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SNAP-OFF OF DENSE NONAQUEOUS PHASE LIQUID DROPS IN WATER SATURATED PORES

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INTRODUCTION

The generation of discrete drops in immiscible two phase flow is interested in their applications to oil recovery and hazardous waste management[1]. The fundamental mechanism associated with the formation of discrete drops is called "snap-off". This is related to the instability of an immiscible fluid as it moves through a water wetted constriction in the porous material. When immiscible fluid emerges from the constriction into the larger part of the channel, the water-fluid interfacial forces are such that a leading portion of the fluid may separate into a drop[2]. The snap-off of a Water-density Equivalent Nonaqueous Phase Liquid (WENAPL) drop occurs in the neck of the constriction and seems to depend on only the geometry of the pore. While the snap-off of a Dense Nonaqueous Phase Liquid (DNAPL) drop would depend on both properties of DNAPL (density, interfacial tension, etc.) and geometry of the pore. The goal of this study is to illuminate experimentally such dependencies of the snap-off of DNAPL drops in water saturated pores.

EXPERIMENTAL APPARATUS AND PROCEDURES

Figure 1 shows the system of experimental set-up. Measurement instruments consist of a Microscopic Video Camera equipped with zoom and close-up lenses. The output of the transducer is analyzed by a Compact Micro Vision System (Hi-scope) before being sent to a Video Color Monitor. The combined images are recorded in floppy disks by a Video Floppy Recorder, thus a record of the size and shape of the DNAPL-water interface along with the process is obtained. Water pores are built of glass beads packed in water filled triangle angular tubes (Fig. 2). Three sizes of glass beads (D = 1, 0.7 and 0.5 cm) are used to produce three different pore systems. DNAPLs taken for experiments are trichloroethylene (TCE) and tetrachloroethylene (PCE). To make clear the importance of interfacial tension, pure and colored TCE/PCE are used. Both TCE and PCE are colored with an organic dye (Fat Red). The density and interfacial tension of sample liquids are determined by drop test. The densities are almost the same for both pure and colored liquids, but the interfacial tension differs from each other. Experiments are conducted in temperature control room maintained at about 20°C. Sample liquid is added into constriction of the pore by means of syringes. Great care is made so that the DNAPL penetrates quite slowly through the constriction. When the equilibrium, beyond which the instability will initiate and permit snap-off, of the interface is attained, liquid supply does not continue. To determined the equilibrium position, a lot of trials have been initially done for each test. Efforts are also motivated to photograph the moment of choking drop.

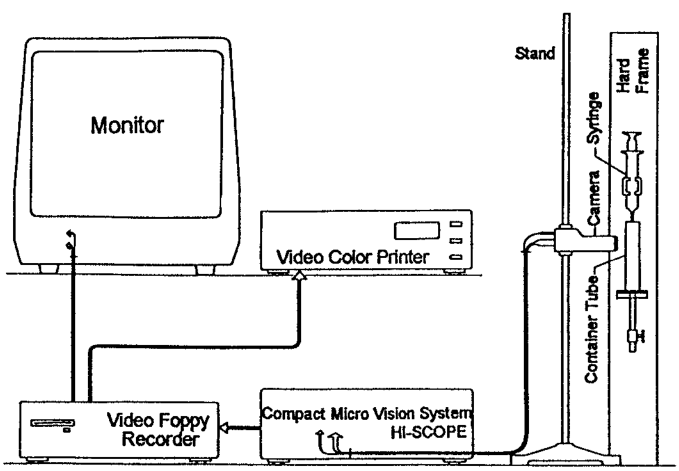

Fig. 1. Schematic Diagram of Experimental Set-up

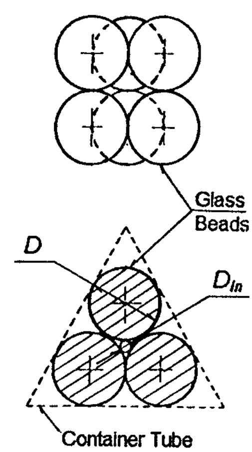

Fig. 2. Structure of Testing Pore

Keywords: Snap-off, dense nonaqueous phase liquid (DNAPL), water saturated pore, interface, interfacial tension.
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RESULTS

The advance of DNAPL and snap-off process are recorded as in Fig. 3. The protruding DNAPL-water interface is observed not spherical like that in the case of a WENAPL. This clearly reflects the effect of gravitational force, which makes the interface elongated. The snap-off observedly occurs within few minutes since the equilibrium attained. It does not necessarily appear in the neck of the constriction, but at a considerable distance below the neck in most of the cases (Fig. 3g). The dependence of snap-off on the interfacial tension σ is depicted, through the change of snap-off drop diameter D_{eq} as varying interfacial tension σ, in Fig.4 and Fig.5. Similarly, the dependence of snap-off, through the variation of D_{eq}, on the geometrical conditions can be shown in Fig.4 and Fig. 6. D_{in} is the diameter of the circle inscribing the neck of constriction (Fig.2). In Fig.5, α is angle inclined against horizontal of the surface containing the neck of constriction.

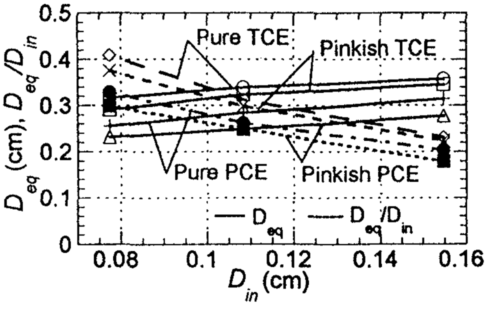

Fig. 4. Variation of Snap-off Drop Diameter D_{eq}

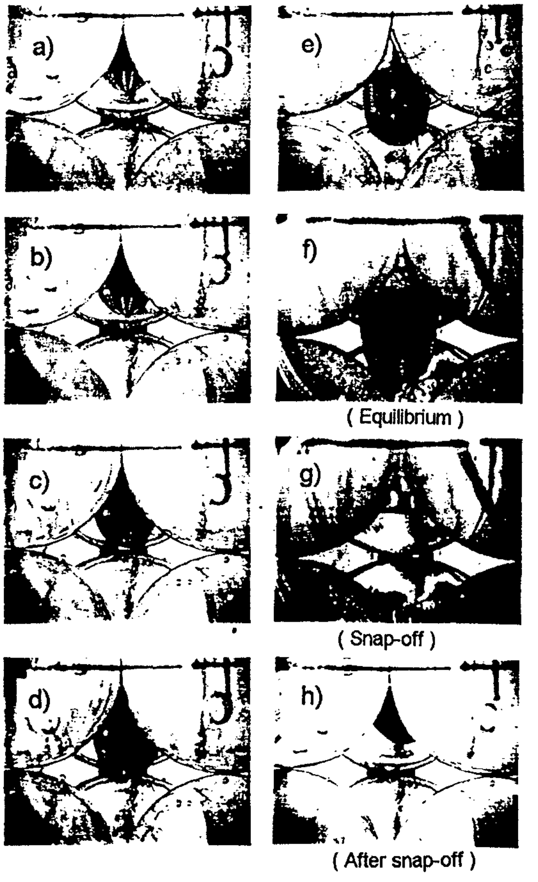

Fig. 3. Photographs of Protruding TCE through a Saturated Pore (Glass beads diameter, D = 1 cm)

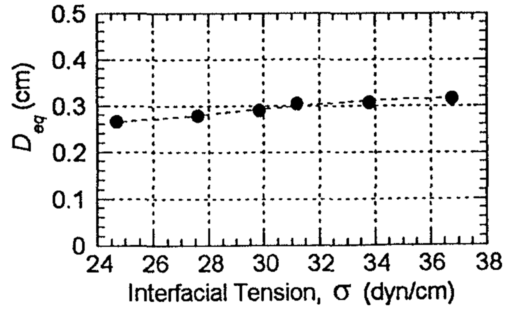

Fig. 5. Dependence of D_{eq} on σ (case D = 0.5cm)

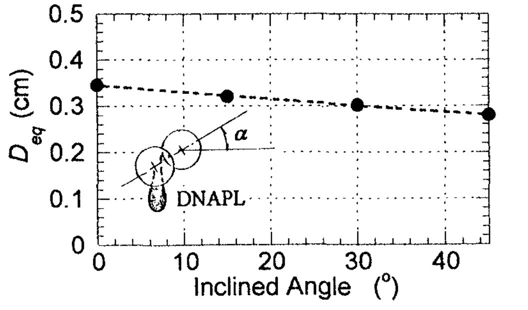

Fig. 6. Dependence of D_{eq} on α (case D = 1.0cm)

CONCLUSIONS

The snap-off of DNAPL drops in single water saturated pores were experimentally studied. Due to the effect of gravitational force the snap-off occurs unconditionally in short time after the equilibrium state of interface is attained. Quantity of snap-off depends on properties of the liquid, e.g., density and interfacial tension, and the geometry of the pores.

REFERENCES

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