



ESDU SPC-M5-1

Fundamental transfer processes

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Part of the CROF Theme III:
Fundamental Transfer Processes

Sub-project C

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FOULING IN HEAT EXCHANGERS OF CRUDE DISTILLATION UNITS

- Heat exchangers use the largest fraction of the energy needed in oil refining.
- Fouling tends to increase the amount of energy required for the process.
- Pressure drop and deterioration of thermal performance.
- The mechanism of **deposition** and **removal** is not yet fully understood.
- Even though complete elimination is not possible, it's important to achieve asymptotic levels to minimise effects of fouling.

SUB-PROJECT C: OBJECTIVES

Currently, fouling rates in a CDU are calculated using semi empirical “fouling threshold” models.

The objectives of sub-project C are to:

- To investigate the **fundamental mechanisms** leading to deposition and removal.
- To **predict** the deposition and removal rates as a function of the relevant system parameters.
- To integrate within sub-project C information from other sub-projects (B) and to **validate** the modelling predictions against experimental observations (obtained in sub-projects E and F).

MISCIBLE & IMMISCIBLE SYSTEMS: TWO DIFFERENT APPROACHES I

IMMISCIBLE

- The two fluids are immiscible, separated by a **sharp interface**.
- Mass and momentum conservation equations are needed for each phase.
- Appropriate interfacial and wall boundary conditions are required.

“MISCIBLE”

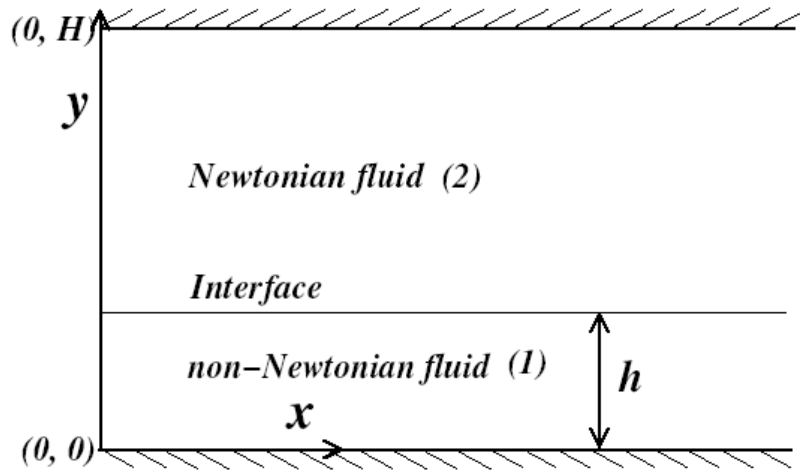
- The two fluids are miscible, separated by **mixing layer**.
- Another equation is present in the system to take into account the variation of concentration of one of the phases in the channel.
- Viscosity is a function of concentration, and hence changes with position.

MISCIBLE & IMMISCIBLE SYSTEMS: TWO DIFFERENT APPROACHES II

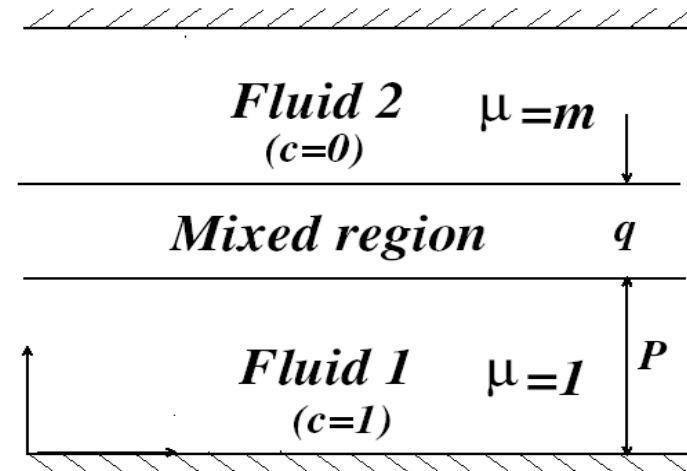
For each system, accurate prediction of removal (and deposition) rates and, ultimately, of a steady-state fouling thickness, requires fundamental understanding of the presence of flow instabilities and physicochemical properties. This motivates the study of

- The **linear** stability of the system;
- The **nonlinear** evolution of disturbances.

MISCIBLE & IMMISCIBLE SYSTEMS: LINEAR STABILITY ANALYSIS



Immiscible fluids



Miscible fluids

Rheological model of the fouling layer:

$$\mu_1 = m \left(\frac{dU}{dy} \right)^{n-1} + Bn \left(\frac{dU}{dy} \right)^{-1}$$

m =viscosity ratio, Bn = Bingham number $\left(\frac{\tau_0 H}{\mu_2 V} \right)$, n =flow index

Ref: Linear instability of pressure-driven channel flow of a Newtonian and a Herschel-Bulkley fluid – *Sahu et al.* – accepted in *Phys. of Fluids*, 2007

LINEAR STABILITY ANALYSIS

Boundary conditions

- No-slip and impermeable conditions at the walls
- Continuity of velocities at the interface
- Continuity of normal and tangential stresses at the interface

Coupled disturbance equations

An eigenvalue problem: $A\psi = cB\psi$

- Solved by a spectral method
- Validated with several known results of Newtonian fluids e.g., South & Hooper (1999) and Yiantsios & Higgins (1988)