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Coupled engineering and chemical approach to the design of a catalytic structured reactor for combustion of VOCs: Cobalt oxide catalyst on knitted wire gauzes

Andrzej Kołodziej [a,d,*], Joanna Łojewska [b], Jacek Tyczkowski [c], Przemysław Jodłowski [b], Wiktor Redzynia [c], Marzena Iwaniszyn [a], Szczepan Zapotoczny [b], Piotr Kuśtrowski [b]

[a] Inst. of Chem. Eng., Polish Acad. Sci., Baltycka 5, 44-100 Gliwice, Poland
[b] Jagiellonian Univ., Faculty of Chemistry, ul. Ingardena 3, 30-060 Kraków, Poland
[c] Lodz Univ. of Technol., Faculty of Process Eng. and Environ. Protection, Wólczańska 213, 90-924 Łódź, Poland
[d] Opole University of Technology, Faculty of Civil Eng., Katowicka 48, 45-061 Opole, Poland

HIGHLIGHTS

- Model of gauze reactor is presented and the impact of axial dispersion discussed.
- Cobalt oxide catalyst is layered on wire gauze surface using plasma technique.
- Raman, XPS and XRD proved presence of about 5 nm CoO_X spinel crystallites.
- Kinetics of *n*-hexane catalytic combustion is studied in a gradientless reactor.
- Modelling is validated by experiments performed in large laboratory reactor.

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ABSTRACT

A structured reactor was built from stacked catalytic knitted wire gauzes. The cobalt oxide catalyst was deposited on the wire gauze surface using the plasma enhanced metal-organic chemical vapour deposition method. The Raman scattering, electron diffraction and photoelectron emission analyses of the catalyst surface evidenced the formation of a cobalt oxide spinel with crystallites of about 5 nm. The results of kinetic studies of VOC combustion (using *n*-hexane as a probe molecule) performed in a gradientless reactor allowed determining the reaction order and activation energy for this catalytic reaction. It has been proved that reaction follows first order kinetics. Two reactor models (plug-flow and plug-dispersion) were compared and the simpler plug-flow one is recommended due to the negligible influence of axial dispersion. Experiments were performed in a large laboratory reactor (temperature up to 873 K, gas stream up to 10 m^3/h STP) for catalytic conversion of VOCs (*n*-hexane). The model validation has shown satisfactory accuracy with maximum and average errors of 12% and 4%, respectively.

1. Introduction

Catalytic combustion seems to be the most successful remedy for the removal of many types of 'combustible' species from exhaust gases. Combustible emissions containing a diverse variety of chemicals, called Volatile Organic Compounds (VOCs), constitute a vital environmental problem worldwide. A typical end-pipe VOC emission is characterised by a very low concentration of the organic species (frequently at the ppm level) and a large gas stream. Anthropogenic sources release almost 150 million tons of carbon in the form of VOCs per year [1]. The majority of them are dangerous poisons, carcinogens or mutagens.

Conventionally applied reactors for catalytic combustion are packed bed (filled with a bed of catalytic grains) and monolithic reactors. The first type can be regarded as a slightly old fashioned solution showing high flow resistance and low effectiveness of the catalyst grains, which in turn leads to high spending on catalyst material. Monolithic reactors are the current standards used for catalytic combustion since they show opposite performance properties when compared to packed bed reactors. However, monolithic reactors often fail for combustion of VOCs. This is because

* Corresponding author at: Inst. of Chem. Eng., Polish Acad. Sci., Baltycka 5, 44-100 Gliwice, Poland. Tel.: +48 32 2310811; fax: +48 32 2310318.
E-mail addresses: ask@iich.gliwice.pl (A. Kołodziej), lojewska@gmail.com (J. Łojewska), jatyczko@wipos.p.lodz.pl (J. Tyczkowski).

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