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Studies, Modification and Application of Electrostatic Precipitators - A Review

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ABSTRACT

Air polllution is a serious problem caused by the growing industrilization. It becomes major problem if exhaust gases contain excess amounts of sulphur dioxide, nitrogen oxides and particulate matter. Removal of particulate matter can be carried out by various methods such as fabric filters, cyclone seperatiors, electrostatic precipitators (ESP). Particulate matter is a major concern in boiler units and power generation sector. It is important to use effective and economical treatment method for the particulate matter removal. Many investigators have carried out studies on modification, design and operation of ESPs. The present review summerizes research and studies carried out on ESPs. This review gives insight into application, advancements and modification of ESPs for better and efficient treatment of waste gases.
Keywords: Particulate Matter, Collection Efficiency, Voltage, Frequency.

I. INTRODUCTION

Air pollution and water pollution are the undesirable side effects of industrilization. The water pollutants like organic matter, heavy metals, pathogens etc. can be removed from wastewater by various physical, chemical and biological methods [1,2,3,4,5]. The air pollutants can be broadly divided into two categories, particulate matter and waste gases. The gaseous pollutants contain oxides of sulphur and nitrogen, hydrogen sulphides and other specific gases with respect to the type of process and reaction [6,7,8].

The gases can be removed from the exhauset by using absorption. Various solvents selectively absorbs certain gases like sulphur dioxide(SO_2), nitrogent oxide(NO_2) etc[9,10]. Various membrane seperation techniques can also be used. The removal of particulate matter can be carried out by using inertial seperators, cyclone seperators, fabric filters and electrostatic seperators. Elecrostatic seperators uses charged electrodes to attract the particles and collect them. The present review summerizes the research and studies carried out on electrostatic seperators.

II. STUDIES AND RESEARCH ON ELECTROSTATIC SEPERATORS

Sharma and Sahu carried out modeling of electrostatic separators [11]. They discussed the performance of ESP's in a power plant, which is situated right in the centre of a mega city. They installed another ESP with existing one and carried out performance guarantee (PG) tests. Their results indicated a significant deterioration of collection efficiency of old ESP unit at the level of (90-93%) against designed value of more than 99%. They also observed that the new ESP unit, which was put ahead of old ESP unit, was operating in the range of (93-96) % of collection efficiency.

Youwen and Weiping carried out review on Chinese electrostatic precipitator technology [12]. According to the author, ESP made in China not only meets the domestic requirement, but also be exported to decades of countries. Power plant is one of the major industrial sectors using ESP. Electric power sector was major customer of the ESP. According to their estimates, from 1990 to 2000, dust emitted from power plant was kept below 4000000 ton while total thermal power units increased from 76011 MW to 220000 MW. Zukeran et.al. carried out investigation on electrostatic precipitator re-entrainment phenomena under diesel flue gases[13]. They used two stages ESP in their research. According to them, collection efficiency often becomes negative in an experimental ESP. This happens because of the re-entrainment of particles. They carried out research to find the reasons for decrease in collection efficiency of ESP. They observed that the decrease in the collection efficiency was caused by re-entrainment of particles during the ESP operation. Also their research revealed that re-entrainment phenomena depended on the gas-flow velocity.

Wanjari and Narkar studied design modification of rapping system to improve the dust collection efficiency of electrostatic precipitator [14]. According to them space required is main constraint in the use of ESP. This constrain can overcome by increase the height and accordingly the collection area. They studied new methods to increase height of rapping system. Commercial software was used for analysis. They concluded that side rapping system is more effective than top rapping for cleaning of collecting plates. Comparative study of the conventional electrostatic precipitator was carried out by Krishnan et.al. [15]. They proposed a new ESP model (smart ESP). They proposed that the location of the transformer rectifier should be on the top of the ESP which is approximately 36 meters above the ground level and thus the total length of control cables used for erection will be around eight to nine kilometers. Thus it was possible to reduce quantity of control cable and perforated cable trays. Also it was possible to reduce the cost for cable laying and the perforated cable tray work. Bohidar et. al. carried out review on role of ESP in industry [16]. According to the studies ESPs are mainly used for particles >1 mm, with dust resistivity's between approximately 104 and 1011 Ω cm. For a given electrode configuration, the efficiency is related to the specific power input (W/m^3).

Haque et.al. carried out investigation on flow distribution inside an electrostatic precipitator [17]. They studied effects of uniform and variable porosity of perforated plate. They presented a numerical flow model applied to a 3D geometry of an electrostatic precipitator (ESP). They modeled the perforated plates as thin porous media of finite thickness with directional permeability. They found that the variable porosity of perforated plate was effective to achieve uniform flow distribution inside the ESP. The model they proposed was useful for operation and maintenance improvement activities by ESP tuning, optimizing flow distribution, field charging and rapping cycles and necessary plant modifications. Vukosavic et.al proposed power electronics solution to dust emissions from thermal power plants[18].They found that the ESPs used need large effective surface of the collection plates and a large weight of steel construction in order to achieve the prescribed emission limits. They found that high frequency high voltage power supply(HF HV) reduces emission two times in controlled conditions while increasing energy efficiency of the precipitator. They concluded that the equipment comprising HF HV supplies are the best solution for new ESP installations, as well as for the reconstruction of existing facilities. Ariana et.al. carried out investigation on exhaust gas recirculation studies to study effect of electrostatic precipitator [19]. The research carried out by them shows that an electrostatic precipitator (ESP) can successfully reduce marine diesel particulate matter. They also developed a combined Exhaust gas recirculation, EGR and ESP system capable of simultaneously reducing NOx and particulate matter (PM). They observed that a combined EGR/ESP system reduces NO_X and PM concentrations in exhaust gas.

Shanthakumar et.al. studied flue gas conditioning for reducing suspended particulate matter (SPM) from thermal power stations[20]. They discussed various equipments used for the reduction of SPM including ESP.They explained advantages of ESP such as high collection efficiency (E99.9%) on removal of submicron particulates; low-operating costs; low-pressure drop; relatively large gas flows, which can be easily handled; and its suitability for dealing with particles of different sizes and variable flue gas volumes. Jagtap et.al. discussed primary details and general information related to plate type ESP's[21]. According to them, resistivity is an important factor that significantly affects collection efficiency. According to them, it is not possible to have an electrostatic precipitator that works at 100 per cent efficiency levels, but with point compromises, the optimal conditions can be achieved. Thonglek and kiatsiriroat used of pulse-energized electrostatic precipitator to remove submicron particulate matter in exhaust gas[22]. They tested a wire-cylinder ESP. They observed that the pulse peak voltage supply could be set much higher than the sparking limit of the DC energized unit. The collection efficiency increased at higher pulse frequency. Kumar and Knapik studied application of ESP for best performers in coal-fired power plants[23]. They discussed the results of stack emissions testing conducted at several coal-fired power plants during the last three years. According to their studies the two important aspects of the investigations on ESPs are the continuing efforts of plant operators to maintain ESP performance, and the co-benefits of wet flue gas desulfurization units, FGDs in reducing stack filterable emissions. According to them proper flyash conditioning is important to achieve maximum collection efficiency.

More and Burande presented FEA approach for modeling and analysis of collecting electrodes in an electrostatic precipitator using Implicit transient dynamic analysis approach [24]. In their investigation, they observed that the vibration excitation of collecting electrodes mainly depends upon impact force and system geometry. Also, there was good agreement between FEA method and testing data. They concluded that the method was much simpler, cost effective and time saving as compared to actual physical testing of the system.

Despotovic and Vukosavic presented theoretical consideration and simulation results for one HF resonant converter, which energizes ESP [25]. According to them the qualitative improvement of electrostatic precipitation of particle from the smoke gas was possible. A new more sophisticated solution which include high voltage high frequency (HVHF) transistor converter instead of conventional thyristor converter module and 50Hz high voltage transformer. According to these studies reaction time and quality precipitation can be bettered compared to the thyristor controlled electrostatic precipitator (ESP). Adner carried out research on generation of nanoparticle-protein solution [26].According to him; one of the most important features regarding deposition efficiency is the possibility to charge the particles. He carried out experiments to test the protein reaction to the materials used in the Aeroid. He also observed that the fractional losses were greater for small particles. Patra and Sarangi carried out experimentation in order to enhance performance of ESP of thermal power plant [27]. They observed that, at the higher frequency operating level of switch-mode power supply, SMPS controller, the response time can be as quick as 100 microseconds compared to the response time of a typical Silicon-Controlled Rectifier, SCR controlled transformer rectifier, 8.33 milliseconds. Jaworek et.al. investigated two-stage electrostatic precipitator for dust particle for dust particle removal[28].They observed that the cohesive forces play the fundamental role in two-stage electrostatic precipitators. According to them, A two-stage ESP can be effective only, if the cohesiveness of the dust is sufficiently large. Nikolic and Stevanovic carried out investigation on power quality measurement analysis of the electrostatic precipitator in thermal power [29].They carried out studies under different working conditions. They proposed measurement methodology based on EU power quality standard EN 50160. They found that this method demonstrated better energy efficiency of intermittent control strategy (about 8%) and lower high-order harmonic values (especially current) up to 25%.

Haque et.al. proposed a Computational Fluid Dynamics (CFD) model for a wire-plate electrostatic precipitator (ESP)[30]. They validated simulated results with experimental data. They found that there was reasonable agreement with experimental data. Adamiec-Wójcik presented a model of a rapping system of an electrostatic precipitator [31].In their model; they combined the rigid finite element (RFE) method with the classical finite element method. They observed that , Motion of an RFE is limited only by the influence of primary elements.Thonglek and Kiatsiriroat developed a wire-cylinder electrostatic precipitator (ESP) for control of submicron particles generated in exhaust gas[32]. They carried out research aimed at improvement of electrostatic precipitator for submicron particle collection by non-thermal plasma pre-charger. During their investigation it was observed that the efficiency was not high. It was in a range of 70-80% for submicron particles. In the improved ESP, very fine particles could be agglomerated to have bigger sizes which can be captured in ESP. By inclusion of non-thermal plasma, NTP precharger, the overall efficiency was greater than 90%.Kawakami et.al. Carried out research for reducing diesel exhaust particle by using ESP [33].They investigated the effect of electrode configuration on collection performance of diesel particulates. They estimated the collection efficiencies as a function of the electrode length and the particle diameter. They observed that the collection efficiency for the collection electrode length of 150 mm decreased with increasing particle size in the two-stage type ESP due to re-entrainment.

III. CONCLUSION

The decrease in the collection efficiency was caused by re-entrainment of particles during the ESP operation. Space requirement is main constraint in the use of ESP. Side rapping system is more effective than top rapping for cleaning of collecting plates. High frequency high voltage power supply(HF HV) reduces emission two times in controlled conditions while increasing energy efficiency of the precipitator. The collection efficiency increased at higher pulse frequency. Non thermal plasma can be used to agglomerate small particles in order to increase collection efficiency. It can be concluded that the coventional ESPs and the collection methods can be modified in order to improve efficiency and economy.

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