

A Catalytic Combustion Technology of Concentrated VOCs in Textile Coating Process

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Abstract—We developed a new process employing catalytic combustion for textile coating aimed at decreasing emissions of volatile organic compounds (VOCs) and saving energy at the same time. For this purpose, the VOCs are concentrated in a temperature swing adsorption (TSA) device. A fraction of the concentrated VOCs is completely oxidized on an electrically heated (EHC) system, and its combustion gas of EHC is supplied as the heating source via heat exchangers. The remaining concentrated VOC is recycled as a renewable energy source for the drying process to dual-type catalytic burners designed specially to operate with LPG and concentrated VOC at the same time. This system minimizes the problem of VOC emission and maximizes energy conservation by reusing the VOC, toluene, from textile coating.

Key words : VOC, Dual-Typed Catalytic Burner, TSA, EHC, Combustion Catalyst

INTRODUCTION

Reduced emission of VOC has drawn much attention due to the increasing interest in minimizing pollution and offering a better environment for human life. In the textile industry, quite large amounts of solvents have been used to dissolve dye, resin etc. for coating on textiles. These solvents include toluene, isobutyl methyl ketone and ethanol. These solvents are usually volatilized with thermal convection heating in order to fix a dye or a resin on the surface of textiles.

Catalytic combustion technology has several advantages over conventional combustion in VOC treatments. It emits small amounts of hazardous gases such as NO and CO since the catalytic combustion proceeds completely at relatively low temperature, compared to thermal combustion [Trim, 1995; Dalla Betta, 1997]. Additionally, the far-infrared radiation emitted from the catalyst accelerates the drying speed of heated textiles, thereby maximizing the energy efficiency.

Catalytic combustion can be achieved in a wide range of concentration of fuel-rich condition or of the lean condition below 1 % concentration of fuel [Dalla Betta, 1997]. However, the VOCs exhausted from the drying process are usually too low to use for catalytic combustion directly. In this work, in order to increase the concentration, the temperature swing adsorption (TSA) device is adopted. The concentrated VOC in the TSA system is reused in a catalytic burner and in an EHC. Most of the VOC that is not recycled is oxidized totally using an electrically heated catalyst (EHC) system before emission to the environment: The additional heat generated from the combustion process is used to heat the combustion air for the process.

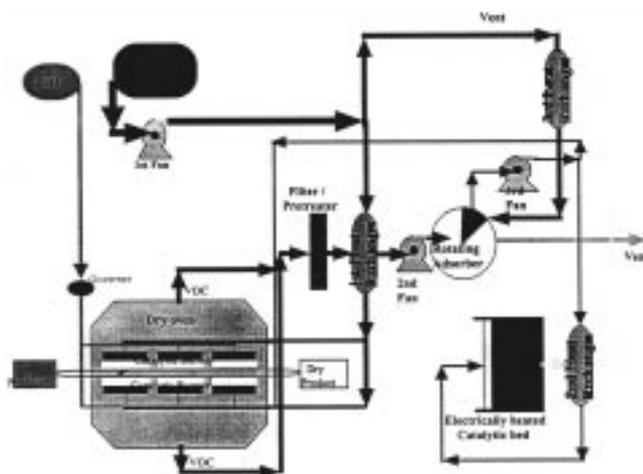


Fig. 1. Layout of demonstration facility for a textile coating process.

The layout for the drying process using the above-mentioned methods is shown in Fig. 1. The pilot plant is constructed on a one-sixth scale of commercial production, in the Taegu area of Korea. Previously, we reported the preliminary results of the demonstration experiment conducted at the plant [Kang et al., 1997]. In the present work, we describe the catalytic combustion technology for the drying process based on full demonstration results.

EXPERIMENTAL

The detailed design of the catalytic burner, TSA and EHC systems is described elsewhere [Kang et al., 1997]. The drying chamber for the demonstration experiment described in Fig. 1 is 7 m×3 m. It is equipped with 8 catalytic burners operated si-

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multaneously with LPG and VOC. The combustion air is supplied by a blower at a rate of 700 m³/hr. In the experiment, textile material is coated with acryl resin. The coating solution consists of 80 % toluene and 20 % acryl resin, which are provided by textile manufacturing companies. The coating work is conducted over the textile bought on the open market of 1,200 mm wide, and is controlled to its feeding speed of 5-25 m/min.

The analysis of VOC and combustion gas is performed with a quadrupole mass spectrometer (GENESYS). And additionally, the concentration of VOC in the chamber is also monitored during the run, using a catalyst sensor in order to escape the dangerous situation of VOC building-up to an explosive level. The drier, EHC system and TSA system in the demonstration experiment are controlled independently.

RESULTS AND DISCUSSION

The arrangement of the dual catalytic burner used is illustrated in Fig. 2. This burner has nozzles for LPG and VOC, respectively [Seo et al., 1997]. Combustible gas is distributed over an alumina fiber mat containing 0.5 wt% Pt. The burner is designed to start its catalytic reaction between fuel and air at the catalyst layers by forced diffusion method and to continue the reaction with concentrated VOC by the premixed method. For the catalyst used, 10 % combustion of LPG is achieved at 523 K at a space velocity of LPG, 42,000 hr⁻¹, and complete oxidation is achieved at 800 K. For this type of burner, the catalyst layer is maintained around 523 K.

Fig. 3 shows the dependence of catalyst temperature on toluene concentration and space velocity. Also, the concentration of unburned toluene is measured as a function of toluene concentration and space velocity (Fig. 4). Alumina fiber can retain its entity up to 1,000 K. Thus, the dependence presented in Fig. 3 and Fig. 4 indicates the range of toluene concentration and space velocity, satisfying 99 % conversion of VOC. In the demonstration experiment, eight catalytic burners are installed in the drier chamber. The operating condition for catalytic burner is controlled in order to satisfy the requirement presented in Fig. 3 and Fig. 4.

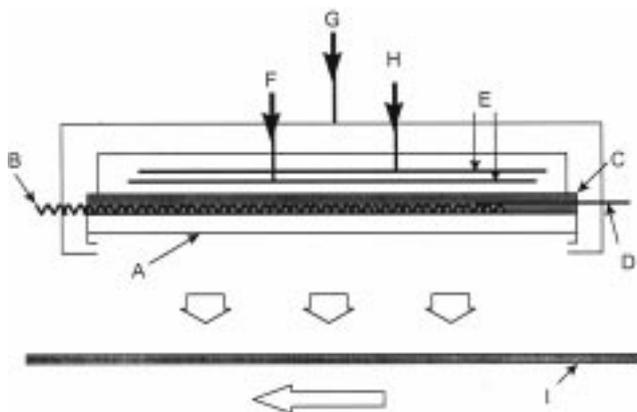


Fig. 2. Schematic diagram of dual catalytic burner.

A, catalysts; B, electrical heater; C, supporter; D, thermocouple; E, gas nozzle; F, LPG line; G, gas line; H, concentrated VOC; I, textile

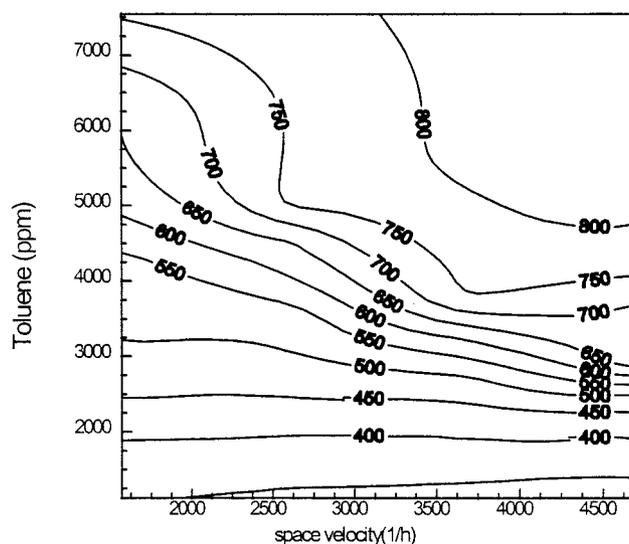


Fig. 3. Contour plot of catalyst bed temperature of burner as a function of toluene concentration and space velocity.

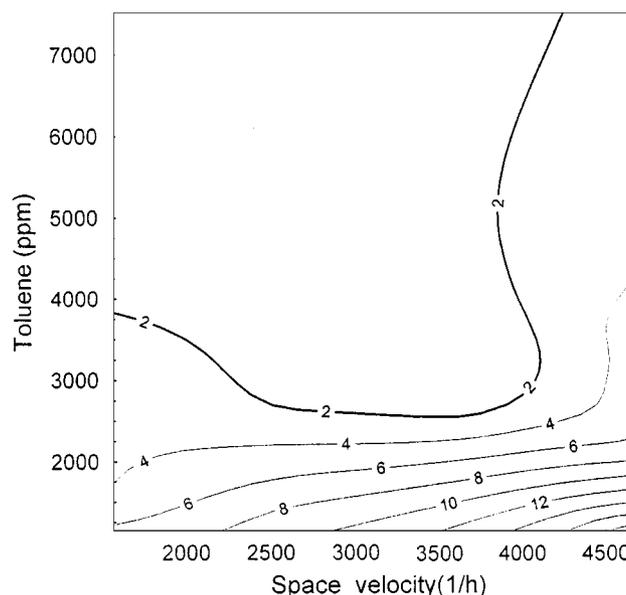


Fig. 4. Contour plot of unburned toluene as a function of toluene concentration and space velocity.

We report the performance of the EHC system. In the report, the effect of toluene concentration, space velocity and heat storage system is shown as a function of performance of the EHC system earlier [Kang et al., 1997]. Here, we expand the previous investigation to a much lower range of toluene concentration in the presence of a heat storage system. For this purpose, an EHC system is installed at the start of incineration of VOC delivered from the TSA system. For the heat storage system, a honeycomb block containing no metal catalyst is added to the system to maintain the inlet temperature without additional energy supply. Fig. 5 shows the effect of the heat storage system on the catalyst temperature. The heat storage of 30 % to the total weight of catalyst and supporter is sufficient to maintain the reaction temperature. Fig. 6 shows the effect of catalyst inlet temperature as a function of inlet toluene concentra-

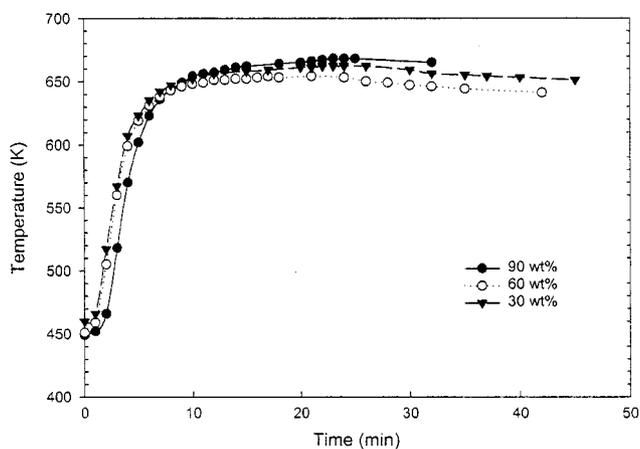


Fig. 5. Temperature of catalyst inlet temperature was measured after electrical power was off, with various heat storages.

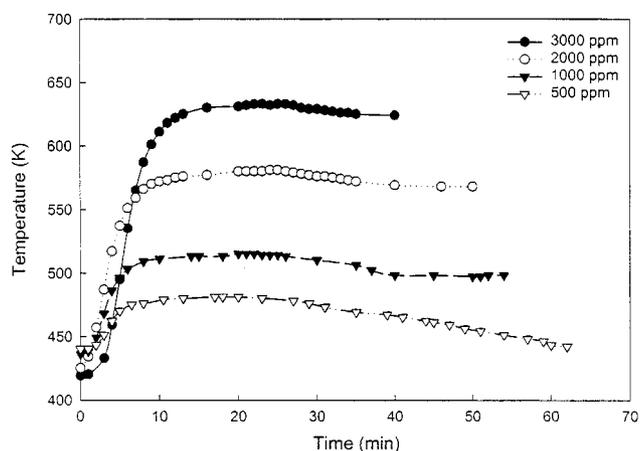


Fig. 6. Temperature of catalyst inlet temperature was measured as a function of toluene concentration after electrical power was off, with 30 wt% heat storage.

tion. Electrical power supply is turned off at 20 min after arriving at steady state in the EHC system. However, in spite of no additional heat supply, the temperature at the catalytic bed is maintained when the toluene concentration is above 1,000 ppm. At 500 ppm toluene, the temperature decreased slowly, indicating the concentration was not enough to maintain the EHC system without additional electrical power supply. Thus, it is believed that the toluene concentration should be higher than 1,000 ppm to maintain catalytic incineration in our pilot system.

In the demonstration experiment, the coating speed is controlled using a roller. Depending on the textile and coating solution, the feeding speed of a textile is adjusted. Depending on this feeding speed, toluene concentration changed as presented in Fig. 7. In the drier chamber, the concentration of VOC increased linearly as the feed speed was increased. However, the concentration decreased abruptly if the feeding speed was much higher than 25 m/min as a consequence of incomplete drying of the coating solution.

The TSA system worked successfully below a feeding speed of 13 m/min. However, it failed to accumulate VOC if the con-

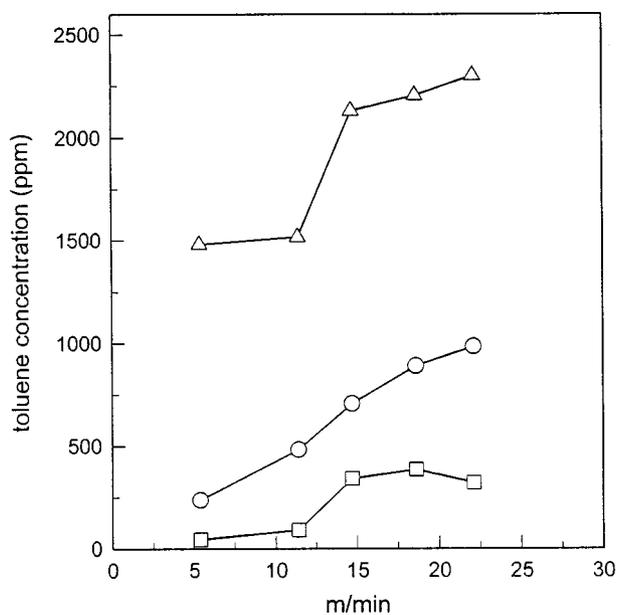


Fig. 7. Toluene concentration from (O) coating machine (Δ) after TSA and (\square) emission as a function of coating speed.

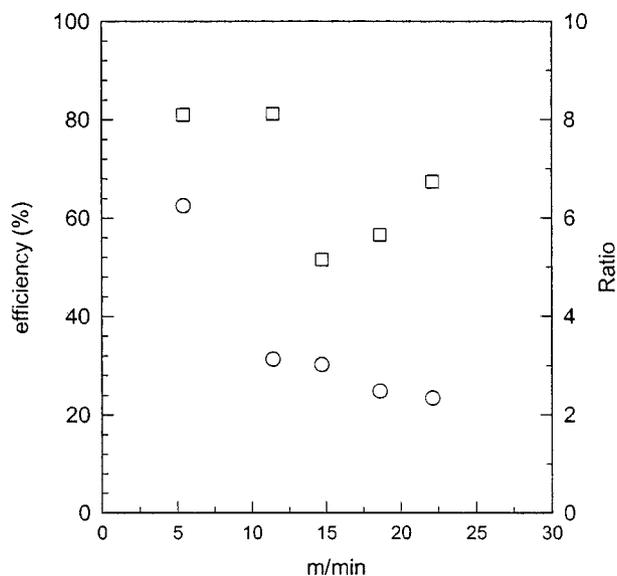


Fig. 8. (\square) Efficiency and (O) accumulation ratio of toluene using TSA plotted as a function of coating speed.

centration of VOC from the drier chamber increased above 500 ppm. Fig. 8 shows the performance of the TSA system; 80% efficiency of TSA expressed as a ratio of concentration of accumulated VOC to raw VOC is achieved at a normal operation. For the TSA operation, it is recommended that the optimal state at which the inlet concentration of TSA system is less than 500 ppm at the present condition be kept. Many more experiments should be performed in order to apply to a bigger one or to a different TSA system.

Fig. 9 shows the catalyst temperature in the burner as a function of the coating speed. Catalyst temperature is reached to 773 K using LPG as a fuel. After the fuel is changed from LPG to VOC, the temperature decreases to 653 K. It is possible to run

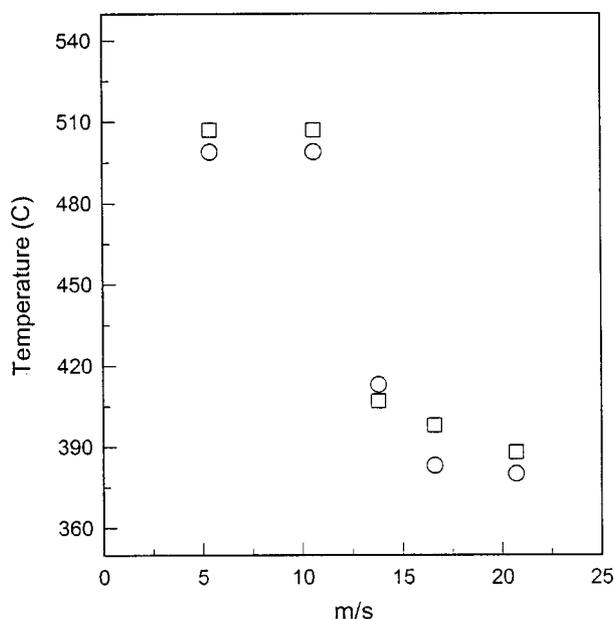


Fig. 9. Temperature of catalytic burner as a function of coating speed. (□) at the middle of the catalytic burner and (○) at the end of the catalytic burner.

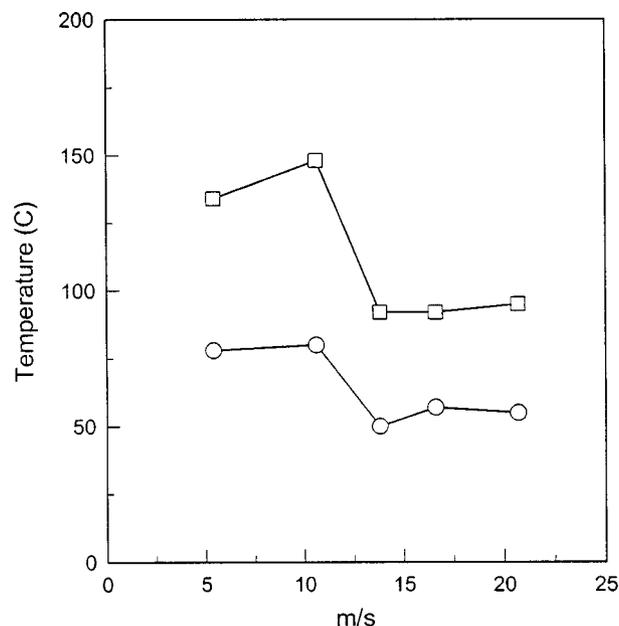


Fig. 10. Temperature of textile measured both (□) inside the chamber and (○) outlet of coating machine plotted as a function of coating speed. The textile was polyester.

the drier chamber using VOC if the concentration is increased above 1,500 ppm.

The coating speed does not so much affect the quality of the coated textile. Fig. 10 shows the temperature of textile measured by infrared thermometer. In these operations using VOC as a fuel, the textile temperature changed within the 20 K range. However, the wetted textile is sufficiently dried out up to the coating speed of 24 m/min.

The effects of process variables such as coating speed and fuel condition have been investigated. The most distinguished advantage of the proposed coating scheme is a direct use of VOC as fuel for catalytic burner and the simultaneous reduction of VOC emission. In the demonstration experiment, it is possible to operate the drier using VOC only, which means 100% energy saving in drier chamber. This demonstration experiment provided sufficient data to show that the process itself is an economical, energy saving, and environmentally friendly catalytic combustion technology.

CONCLUSION

Catalytic combustion technology coupled with the TSA and the EHC systems is successfully applied to a textile processing unit to use VOC as a renewable energy for the coating process. The demonstration is performed in a sixth scale of commercial system. The results indicate that the process developed here bears several advantages: a considerable reduction of VOC and an

economical operation due to energy saving achieved. However, for its commercial implementation, it is believed that many more case studies are needed to optimize the conditions for operation and construction.

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