FORMULATION OF A NEW FILTER AIDS MATERIAL FOR FABRIC FILTRATION SYSTEM

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A thesis submitted in fulfillment of the
requirements for the award of the degree of
Master of Philosophy

Malaysia Japan International Institute of Technology
Universiti Teknologi Malaysia

JUNE 2015

"Dedicated to my beloved parents and family for their love, endless support, encouragement and sacrifices"

ACKNOWLEDGEMENT

First and foremost I would like to express my heartfelt appreciation and gratitude to my supervisor, Prof. Dr. Mohd. Rashid Mohd. Yusof for his continuous encouragement, guidance, as well as support which made it possible for me to work on my master and complete my thesis. Without his continued support and interest, this thesis would not have been the same as presented here. I greatly appreciate the importance and positive contributions that he has made to the career that I enjoy so much. He has been an excellent example to me.

I am also indebted to Malaysia-Japan International Institute of Technology (MJIIT), UTM KL for funding my master study as well as providing me with all the necessary facilities. Also, the assistance as well as technical support from Crest Group of Companies and UPM are greatly appreciated. My fellow Air Resources family members should also be recognised for their continuos support. I have enjoyed many useful and entertaining discussions with my fellow friends which made me truly grateful to be a part of this family.

I would also like to express my gratitude towards my beloved parents (Abd Rahim and Ruzaini), family members (Muhammad, Diyana Farah, Burhanuddin, Wan Nurul Azura, Abd Aziz and Siti Sarah) and friends especially Nurziha for their unceasing encouragement and support throughout my study.

My final thank you goes to one and all who directly or indirectly have lent their helping hand in this venture.

ABSTRACT

A fabric filtration system has an advantage of a very high collection efficiency of more than ninety nine percent. However, the problem associated with fabric filter is that it has a short life span due to wear and tear connected with the operating conditions of the system. Treatment of fabric filter using pre-coating material is one of the simplest techniques to overcome this problem. The material works as a filter aids that will coat a layer of inert material onto the surface of the fabric and simultaneously acts as a filter cake barrier allowing a uniform airflow passing through the filter media. Thus, the study is to investigate and evaluate the characteristics and performance of a newly formulated filter aids designated as PrekotAC (a combination of filter aids material, PreKot™ and activated carbon) that will work as two in one material i.e. an adsorbent and a pre-coating material for a fabric filtration system. The PreKot™ and activated carbon were mixed in four different weight combinations of 10:90, 20:80, 30:70 and 40:60. Each material was tested on its physical characteristics, pressure drop, air permeability and particle penetration properties across a polytetrafluoroethylene (PTFE) filter media. It was found that the application of PrekotAC as a filter aids in the filtration system helped to reduce the pressure drop across the filter cake as well as increased the collection efficiency of fine particles compared to the performance of PTFE filter media alone. The results showed that PrekotAC possesses the suitable characteristics as a filter aids and flue gas cleaning agent, with low pressure drop, high air permeability and low particle penetration across the filter media in comparison of using activated carbon alone.

ABSTRAK

Sistem penurasan fabrik mempunyai kelebihan kecekapan pengumpulan yang sangat tinggi sehingga sembilan puluh sembilan peratus. Walau bagaimanapun, masalah yang berkaitan dengan penuras fabrik ialah ianya mempunyai jangka hayat yang singkat disebabkan oleh haus dan lusuh berpunca daripada keadaan sistem beroperasi. Rawatan penuras fabrik menggunakan bahan pra-salutan adalah salah satu daripada teknik yang paling ringkas untuk mengatasi masalah ini. Bahan tersebut berfungsi sebagai bahan bantuan turas yang akan menyalut lapisan bahan lengai ke atas permukaan fabrik dan sekaligus bertindak sebagai kek turas penghalang yang membenarkan aliran udara seragam melepasi media penuras. Oleh itu, kajian ini adalah untuk mengkaji dan menilai ciri-ciri dan prestasi satu bahan bantuan turas berformula baru yang dinamakan sebagai PrekotAC (gabungan antara bahan bantuan turas PreKot™ dan karbon teraktif) yang bertindak sebagai bahan dua dalam satu iaitu bahan penyerap dan pra-salutan untuk sistem penurasan fabrik. PreKot™ dan karbon teraktif telah dicampurkan ke dalam empat kombinasi berat yang berbeza iaitu 10:90, 20:80, 30:70 dan 40:60. Setiap bahan tersebut telah diuji dari segi ciri-ciri fizikal, kejatuhan tekanan, kebolehtelapan udara dan penusukan partikel melalui media penapis politetrafluoroetilena (PTFE). Kajian menunjukkan bahawa penggunaan PrekotAC sebagai bahan bantuan turas ke dalam sistem penurusan membantu untuk mengurangkan susutan tekanan merentasi kek turas serta meningkatkan kecekapan pengumpulan partikel halus berbanding dengan prestasi media penuras PTFE sahaja. Keputusan menunjukkan bahawa PrekotAC mempunyai ciri-ciri yang sesuai sebagai bahan bantuan turas dan agen pembersih gas serombong dengan susutan tekanan yang rendah, kebolehtelapan udara yang tinggi, dan penusukan partikel yang rendah melalui media penuras berbanding dengan hanya menggunakan karbon teraktif.

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d_p	-	Particle size, (μm)
K	-	The permeability of filter media and dust layer (m^2)
PTFE	-	Polytetrafluoroethylene
R_{pp}	-	Ratio of the number of penetrated particles
S_a	-	Weight of petri dish with sample after drying (g)
S_i	-	Initial weight of petri dish with sample (g)
t_c	-	Thickness of the filter cake (m)
t_m	-	Thickness of the filter media (m)
T_f	-	Total number of penetrated particles after filter aids was added
T_i	-	Total number of penetrated particles for ambient air particles
V_c	-	Volume of the cylinder (m^3)
V_f	-	Filtration velocity (m/s)
W_m	-	Weight of the dried material (kg)
W_p	-	Weight of the petri dish (g)
ΔP	-	Pressure drop across the filter media and filter cake ($kg/m.s^2$)
μ	-	Air viscosity, 0.067 kg/m-hr or 1.86 X 10^{-5} kg/m-s at 25°C

CHAPTER 1

INTRODUCTION AND OVERVIEW

1.1 Introduction

Issues involving air pollution like global warming, climates change, and greenhouse gas causes environmental problem has become an international issue of 21st century. Thus, air pollution problem has been continued to be a serious problem and received immense attention for its deleterious effects on human health. Air pollution is referred to the presence of any unwanted constituents of solids, liquids or gases in the ambient air that causes harmful health impact on human. The sources of the air pollution can be divided into two categories, natural and man-made sources (Vesilind *et al.,* 2010). However, the latter which is resulting from industrialization is the main contributor (Nemerow *et al.,* 2009).

For the past decades, the total amount of particulate matter emitted from the industry has been increasing significantly. The existence of the micron and submicron sized particles in air released from industrial processes is known to be harmful either to human health or even to the environment (Dharmanolla and Chase, 2008). Thus, concern about air pollution underlies the effort to develop new air pollution control technology by improving the air purification method in the industry. There are various types of air purification methods to remove the undesired particles in the industry including filtration, vacuum filters, cyclone, and centrifugal industry (Al-Otoom, 2005). However, among the several air purification methods, baghouse or fabric filter stands out as the main approach to gas-particulate separation process to remove fine particulate matter from flue gas streams. Fabric filter is an increasingly popular option for air pollution control system especially for incineration processes when stringent emission is regulated (Rozainee, 2008).

In comparison to other air purification methods, fabric filter has an excellent separation efficiency up to 99.9+ percent. It gives a good separation result not only for coarse particles but also for fine particles, thus it can operate on a very wide variety of dust (Cooper and Alley, 2002). Due to its high collection efficiency, fabric filter has been widely used in the industry to block and remove the undesired particles in the air which are increasingly suspected to cause severe adverse health effects and also harmful to the property. Fabric filter filtration also possesses other advantages including easy to operate since the installation is very simple and relatively inexpensive (Tanabe *et al.*, 2011).

Despite all the advantages mentioned, there are also drawbacks of fabric filter system. For an example, fabric filter can only operate at low temperature as it may be harmed by high temperature. In addition, fabric filter has to operate with low filtration velocity that requires a large space area (Silva *et al.*, 1999). Also the main concern on the application of fabric filter is its short life span due to wear and tear problem during operation. The life span of the fabric filter is closely related to pressure drop across the fabric filter. As the filtration process proceeds, the accumulated dust cake grows in thickness thus increases the differential pressure drop across the fabric filter. Thus, a constant cleaning of the dust cake on the fabric filter is required in order to maintain low differential pressure drop across the fabric filter and avoid throttling of the fan (Morris and Allen, 1996). Generally, the number of cleaning cycle frequency affects the life span and consequently increased the operating costs of the fabric filter. It has been reported that by reducing the number of cleaning cycles will result in low operation costs and increase the life span of the fabric filter (Ariman and Helfritch, 1981). Thus, filtration system performance with high dust collection efficiency along with a low pressure drop is demanded in many industries.

With these points in mind, one of the simple approaches that has been used by the industry is to apply filter aids also called as pre-coating material onto the surface of fabric filter. Although fabric filter minimizes the penetration of particulate matter through the fabric filter, fine particles of less than 0.5 µm can easily leak through a new fabric filter. Pre-coating material provides a layer of inert material onto the surface of fabric filter that serves as an additional barrier for protection that prevents particles from passing through it. Besides, pre-coating material allows a uniform air flow passing through the fabric filter, improving filtering performance while extending the life span of the fabric filter (Ravert, 2006).

1.2 Problem statements

Fabric filter is frequently used as an air pollution control system because it is relatively inexpensive, easy to operate and highly efficient in collecting particles compared to other air purification methods. With its excellent filtration efficiency up to 99.9+ percent, many of the systems are being applied to control dust and gaseous emission in incineration plant. However despite of its high collection efficiency, the disadvantages of using fabric filter are short life span due to wear and tear problem as well as the emission of sub-micron pollutants.

Life span of a fabric filter is highly influenced by the cleaning process as the permissible pressure drop across the filter cake is reached. As the permissible pressure drop across the filter cake is reached, a regular cleaning process using pulse jet air is necessary in order to remove the accumulated filter cake as well as to keep the pressure drop at a certain level. Frequent cleaning process thus reduce the life span of the fabric filter. A simple technique to overcome this problem is by applying a pre-coating material known as filter aids on the surface of the fabric filter. Pre-coating material will allows a uniform airflow passing through the fabric filter as well as prevents against blinding and clogging. As a result, pre-coating material helps to reduce the number of cleaning cycle resulting in longer life span of the fabric filter and reducing the maintenance costs.

Another disadvantages of using fabric filter is the emission of sub-micron pollutants during filtration process. In incineration plant, combustion during incineration process is not always perfect. There are some concern on sub-micron pollutants emission due to chemical transformation during the incineration process. Thus, by applying an adsorbent also known as filter aids material helps to control the sub-micron pollutants emission as well as increase the collection efficiencies of fine particles.

Hence, in this study, the characteristics and performance of a newly formulated filter aids material, designated as PrekotAC was investigated. PrekotAC is a combination of readily available pre-coating material in the market known as PreKot™ and an adsorbent material, activated carbon. This newly formulated filter aids material, PrekotAC will serve as a two in one filter aids material (adsorbent and pre-coating material) that helps to overcome the wear and tear problem as well as control the emission of sub-micron pollutants during filtration process. It was expected that by applying PrekotAC during filtration process will reduce the number of fine particles that able to pass through the fabric filter. Besides, PrekotAC also helps to reduce the maintenance costs by reducing the pressure drop across the filter cake and expanding the life span of the fabric filter.

1.3 Objectives of the study

The main objective of this study is to formulate a new filter aids material that will be utilized as both pre-coating and adsorbent in fabric filtration system. The specific objectives of the study are:

i. to study the characteristics of the newly formulated filter aids material in term of its moisture content, bulk density, particle size distribution and morphology of the material.

ii. to study the performance of the formulated filter aids cake in terms of its pressure drop and permeability across the filter membrane.

iii. to study the performance of the formulated filter aids, in terms of its total particle count penetrating through a filter media.

Each of the study objectives is addressed accordingly in a separate chapter (4, 5 and 6) of this thesis. Chapters 4, 5 and 6 were organized as an independent journal papers which are suitable for submission for publications. In fact, part of chapter 4 and 5 have been presented in *International Conference on Separation Technology*, *MJIIT-JUC Joint International symposium* and *3rd International Science Postgraduate Conference 2015* as well as published in *Jurnal Teknologi* and *Powder Technology*, while others are still waiting to be submitted to relevant journals.

1.4 Scopes of the study

The scopes of study involved in this study are divided into three different stages; i) material preparation, ii) material characterization and iii) experimental work. PrekotAC was prepared in four different weight ratios of 10:90, 20:80, 30:70 and 40:60 of PreKot™ and activated carbon. Initially before mixing, the material was dried in an oven at 105ºC for about 24 hours to discard any moisture contained in the material.

Then, each the formulated material was characterized further in terms of its particle size distribution, morphology, bulk density and moisture content. The morphology of the formulated sample was observed using a Scanning Electron Microscopy (SEM) while the particle size distribution of the materials was carried out using a sieving method. The moisture content and bulk density of the sample were determined following a standard reference method found in literature. The characteristics of each formulated PrekotAC was then compared to the raw materials in order to preliminary find the most suitable combination of PreKot™ and activated carbon to be formulated as filter aids in fabric filtration system.

A special laboratory scale filtration test system was fabricated to study the performance of the sample that consists of a dust feeder, fabric filter holder, pressure transducer, particulate counter, rotameter as well as vacuum pump. The formulated material was tested under various volumetric air flow rates of 4, 5, and 6 L/min (or filtration velocity, V_f of 5, 6 and 8 m/min respectively) with different material loading of 0.2, 0.4 and 0.6 mg/mm^2. The performance of the newly formulated PrekotAC was determined based on its pressure drop, permeability and particle penetration properties across the filter media in comparison to its raw materials. Hence, the best combination of the newly formulated filter aids was determined based on the findings of the study.

1.5 Significance of the study

This study introduces a newly formulated filter aids material based on PreKot™ and activated carbon designated as PrekotAC to be utilized as both pre-coating and adsorbent for a flue gas cleaning in fabric filtration system. It has a positive potential for commercialization due to its new added values in Malaysian industry in controlling dust and volatile organic compound as well as metal in air pollution control system. Hence, this study helps to understand the characteristics and performances of the newly formulated filter aids, which is not readily available in literatures.

1.6 Overview of the thesis

The thesis had been written on seven chapters and the content of each of the chapter is briefly presented below.

Chapter 1 presents an overview of this thesis to readers that includes an information on the background and the basis of the study. This chapter also states the objectives, scopes and significances of the study in formulating a new filter aids material consisting of pre-coating and flue gas cleaning adsorbent.

Chapter 2 presents the background of the study and briefly describes about the type of filter aids that has been used in industry. Besides, parameters that could influenced the performance of a good filter aids during air filtration processes are also presented in this chapter.

Chapter 3 presents the methodology of the whole study that is involving formulation, characterization and performance of the newly formulated filter aids material. The descriptions and procedures of the experiment performed in the study are presented in this chapter.

Chapter 4 presents the characteristics of the newly formulated filter aids material in term of its morphology, particle size distribution, bulk density as well as moisture content. Then the characteristics of the newly formulated filter aids were compared to the raw materials in order to preliminary identify the best combination of PreKot™ and activated carbon to be applied as filter aids in fabric filtration system.

Chapter 5 presents the performance of the newly formulated filter aids cake in terms of its pressure drop and permeability across the filter media. The effect of material characteristics on pressure drop across the filter media were discussed in this chapter. Besides that, the material was tested under various air flow rate of 4, 5, and 6 L/min (or filtration velocity, V_f of 5, 6 and 8 m/min respectively) and material loading of 0.2, 0.4 and 0.6 mg/mm^2 in order to study the effect of operating conditions on pressure drop across the filter media. The comparison between the performance of the newly formulated filter aids material and the raw material are presented in this chapter.

Chapter 6 presents the performance of the newly formulated filter aids, in terms of its total particle count penetrating through a filter media. It was tested under various air flow rates as well as material loadings and the relation between the material characteristics and operating conditions on the performance of the material are discussed in this chapter. The results are further discussed in this chapter in order to determine the best combination ratio of PreKot™ and activated carbon that can be applied as filter aids in fabric filtration system.

Chapter 7 is the concluding chapter of this study. This chapter gives overall conclusion of the study on which combination of PreKot™ and activated carbon was found to be ideal and suitable to be applied as filter aids material in fabric filtration system. Besides, the recommendation for possible work in the future are also presented in this chapter.

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