Development of Highly Efficient Continuous Regeneration Type PM2.5 Removal Device Operated at Waste Heat

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[Abstract]

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We have developed a highly efficient $PM_{2.5}$ Removal device of the continuous regeneration type, which could be operated at a bed temperature of 400°C, utilizing low-temperature fluidized bed combustion and relying on adhesion forces for the effective collection of small PM particles. In this study, to decrease the continuous regeneration temperature and develop the $PM_{2.5}$ removal device that can be operated with waste heat, the combustion rate of PM is promoted by the effect of promoting low-temperature combustion of water vapor and the catalytic effect of potassium. When water vapor exists, water vapor promotes PM combustion and the concentration of CO_2 significantly increases. It is reported that complex groups (e.g., carboxyl groups) are generated with water vapor and carboxyl groups transfer into CO_2 even at several hundred degrees. Potassium was doped on the bed particles as K_2CO_3. K_2CO_3 promotes PM combustion and selectively enhances CO_2 generation. CO_2 is generated from the oxidation of K_2CO_3 and transformation of K_2O_2 to K_2O with the consumption of PM. K_2O is converted to K_2CO_3 with the re-absorption of CO_2. The lowest continuous regeneration temperature decreases to 330°C with maintaining the collection efficiency 100% owing to the promoting effect of water vapor and the catalytic effect of potassium on PM combustion. To further reduce continuous regeneration temperature, a rough surface bed particle was selected, and the potassium supported amount was increased. As a result, although existing continuous regeneration devices require temperatures of 600°C for PM combustion, the device reported herein could be operated at a bed temperature of 300°C. In addition, scale-up data was acquired by scaling up the experimental equipment and a demonstration experiment using diesel was conducted with the aim of putting this device into practical use. From the comparison before and after the scale-up, it is shown that the scale-up device has the same results as the device before the scale-up. The demonstration experiment using diesel was carried out continuously for 540 min. The collection efficiency is maintained at 100%, and it is shown that this device has the excellent PM collection characteristics. On the other hand, a feasibility study was conducted based on experimental data. It is indicated that the superiority of this device in terms of $PM_{2.5}$ collection performance, initial cost, and running cost. A detailed production drawing of this device was designed considering the transportation and installation of the device, and the path to cost reduction was shown.

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