Abstract

Fouling is a complex phenomenon which commonly occurs in crude oil heat transfer equipment, reducing heat transfer, increasing pressure drops and in general resulting in reduced energy recovery efficiency and increased capital and operating costs of refineries.

Measuring with accuracy the fouling behaviour of an oil at or close to industrial conditions is not easy. A High Pressure Oil Rig (HIPOR), designed to overcome current limitations and operate in a regime close to refinery shell-and-tube exchangers, has been developed at Imperial College London under the direction of Prof. G.F. Hewitt. The apparatus includes a tubular and annulus flow sections with heat input supplied via Joule heating (Macchietto et al, 2011), and an experimental programme is under way.

The aim of this paper is two-fold: First, a predictive model of the HIPOR test section is briefly presented. The model is intended to assist in the analysis and interpretation of the experimental fouling data collected, and also in the development of the experimental programme itself. Second, some results are reported in respect of the calibration of the model to the equipment in clean (no-fouling) conditions, so as to establish a properly validated performance of the equipment (sensors and controllers, as well as thermo-hydraulic behaviour) in the absence of fouling and a reliable base-line for the assessment of differences due to fouling.

For the first objective, a dynamic, distributed thermo-hydraulic model of the tubular and annulus flow sections of HIPOR is presented. The model, an extension of Hexxcell's model for HiPOR, considers the two dimensional (axial and radial) heat transfer in different domains with variable thermal conductivity (heat generation), boundary conditions and other aspects (for example, heat losses) which are carefully determined. The calibration and validation of various model components through a variety of tests is described. The model predicts temperature profile and pressure drop of fluid in the test section as well as local conditions of the physical plant and fluid properties.

Instrumentation for temperature, flow rate and differential pressure measurement has been installed to record primary data for validation purposes. Heat input (heat flux) supplied via Joule heating is also carefully measured.

Tests were performed for varying inlet fluid temperatures and step changes in the heat input, enabling experimental results and model predictions to be compared. The simulation results (*temperature profile, wall temperature, differential pressure and temperature difference, outlet and inlet temperature*) show a consistent agreement with primary measurements from

the rig at different process conditions, including transient responses. Furthermore, results also demonstrate the sensitivity of operating process parameters to differential pressure.

It is concluded that the model of the HIPOR rig at 'clean' oil conditions was successfully validated and could be a used as a reliable reference base to assist in the interpretation and validation of crude oil fouling data from HIPOR.

References

S. Macchietto, G.F. Hewitt, F. Coletti, B.D. Crittenden, D.R. Dugwell, A. Galindo, G. Jackson, R. Kandiyoti, S.G. Kazarian, P.F. Luckham, O.K. Matar, M. Millan-Agorio, E.A. Müller, W. Paterson, S.J. Pugh, S.M. Richardson, D.I. Wilson, "Fouling in crude oil preheat trains: a systematic solution to an old problem"*, Heat Transfer Engineering*, **32**, 3, 197-215 (2011).

F. Coletti and S. Macchietto A dynamic, distributed model of shell-and-tube heat exchangers undergoing crude oil fouling. *Ind. Eng. Chem. Res*. **50** (8), pp 4515–4533 (2011).