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A study of radial heat transfer in fixed bed Fischer-Tropsch synthesis reactors

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ABSTRACT

A series of experiments were performed to investigate and compare the heat transfer characteristics of a catalyst bed both during the Fischer-Tropsch synthesis (FTS) reaction and with heating but without a reaction. Two reactors of different dimensions were used in this study. The first one was a laboratory scale reactor with a diameter of 23mm and length of 300mm, and the second was a bench scale reactor with a 50mm diameter and 1 000mm length. Three materials, namely SiO_2, TiO_2, and SiC were chosen as supports for the cobalt catalyst in the laboratory experiments. These supports were chosen because they have very different thermal conductivity characteristics, and hence could offer a wide range of heat transfer properties in the catalyst bed.

In order to measure the experimental data accurately, the researcher designed and set up the reactor systems carefully. Three thin thermocouples with sheaths were placed at different radial positions in the bed. Each thermocouple could slide up and down in the sheath and in this way measure the temperature profile axially, at a fixed radius. Two stainless steel sieve plates were placed at either end of the catalyst bed to prevent any radial shifting of the thermocouples. The placement of three heating zones along the reactor ensured a flat axial temperature profile throughout the reactor under both non-reaction and non-heating conditions. This was especially important in the catalytic bed to ensure that any temperature gradient measured was the result of reaction or of heating, rather than unequal heat input along the reactor by the reactor wall heaters.

Two sets of heat transfer experiments for each catalyst were carried out in the laboratory scale reactor, namely a set with FT reacting conditions and a set without. In the first set of experiments, the catalyst bed was run under typical low-temperature FTS conditions (P = 20 bar(g), reactor wall temperature T_{wall} = 190-240^{o}C, space velocity SV = 0.9-2.25 NL/h/gcat) with syngas feed (H_2/CO = 2); while in the second set an inert gas, N_2, was fed to the bed and a heater in the centre of the reactor was used to generate a controlled variable heat output across the catalyst bed.

The radial temperature profiles at different radii in the bed were measured in both cases for

varying flow rates and reactor wall temperatures. Simple radial heat transfer models were derived for these two sets of experiments, and the effective thermal conductivity coefficients of the catalyst bed were estimated. Comparisons of the results showed that there were considerable differences between both the values of the coefficients and the shape of the temperature profiles in the reaction and non-reaction cases. The effective thermal conductivity coefficient when FT reaction took place was up to three times higher than that obtained when a heater was used as the heat source.

In order to test the hypothesis that liquid in the bed might change its heat transfer characteristics, the reactor operation was switched from reacting to non-reacting conditions, and the effective thermal conductivity post-reaction was measured over a period of up to two weeks. The measurements showed that the effective thermal conductivity gradually reduced from the value recorded under reaction conditions to that found in the reduced catalyst bed. These results suggest that the liquid formed by the FT reaction may play an important role in affecting the heat transfer characteristics of the catalyst bed.

The effective thermal conductivity was further correlated with the chain growth probability, α. In addition to the heat transfer experiments, the researcher also investigated and compared the performance of the three catalysts.

It should be noted that the FT reaction was actually run under non-isothermal conditions when it was conducted in the large diameter (bench scale) reactor. The reaction rate and product selectivity as a function of operating conditions were recorded and discussed. In the heat transfer experiments carried out in the bench scale reactor, syngas produced from biomass was used as the feed, and the heat transfer experiments were performed with FT reaction only. The size of the catalyst used was 2-4mm, instead of 0.5-1.0mm (which was the case in the laboratory scale reactor). The temperature distribution and the effective thermal conductivity as well as the performance of the catalyst were discussed, and these results were also compared with those derived from the laboratory scale reactor.