Deformation and Detachment of Crude Oil Droplet in the Presence of Different Concentration of Surfactant from Solid Substrate

Amar Kumar[1], Amit Kumar Gupta[2]

[1,2]Chemical Engineering department, BIT Sindri Dhanbad

Abstract— *Previously the deformation and detachment of carbon tetrachloride droplet was studied in presence of different concentration of surfactant from solid substrate and it was found that carbon tetra chloride droplet detached partially. Now the work has been carried forward and deformation and detachment of crude oil droplet in the presence of different concentration of surfactant from solid substrate is studied also the effect of temperature on the deformation and detachment of crude oil is observed.*

Keywords— Droplets, Detachment, Deformation, Crude Oil, Surfactant.

I. INTRODUCTION

SCHLEIZER A.D. AND ROGER BONNECAZE R. T (1998) explained the dynamic behaviour and stability of a two-dimensional immiscible droplet subject to shear or pressure-driven flow between parallel plates was studied under conditions of negligible inertial and gravitational forces. The droplet is attached to the lower plate and forms two contact lines that are either fixed or mobile. The boundary-integral method was used to numerically determine the flow along and dynamics of the free surface. For surfactant-free interfaces with fixed contact lines, the deformation of the interface was determined for a range of capillary numbers, droplet to displacing fluid viscosity ratios, droplet sizes and flow type. FENG.J.Q. AND BASARAN O.A. (1994) described Steady states of a translationally-symmetric cylindrical bubble protruding from a slot in a solid wall into a liquid undergoing a simple shear flow were investigated. Deformations of and the flow past the bubble were determined by solving the nonlinear free-boundary problem comprised of the two-dimensional Navier-Stokes system by the Galerk infinite element method. Under conditions of creeping flow, the results of finite element computations were shown to agree well with asymptotic results. When the Reynolds number *Re* is finite, flow separated from the free surface and a recalculating eddy was formed behind the bubble.

DIMITRAKOPOULOS P. *AND HIGDON J.J.L (2000) described* the yield conditions for the displacement of three-dimensional fluid droplets adhering to a plane solid boundary in pressure driven flows which were studied through a series of numerical computations.

DING H. AND SPELT P.D.M. (2007) investigated the critical conditions for the onset of motion of a three-dimensional droplet on a wall in shear flow at moderate Reynolds number. A diffuse-interface method was used for this purpose, which also circumvents the stress singularity at the moving contact line, and the method allowed for a density and viscosity contrast between the fluids. SPELT P.D.M. (2006) described that when the numerical simulations were presented to shear flow past two-dimensional droplets adhering to a wall, at moderate Reynolds numbers. The results were obtained using a level-set method to track the interface, with measures to eliminate any errors in the conservation of mass of droplets. First, the case of droplets whose contact lines are pinned is considered. Data are presented for the critical value of the dimensionless shear rate (Weber number, We), beyond which no steady state was found, as a function of Reynolds number, Re. We and Re are based on the initial height of the droplet and shear rate.

LI X. AND POZRIKIDIS C.(1995) elucidated the hydrostatic shape, transient deformation, and asymptotic shape of a small liquid drop with uniform surface tension adhering to a planar wall subject to an over passing simple shear flow which were studied under conditions of Stokes flow. *KANG*1 Q. *ZHANG*2 D. *AND CHEN S.*(2005) explained the displacement of a three-dimensional immiscible droplet subjected to gravitational forces in a duct was studied with the lattice Boltzmann method. The effects of the contact angle and capillary number (the ratio of viscous to surface forces) on droplet dynamics are investigated. It was found that there exists a critical capillary number for a droplet with a given contact angle.

Oil droplets used in this experiment is of crude oil and water is used as shearing fluid and properties of crude oil are given below in table number 1.

TABLE 1
PROPERTIES OF CRUDE OIL

Material	Density ρ(15.5°C) (kg m^{-3})	Viscosity μ (cp)at 30°C	Oil-water interfacial tension, (mN m^{-1})
Crude oil	855.60	525	27

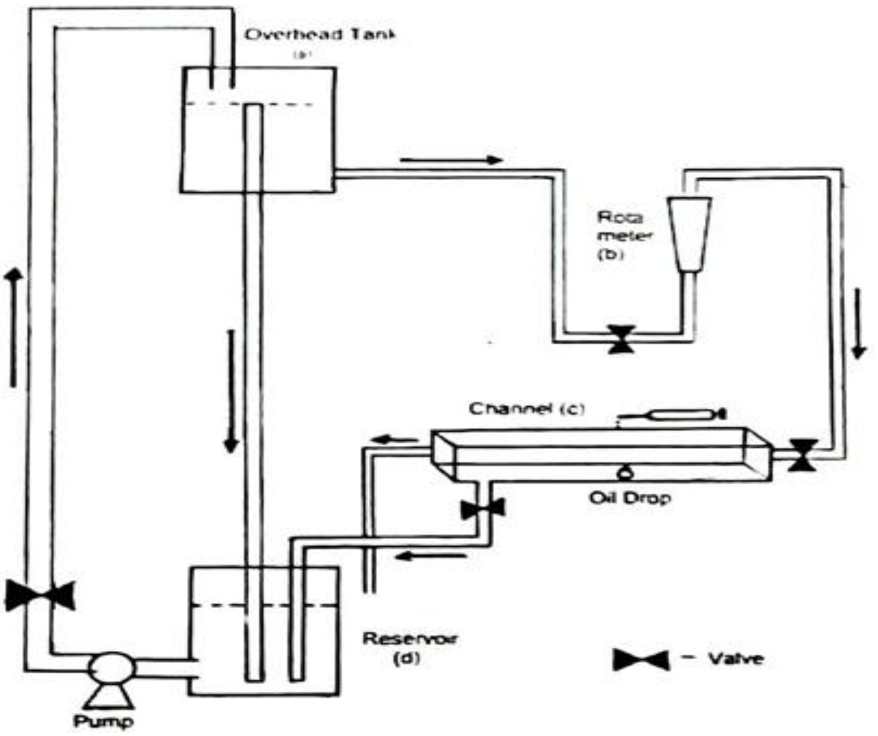

FIG.1. DIAGRAM EXPERIMENTAL SETUP USED FOR OIL DROP DETACHMENT

II. EXPERIMENT

This experimental setup is used for the visualization of droplet deformation and detachment by shear force. Diagram of experimental setup is given in figure 1. Overhead (a), field with water as a shearing fluid is installed at a constant height of 10 ft. the shearing fluid from this tank is made to flow on the required channel (c) made of silicate glass, through the rotameter (b). The channel dimensions are, and its dimension was such in comparison of size of oil droplets (0.5-3ml), that the effect of side walls, entry and exit length may be neglected. The range of flow in rotameter used is 0-100 lit/min and dimension of the channel which is 0.1 m (dia) resulted in maintaining laminar flow of the shearing force during the experiment. The test section (c) is made of silica glass which is molecularly smooth and preferentially wetted by water. A hole of 50 mm diameter is located on the top of the channel and hear the half the length of the test section (channel) to release oil droplets on the bottom wall of the channel. The whole is covered with a lid during experiment so that the water does not spill out and no disturbance is created in the flow pattern of aqueous phase inside the test section. The loop is being flushed throughout the flow system, to check any leakage or bubble formation and anomalies if any, which is checked and corrected. A emersion rod is place in the upper tank of the system. Once the flow system became stable, a dimensional oil drop is placed in the channel through the lid provided on top of the channel. The oil drop is allowed to settle down for at least 10 min, so the oil droplets properly adhere to the solid surface. Once the contact angle of the droplet becomes constant, the lid is closed and the valves are opened slowly, and the rotameter reading gives the value of flow rate of the aqueous shearing force. The flow rate of shearing fluid gives the result of the amount of force and velocity required for drop detachment. The oil drop detachment from the solid surface is noted by visual methods.

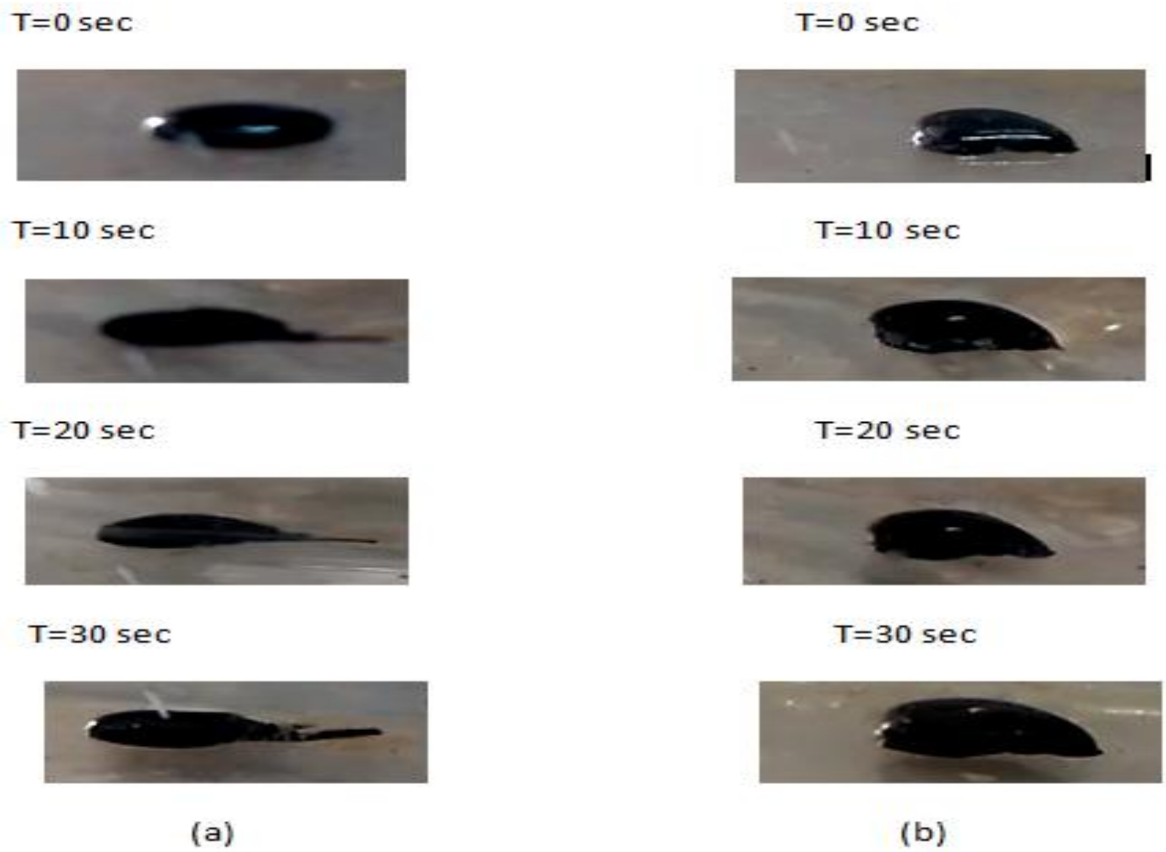

FIG.2 DEFORMATION OF 0.5 ML DROPLET WITH TIME (A) WITHOUT SURFACTANT (B) WITH SURFACTANT

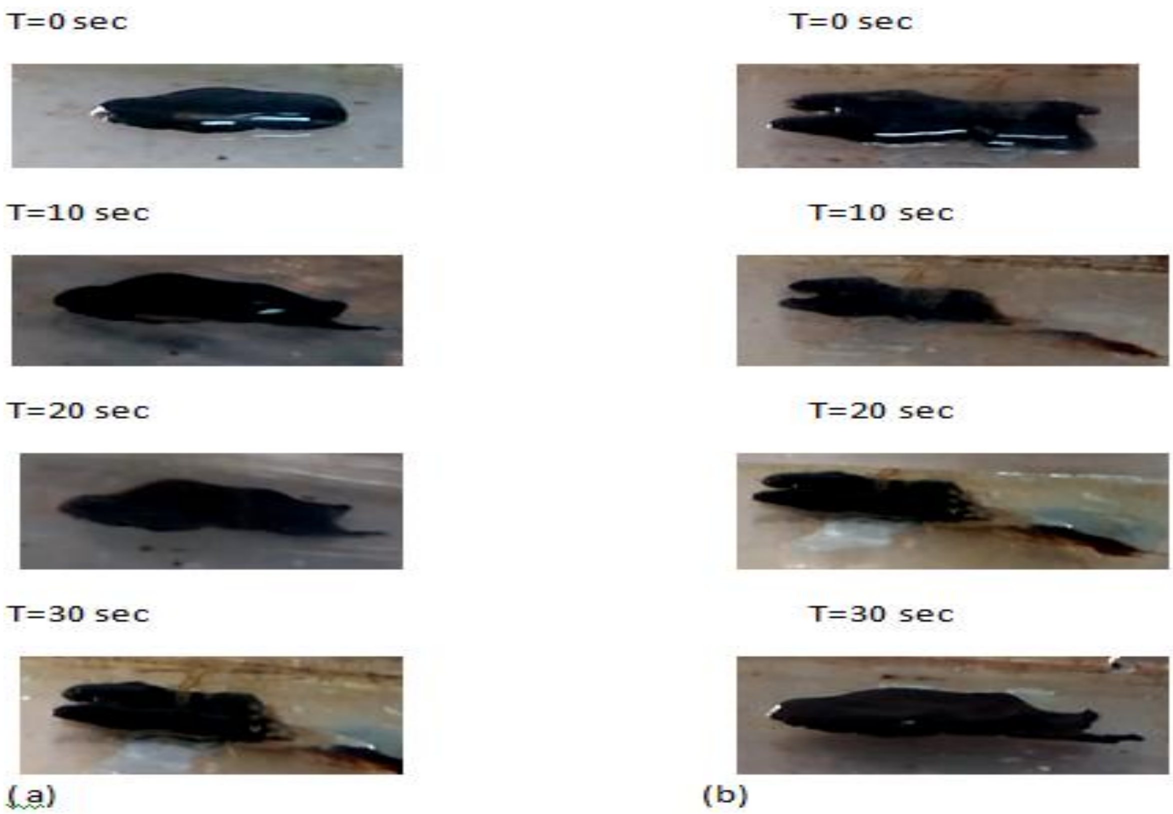

FIG.3 DEFORMATION OF 2 ML DROPLET WITH TIME (A) WITHOUT SURFACTANT (B) WITH SURFACTANT

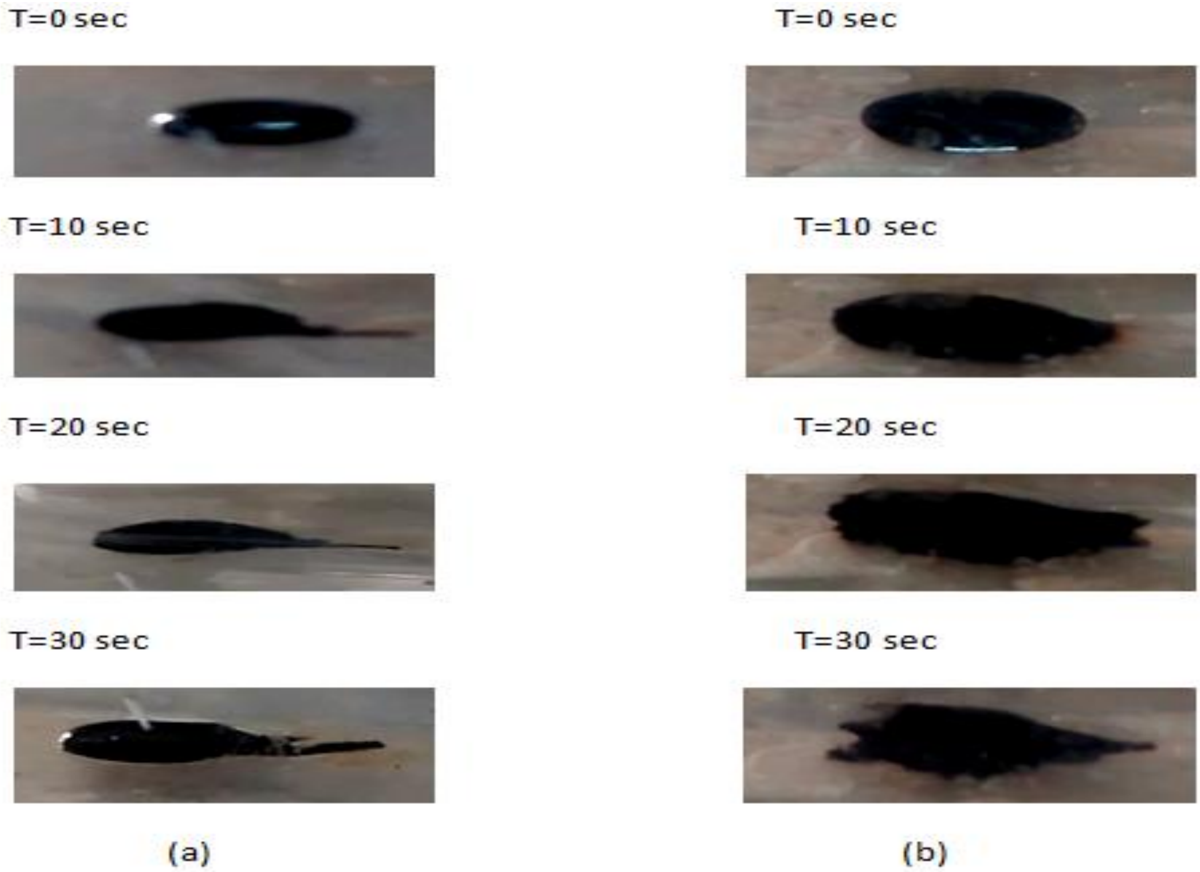

FIG. 4 DEFORMATION OF 0.5 ML DROPLET WITH TIME IN THE ABSENCE OF SURFACTANT (A) AT TEMPERATURE 260C (B) AT TEMPERATURE 320C

III. RESULTS

Figure 2 and 3 show the deformation of 0.5 ml and 2ml crude oil droplet without and with the presence of surfactant It shows the adverse effect of surfactant on the deformation of crude oil. Surfactant concentration is more on the surface of droplet compare to inside of droplet. Because of surfactant concentration gradient the deformation of droplet is less compare to deformation of droplet without surfactant Figure 4 shows the deformation of 0.5 ml crude oil droplet at temperature 26 and 32 ^{0}c. With the increase of temperature interfacial tension between fluids becomes less. That's why deformation of crude oil droplet at 32^{0}c is more compare to droplet at temperature 26^{0}c.

IV. CONCLUSION

Results show that temperature put effect significantly on the deformation and detachment of different sizes of crude oil droplets. Temperature reduces interfacial tension between droplet and water. That's why droplet detaches easily. Surfactant also reduces interfacial tension but due to surfactant concentration gradient, droplet deforms hardly.

REFERENCES

[1] Dimitrakopoulos P. and Higdon J.J.L .2000. On the displacement of three-dimensional fluid droplets adhering to a plane wall in viscous pressure-driven flows. J. Fluid Mech. 435, 327-350.
[2] Ding H. and Spelt P.D.M and Shu Chang. 2007. Diffuse interface model for incompressible two-phase flows with large density ratios. J. Computational Physics 226, 2078–2095.
[3] Feng, J. Q. and Basaran, O. A. 1994. Shear flow over a translationally symmetric cylindrical bubble pinned on a slot in a plane wall. J. Fluid Mech. 275, 351-378.
[4] Kang, Q. Zhang, D. and Chen S. 2005. Displacement of a three dimensional immiscible droplet in aduct. J. Fluid Mech. 545, 41-66.
[5] Li, X. and Pozrikidis, C. 1996. Shear flow over a liquid drop adhering to a solid surface. J. Fluid Mech. 307, 167-190.
[6] Schleizer Anthony d.and Bonnecaze Roger t. 1998. Displacement of a two-dimensional immiscible droplet adhering to a wall in shear and pressure-driven flows. J. Fluid Mech. 383, 29-54.
[7] Spelt P.D.M . 2006. Shear flow past two-dimensional droplets pinned or moving on an adhering channel wall at moderate Reynolds numbers: a numerical study. J. Fluid Mech. 561, 439-463.