CO removal using single stage plasma- catalytic hybrid process in laboratory scale

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Received: March 6, 2018 Accepted: February 4, 2019

Extended abstract

Introduction

Air pollution treatment using plasma- catalytic hybrid process is an acceptable approach, accounts for high efficiency and economic effectiveness in the world. In spite of various advantages of non- thermal plasma, two technical problems associated with this technology should be solved before its industrial application. In addition, catalytic treatment alone has limitations such as performance at high temperature, deactivation of catalytic active sites, not economic for treatment of low concentration of pollutants. Therefore, the combination of plasma with catalyst has been interested by most of the researchers.

The technology of Plasma Driven Catalysis (PDC) possess energy saving importance to treatment of exhaust gases from stationary and mobile sources. In comparison with common catalyst, PDC has advantages including high distribution of active species, reduction of energy consumption, increase of catalytic activity and selectivity as well as low sensitivity to poisonous.

Removal of carbon monoxide pollutant emitted from stationary and mobile sources at indoors and outdoors based on plasma combined catalyst supported on precious metals, in particular, Platinum Group Metals (PGM) had been investigated by most of the researchers. In addition to the high cost of these catalysts, they have also performance limitation in low temperatures. At the present study, CO removal using plasma combined mixed metal oxide catalyst has been investigated.

Materials & Methods

In present study, three types of reactors have been applied. A coaxial Double Dielectric Barrier Discharge reactor (DDBD), a catalytic reactor including catalytic mixed metal oxide film of Ceria-Zirconia- gamma Alumina (CZA) coated on quartz tube by sol- gel dipping method, and a single stage plasma- catalytic reactor (plasma driven catalysis) which is combination of two above mention reactors and catalytic film has been applied in NTP discharge zone. In design of reactors, two inner and outer tubes of quartz and Pyrex have been used with outer diameter of 4 and 10 mm, respectively. It is notable, in catalytic and hybrid reactors, quartz substrate (inner tube with D_{out} = 4mm) is coated by catalytic film of CZA.

In plasma alone and plasma- catalytic reactors, Tungsten wire is used as cathode, copper foil as anode, and high voltage AC power supply has been applied to support strong electric field.

Design of Experiment (DOE) and desired performance conditions for hybrid reactor have been chose by considering of optimum performance condition of plasma and catalytic reactors.

Discussion of Results & Conclusions

The effect of gas stream temperature on removal efficiency. This effect is found significant in plasma alone reactor ($p < 0.05$) but not significant in catalytic alone and hybrid reactors ($p > 0.05$). The positive effect of temperature on removal efficiency is described by improvement in the secondary decomposition of hydrocarbons as well as increase of impaction surface of active molecules following suitable temperature and decrease of gas stream viscosity in reactor space.

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The interaction of gas stream temperature and space time is found significant ($p < 0.05$) in hybrid reactor which could be important from specific input energy aspect.

The effect of space time on removal efficiency. This effect in plasma alone reactor is significant ($p < 0.05$) and the mean removal efficiency is improve with increase of space time. At the catalytic and hybrid reactors, this effect is not significant ($p > 0.05$). However, the optimum condition of removal efficiency is when the space time is decreased. Improvement in removal efficiency of CO due to positive effect of space time is explained by mean power enhancement of discharges and thereby space time increase, as mean power determines the mean electron density which in turn, gives the excitation rates and molecule separation in gas. Also, from specific input energy aspect, optimum removal efficiency is achieved at low specific input energy (SIE) and lower space time of experiments (0.13 s) at 80^{o}C.

The effect of C_3H_8/CO ratio on removal efficiency. This effect is positively significant in the catalytic reactor ($p < 0.05$), but not significant in plasma and hybrid reactors (p> 0.05). However, presence of propane shows better removal efficiency in both NTP and Hybrid reactors. It is concluded that carbon monoxide removal is being improved due to hydrocarbon decomposition and thereby, generation of hydrocarbon radicals.

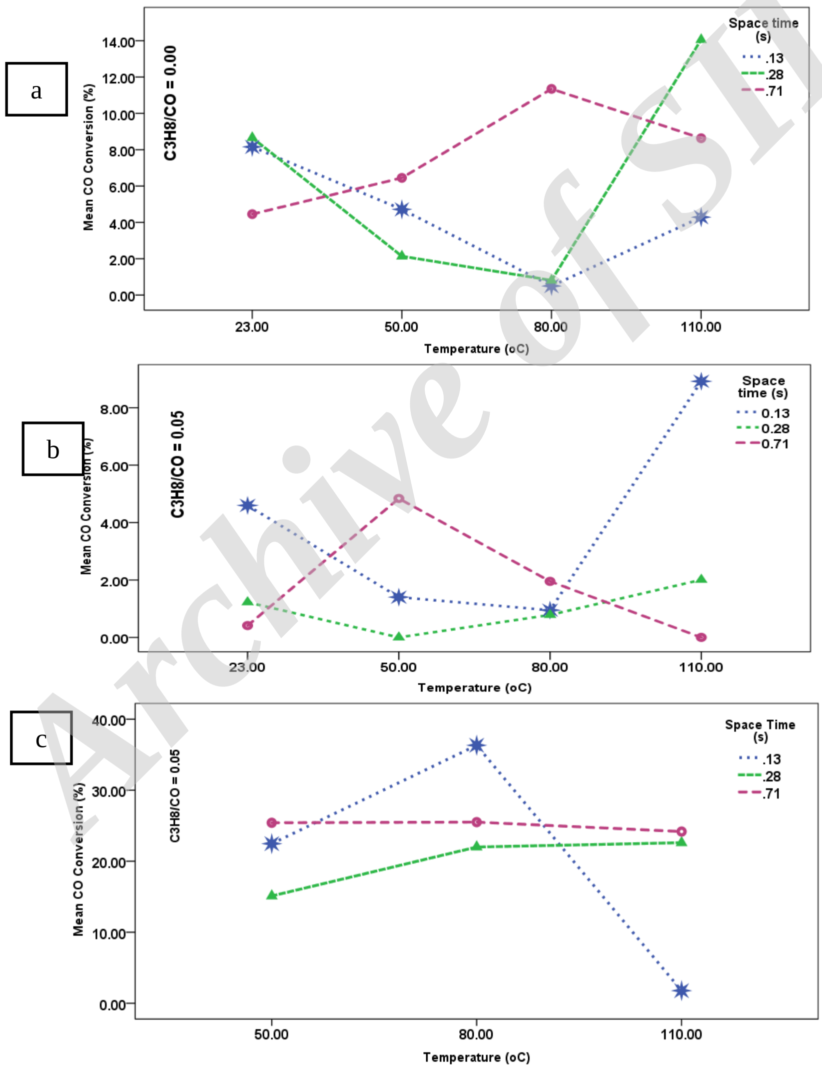

Fig.1. The optimum performance conditions of CO removal using non- thermal plasma only (a), catalytic only (b) and plasma- catalytic hybrid reactor (c)

Temperature and space time interaction. According to data analysis, the interaction of temperature and space time in hybrid reactor is significantly positive (p= 0.001, Fig. 2). Based on the studies, this effect can be explained by the key role of some active species, in particular, OH radicals at the presence of hydrocarbons.

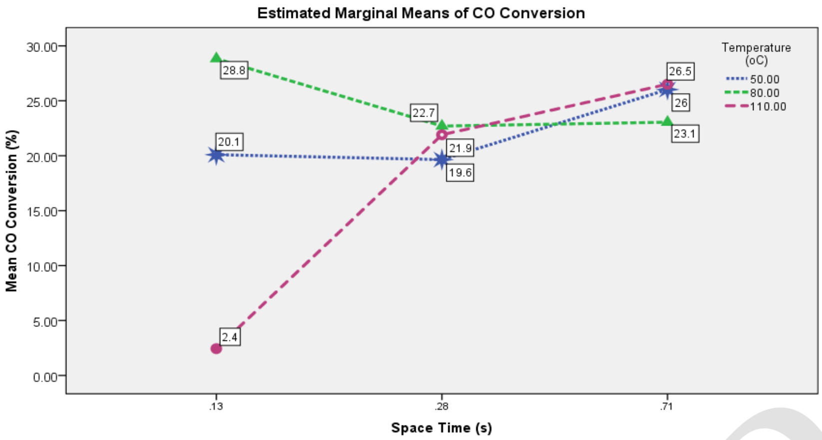

Fig. 2. Temperature and space time interaction in hybrid reactor

Synergy factor. The synergistic effect of plasma combined with catalyst on CO removal at 80°C is better, due to improvement in catalyst activation temperature, reduction of activation energy and also, better selectivity results from positive interaction of plasma discharges and catalyst active sites (Fig. 3).

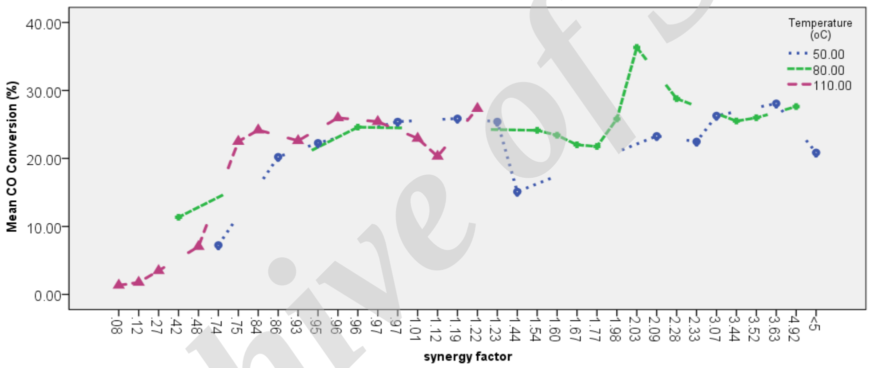

Fig. 3. Synergy factor of plasma catalyst hybrid process in CO removal

Conclusion

Air pollution is a worldwide challenge and its control using clean technologies are being interested of many researchers from different aspects. Carbon monoxide removal using plasma- catalytic hybrid reactor has been studied from different viewpoints of improving removal efficiency, catalytic performance temperature, energy consumption, hydrocarbon decomposition, and synergy factor of hybrid process. The mean removal efficiency of CO (36.33%) is achieved using single stage hybrid reactor at optimum experimental condition of temperature= 80°C, space time= 0.13 s, C_3H_8/CO= 0.05 and specific input energy of 860 j/l. Also, our findings confirm positive synergy effects of plasma and catalytic techniques in pollutant removal and synergy factor of 2.03 is achieved.

Keywords: carbon monoxide, PDC, plasma- catalyst, removal, synergy.