1. INTRODUCTION

1.1 General Background

Thailand is the world biggest ribbed smoked sheets (RSS) producer. Rubber smoking is an important industry, especially in Southern Thailand. In rubber smoking process, the rubber sheets are washed in a pool and hung on bamboo bars for drip drying before entering the smoking rooms where rubberwood was burned to produce hot gas as a heat supply to remove moisture from the rubber sheets. The smoking time is generally 5-9 days depending on the moisture and thickness of the sheets and weather (Prasertsan, 1994).

In rubber smoking process, rubberwood is used as a heat supply to remove moisture from the rubber sheets. When wood is burned, its waste products are carbon, ash residue, water vapor and soot particles. Soot particles are the result from incomplete combustion of carbonaceous materials (Ndiema et al., 1998). Presence of soot particles in rubber smoking room from wood combustion affect quality of the rubber sheets. Excessive deposition of the particles on the sheet surface results in the darker color than market requirement. This, then devalue the price of the rubber sheets (Wachara et al., 2003). Besides, soot particles affect workplace environment in the smoking factory and can cause health problem to the workers. In order to reduce these problems, reduction method for soot particles is essential.

1.2 Literature Review

1.2.1 Size distribution of soot particles

In order to select an appropriate method or device for collection of soot particles from wood combustion, size distribution of soot particles is essential to be studied first. The size distribution of soot particles has been investigated by many researchers.

Venkataraman et al. (2002) investigated size distribution of polycyclic aromatic hydrocarbons (PAHs) from biofuel combustion i.e. wood (Acacia nilotica, local names keekar or babul in India), briquette and dung cake in cooking stoves. Their results indicated that the PAH size distribution from all stove–fuel systems was unimodal with mass median aerodynamic diameters (MMADs) in submicron range 0.40–1.01 micrometer.

Wachara et al. (2003) studied the soot particles produced from rubberwood combustion in rubber smoking process. It was found that the size distribution of soot particles in the smoking room ranges from less than 0.43 micrometer to 4.7 micrometer. The mass median aerodynamics diameter (MMAD) was found to be 0.95 micrometer. Particle concentration depends strongly on moisture content of the rubberwood.

1.2.2 Particulate Control

There are many methods and devices for aerosol collection to prevent or reduce emission of aerosol particles escaping to the air or atmosphere such as filtration method by filters, gravitational settling, centrifuged cyclones, scrubbers, etc. However, these methods are not effectively for capturing small particles, especially fine particles between submicron and micron size ranges (0.01 to 10 micrometer particle sizes). Filtration induces more pressure drop when filters are contaminated with particulates as a long operation times. Gravitational settling can capture only large particles (greater than 10 micrometer) and needs large space for installation. Cyclones and scrubbers give low collection efficiency for particles below 5-10 micrometer in diameter. One possibility method to reduce aerosol particles is by the use of electrostatic precipitators or ESPs which are widely used since they are effective to remove the small particles or particulate matter in the atmosphere including aerosol, dust, fume or smoke. ESPs are particulate collection devices that use electrostatic force to remove the particles in a wide range of submicron particle size. It is difficult to use other devices such as filters, cyclones or scrubbers effectively for collecting these small particles. Particles as small as one-tenth of a micrometer can be removed with almost 100% efficiency using electrostatic precipitators. Nowadays, ESPs are one of the more frequently used in larger facilities such as power plants or incinerators. In many industrial applications, its collection efficiency can go as high as 99%. The ESP is unique among air pollution control devices in that the forces of collection act only on the particles and not on the entire air stream. This phenomenon typically results in a high collection efficiency with a very low air pressure drop when compared with other devices. Furthermore, ESPs have other advantages such as there is no limit to solid or liquid particles, or corrosive chemical usage and particles as small as 0.1 micrometer can be removed. However, they have some disadvantages when using the ESPs such as the formation of ozone by the negatively charged electrodes during gas ionization or possible explosion hazards during collection of combustible gases or particulate. Precautions are therefore necessary to maintain safety during operation.

Zukeran et al. (1997) tested performance of a wire-plate type air cleaning electrostatic precipitator (three corona wire sections) under air flow with incense smoke (particle diameter $d_p < 0.1$ micrometer). Their experiments were conducted for the air flow rate from 10 to 100 L/min, and the applied voltage from 9 to 30 kV with a single to three corona wire sections. Ultrafine particle density was controlled by the number of incense burning and the gas flow. The collection efficiency was evaluated in term of weight per volume (mg/m^3) and number of particles ($\#/cm^3$) as a function of applied voltage. From their results, the collection efficiency based on the weight was 99.999%, however, the collection efficiency based on the number of particles was below 30% as expected from the Chang's ESP model (1979), since a majority of the ultrafine particles still escaped from the electrostatic precipitator due to the insufficient charging of nanometer particles.

Kim et al. (1999) designed and built a laboratory-scale single-stage electrostatic precipitator and tested it in a wind tunnel. A series of experiments were conducted to seek the operating conditions for increasing the particle collection efficiency. The basic operating parameters including the wire-to-plate spacing, the wire radius, the air velocity, the turbulence intensity and the applied voltage were investigated. Results showed that, as the diameter of the discharging wires and the wire-to-plate spacing were decreased, the higher collection efficiency has been obtained.

Jedrusik et al. (2001) investigated the movement of fly ash particles in the electrostatic precipitator with different corona electrodes: barbed plate, barbed tube, wire and spiked band. The experiments were performed with the use of one type of fly ash with different diameters, for given supply voltages and a constant inlet gas velocity. The collection of solid particles in the electrostatic precipitator can be determined by the migration velocity (w) since it is proportional to the collection efficiency. Results showed that the supply voltage had a significant effect on the migration velocity of solid particles over the range of the particle diameters of fly ash tested because migration velocity was directly proportional to the supply voltage. The performance efficiency of the electrostatic precipitator was strongly dependent on the geometry of electrodes. The barbed plate and wire electrode geometry had a highest value of the migration velocity for the diameters from 63 to 160 micrometer. For the spiked band geometry, the migration velocity depended only slightly on the diameter.

Laskin et al. (2002) studied the deposition efficiency of monodisperse latex sphere particles of a point-to-plate electrostatic precipitator onto a large conductive (vitreous carbon) substrate. The precipitator, designed as “Rochester design”, consisted of a needle electrode (point) and a flat collection surface (plate). The collection efficiency was evaluated into two types i.e. gross and net deposition efficiency. The gross deposition efficiency was measured in traditional way by the loss of particles from the exiting air and calculated from $E_{gross} = 1 - C_{inlet}/C_{exit}$ while the net deposition efficiency was calculated by counting the collected particles using automated particle counting software on an electron microscope and defined by $E_{net} = N_{found}/N_{total}$. Results indicated that it was easy to achieve 85–90% gross collection efficiencies for 0.1–2.0 micrometer aerosols. However, the net deposition efficiency was never more than 50% and sometime as low as a few percent only because the measurement and calculation methods were difference.

Jedrusik et al. (2003) investigated the influence of the physicochemical properties (chemical composition, particle size distribution and resistivity) of the fly ash on the collection efficiency of a single-stage electrostatic precipitator. The fly ash was produced by a pulverized-fuel boiler fired with bituminous coal (fly ash A) and a lignite-fired fluidized-bed boiler (fly ash B). Three electrodes, i.e. a spiked band electrode, a 95-mm-distance pipe and double-spike electrode and a 180-mm-distance pipe and double-spike electrode were tested. The experiments were carried out under laboratory conditions with a single-stage electrostatic precipitator test facility. The chamber of the experimental setup was made of Plexiglass, with a length of 2 m, a height of 0.45 m and an inter-electrode spacing of 0.45 m. From the results, the highest collection efficiency was obtained with the pipe and double-spike electrode in both fly ash A and B. With the same design of the discharging electrode, the efficiency of the electrostatic precipitator was influenced by physicochemical and electrical properties of fly ash. Fly ash B was removed easily than fly ash A because the more presence of sulphur compounds (SO_3) and sodium compounds (Na_2O) in the fly ash B reduced the resistivity and raised the sorbing activity between fly ash particles.

Kocik et al. (2005) measured the size distribution of seed particles after their precipitation in a wire-plate-type ESP with seven wire electrodes. The cigarette smoke was used as a source of seed particles. Their results showed that almost 90% of all particles of the cigarette smoke were smaller than 1 micrometer and the negative polarity voltage applied to the ESP was more effective in precipitation of submicron particles, especially when low-voltage (16 kV) discharge was applied.

1.3 Scopes and Research objectives

Initially, an appropriate electrostatic precipitator (ESP) will be designed and built for collecting the soot particles from wood combustion. Its collection performance will then be investigated in laboratory by varying various operation parameters to obtain the optimum collection efficiency for collection of soot particles. Finally, the performance at working condition of the wood combustion furnace will then be investigated. The objectives for this work are:

1. To design and build an electrostatic precipitator device that is suitable for collection of soot particles in rubber smoking room.

2. To investigate the collection performance of the designed ESP for particle sizes between 0.3 and 1.0 micrometer which are the particle sizes of soot particles from wood combustion.

3. To investigate basic operation parameters effect on the collection efficiency such as air velocity, particle size and the applied voltage.

4. To study collection efficiency at working condition and investigate dust-loading effect on the collection efficiency of the designed ESP.