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Research Article

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Research progress of PM2.5 fine particles pollution control

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ABSTRACT

PM2.5 concentration in atmospheric environment has been strictly limited at home and abroad. This paper reviews the latest domestic research findings and the international control measures for reducing PM2.5 concentration, including PM2.5 distribution and composition, and the new devices and technologies for controlling PM2.5. Furthermore, the paper compares and analyzes various technologies, lists out their strengths and weaknesses, and evaluates its progress trends.

Keywords: PM2.5, distribution and composition, removal devices and techniques

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INTRODUCTION

At present, both homeland and abroad are facing the tough task to control PM2.5 in the atmosphere pollution. The USA and EUROPE has implemented PM2.5 target value for Air Quality Guidelines appointed by WHO in 2006 and 2008, daily PM2.5 concentration is less than 35μg/m^3 and the average annual PM2.5 concentration is less than 15μg/m^3. China announced that PM2.5 target value will be implemented in 2016 according to Environment Air Quality Targets, daily PM2.5 concentration is less than 75μg/m^3, and average annual PM2.5 concentration is less than 35μg/m^3. Therefore, China is facing the daunting task of controlling PM2.5.

1 Distribution and Composition of PM2.5

In our country, PM2.5 Pollution hits many areas, which mainly focus on Beijing, Tianjin, Shanghai and other places. Daily PM2.5 distribution features double-peak curve, namely, nighttime PM2.5 concentrations is higher than daytime one in winter, while daytime PM2.5 concentration is greater in summer. PM2.5 concentrations has also seasonal variation, it is greater in winter than in summer. PM2.5 concentration exponentially reduces along the height[1].

PM2.5 chemical composition consists of inorganic elements, water-soluble and carbon components. Water-soluble component includes organic and inorganic parts, which is 20-60%. Among it, water-soluble ions mass is one third of total PM2.5 mass, including SO_4^{2-}, NO_X and NH_4^+. They is mainly from the secondary conversion of gaseous precursors SO_2, NO_X and NH_3. Therefore, control of PM2.5 requires the coordinated control of gaseous precursors. Carbon components include organic carbon OC, elemental carbon EC and carbonate carbon CC. OC and EC is 10-70%, they are mainly from the exhaust of motor vehicles, industrial flue gas emissions, biomass burning, etc. Inorganic EC is mainly from gas emissions of fuel combustion. PM2.5 from flue gas of the coal-fired furnace contains mainly two kinds [2]: one is mineral or its polymer, such as Si, Al, Ca and Fe; another is the volatile metal element which contains lots of heavy and alkali metals, such as Na, K, Ni, Cr, Cu and Pb. The former diameter is greater than 1.0 μm and the latter diameter is less than 1.0μm. The higher combustion temperature , the larger PM2.5 concentration [3]. These heavy metals greatly harms human body, so the current primary task is to control PM2.5 in flue gas.

2 Control measures to PM2.5

PM2.5 in Europe and other countries is mainly from SO_X, NO_X and the conversion of gaseous volatile organic compounds. International control measures to PM2.5 is to carry out comprehensive management of the first PM2.5, and to reduce the conservation of gaseous precursors. To improve air quality, Europe has introduced nearly 20 regulations and directives, and also developed other standards on motor vehicle and other polluted source emissions. Furthermore, Europe and USA actively changes the development model, and commits to achieving a win-win model of both economic development and environmental protection. Many cities in their countries has begun to shift heavy industry outwards and developed knowledge-intensive industries. Most of countries improve the energy structure, vigorously use clean energy, and develop transit-oriented traffic.

Scale of heavy industry in China is the first one in the world, including power generation, coal conversion, steel, cement, chemicals,etc. So the key to reduce PM2.5 is to diminish PM2.5 emissions from fuel gases, comprehensively renovate the coal-fired small boilers, and accelerate the transformation of desulfurization and denitrification industries. Because higher amount of PM2.5 is formed in boilers that burns finer pulverized-coal with the lower ash[4], both the layer-burned method and the larger powder fuel particles is available effective ways to reduce PM2.5. However, PM0.38 concentration in the layer-fired boiler is higher than that of both the pulverized-coal boilers and circulating fluidized-bed boiler[5]. It needs to improve PM2.5 removal efficiency of dust wiper.

In recent years, many new devices to remove PM2.5 emerges. A kind of new device named the bag-type dust wiper to control PM2.5 has been proposed[6]. This devices installed dust bag for cleaning ash with the nano coating-layer, which can adsorb PM2.5, but it must be operate at less than atmospheric pressure. A kind of new device named Electrostatic Precipitator to Remove PM2.5 with Box-type Dust Region has been published[7], which uses many same-spaced collecting plates to construct microdust-channels with electrode after conventional filter so as to agglomerate finer particles into larger particles. A new device on Particle Coalescence Device and PM2.5 Poly and Dust-removal System is proposed[8]. A new device named Flue Gas Purification Device on Removal PM2.5 with Ultrasonic Agglomeration is proposed[9], which provides with an ultrasonic spray agglomerator in order to reunite PM2.5 into larger particles. They[10] also announced a kind of new device on Tourmaline Negative Oxygen Particles Device on Purifying PM2.5 in Fuel Gas from Power Plant. The device uses a tourmaline O^-generator, which can combine PM2.5 and O^- into larger particles, and then enter into electrostatic precipitator and discharged from the chimney.

In western countries, wet electrostatic precipitator technology is mainly method to removal PM2.5 from industrial emission sources. It is more suitable for metallurgy, chemicals, building materials, petroleum and food processing industry. However, it needs higher cost. Atmospheric rainfall can effectively remove soluble PM2.5, this is because PM2.5 easily accumulate and grow due to moisture absorption[11]. It is removed by sedimentation, and efficiency is about 40~67%.

China has proposed the method of the exhaust gas-water multiphase cross-flow array variable temperature based on the principle that the particles in the boundary layer may move to the gas-liquid interface under internal source fields. This technology has been applied to Drilling Diesel Engine Exhaust, the removal efficiency is up to 91.4%[12]. However, it needs lots of water, huge power consumption, wider area, suitable to install near rivers and lakes. The particles bed layer combined quartz sand with sea sand is adopted to filter PM2.5 fine soot particles[13], however, it requires thicker powder particles bed and slower gas velocity. At about 4mm thick powder particles bed with 100mm, average filter efficiency may reach 99%.

In practical, an electrostatic precipitator removes PM2.5 depending on absorbing the charged particles, 1μm particles lies in the mixing zone of both field and diffusion charges, and it has poor charge capacity, so it is difficult to remove. Because bag-type dust collector mainly depends on collision, interception and diffusion removal, 1μm particles is just in the vicinity of the inertia and diffusion-controlled mixing zone, which has the same low removal efficiency. Technically speaking, bag-type dust method[14] is easy to paste bag, poor adaptability to different types of smoke, bigger bag consumption. So it is difficult to treats filter cloth. Existing electrostatic precipitator has lower PM2.5 collection efficiency. So a hybrid removal dust system was developed to improve PM2.5 agglomeration process[15], such as the "static+Tornado", "Electrostatic+dust particles" and "Electrostatic+bag filter". Due to adding corona electrode and pulse electricity in the hollow spindle of cyclone separator to produce higher electron density and strong electric field force around it, the fine particles in gas dust enters into upstream area with gas flow and is captured on the wall by strong electric field force. This kind of technology requires to control suitable speed, too higher wind speed causes shorter residence time, reducing the electrostatic interaction. Wind speed is too small, the cyclone is weakened. Electrostatic and Dust Particles uses the granular materials as filter media to achieve flue gas purification, removes fine particles through the dust charged or particles layer with external power plant, has

been widely used in cement, coking, chemical and metallurgical industries. Electrostatic and Bag adds a pulse-type bag filter after the original electrostatic precipitators. But the technology has higher requirements to filter film and bag. Another idea is to add the pre-treatment prior to conventional electrostatic precipitator device so that ultrafine particles agglomerate into large particles by physical and chemical methods. PM2.5 is successfully removed in the electrostatic precipitator. Successful technology is the bipolar charged - turbulence condensation technique [15], which utilizes Coulomb cohesion and flow field to make particles enriched, generating particle nucleation and aggregation phenomena. Fida Soot Precharged Particle Trapping Efficiency Device is successfully application cases that reduces outlet PM2.5 concentration by 30%. Both CFD population balance model and free molecular coagulation kernel is used to model coagulation process of fine particles, it found that outlet average particle size is the product of the third power of solid holdup rate and residence time[16].

CONCLUSION

The development of existing devices of removing PM2.5 has three main trends. One is to add PM2.5 collision by means of turbulence, pulse electricity or ultrasonic pulse on the basis of the existing electrostatic precipitator, and then remove them in the electrostatic precipitator. Two is to apply water spray to make PM2.5 grows up and remove from the flue gas. Three is to use the granular powder bed to make PM2.5 retained in micro-pore channel. For the first, since bigger reunited PM2.5 finally are removed in electrostatic precipitator, the removal efficiency is restricted. But there is no need to replace the electrostatic precipitator, the cost has been greatly reduced. For the second, the water spray is not too high removal efficiency, which can be learned about rainwater removal efficiency of only about 67%. For the third, the fuel velocity through the powder bed can not be too high, otherwise, the flue gas will be carried out of the powder bed pore channels, greatly affects the removal efficiency.

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