Hot Gas Filtration System for High-Temperature Dust Emission Control in Palm Oil Mill Industry

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ABSTRACT

This paper provides brief information on the latest dust emission control based on hot gas filtration system for high temperature flue gas environment such as in the palm oil mill industry. The hot gas filter element is able to withstand temperature up to 1000°C and has high dust removal efficiency of 99.9% even for 1.0 micron particulate size fraction. The suitability and advantages of the hot gas filtration for dust emission control in palm oil milling is presented and discussed in this paper.

INTRODUCTION

Biomass fuel utilisation for steam and electrical energy generation is a common practice in countries abundant with waste material. The palm oil mill industry is a typical case in the local context. The waste by-products in the form of fiber and shell are reutilised in the mill boiler to generate steam and electricity which are consumed within the plant.

The motivation in utilising waste by-products such as in the palm oil mill industry has two main benefits in terms of sustainability and environmental aspects. Unlike fossil fuels, biomass grows and is a renewable resource where continuous replanting and harvesting cycles remained for many years. Thus, biomass is not a finite or depleting energy source compared to fossil fuels.

In addition, biomass energy is considered carbon-neutral energy. Trees in plantations absorb carbon dioxide (CO_2) and release oxygen (O_2) instead, acting as one of the largest CO_2 sink just within the mill perimeter. The cycle of CO_2 release and uptake is a positive contribution towards avoiding global climatic change.

PARTICULATE EMISSION FROM PALM OIL MILL INDUSTRY

Generally, dust emission is the main concern for any given solid fuel such as biomass combustion. The degree of emission depends on how well the combustion process is taking place in the boiler or furnace and most importantly, the type of dust emission control system installed. The dust emission standard for palm oil mill has been enforced for many years since 1978. However, a new regulation known as Clean Air Regulation 2014 as CAR2014 was introduced after 36 years in which the dust emission standard was revised from 400 to 150 mg Nm^{-3} at 12% CO_2. The Increase of 60% dust emission removal requirement from the previous limit is a challenge to the millers.

The new emission standards promulgation means that a new and more efficient dust emission control technology must be sought without delay. Nevertheless, mill owners have been given five years of grace period to study and investigate what would be the best available air pollution system that could meet the new regulation.

There are approximately 457 mills spread over the country (Parveez *et al., 2021*). Based on 150 mg Nm^{-3} and an average of 20 Nm^3 sec^{-1} flue generated gas per mill, the total particulate emission loading in terms of fly ash released from this industry alone is estimated to be 118 tonnes per day or 43 230 tonnes per year. The dust emission limit from biomass boiler fuel-burning equipment is considered to be the most lenient standard regulated in the CAR2014 compared to any other activities.

The mill biomass boiler particulate released to the atmosphere are substantial, especially for sub-micron fine particulate matter with less than 10 microns in size. This fine particulate size fraction is not easily removed by dust separator that applies centrifugal or even electrical forces such as electrostatic precipitator.

Rashid *et al*., (2013) evaluated the particulate emission from a palm oil mill boiler equipped with a multi-cyclones particulate arrestor. It was reported that the particulate emission rates varied from 8.51 to 126 g s^{-1} with an average of 44.3 ± 31.6 g s^{-1} or with concentration ranging from 1.50 to 17.7 g Nm^{-3} with an average of 7.75 ± 4.71 g Nm^{-3} (corrected to 7% O_2). The authors concluded that the collection efficiency for any given dust arrestor must be between 73% and 98% in order to comply with the emission limits of 0.40 g Nm^{-3}. However, an extremely high collection efficiency will be required for the existing limits of 0.15 g Nm^{-3}.

Syahirah *et al*., (2014) reported that fine PM2.5 (particulate less than 2.5 aerodynamic diameters) and PM10 particulate matter sampled from a palm oil mill boiler was 0.140 ± 0.070 and 0.780 ± 290 g Nm^{-3} (corrected to 7% O_2), respectively. On average, PM2.5 constituted 18% of the PM10 particulate concentration emitted from the mill boiler. The authors observed that the coefficient of variation (CV) for PM2.5 size fraction (CV=50%) was much more than PM10 (CV=37%), illustrating the wide range variation of fine size particulate generated in the combustion process. The study showed that there was a considerable amount of sub-micron particulate matter that needs to be addressed before a new dust arrestor is proposed to bw installed in the mill.

Syahirah *et al*., (2015) investigated the mass size distribution of particulate matter sampled after multi-cyclone dust arrestors from several palm oil mills with different boiler capacities. The particulate emission sampling was performed at the stack according to US EPA Method 17 while the particulate size distribution was determined by using a particle size analyzer. Results showed that the mass concentration of total particulate varied between 0.42 and 3.77 g Nm^{-3} (corrected at 7% O_2). The emitted particulate was mainly found in the coarse particles, with 50% cumulative under-size distribution ranging from 21 to 38 µm. The PM2.5 and PM10 particulate mass concentration in total particulate emission varied from 0.03 to 0.30 g Nm^{-3} and 0.37 to 0.73 g Nm^{-3} (corrected to 7% O_2), respectively. The particulate size fraction contributed to 0.8% to 71% and 13% to 95% of the total particulate mass concentration collected, respectively.

Jamian *et al*., (2019) who studied the particulate emission concentration from five different palm oil mill boilers each equipped with a multi-cyclone found that the average particulate emission was 2.20 ± 0.90 g Nm^{-3}, exceeding the CAR2014 limits. The authors stated that the additional emission control efficiency requirement was between 64% and 96%, which is not easily achieved by any ordinary emission control system. The study estimated that 26% of the ash content in both palm fiber and shell combusted in the mill boiler were released to the stack.

The above literatures and many others illustrated that there is a dire need to consider and investigate the most appropriate dust emission control system for the palm oil mill. As depicted in *Figure 1*, a high particulate emission control technology of more than 98% efficiency as compared to the previous 400 mg Nm^{-3} is warranted to meet the requirement of the new 150 mg Nm^{-3} requirement stipulated seeking a better CAR2104. Nevertheless, continuous improvement in particulate emission control is important as the need to safeguard and maintain the nation's air quality is critical.

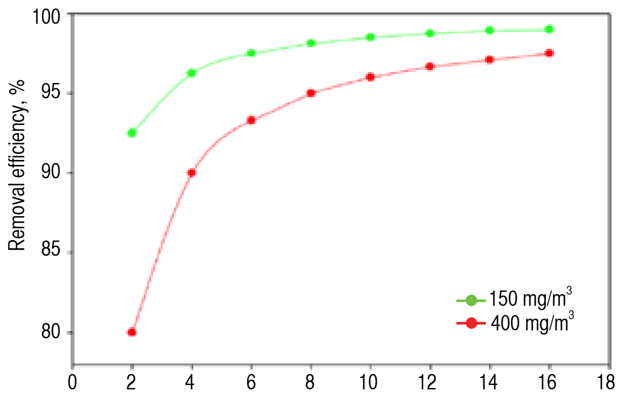

Figure 1. Removal efficiency vs particulate loading from a palm oil mill boiler.

PARTICULATE EMISSION CONTROL IN PALM OIL MILL: WHY IT IS NOT EASILY ACHIEVABLE?

Yahya *et al*., (2018) presented a comprehensive review of the available technology advancement for particulate emission control reduction in the palm oil mill industry. The authors discussed the pro-and-con of cyclonic and electrical-based Electrostatic Precipitator (ESP) along with other technologies such as wet-scrubber systems.

First and foremost, there is always an option of handling any emission problems, subjected to the fundamental understanding of the basic characteristics of the process or the nature of how the pollutant is being generated in the boiler. The fuel moisture content, fiber-shell ratio, boiler and operating conditions, variations in feeding rates or loadings, fuel-to-air ratio, variation in steam demands *etc.*, all play their roles in generating fly ash of various size distribution and loading exiting the boiler, which is not uniform or constant in most cases.

Acknowledging these uncertainties at the early stage of combustion, is important where the choice of selecting the most appropriate particulate emission control system should be able to handle these variations. In addition, the basic pollutant characteristics such as composition, size distribution, particulate loading, density, abrasiveness, combustibility, electrical properties such as particle resistivity *etc.*, should also be known as these are also critical factors in selecting the most appropriate emission control system.

Figure 2 presents the size distribution of palm oil mill boiler fly ash collected by multi-cyclone downstream boiler at different mills (A to E). The size distribution of particulate emitted from these boilers was widespread. The finding illustrated that the dust arrestor performance was inconsistent due to the variations in the dust emission loading and size distribution generated in the combustion process. It is noteworthy that it is complex to deal with combustion-generated particulate emission and such uncertainties must be understood by the designer before the most appropriate emission control system is selected.

THE DUST EMISSION CONTROL OPTION: HOT GAS FILTRATION SYSTEM

The fractional separation efficiency shown in *Figure 3* concluded that filtration technique to be the most efficient dust emission control system compared to other emission control systems available in the market. The filtration system has been installed in many industrial applications such as coal-fired power plants, incineration, cement, biomass boiler, metallurgy, waste to energy plant *etc*, where emission performance must be strictly abided at all times.

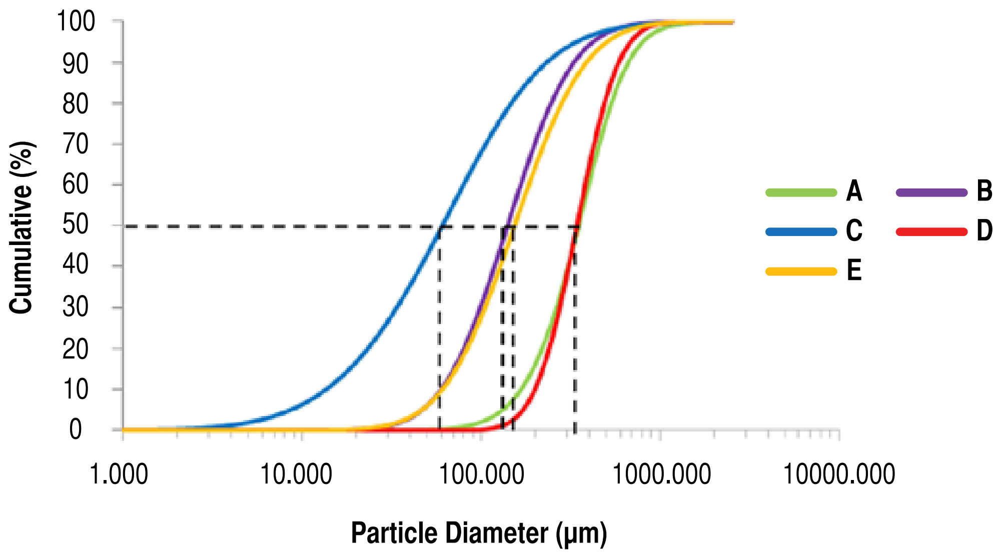

Figure 2. Size distribution of palm oil mill boiler fly ash collected in multi-cyclone from various mills (A-E)

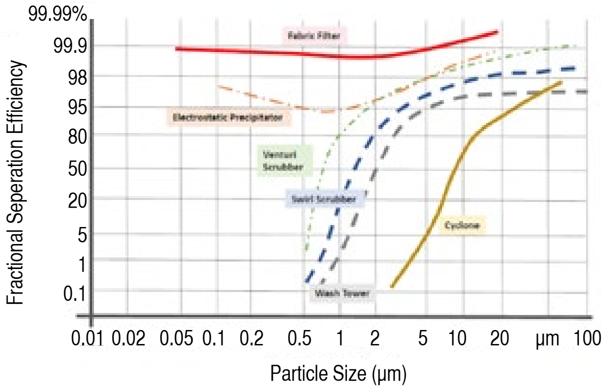

Figure 3. Fractional separation efficiency of various types flue gas cleaning system.

The ideal particulate emission control for biomass fired boiler dealing with carbon particles emission will have to fulfill the following criteria;

- High Removal Efficiency with continuous emission guaranteed to be less than 150 mg Nm^{-3} or for any future emission limits,
- Robust and independent of flue gas temperature, boiler operation, boiler types and conditions, feeding rate and loading variations,
- high strength, no fire or spark-proof,
- Low maintenance with continuous operation and performance.

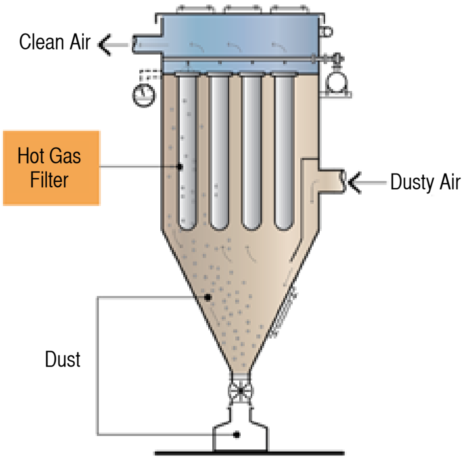

Figure 4. Hot gas filtration system schematic diagram.

There is a new emerging particulate control technology for high-temperature dust emission control such as in the mill industry based on a filtration system that has a very high collection efficiency (above 99.9% even for 1.0 microns particulate size fraction). The hot gas filtration system is rigid, able to withstand high temperatures up to 1000°C, and is lighter than the ceramic-type filter candle. The basic schematic diagram of the Hot Gas Filter system is as shown in *Figure 4*, while *Figure 5* shows the Hot Gas Filter candle installation.

The advantages of the Hot Gas Filtration system are;

- Typical collection efficiency >99.9+%.
- Physical remove adust particles through porous filtration media.
- Not influenced by particle size distribution.
- Not influenced by fly ash physical and chemical characteristics.
- Not influence by the resistivity of the fly ash particle as in the case of ESP.
- Removal efficiency increases with dust loading where thicker dust cake layer provides additional barrier for better collection.
- Could withstand temperature up to 1000°C.
- Performance is not influenced by variation in flue gas temperature.
- Removal efficiency remained the same with variation in flue gas properties and volumetric flow rates.
- Dust removal efficiency remained the same regardless of variation in the boiler operation.
- Easy to install and maintains- plug and play concept.
- Ready to accommodate future emission standards without having to make any changes to the existing unit. The existing unit is able to meet the EU limits of 30 mg m^{-3}.
- Able to remove other pollutants such as heavy metals, VOCs, acid mists, and gasses with an injection of adsorbents.

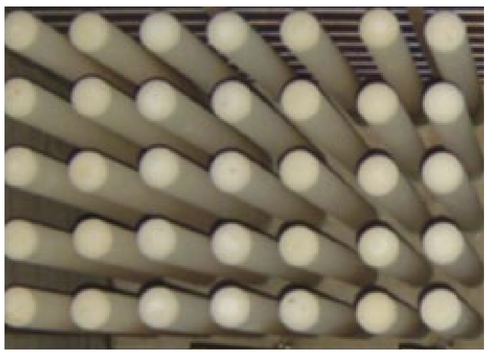

Figure 5. Hot gas installation.

The performance of Hot Gas Filter has been tested on palm oil mill boiler fly ash in a pilot-scale filtration unit in collaboration with Air Resources Research Laboratory, Malaysia Japan International Institute of Technology, and the Sunway University (*Figure 6*). The study showed that the concentration of PM10 and lower (including PM2.5 and PM1.0 micron) fine particulate mass size fraction was less than 1.0 mg m^{-3} as depicted in *Figure 7.* The performance of Hot Gas Filtration increased with fly ash loading even at higher filtration velocity than normal case. The dust cake layer forms a barrier to further enhance the system removal efficiency.

Other Hot Gas Filters applications (but not limited to):

- Clinical waste
- Aluminum Scrap Melting
- Chicken waste incinerator
- Pharmaceutical waste
- Wood waste incineration
- Waste to energy
- Animal waste incineration
- Tree bark burning
- Alloy furnaces
- Zirconium oxide recovery
- Soil remediation thermal treatment
- Biomass gasification
- Chemical waste boiler
- Tyre incineration
- General waste incineration
- Metal furnaces

Figure 6. Pilot plant of hot gas filtration system.

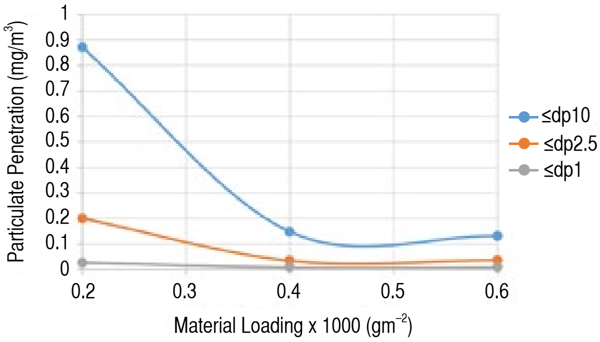

Figure 7. Particulate mass penetration vs dust loading on palm oil boiler fly ash.

THE HOT GAS FILTER ELEMENT AVAILABILITY

Table 1 presents the Hot Gas Filter elements in different sizes (diameter and length) depending on specific clients' requirements. The various range provides flexibility to suit the process needs and space availability for the system installation. In addition, this will also provide a smaller footprint for the system installation in limited space.

TABLE 1. DIMENSION AVAILABILITY OF THE HOT GAS FILTER

DIMENSION	CS1150F			CS1255F		
External Diameter (mm)	60	60	60	150	150	150
Internal Diameter (mm)	40	40	40	110	110	110
Length (mm)	1000	1250	1500	1800	2400	3000
Flange Diameter (mm)	80	80	80	190	190	190
Surface Area (m^2)	0.19	0.23	0.28	0.83	1.11	1.40

Note: The AMR Hot Gas Filter is supplied by AMR Environmental Sdn Bhd.

The Hot Gas Filtration system can be easily installed at the mill downstream of the boiler either with or without multi-cyclone as shown in *Figure 8* where a simple installation can quickly be arranged at any existing site.

The Hot Gas Filtration system had been installed on a 40TPD local municipal solid waste incineration plant as shown in *Figure 9*, where a small system footprint was established at the site. A small number of Hot Gas Filter elements were installed in Brunei on a medical waste incineration plant while another installation (250 kg hr^{-1} medical waste incineration plant) will soon be made in the southern part of the country.

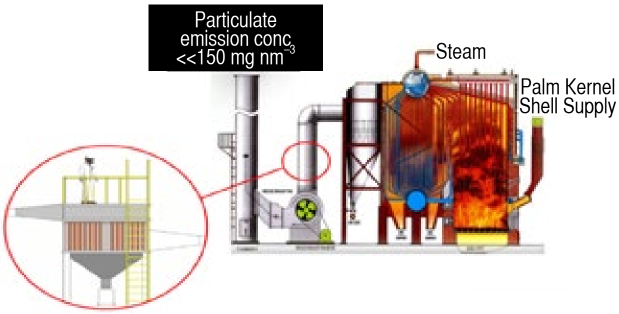

Figure 8. Proposed hot gas filtration installation in a palm oil mill.

Figure 9. Hot gas filtration on 40TPD municipal solid waste incineration plant.

CONCLUSION

Selecting appropriate air pollution control system for specific application requires thorough understanding of process and the mechanism leading to pollution generation. In addition, detailed knowledge of the quantities and emission character is a prerequisite. With this background information, one would be able to specify the most appropriate pollution control system that meets the imposed emission regulations. Similarly, in the palm oil mill industry, the most appropriate dust emission control method should be thoroughly studied and investigated before selection.

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