

Supercritical Catalytic Cracking of n-dodecane for Cooling in Scramjet Engines.

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1. Introduction

Modern advanced aircrafts are being pushed to high supersonic and hypersonic flight speeds (Mach number > 5), employing scramjet engines. In these flight regimes, the temperature of the air taken on board the vehicle becomes too high to cool the aircraft. Coupling endothermic reactions of cracking to the exothermic reactions of fuel combustion is a promising strategy for cooling in scramjet engines. The formation of certain products such as hydrogen may also improve the combustion properties.

n-dodecane has been used as a model compound for jet fuels in lab-scale kinetic tests. Several studies have been published on n-dodecane cracking. These studies investigated the cracking of n-dodecane under supercritical conditions. It was found that the conversion of the cracking reaction of n-dodecane is relatively low and the coke formation is negligible at low pressures and temperatures¹. However, high pressures and temperatures result in high conversion rates, but the coke formation is not negligible. We are interested in developing a simplified model which will consider the reaction rate and the deactivation rate of the catalyst, depending on operating conditions of temperature and pressure for selected cracking catalysts.

2. Methods

We use n-dodecane as a model compound in a lab-scale reactor to test the catalytic cracking kinetics at **supercritical conditions** (temperatures above 500 °C and pressures above 20 bars). Catalytic cracking of n-C12 in packed-bed reactors at such conditions have not been reported to date. The reactor unit is connected directly to a GC for compositional analysis of the gas phase products. Downstream of the reactor, the product stream is quenched and separated into vapor and liquid products. Liquid product samples are collected for compositional analysis in a GC. **We have tested commercial FCC catalysts as well as powder and pellet forms of Y-zeolites.**

We have developed a global kinetic model, which is embedded in a reactor-heat exchanger model, and predict the heat sink capacity for various operating conditions. The transient performance due to coke formation is also considered.

3. Results and discussion

The selectivity of the gas phase changes with increasing the WHSV from 120 hr⁻¹ to 300 hr⁻¹ by using 0.3 grams and 0.12 grams of catalyst, respectively. With increasing the WHSV, the molar fractions of methane and hydrogen decrease, and the molar fraction of the other hydrocarbons (C2-C6) increase, Figure 1. The gas yield decreases from 13% to 7% by increasing the WHSV.

According to the model that we have developed, at temperatures below 400 °C, the reaction rate is negligible. With increasing temperature, the heat sink increases, and with increasing the WHSV at the same temperature, the heat sink decreases, Figure 2.

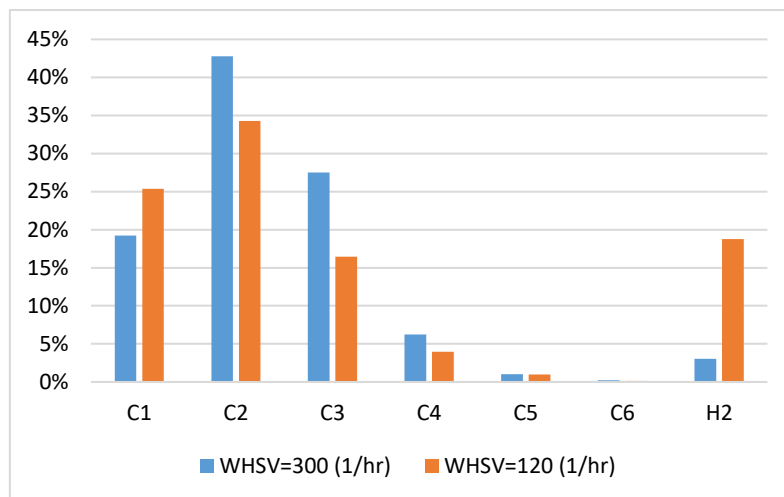


Figure 1. Catalytic cracking of n-C12: Selectivity of gas phase products at 20 bar and 550 °C at different WHSV values (Using 0.12 grams and 0.3 grams of Y-zeolite catalyst respectively, and 0.6 gr/min n-C12 flow).

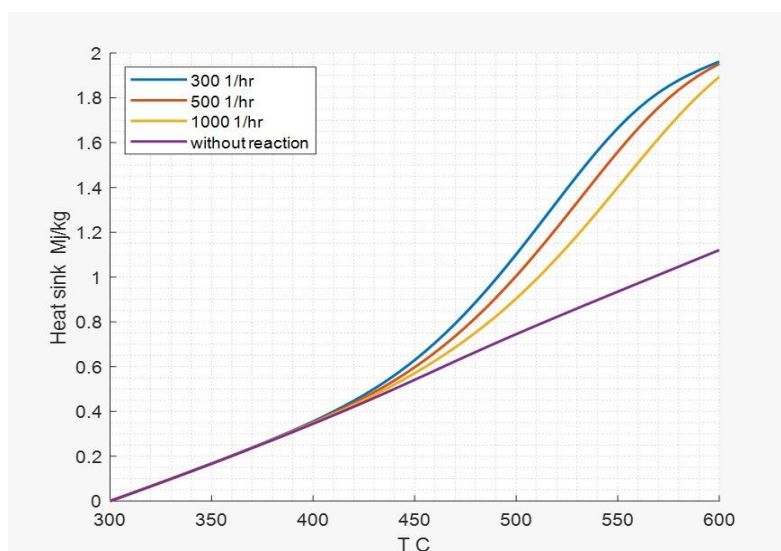


Figure 2. Model predictions of heat sink as a function of temperature at varying WHSV.

4. Conclusions

The gas phase selectivity changes with changing WHSV by changing the catalyst mass that we use. We have developed a preliminary kinetic model designed to predict the amount of heat absorption within the reaction under varying reaction conditions. It considers the reaction rate and the deactivation rate of the catalyst. According to this model, the heat sink changes due to a change in conditions such as temperature, fuel flow, and mass of catalyst.

References

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Keywords

Cracking; Supercritical fluids; Catalysts; Heat sink.