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Edited by G. D. Megersa, E. Maťaš, J. Országh, P. Papp, Š. Matejčík

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POSTER PRESENTATIONS

CYCLIC PLASMA-CATALYTIC SYSTEM OF CATALYST DEACTIVATION AND REGENERATION APPLIED FOR VOC REMOVAL

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This study examines a cyclic system of catalyst deactivation and regeneration used for toluene removal via plasma catalysis. The system, tested with various catalysts, shows that plasma-regenerated catalysts exhibit higher toluene removal efficiency compared to those non-regenerated. The findings highlight the potential of nonthermal plasma as an economical and efficient solution for VOC removal and catalyst regeneration.

1. Introduction

Volatile organic compounds (VOCs) are major contributors to one of the most pressing global environmental issues - air pollution. A promising approach to their removal from the air is through catalysis. However, catalysts are often subject to deactivation (i.e., losing their catalytic activity) by use. This deactivation of the catalysts is mainly caused by the adsorption of undesired reaction products on their surface resulting in their limited lifetime. As a result, the catalysts need to be regularly replaced or regenerated. Replacement of the catalysts produces waste and conventional regeneration requires high temperatures. Both high temperatures and waste production are associated with high costs. Although the regeneration of the deactivated catalysts (i.e., restoring their catalytic activity) is a more appropriate approach to extend their lifetime, conventional (thermal) methods of catalyst regeneration are often insufficient. Therefore, it is necessary to search for new or improve existing regeneration methods. An innovative way of removing VOCs from the gas [1, 2] as well as regeneration of catalysts deactivated by the undesired products, such as those from the VOC removal process [3], involves utilizing nonthermal plasma in these processes.

2. Methodology

In our research, we focused on testing a cyclic system that, in the first step, removes a model pollutant (toluene) from the air using plasma catalysis (a combination of nonthermal plasma with catalysis) followed by, in the second step, the catalyst regeneration using the nonthermal plasma in oxygen. The regenerated catalyst was then reused in the toluene removal process. A cycle of toluene removal with subsequent catalyst regeneration was repeated three times for two different catalysts (TiO_2 and $Pt/\gamma Al_2O_3$). Each toluene removal process lasted 180 min with a fixed discharge power of 6 W, while regeneration lasted 120 min with a fixed discharge power of 3 W. In order to evaluate the regeneration efficiency, three cycles of toluene removal without subsequent regeneration were also performed. The toluene removal efficiencies achieved with regenerated and non-regenerated catalysts were compared. Gaseous oxidation products of both the toluene removal process and catalyst regeneration were monitored using Fourier-transform infrared (FTIR) spectroscopy. In addition, the efficiency of plasma regeneration in one 120 min cycle was compared with other regeneration methods, including ozone and thermal regeneration of the same duration. Moreover, sequential plasma catalyst regeneration (i.e. regeneration for 40 min cycles + mixing of pellets, repeated 3 times) was tested, too. To evaluate the regeneration efficiency, time courses of concentrations of gaseous regeneration products (CO_2, CO, HCOOH) were evaluated. The catalysts were analyzed by thermogravimetric analysis (TGA) and scanning electron microscopy (SEM). The chemical identification of solid undesired products adsorbed on the surface of the catalysts was carried out by gas chromatography coupled with mass spectrometry (GC-MS).

3. Results and discussion

A Figure 1 shows a comparison of the toluene removal efficiency achieved by two different catalysts (TiO_2 and Pt/γAl_2O_3) over three cycles, comparing regenerated and non-regenerated catalysts. The achieved toluene removal efficiency is higher for the Pt/γAl_2O_3 than for the TiO_2 in each individual cycle. This result was expected due to the higher catalytic activity and high oxidation properties of Pt/γAl_2O_3. The results show that the toluene removal efficiency mostly decreases with an increasing number of cycles for both regenerated and non-regenerated catalysts due to gradual catalyst deactivation caused by the adsorption of solid undesired products. However, regenerated catalysts exhibit higher toluene removal efficiency across all cycles than those non-regenerated. Therefore, the catalyst regeneration partially restores their catalytic activity.

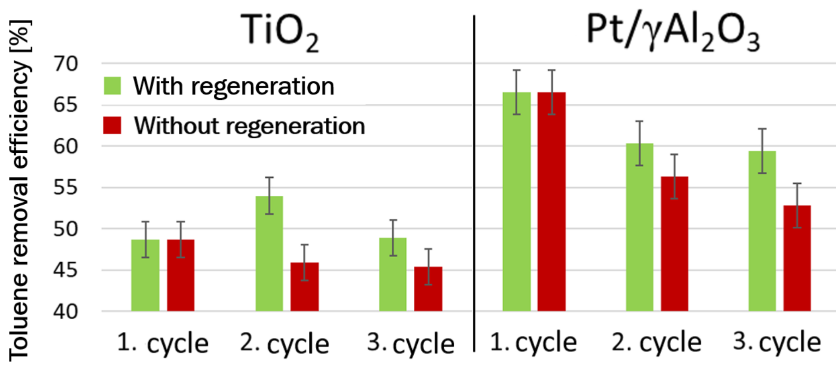

Fig. 1. Comparison of toluene removal efficiency for cycles with and without regeneration for TiO_2 (left) and Pt/γAl_2O_3 (right).

Moreover, plasma catalyst regeneration in one cycle was compared to ozone, thermal and sequential plasma catalyst regeneration. The results show that both plasma and plasma sequential regenerations are more effective than ozone or thermal regeneration; with plasma sequential regeneration being the most effective.

4. Conclusion

Investigation of cyclic system of catalyst deactivation in a plasma catalytic toluene removal followed by its regeneration demonstrates that plasma-regenerated catalysts maintain higher toluene removal efficiency in each cycle, compared to those non-regenerated. This indicates that plasma regeneration restored catalytic activity, offering a cost-effective and efficient alternative.

5. Acknowledgements

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