

Kinetics of Short Contact Time Coal Liquefaction

Part I: Effect of Operating Variables

The liquefaction kinetics of Pockhams No. 5 sub-bit coal (Pittsburgh Seam) in the presence of SRC-II recycle solvent at short contact times (<10 min) and temperature and pressure ranges of 673–723 K and 10.5–13.6 MPa is examined in a well-mixed reactor. In the initial stages of liquefaction, while overall coal conversion (tetrahydrofuran-solubles) increases with temperature, oil (pentane-solubles) is lost with an increase in temperature. An increase in solvent-to-coal ratio results in an increase of conversion. The initial coal particle size distribution, total pressure, and nature of gas phase (nitrogen or hydrogen) have no significant effect on the production of any of the product of liquefaction for contact times up to 10 min. A lumped kinetic model is presented to describe the product distribution.

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SCOPE

The primary reactions in conversion of coal to liquid fuels in any coal-oil slurry liquefaction process are pyrolytic in nature and require high temperature to overcome the distribution of activation energies involved in the rupture of bond linkages in the macromolecular network of coal. It is known that when coal is contacted with a hydrogen-donor solvent, at elevated temperatures (693–723 K), much of the coal conversion to soluble products takes place in the initial 2–5 min. Hence, the preheater in the coal liquefaction process is a critical component, as it behaves as a short contact time reactor. Usually, there has been a considerable interest in the development of a short contact

time two-stage process. This paper presents a short contact time (<10 min) coal liquefaction kinetic study which is carried out in a well-mixed, 1-L stainless autoclave reactor. The experimental data are obtained for Pockhams No. 5 sub-bit coal at various practical ranges of temperatures, pressures, solvent-to-coal ratio, and initial coal particle size. Both nitrogen and hydrogen was used as the gas phase. The data are correlated by a lumped kinetic model which would be useful in predicting the performance of a preheater or a short contact time coal liquefaction reactor.

CONCLUSIONS AND SIGNIFICANCE

The kinetics of coal liquefaction at short residence times (under 10 min) has been studied. The products of liquefaction were characterized as:

Preasphaltenes	{ Soluble in Tetrahydrofuran Insoluble in Toluene
Asphaltenes	
	{ Soluble in Toluene Insoluble in Pentane
	Oil Solubles in Pentane

It is shown that initially there is an effective loss of oil, whereas the preasphaltenes and asphaltenes are rapidly formed indicating a fast dissolution of coal in the initial stages. A statistical analysis of the experiments shows that the temperature has a significant negative influence on oil concentration with a

minimum at around 2–4 min of reaction time. This result indicates the occurrence of an additive reaction between coal and oil leading to some intermediate products which in turn react to give oils. The production of toluene and tetrahydrofuran solubles is shown to be positively influenced by temperature. The solvent-to-coal ratio also significantly influences the product distribution.

An investigation of the influence of gas phase (nitrogen and hydrogen), particle size, and total pressure, at short-time liquefaction show no statistically significant effect in the range of variables studied. From a kinetic standpoint, it appears that there is no need to add hydrogen to the first stage of the short contact time two-stage processes or the preheater or other processes; however, hydrogen may be needed to prevent coke formation. A kinetic model is developed to predict the product distribution over the entire range of operating variables studied. This model should be useful in predicting the product distribution coming out of a preheater or a short contact time coal liquefaction reactor.

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