Real time analysis of combustion emissions: a comparison of catalyst treated and untreated solid fuels

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Abstract

Carbon monoxide (CO) from combustion of solid fuels causes some deaths worldwide every year. This study has been undertaken to evaluate the amount of carbon monoxide, (and carbon dioxide, nitrogen oxide & methane) evolved from catalyst (Pd-Sn/alumina and Cu-Mn/graphite) treated charcoal briquettes, untreated charcoal briquettes, commercial charcoal and coal at non-isothermal temperatures between 50 to 800 ^{o}C attained at different heating rates of 20-40 (^{o}C/min). Samples were heated in a thermal analysis instrument coupled with a multi-gas analyser under flowing air at different flow rates 20-100 (ml/min). Results showed a significant CO and NO reduction with catalyst treated charcoal compared to untreated charcoal briquettes and coal. There is also a strong dependence of CO emissions on heating rate and air flow. This study shows that catalyst treatment of solid fuels helps to minimise harmful combustion emissions.

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What is the project about?

Impregnation of Pd-Sn/alumina catalyst on solid fuels has been used as a viable way to minimise toxic combustion emissions while enhancing energy output and combustion efficiency.

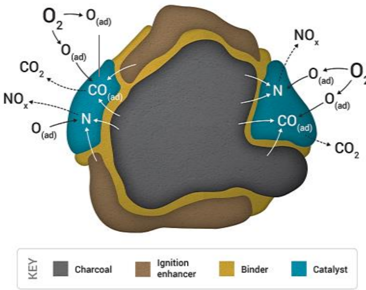
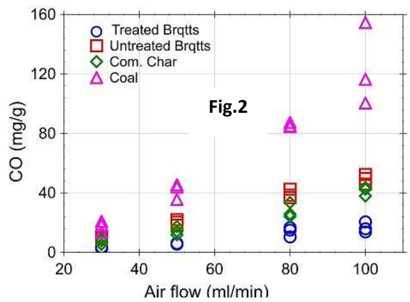


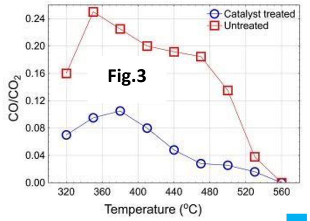
Fig.1: Catalyst treated briquette

The thermal responses of catalyst treated (**Fig.1**) and untreated briquettes, commercial charcoal and coal were analysed with TGA/DSC combined with a MultiRae lite gas analyser for combustion products CO, CO_2, NO_x, and CH_4. Samples were heated at 20–40 °C/min and 30–100 ml/min in air (21% O_2)

CO-CO₂



$$C_{(s)} + O_{2(g)} \frac{W.cat.}{w.out.cat} = \frac{CO}{CO_2}$$



Combustion energy

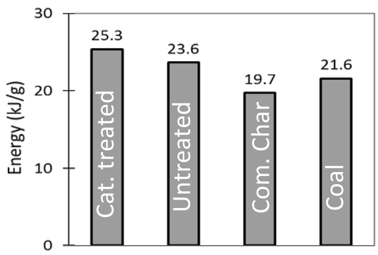


Fig.4

Catalyst treated briquettes produced up to 6.7%, 22.3%, and 14.8% more energy compared to untreated briquettes, Com. Char and coal respectively

Kinetics

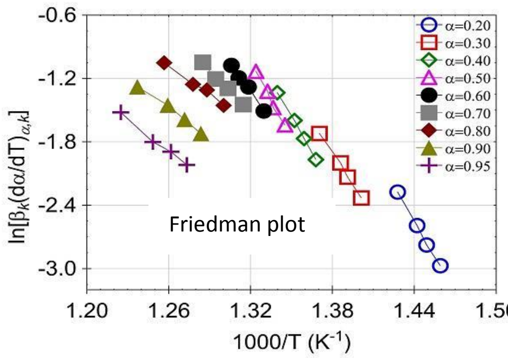


Fig.5a: Friedman Plot to determine E_a at different conversions

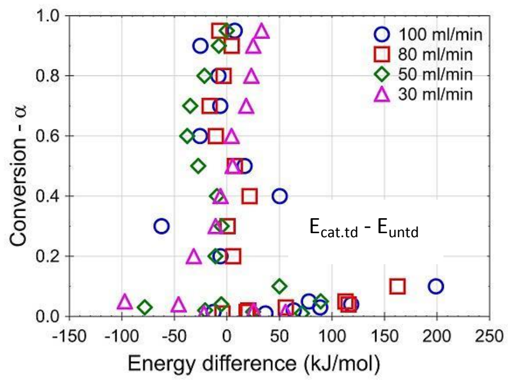
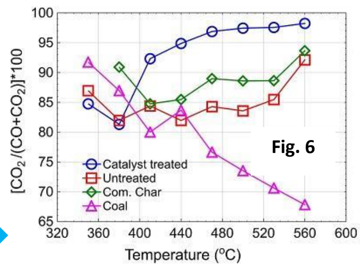


Fig. 5b: Scatter plot for E_a difference ($E_{cat.td}$–E_{untd})

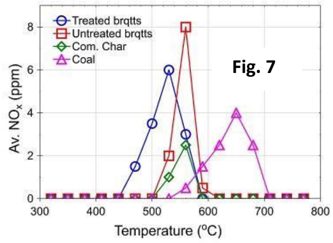
The negative E_a difference at 0.05<α<0.5 for 30 ml/min; 0.2<α<0.9 for 50 ml/min, and 0.5<α<0.9 for 80, and 100 ml/min implied that catalyst treatment lowered the activation energy for char oxidation

Combustion efficiency



Catalyst treated char had high combustion efficiency due to enhanced CO oxidation

NOₓ emissions



The catalyst reduced the temperature at which NO_x were produced but did not affect the quantity emitted.

Conclusions

Treatment of solid fuels with Pd-Sn/alumina catalyst:

- reduced CO emission factors by up to 87.1%
- enhanced the energy output by up to 22%
- reduced activation energy for heterogeneous reactions
- increased the combustion efficiency
- reduced the temperature at which NO_x were produced

Related literature

- https://doi.org/10.1016/j.cplett.2018.11.041
- https://doi.org/10.1080/15567036.2019.1623348
- https://doi.org/10.1007/s40789-018-0229-y
- https://doi.org/10.3389/fchem.2018.00032
- https://doi.org/10.1016/j.catcom.2018.03.011
- https://doi.org/10.3390/agriculture5030561

Future work

- Food safety aspects of catalyst treated solid fuels
- Environmental friendliness
- Synthesis of high temp. (>600°C) stable catalysts

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