

The proposal “Foam control using a fluidized bed” is of interest for all foaming reactors, including those used in refining. The reactor and methods used in these studies also present new approaches to problems of production associated with

1. In-situ foaming
2. Proppant transport using foams
3. Underbalanced drilling using foam

IN-SITU FOAMING. In many applications you would like to block a high permeability crack so as to get a fluid preferentially into a lower permeability (less damaged) crack. One way to do this is by *in situ* foaming; the gas and liquid surfactant are injected through separate conduits and foamed downhole.

José Guitian and I found a criterion for foaming. If gas and liquid are injected continuously with superficial velocities U_g and U_l , respectively, then there is a critical condition

$$U_l = aU_g + b \tag{1}$$

for foam formation. If you fix U_l the reactor will not foam for low U_g and will foam when U_g is increased by the value given by (1). The more gas you put in, the greater is the amount of foam. You can stop foaming by fixing U_g and increasing U_l above the value given by (1). In general, to get a surfactant to foam you have to shake it up; even detergent in water won't foam unless you stir it.

In our video you could see that we can make foam in a fixed bed according to (1). The fixed bed is formed by spheres too heavy to fluidize. Probably you could foam a sand pack in this way.

Experiment 1. Try to determine a critical condition like (1) for foaming a sand pack

First we inject water plus surfactant; then we increase the gas flow until foam appears. This is an option for foam production which could find applications for proppant transport and possibly secondary recovery.

The advantage of *in situ* foaming is that it is easier to inject gas and water separately and produce foam in place than to mix and transport the

foam to place. A technology for *in situ* foaming requires separate liquid and gas lines.

ACIDIZING IN SITU. We want to block the more permeable undamaged cracks with foam so that we acidize the damaged cracks. Here is the plan. Flood the reservoir with surfactant and water. Then inject gas fast enough to foam; the most conductive cracks will foam first. Then the acid will flow into the less conductive (damaged) cracks. Maybe this is a better way to foam an undamaged crack.

EXPERIMENT ON THE SELECTIVE FOAMING OF CRACKS. Here is one kind of experiment we can do; it is described in the caption of Figure 1.

IN SITU FOAMING FOR DOWNHOLE CLEANING IN HORIZONTAL DRILLING. It should be easier to pump liquid and gas to the bit separately than as a foam. We should use the technology that is used now as much as possible. As I see it, the main problem is how to pump in the gas. One idea is to use an annular drill string, or a drill string with an auxiliary gas line. I don't know what would be best but different ideas could be proposed and tested with cheap experiments before going to the fields.

PROPPANT TRANSPORT AND UNDERBALANCED DRILLING USING FOAMS. Our foaming reactor already simulates some properties of foam drilling muds in vertical holes. With GPRI funding I would construct an apparatus of similar type that could be tilted to study particle transport in deviated holes. We are going to use those slit see-through devices which encourage us to believe by seeing. Tilt slit devices are good models for cracks in reservoirs. Crucial to these applications is the modification of the slit reactor to allow for continuous injection of particles at controlled rates, simulating the injection of cuttings at the drill bit. An important quantity to understand and measure when particles are continuously injected is the solids hold-up. The performance of any multiphase flow in conduits is controlled by the hold-up.

Foam rheology may also be better understood in the controlled environment in our slit reactor. In applications involving cuttings and proppant transport it is very important to know the rheological properties of the suspending fluid. Foams exhibit viscoelastic properties that impact strongly not only the particle carrying capacity of foams but the forces that govern the cross stream migration of particles.

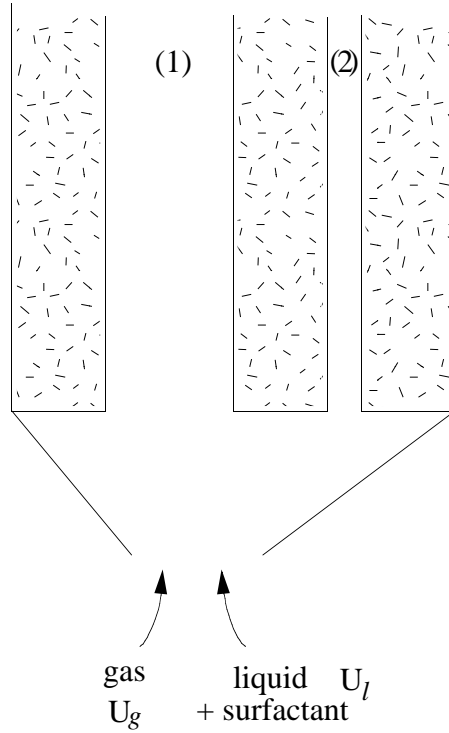


Figure 1: Selective foaming. Channels (1) and (2) have different flow resistance and holdup of gas and liquid. These can be manipulated by design. According to equation (1) we can expect that as we increase U_g at a fixed U_l one of the channels will foam first. In this way we can determine properties for in situ foaming.

Bob Chin has some other ideas about the applications of our research to production which he is going to write down. Other approaches to different E & P problems are likely to emerge as our understanding progresses. Perhaps a point in our favor is that we are going to look at the problems of production using foams in a different way.