection efficiency.

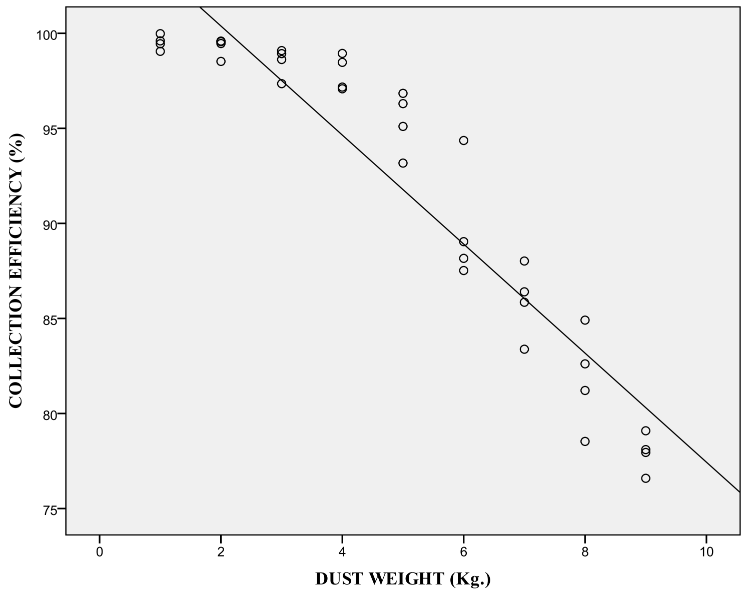


Figure 4.4 Relation between dust weight and collection efficiency.

Figure 4.3 and 4.4 show that dust weight and static pressure drop had relevant to collection efficiency. The researcher analyzed data of dust weight at 1 to 8 kg by using Pearson Correlation to identify quantitative relation, but not using dust weight at 9 kg since it was non-linear relation.

Table 4.3 indicates statistical analysis between dust weight, static pressure drop, and collection efficiency. The results showed that collection efficiency has high significant negative relation ($r<-0.913$ to -0.953) with dust weight and static pressure drop at confidence level 0.01. It means, the higher dust weight, the higher static pressure drop, the lower collection efficiency. Additionally, it was found that dust weight has high significant positive relation ($r<0.962$) with static pressure drop at confidence level 0.01. It means the higher dust weight, the higher static pressure drop.

Table 4.3 Statistic relation between dust weight, static pressure drop, and collection efficiency

Variable	Dust Weight	Static pressure drop	Collection Efficiency
Dust Weight	1	.962(**)	-.913(**)
Static pressure drop	.962(**)	1	-.959(**)
Collection Efficiency	-.913(**)	-.959(**)	1

** Correlation is significant at the 0.01 level (2-tailed).

From statistical analysis of relation between dust weight, static pressure drop, and collection efficiency (Table 4.3), it was found that dust weight had high relation with static pressure drop and indicated collinearity between these two dependent variables. Therefore, the researcher had separately by multi-linear regression analysis to identify predictive relation between dependent variable; dust weight and independent variable: collection efficiency; and dependent variable: static pressure drop and independent variable: collection efficiency. The results are shown in Table 4.4 and 4.5.

Table 4.4 indicates that dust weight can predict determinant coefficient by 83.30%. When considering the relation between these two variables, it was found that dust weight can predict collection efficiency significantly at the level of 0.05. From this analysis, the predicted equation (1) of collection efficiency is:

$$\text{Collection efficiency (\%)} = 105.269 - 2.613\ Wt \qquad (1)$$

Wt : Weight (1 to 9 kg in this study)

Table 4.4 Results of multi-linear regression analysis for prediction of collection efficiency, equation (1).

	Unstandardized Coefficients	Standardized Coefficients	t	Sig.
Dust weight (Wt)	-2.613	-.913	-12.226	.000
(Constant)	105.269		97.521	.000
R = .913(a) ; R^2 = .833 ; F = 149.475 ; Sig. of F = .000(a)				

Table 4.5 indicates that static pressure drop can predict determinant coefficient by 92.00%. When considering of these two variables relation, it was found that static pressure drop can predict collection efficiency significantly at the level of 0.05. From this analysis, the predicted equation (2) of collection efficiency is:

$$\text{Collection efficiency (\%)} = 106.745 - 0.117\ \text{Pa} \qquad (2)$$

Table 4.5 Results of multi-linear regression analysis for prediction of collection efficiency, equation (2).

	Unstandardized Coefficients	Standardized Coefficients	t	Sig.
Static pressure drop (Pa)	-.117	-.959	-18.54	.000
(Constant)	106.745		135.06	.000
R = .959(a) ; R^2 = .920 ; F = 343.904 ; Sig. of F = .000(a)				

CHAPTER V
DISCUSSION

This study was to investigate collection efficiency of a dust collection system using wood dust as the filter media by determining the pressure drop that had influence on collection efficiency of the dust collection system. The study can be summarized as following:

5.1 Discussion

This study was to investigate collection efficiency of a dust collection system using wood dust as the filter media, by measuring quantity of dust pre and post sampling filters and calculating of collection efficiency in order to prove that existing pressure drop had relation with collection efficiency of the dust collector.

From the study on measurement of collection efficiency of the dust collector using wood dust as the filter media, it was found that the average pressure drop was at 55 Pa. and collection efficiency was at 99.52% at the beginning period, after dust collector had been operated for a period of time until the maximum average pressure drop was 213 Pa, and the collection efficiency decreased to 81.81%, since then, the pressure drop was found decreasing which may be resulted from these following causes;

1. At the beginning, when the system was operated, air stream approaching to the panel filter brought small dust filling to the gaps between wood dust medias which was consistent with the study conducted by Sira Srinives et.al., and Toshiaki Hayashi et.al.(2000) according to diffusion principle. For capturing of dust in a dust collector using wood dust as the filter media, small dust that could not penetrate the gaps of filter would form the dust cake (Jungmin Seok et al., 2015, Jin-Do Chung et al. 2003) then contributing to lessen air stream passing to the filter. Therefore, pressure drop before and after filtration increased. When the dust collector was

operated for a period of time, dust that penetrating between the filter's gaps was sucked out of the gaps by air stream, the neighbouring dust moved in and replaced the previous one. This was contributed to increase the amount of dust after filtered. When conducting the calculation, therefor collection efficiency decreased, while the pressure drop increased.

2. Air stream in duct may be turbulent from rough surface of duct wall. This may contribute to unexpected amount of dust passing though the panel filter, and contribute to calculation of collection efficiency of the collector.

3. Using of bag for dispersion prevention of small dust passing through the panel filter at the outlet may contribute to backward pressure and resulted to gain the lower pressure drop.

Moreover, deviation of collection efficiency of the collector may be due to research methodology:

1. Using of analog pressure gauge may contribute to pressure drop reading by eyes estimation which may from human error of this study.

2. This study allowed the wood dust precipitate naturally without any compressed force in the panel filter. When the collection system worked for a period of time, small wood dust that approached to the panel filter earlier might be sucked out the filter by blower. The quantity of dust after panel filter, therefore, increasing and contributed to decreasing of collection efficiency.

CHAPTER VI
CONCLUSION AND RECOMMENTATION

6.1 Conclusion

1. The collection efficiency decreased in contrary with dust weight loading into the collection system. The collection efficiency decreased obviously at dust weight of 5 kg. This might be the results of small wood dust detaching from coarse wood dust used as in panel filter and the penetration of small wood dust breaking through dust cake filter.

2. The relation of static pressure drop and dust weight loading into the collection system, the static pressure drop increased its maximum value at 8 kg of dust load, then the static pressure drop decreased at 9 kg of dust load. This phenomena supported the results of collection efficiency decreasing.

6.2 Recommendation

Recommendation from the study were;

1. This study used the dust collector using wood dust filter as the media thickness of 10 cm. The further study should use the media thickness of 15 cm to investigate the collection efficiency and the maximum duration for filtration prior to filter replacement.

2. The further study should apply the filtration velocity at 0.05 m/s and 1.0 m/s in order to investigate the maximum collection efficiency and maximum filtration prior to make filter replacement.

3. The bulk density of this study was 150 Kg/m^3. The further study should increase the bulk density to prevent the penetration of panel filter.

4. This study is a preliminary study. Application of this study in actual situation may need additional collection equipment in order to obtain higher collection efficiency and longer period for filter replacement.

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APPENDICES

APPENDIX A
RECORD OF DATA

A1 Record of air velocity due to duct cross-sectional area

NO.	Distance of 8” duct cross-sectional area					
	0.62	2.63	6.25	13.24	16.86	18.87

A2 Record of dust weight, pressure drop, inlet-outlet dust weight

NO.	Face velocity (m/s)	Dust weight (Kg.)			Pressure drop (Pascal)		Inlet				Outlet			
		Weight	Start	Stop	Start	Stop	No.	Filter weight	Total weight	Dust weight	No.	Filter weight	Total weight	Dust weight

APPENDIX B

DATA OF DUCT VELOCITY AND COLLECTION EFFICIENCY

B1 Air velocity due to duct cross-sectional area and average air velocity, 1st measurement

NO.	Distance on 8” duct cross-sectional area						Average velocity (m/s)
	0.62	2.63	6.25	13.24	16.86	18.87	
1	4.7	4.7	4.6	5.1	5.3	5.2	4.9
2	5.1	5.3	5.3	5.2	5.3	5.1	5.2
3	5.1	5.3	5.5	5.6	5.2	5.2	5.3

B2 Air velocity due to duct cross-sectional area and average air velocity, 2nd measurement

NO.	Distance on 8” duct cross-sectional area						Average velocity (m/s)
	0.62	2.63	6.25	13.24	16.86	18.87	
1	4.1	4.6	4.6	5.1	5.1	5.0	4.63
2	4.0	4.6	5.2	5.5	5.2	5.1	4.93
3	4.1	4.6	5.0	5.4	5.1	5.1	4.88

B3 Data of dust weight, pressure drop, inlet-outlet dust weight, and collection efficiency, 1st collection

NO.	Face velocity (m/s)	Dust weight (Kg.)			Pressure drop (Pascal)		Inlet				Outlet				Collection Efficiency (%)
		Weight (Kg)	Start	Stop	Start	Stop	No.	Filter weight	Total weight	Dust weight	No.	Filter weight	Total weight	Dust weight	
1	0.2	1	12.53	13.04	57	63	31	0.5558	1.0133	0.4575	31	0.5198	0.5241	0.0043	99.05
2		2	13.24	13.34	63	67	32	0.5607	1.0464	0.4857	32	0.5569	0.5641	0.0072	98.52
3		3	13.54	14.04	67	80	33	0.5151	0.9839	0.4688	33	0.5530	0.5654	0.0124	97.35
4		4	14.24	14.35	80	107	34	0.5122	0.9272	0.4150	34	0.5478	0.5595	0.0118	97.17
5		5	14.55	15.05	107	148	35	0.5189	0.9711	0.4522	35	0.5464	0.5631	0.0167	96.30
6		6	15.25	15.36	148	170	36	0.5461	0.9764	0.4303	36	0.5400	0.5937	0.0537	87.52
7		7	15.57	16.07	170	212	37	0.5412	0.9432	0.4020	37	0.5174	0.5656	0.0482	88.02
8		8	16.27	16.37	212	172	38	0.5115	0.9052	0.3937	38	0.5430	0.6025	0.0594	84.91
9		9	16.57	17.07	172	163	39	0.5397	0.9235	0.3838	39	0.5205	0.6045	0.0841	78.10

B4 Data of dust weight, pressure drop, inlet-outlet dust weight, and collection efficiency, 2nd collection

NO.	Face velocity (m/s)	Dust weight (Kg.)			Pressure drop (Pascal)		Inlet				Outlet				Collection Efficiency (%)
		Weight (Kg)	Start	Stop	Start	Stop	No.	Filter weight	Total weight	Dust weight	No.	Filter weight	Total weight	Dust weight	
1	0.2	1	12.00	12.10	57	61	21	0.5170	0.8525	0.3355	21	0.5495	0.5508	0.0014	99.60
2		2	12.30	12.40	61	64	22	0.5205	0.8315	0.3110	22	0.5479	0.5496	0.0017	99.46
3		3	13.00	13.11	70	76	23	0.5232	0.8597	0.3364	23	0.5563	0.5609	0.0046	98.62
4		4	13.31	13.41	82	87.5	24	0.5233	0.8439	0.3206	24	0.5460	0.5553	0.0094	97.08
5		5	14.00	14.10	99	130	25	0.5178	0.9240	0.4062	25	0.5517	0.5716	0.0199	95.10
6		6	14.30	14.41	160	185	26	0.5415	0.9519	0.4103	26	0.5134	0.5584	0.0450	89.04
7		7	15.00	15.10	185	203	27	0.5616	0.9519	0.3903	27	0.5625	0.6273	0.0649	83.38
8		8	15.30	15.40	203	217.5	28	0.5664	0.9094	0.3430	28	0.5643	0.6287	0.0645	81.21
9		9	16.00	16.11	168	159	29	0.5665	0.9052	0.3387	29	0.5188	0.5896	0.0708	79.09

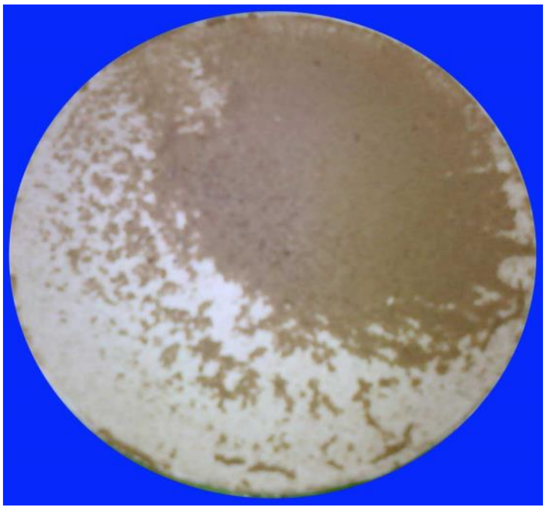
B5 Data of dust weight, pressure drop, inlet-outlet dust weight, and collection efficiency, 3rd collection

NO.	Face velocity (m/s)	Dust weight (Kg.)			Pressure drop (Pascal)		Inlet				Outlet				Collection Efficiency (%)
		Weight (Kg)	Start	Stop	Start	Stop	No.	Filter weight	Total weight	Dust weight	No.	Filter weight	Total weight	Dust weight	
1	0.2	1	11.25	11.35	53	60	31	0.5638	1.0710	0.5072	31	0.5528	0.5556	0.0028	99.45
2		2	11.55	12.06	60	70	32	0.5578	1.0874	0.5296	32	0.5666	0.5689	0.0023	99.56
3		3	12.26	12.36	70	81	33	0.5670	1.0679	0.5009	33	0.5560	0.5606	0.0046	99.09
4		4	12.56	13.06	81	117	34	0.5664	1.1269	0.5605	34	0.5686	0.5772	0.0086	98.47
5		5	13.26	13.36	117	153	35	0.5388	1.0751	0.5363	35	0.5180	0.5349	0.0169	96.84
6		6	13.56	14.06	153	175	36	0.5525	1.0023	0.4498	36	0.5296	0.5549	0.0254	94.36
7		7	14.26	14.37	175	198	37	0.5587	1.0891	0.5304	37	0.5646	0.6368	0.0722	86.40
8		8	14.57	15.07	198	167	38	0.5536	1.0542	0.5007	38	0.5623	0.6698	0.1075	78.53
9		9	15.27	15.37	167	160	39	0.5722	1.0202	0.4480	39	0.5656	0.6644	0.0988	77.95

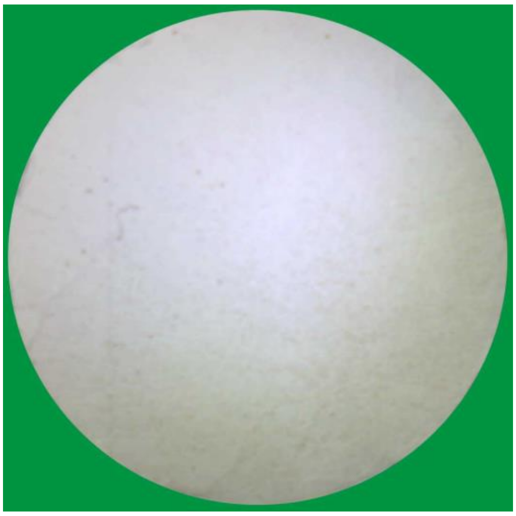
B6 Data of dust weight, pressure drop, inlet-outlet dust weight, and collection efficiency, 4th collection

NO.	Face velocity (m/s)	Dust weight (Kg.)			Pressure drop (Pascal)		Inlet				Outlet				Collection Efficiency (%)
		Weight (Kg)	Start	Stop	Start	Stop	No.	Filter weight	Total weight	Dust weight	No.	Filter weight	Total weight	Dust weight	
1	0.2	1	12.01	12.11	55	60	41	0.5640	1.0793	0.5153	41	0.5496	0.5497	0.0001	99.98
2		2	12.31	12.41	60	65	42	0.5219	1.0100	0.4881	42	0.5487	0.5507	0.0020	99.59
3		3	13.01	13.11	70	80	43	0.5593	0.9764	0.4171	43	0.5580	0.5625	0.0045	98.93
4		4	13.31	13.42	80	90	44	0.5509	0.9384	0.3875	44	0.5490	0.5531	0.0041	98.94
5		5	14.02	14.13	105	124	45	0.5282	0.9029	0.3747	45	0.5327	0.5583	0.0256	93.17
6		6	14.33	14.43	150	168	46	0.5682	0.8913	0.3231	46	0.5732	0.6115	0.0383	88.16
7		7	15.03	15.13	168	182	47	0.5706	0.8328	0.2622	47	0.5588	0.5959	0.0371	85.85
8		8	15.33	15.45	213	191	48	0.5581	0.8396	0.2815	48	0.5595	0.6085	0.0489	82.61
9		9	16.05	16.15	161	153	49	0.5621	0.8858	0.3237	49	0.5605	0.6363	0.0758	76.59

APPENDIX C
QUANTITY OF DUST PRE AND POST SAMPLING FILTER

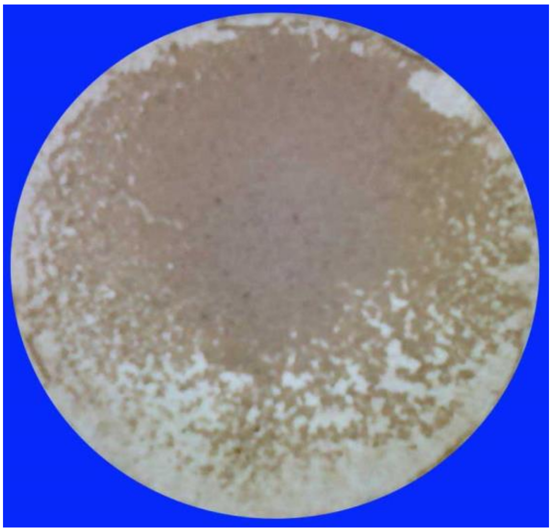


Inlet dust amount

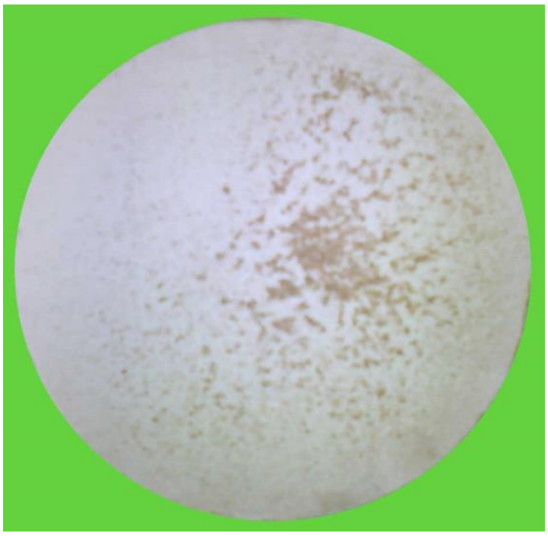


Outlet dust amount

C1 Inlet and outlet dust amount from sample filter (dust weight at 3 kg)

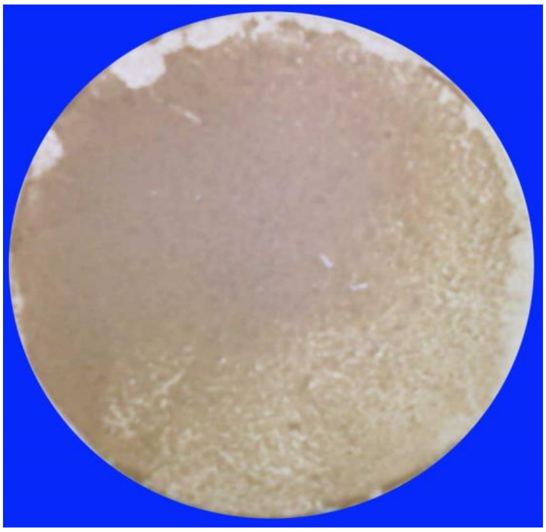


Inlet dust amount

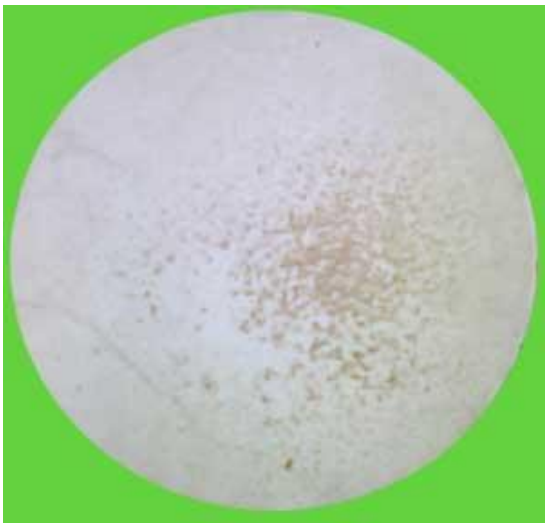


Outlet dust amount

C2 Inlet and outlet dust amount from sample filter (dust weight at 5 kg)

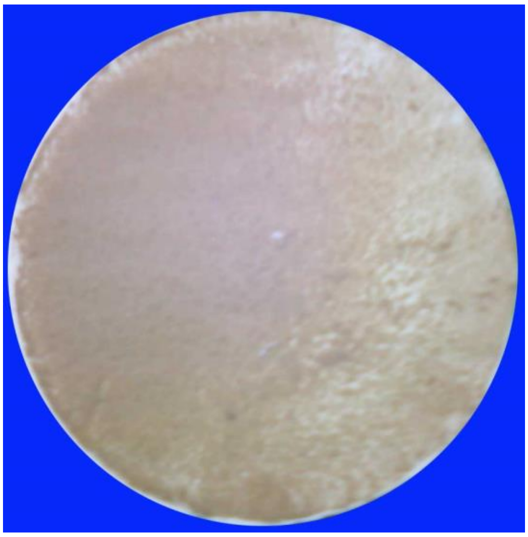


Inlet dust amount



Outlet dust amount

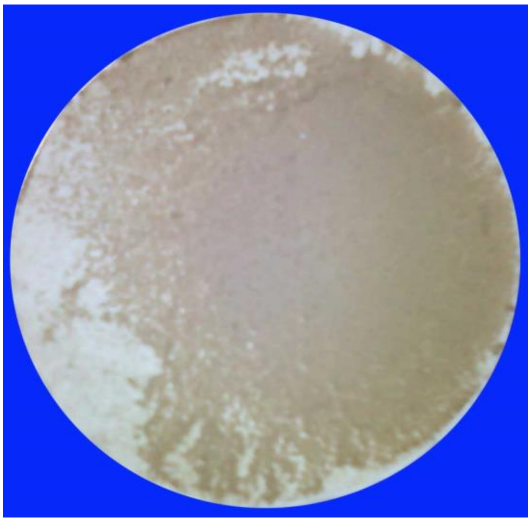
C3 Inlet and outlet dust amount from sample filter (dust weight at 6 kg)



Inlet dust amount

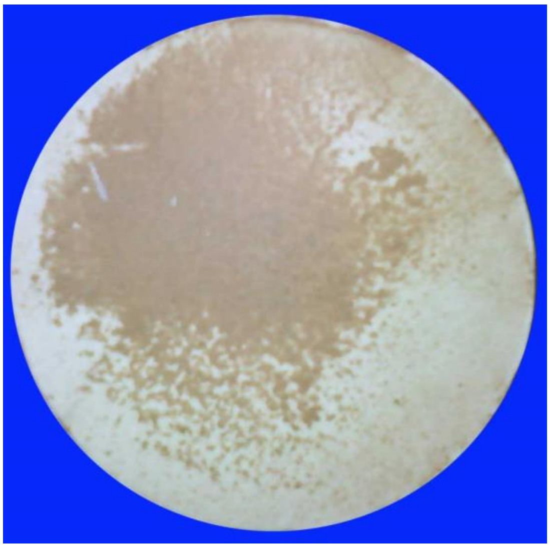
Outlet dust amount

C4 Inlet and outlet dust amount from sample filter (dust weight at 7 kg)



Inlet dust amount Outlet dust amount

C5 Inlet and outlet dust amount from sample filter (dust weight at 8 kg)



Inlet dust amount Outlet dust amount

C6 Inlet and outlet dust amount from sample filter (dust weight at 9 kg)

APPENDIX D
COMPONENTS OF EXPERIMENTAL DUST COLLECTION SYSTEM

D1 Dust collection equipment

D2 Air sampling equipment

D3 Magnehelic pressure gauge

D4 Coarse wood dust

D5 Small wood dust

D6 Measuring air velocity approaching to the filter by probe

D7 Characteristic of wood dust inside panel filter

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