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Desulphurisation of petroleum sistillates using adsorption method

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Abstract

Experiments were conducted to investigate the applicability of activated carbon in removing sulphur from petroleum distillate at different sulphur concentrations. The study was therefore divided into two: The first part was the desulphurisation of a diesel stream containing 5200 mg/kg sulphur. This was referred in this report as Case 1. On a typical refinery, this is the feed stream of the hydrotreater unit. The second part of the study was the desulphurisation of a diesel stream containing 120 mg/kg sulphur. This sulphur concentration referred to case 2, which resembles an exit stream of the hydrotreater unit on a typical refinery.

In Case 1, the activated carbon managed to reduce the sulphur content from 5200 mg/kg to 3390 mg/kg. Only about 35% of the sulphur was removed. In Case 2 however, the diesel stream was desulphurised from 120 mg/kg to 22 mg/kg. About 82% of the sulphur was removed from the feed-stream depicting activated carbon's desulphurisation capability when dealing with lower sulphur concentration petroleum distillate.

Adsorption isotherms and kinetics models were applied to the experiment data to understand the extent and rate of sulphur adsorption on the surface of the activated carbon. The applicability of both adsorption isotherm and kinetics models to the experiment data were evaluated by the correlation coefficient (R^2) value with 5% statistical significance. The Langmuir isotherm model fitted well Case 1 experiment data. The obtained Langmuir isotherm constant (K_L) was 1.19 X 10^{-4} g/mg. This K_L value was lower compared to Case 2 value of 0.0123 g/mg. This indicated that each sulphur molecule on activated carbon adsorption surface had a better equal adsorption activation energy in Case 2 than in Case 1. In Case 2, the obtained Freundlich isotherm constants, K_F and n were 5.22 and 1.04 respectively. The n value for Case 2 was higher than Case 1 n value (1.04 vs 0.55). This clearly indicated that the sulphur molecules adsorption intensity on the surface of the

activated carbon was higher in Case 2 than in Case 1. The K_F value for both cases indicated the activated carbon adsorptive capacity. Pseudo-first-order kinetic model fitted well case 2 experiment data. The kinetic rate constant obtained for Case 2 was 0.206 min^{-1}, whilst the kinetic rate for Case 1 was 0.0423 min^{-1}. This indicated a slower sorbate uptake rate in the higher sulphur concentrated diesel stream than the lower concentrated stream. It is well understood that no adsorption processes are exactly the same as many studies have indicated, however these comparisons of these Case's isotherms and kinetics were highlighted to indicate the impact of higher sorbate concentration in the desulphurisation of petroleum distillate. For both case 1and 2, it was established that the adsorption of sulphur on activated carbon was particle diffusion in nature.

The results of the study therefore indicated that application of adsorption desulphurisation method seem not capable to achieve ultra-low sulphur specification when treating diesel feed with high sulphur content. On the other hand, the results of the study also revealed that there is an opportunity for synergistically employing activated carbon adsorption in combination with hydrodesulphurisation to achieve low sulphur diesel specification.