Model of water – oil separation in the oil zone of wash tank separators

Thierry Palermo*, Anne-Laure Bouthier, Benjamin Brocart, Jean-Philippe Lebrun

TOTAL – Avenue Larribau – 64018 Pau – France
(corresponding author: thierry.palermo@total.com)*

Wash tanks are very large liquid – liquid gravity separators generally installed on onshore oil production sites or in refineries. In order to reduce size and weight of separation modules on the topsides of FPSO's (Floating Production Storage and Offloading units), and to benefit from the hull capacity, TOTAL is considering the installation of wash tank units in FPSO's hull for new developments as modules for water-in-oil separation and desalting.

Inside a wash tank, the entering water-in-oil emulsion is injected at the bottom of the tank. The emulsion globules (more than 1 cm in diameter) composed of an oil continuous phase containing fine water droplets then rise through the water leg to the water-oil interface where they coalesce with the oil phase. The oil zone can be represented, close to the interface, by a dense packed zone (DPZ), and upper, by a diluted emulsion zone. In the oil zone, water droplets coalesce to form large droplets that can move down oppositely to the oil phase and coalesce with the water leg.

In order to optimize the design of wash tanks, particularly in terms of maximum rising velocity of the oil phase, a pilot loop has been built. It is mainly composed of a vertical temperature controlled column (height = 6 m, diameter = 10 cm). The water-in-oil emulsion is formed thanks to a dynamic mixer and is injected at the bottom of the column under constant flow rate conditions.

Modelling of liquid-liquid separation in a vertical gravity settler has been reported in reference [1]. Unfortunately, attempts in using this model showed that some assumptions were too severe to correctly interpret our data. Particularly, slipping velocity between the water droplets and the oil phase was neglected. A simple mass balance model, including coalescence phenomena has therefore been developed to predict the quantity of water in the oil zone as a function of the height.

Each class of droplet is referred to the index i corresponding to a droplet volume V_i. Successive classes are defined in such a way the droplet volume ratio obeys:

$$d_i, d_{i+1} \rightarrow \frac{V_{i+1}}{V_i} = 5 \qquad (1)$$

The droplet velocity U_i of class i is given by:

$$U_i = U_{st}(1-\phi)^{5.3} - U_c \qquad (2)$$

where ϕ is the volume fraction of water dispersed in oil (BSW), U_{st} the Stokes velocity and U_c the superficial velocity of the oil phase. According to eq. (1), we consider that a droplet of class i that coalesces with a droplet of class j with j<I, remains in class i. Only coalescence between droplets of class (i-1) lead to a droplet of class i. With such an assumption we can write the coalescence Kernel as:

$$\left.\frac{d\phi_i}{dt}\right|_{coal} = \sum_{n=1}^{i}\left(K_{i,n}.\phi_i.\phi_n\right) - \sum_{n=i}^{i_{\max}}\left(K_{n,i}.\phi_i.\phi_n\right)$$

$$i \neq n \rightarrow K_{i,n} = \alpha\left(1+\frac{d_n}{d_i}\right)^3 \qquad (3)$$

$$K_{i,i} = \tfrac{1}{2}\alpha\left(1+\frac{d_i}{d_i}\right)^3$$

Finally, coalescence between droplets and the water leg is controlled by the following equation:

$$U_i = \beta(U_{st} - U_c) \qquad (4)$$

The two parameters α and β characterize the coalescence efficiency for a given system. An example of result is presented below.

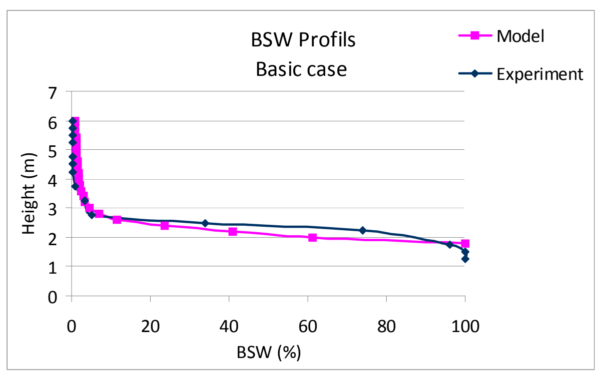

Fig. 1. BSW along the column. Inlet conditions: BSW = 30%, salted water dispersed in a crude oil; oil superficial velocity = 1.8 m/hr; mean droplet diameter = 110 µm.

By matching α and β parameters on one experiment, it is then possible to estimate the maximum oil velocity for which the outlet BSW would become larger than specifications.

Reference

[1] Berman, Y, Tamir, A. , The Can. J. of Chem. Eng., Vol. 79, June 2001.