VI. TASK 4 - CORRELATION DEVELOPMENT AND DATA REDUCTION

A. PHYSICAL PROPERTY MEASUREMENTS

The density and viscosity of the various waxes used in the present study were measured at different temperatures to better understand the role of physical properties in determining the hydrodynamic properties of these waxes. The physical properties of the different liquid media are also needed for correlation of data. It was not possible to measure the surface tension of the waxes and literature values for this property were used. Physical properties obtained from measurements made in the present study are compared with existing literature data in Table VI-1.

A.1. Density Measurements

Densities of the various liquid media were estimated by measuring the pressure drop across known heights of liquid in the 0.051 m ID glass column. The differential pressure (DP) cell (Validyne Model DP-15) was connected to the 0.051 m ID glass column so as to measure the pressure drop across the column. The column was filled with the test liquid up to a height of about 2.5 m (height was measured on a vertical scale placed along the column). The pressure drop was recorded for this height and some of the liquid was drained out and the pressure drop recorded again. This process was repeated for every 0.25 m drop in the liquid level. Measurements were first made using distilled water in order to calibrate the DP cell. The column was then preheated to the desired temperature and hot wax introduced into the column. The density for the wax at that temperature was obtained from the slope of the pressure drop versus height plot, after appropriate corrections for the calibration factor.

Results from the density measurements are included in Table VI-1.

Table VI-1. Physical properties of waxes.

Wax Type	Temp. (°C)	Density (kg/m^3)	Viscosity (mPa.s)	Surface Tension (N/m)	Reference
Krupp wax	200	723	3.0		Calderbank et al. (1963)
	230	705	2.2		
	260	694	1.6		
Paraffin wax	143	730	13.0	0.029	Deckwer et al. (1980)
	220	690	4.0	0.024	
	260	670	2.0	0.021	
FT-200 wax	149		4.4		Kuo et al. (1985)
	204		2.2		
	260	720	1.7	0.024	
FT-200 wax	150		4.4		This work
	200	712	2.8		
	230		2.4		
	265	675	1.9 *		
FT-300 wax	150		6.4		This work
	200	722	4.2		
	230	706	3.6		
	265	681	2.7 *		
SASOL's Arge wax	150		4.2		This work
	200	701	2.9		
	230		2.5		
	265	655	2.0 *		

* estimated from data at lower temperatures.

Table VI-1. Physical properties of waxes (contd.).

Wax Type	Temp. (°C)	Density (kg/m^3)	Viscosity (mPa.s)	Surface Tension (N/m)	Reference
MOBIL REACTOR WAXES					
Run CT-256-4	149		6.1		Kuo et al. (1985)
	204		4.3		
	260		3.4	0.026 - 0.027	
Run CT-256-5	149		17.6		Kuo et al. (1985)
	204		8.5		
	260		5.5	0.028	
Run CT-256-7	149		8.2		Kuo et al. (1985)
	204		4.1		
	260		2.3	0.026 - 0.027	
Run CT-256-8	149		13.1		Kuo et al. (1985)
	204		6.8		
	260		-	0.026 - 0.027	
Run CT-256-9	149		5.7 - 7.5		Kuo et al. (1985)
	204		3.1 - 4.0		
Run CT-256-11	149		6.1 - 6.7		Kuo et al. (1985)
	204		3.2 - 3.7		
Run CT-256-4	150		9.1		This work
CT-256-7	200		5.5		
composite	230		4.5		
	265		3.9 *		
Run CT-256-5	150		13.9		This work
CT-256-8	200		7.3		
composite	230		5.7		
	265		3.9 *		
Run CT-256-9,	150		6.6		This work
CT-256-11,	200	716	3.8		
CT-256-12	230		3.1		
composite	265	674	2.3 *		

* estimated from data at lower temperatures.

These values are in good agreement with densities for different waxes reported in literature (Calderbank et al., 1963; Deckwer et al., 1980; Kuo et al., 1985). Calderbank et al. used a pyknometer to measure densities, while the procedure used by other workers is not known. The effect of temperature on density is as expected, i.e. density increases as temperature is decreased. These results also show that the different types of waxes have similar densities (between 655 and 694 kg/m^3 in the temperature range 260-265°C).

A.2. Viscosity Measurements

Viscosity measurements were made in a Brookfield viscometer (LV series, 2.5X) using a cylindrical spindle (SC4-18) operating at 60 RPM. A Brookfield Thermosel system allowed measurements up to temperatures of 250°C. The measurements were made in the temperature range 150-230°C and the wax viscosity at higher temperatures was estimated from data at lower temperatures assuming Arrhenius type of dependence of viscosity with temperature. The system was first calibrated using fluids of known viscosities. Three fluids were used: water (0.89 mPa.s), and two viscosity standards (5.1 and 8.9 mPa.s - supplied by Brookfield). The standards were used before and after viscosity measurements with waxes to prevent errors due to device drift. Each measurement required a 8 ml sample of the test fluid.

Results obtained from these measurements are presented in Table VI-1 along with data from literature. Calderbank et al. (1963) measured viscosity of Krupp wax with an Ostwald viscometer (capillary type). Other workers (Deckwer et al., 1980; Kuo et al., 1985) did not provide information on experimental methods used to determine physical properties.

Comparison of data obtained with the same type of wax is possible only for FT-200 and some of Mobil's reactor waxes. Values of viscosity of the FT-200 paraffin wax obtained in this study and Mobil's study (Kuo et al., 1985) are in good agreement at low (~150°C) and high (~260°C) temperatures, whereas the agreement is less than satisfactory at intermediate temperatures (~200°C). Viscosities of the composite Mobil reactor wax from runs 4 and 7 are consistently higher than values reported by Kuo et al. for either run 4 or run 7 waxes, whereas viscosities of the composite, from runs 5 and 8, are between values reported by Kuo et al. for waxes from the two runs. Viscosities of the composite from runs 9, 11 and 12 are in good agreement with values reported by Kuo et al for waxes produced in runs 9 and 11. Kuo et al. reported values of viscosity of wax samples produced at different times during a given run. In Table VI-1 only the lowest and the highest values obtained during the entire run are listed.

A.3. Surface Tension

The surface tension of different waxes was not measured in the present study. However, from the data reported in literature it may be concluded that different waxes have similar values of surface tension (e.g. compare results of Deckwer et al., 1980; and Kuo et al., 1985; shown in Table VI-1).

The data summarized in Table VI-1 show that physical properties of different waxes at a given temperature are similar. In particular there are no significant differences in physical properties between the paraffin and the reactor waxes at higher temperatures (260-265°C).