

ESDU-SPE-M12-1



Sept.09: Stirred vessel fouling tests

Unamended
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SUB-PROJECT E: STIRRED VESSEL FOULING TESTS

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CROF Meeting - 30th September 2009



SUB-PROJECT E - OBJECTIVES

2. Obtain representative data over wide range of conditions for comparison with theoretical models developed under Sub-Project C & for input to Sub-Projects involved in chemistry & thermodynamics

1. Design & construct stirred cell to Eaton & Lux design (c.30 bar & c. 300°C surface temperature)

4. Provide representative samples of deposits for the Sub-Projects involved in chemistry & thermodynamics

3. Modelling fouling processes under controlled & known conditions of shear stress and temperature (surface & bulk) for further development in Sub-Projects G & H

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Many runs with four crude oils



4. Provide representative samples of deposits for the Sub-Projects involved in chemistry & thermodynamics

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3D & axially-symmetric 2D CFD

Arrhenius apparent activation

Induction Period

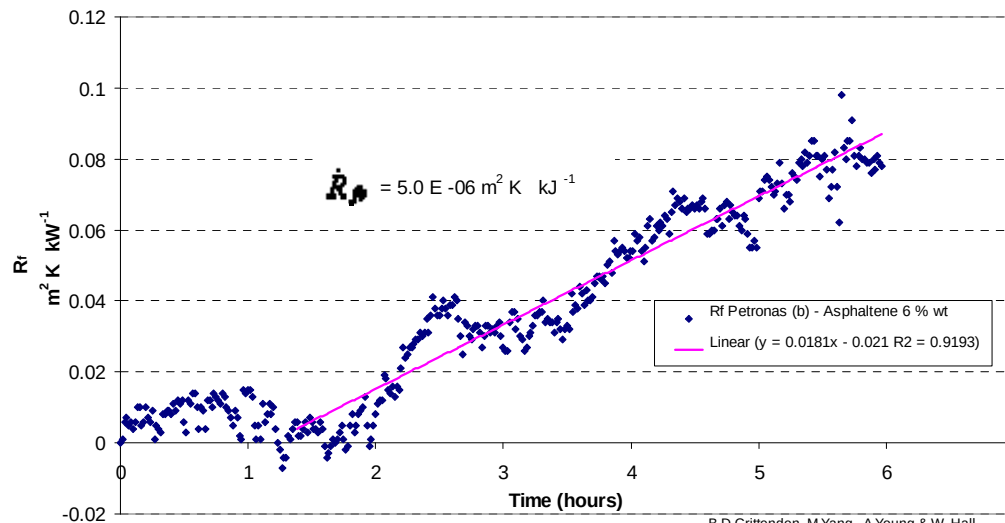
Compensation? Threshold?

EXAMPLE FOULING RUNS

Sample	Run hours	T _{wb} °C	Heat flux kW m ⁻²	rpm	T _{bulk} °C	dR _f /dt m ² K kJ ⁻¹ x10 ⁶
Petronas B	5	390	106	200	260	3.94
Petronas B	4	409	116	200	260	4.72
Petronas B	4	422	127	200	260	4.64
Petronas B	4	404	108	400	260	1.51
Petronas B	2	444	136	200	260	9.5
BP Orient	5	345	106	500	245	Not detected
ExxonMobil	6.6	327	106	300	260	Not detected
ExxonMobil	6	340	116	200	150	Not detected
ExxonMobil	4	385	106	500	260	7.4
ExxonMobil	1	404	116	500	260	13.8
Petronas-DS	4	309	63	600	240	Not detected
Petronas-DS	4	320	85	600	240	Very low
Petronas-DS	4	330	106	600	240	2.7

TYPICAL FOULING CURVE (PETRONAS B, ≈ 6 WT% ASPHALTENE)

(BP Rotterdam; Downey *et al*,1992) $\dot{R}_f = 3.5\text{E-}07 \text{ m}^2 \text{ K kW}^{-1}$,
 $t_{\text{wall}} = 260 \text{ }^\circ\text{C}$, Reynolds Number = 30000



<http://www.imperial.ac.uk/crudeoilfouling>
 20 February 2008

B.D.Crittenden, M.Yang, A.Young & W. Hall
 NB $t_{s0} \approx 375 \text{ }^\circ\text{C}$, $t_{b0} = 260 \text{ }^\circ\text{C}$
 Shear Stress $\approx 0.5 \text{ Pa}$

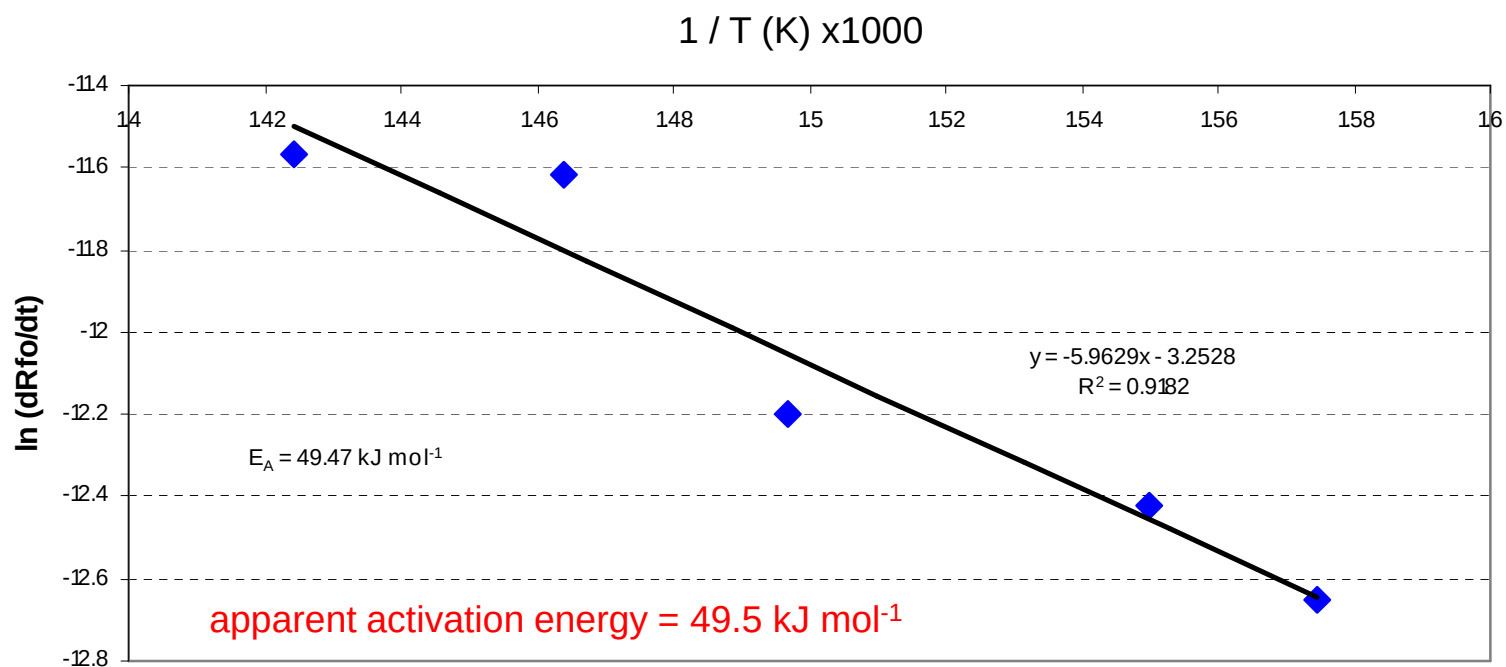
$$R_f = \left(\frac{T_s - T_b}{q} \right)_t - \left(\frac{T_s - T_b}{q} \right)_{t=0}$$

$$R_f = \left(\frac{T_{st} - T_{so}}{q} \right)$$



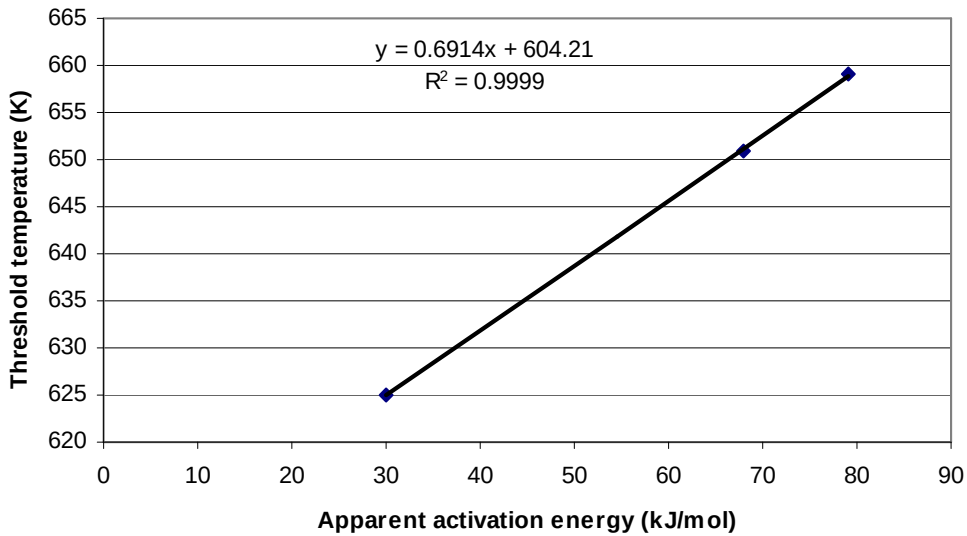
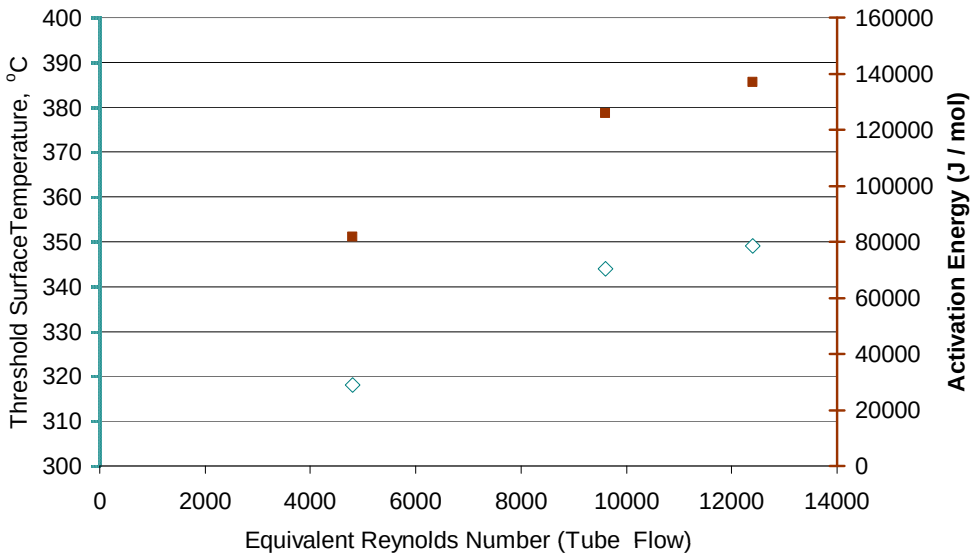
500 W & 200 rpm ($T_{s0} \approx 375 \text{ }^\circ\text{C}$; Reynolds Number = 12700)

ARRHENIUS PLOT FOR PETRONAS B (200RPM)



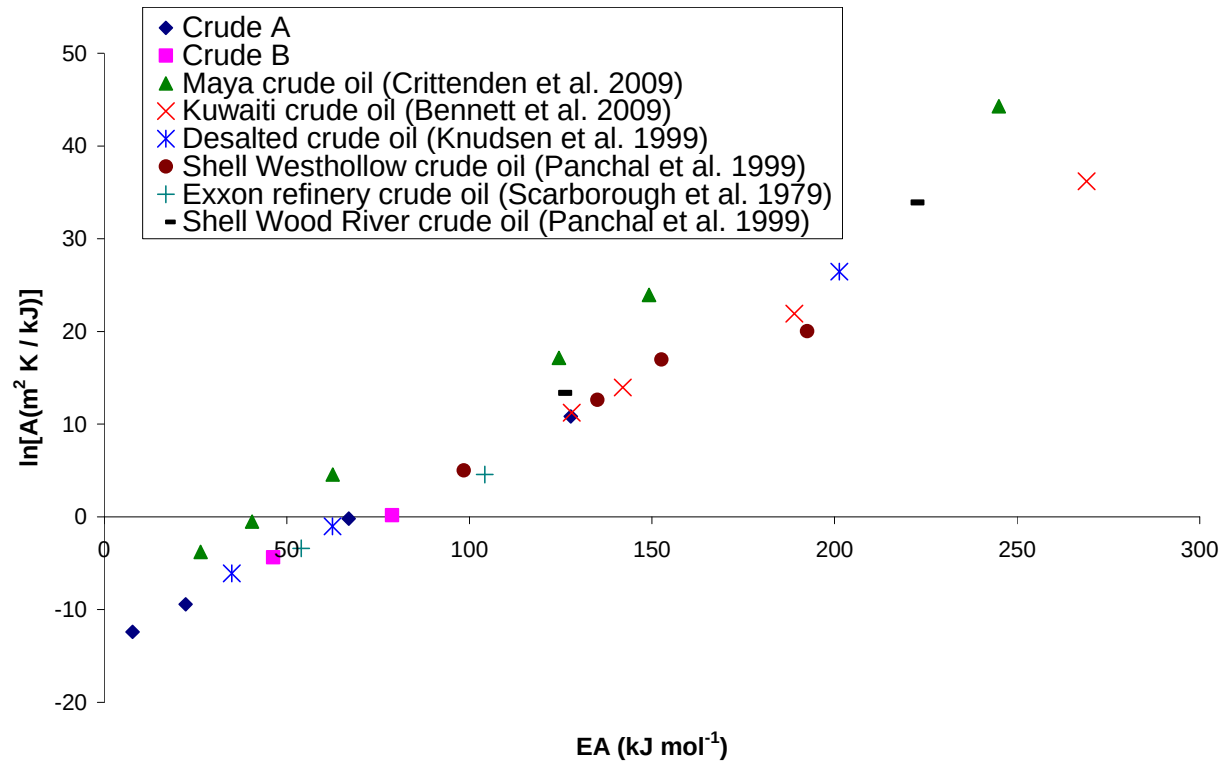
$$\ln (dR_f / dt) = A - E/RT$$

EXXONMOBIL: THRESHOLD CONDITIONS & APPARENT ACTIVATION ENERGY



COMPENSATION PLOT FOR ALL CRUDE OIL FOULING

$$\ln A = aE_A + b$$



Whether the effect is “true” or “false” is not known at present.

Crittenden B D, Kolaczowski S T, Takemoto T and Phillips D Z, Crude oil fouling in a pilot-scale parallel tube apparatus, J Heat Transfer Eng, 30: 777-785, (2009)

EFFECT OF SURFACE SHEAR STRESS

Sample A (Shear Stress Stepped 0.75 Pa to 2.5 Pa)

