Review of the development of models for the prediction of fouling rates in exchangers heating crude oil

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Models for the prediction of fouling rates in heat exchangers quantify the relationship between fouling, fluid flow (wall shear) and temperature field. Such relationships can then be used to either alleviate the consequences of fouling or reduce the rates at which individual heat exchangers foul in a variety of ways. These include selection of heat exchanger types providing superior performance over standard shell-and-tube configurations; the modification of pre-heat train structures to provide better overall performance; the design of heat exchangers to provide an acceptable level of performance over a pre-specified operating period; and, the identification of cleaning strategies that provide the least disruption to pre-heat train operation.

The mechanism underlying fouling in these heat exchangers depend upon whereabouts in the train the exchanger is located. So far, fouling models have only been successfully employed at the hot end of the train. Here it is assumed that fouling results from deposition of asphaltenes.

The development of fouling models in recent years is largely a response to the pioneering work of Wayne Ebert and C.B.Panchal. They produced a model based upon on the assumption that fouling resulted from a chemical reaction occurring in the hot film adjacent to the hot surface of the exchanger.

This model has been generalised and extended to cover fouling in heat exchanger bundles as well as inside plain tubes; fouling in tubes fitted with tube inserts; and, fouling in welded plate exchangers (Compabloc units). These developments are reviewed and the insights coming from such developments are outlined.

These models assume that the mitigation of fouling as a result of a fouling suppression term that is a linear function of wall shear stress. Their does not appear to be any theoretical justification for this assumption.

Furthermore, application of the model requires the identification of three separate parameters: Activation Energy of reaction, a deposition constant and a suppression constant.

Recent work has suggested that the mitigating effect of wall shear could be based on the frequency at which turbulent bursts disrupt the laminar boundary layer. This frequency affects that time at which fluid is close to the surface of the deposit and will influence the probability of foulant contained within that fluid actually attaching to the surface of the deposit.

The rate at which asphaltenes precipitate when oil is heated has been studied by Wiehe, who has proposed a two stage reaction. An Activation Energy of 44.3 kJ/mole has been reported for the rate controlling step. This value for Activation Energy is adopted for the new model.

Comparisons between the new model and data obtained in the laboratory and extracted from measurements of actual exchanger performance are described.

Whilst the results of these comparisons are encouraging a number of questions remain. These are outlined and discussed.

Ways in which the research can be carried forward are discussed.