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SAFFMAN-TAYLOR INSTABILITY IN A LIQUID-LIQUID DISPLACEMENT FLOW INCLUDING NON-NEWTONIAN EFFECTS

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Abstract. *Viscous fingering in non-Newtonian fluids in a rectangular Hele-Shaw cell was investigated numerically and experimentally. Visualization experiments were performed using Xanthan Gum and a Newtonian mineral oil. The channel, made of transparent glass, is 150mm wide and 700mm long, and the gap between the glass plates is 0.70mm. A digital camera is used to capture images of the interface between the fluids during the flow. The interface shape is given for different values of flow rate and viscosity ratio. The main parameters that govern this flow are the viscosity ratio, the rheological capillary number, and the (dimensionless) flow rate. The Reynolds number is kept low for all cases investigated, to ensure negligible inertia.*

Keywords: *Hele-Shaw cell, Invasion and drilling fluidl, Viscous fingering.*

1. INTRODUCTION

Designing drilling fluids which can guarantee minimum invasion into the reservoir rock is a must for open hole completion wells. The industry has proposed several ideas to deal with the problem, most of them based on adding bridging agents to the fluid formulation. Such agents would block pores near the well bore and, consequently, prevent additional fluid to invade the rock, but often require acid treatment for their removal. Thus in this work we studied the displacement of fluids in porous media using Hele-Shaw. Specifically, a fluid non-Newtoniano displacing a fluid Newtoniano through a Hele-Shaw cell. As from this experiment is possible to observe the Saffman-Taylor or viscous fingers instability occurs when one fluid pushes a more viscous one. The interface between the fluids may become unstable, leading to the formation of fingerlike patterns. Figure 1 illustrates a schematic diagram of the displacement flow in a Hele-Shaw cell and gives the cell dimensions in millimeters. This phenomenon is very important in many applications, for exemple: displacement of heavy crude oil reservoirs, drilling fluid invasion through poruos media, fracture conductivity, polymer processing, hydrology and filtration.

The Saffman-Taylor instability has been extensively studied for Newtonian fluids . For gas-displaced non-Newtonian liquids (zero viscosity ratio), a large number of articles is also found in the literature. Yamamoto studied the growth phenomenon of viscous fingering which repeat three patterns: spreading, splitting and shielding. Chevalier et al. investigated the effects of inertia on the width of the viscous fingers. Amar and Poiré simplified the Hele-Shaw cell into a two-dimensional problem. Displacement flows involving two liquids of comparable viscosity, however, have received very little attention.

The cell was filled with a Newtonian mineral oil and then an aqueous solution of xantathan gum 86% is injected into the cell, thus displacing the Newtonian liquid. A digital camera is used to capture images of the interface between the fluids during the flow. The evolution of the interface shape is obtained for different dynamic and rheological parameters. From tracing the shape of the interface, was determined the displacement efficiency. Thus, it was defined the spectrum of situations in which there is formation of fingers and plugs relating to displacement of a mineral oil by xanthan gum.

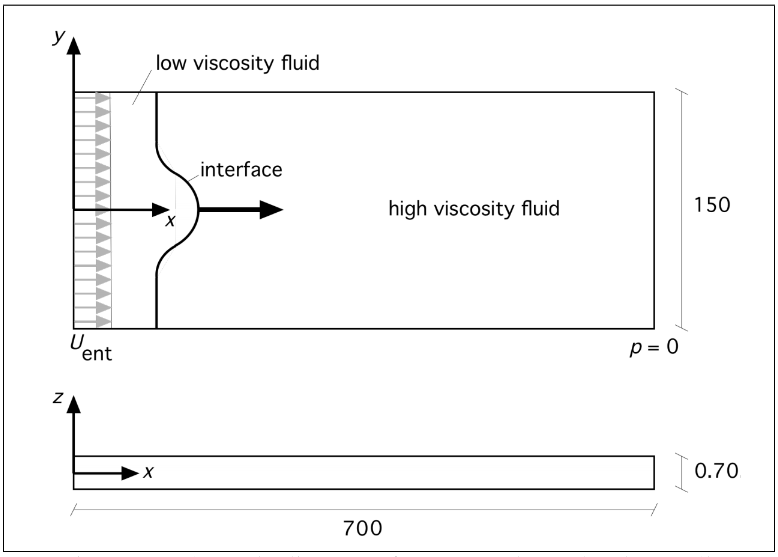

Figure 1. Schematic diagram of a rectangular Hele-Shaw cell.

2. EXPERIMENTAL ANALYSIS

The visualization experiments were performed to investigate the phenomenon of viscous fingering during the displacement a less viscous Newtonian oil by of xanthan gum solutions flowing through a Hele-Shaw cell. The interface shape is recorded as it proceeds along the cell. Different flow rate values are investigated to determine the conditions under which fingering occurs. The flow curves of the non-Newtonian solutions were determined with the aid of a rotational rheometer, and a shear thinning behavior was observed. The power-law viscosity function was employed to fit the data.

Rheological tests to obtain the behavior of the xanthan gum were performed. It was observed that the xanthan gum has a pseudoplastic behavior, since the viscosity decreases with shear rate. The power-law viscosity function was used for an adjustment of the stress curve and thus obtain the rheological parameter settings (Figure 2).

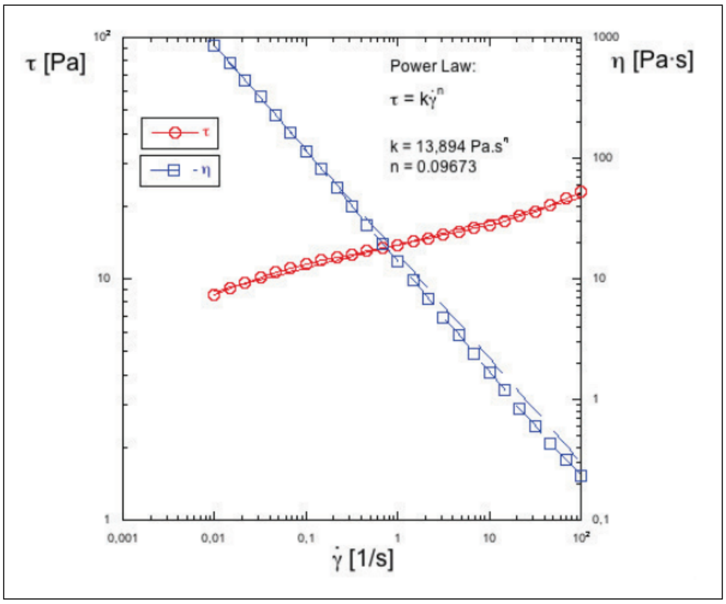

Figure 2. Rheology of the xanthan gum.

Figures 3 and 4 depict the flow visualization apparatus. For all cases investigated, the Reynolds number was kept low enough to ensure negligible inertia.

Figure 3. Experimental setup.

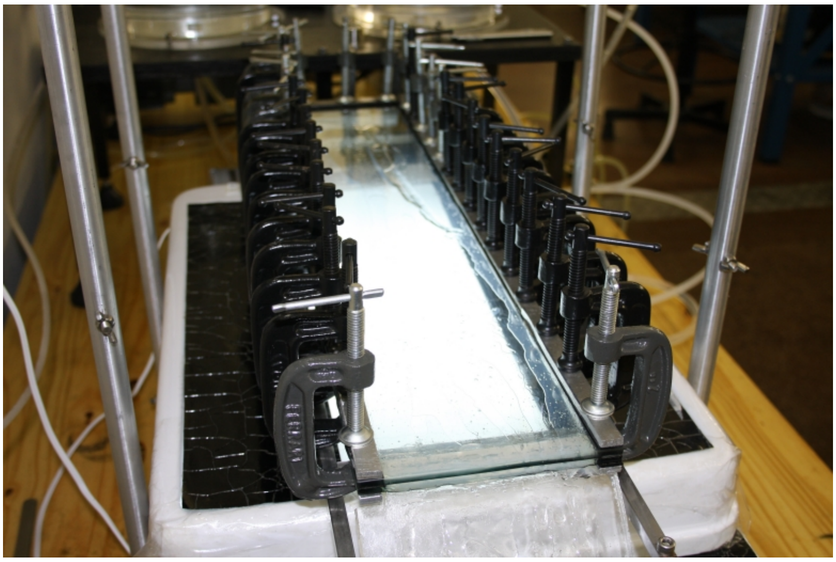

Figure 4. The Hele-Shaw cell apparatus.

A systematic study of the influence of the parameters that govern this flow is under way, and its results will be presented at the conference. In general, it was already observed that the displacement efficiency increases with the viscosity ratio, while decreasing with the flow rate.

3. ACKNOWLEDGEMENTS

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