Coupled Fluid Flow and Elasto-plastic Damage Analysis of Acid Stimulated Chalk Reservoirs

1: Introduction

Oil consumption in the world is going to increase and oil supply declining rapidly and running out of cheap production. Therefore, there is a need to use a new technology to recover more oil. Recovery is extracting more oil and gas from existing reservoir. During drilling, natural pressure within the reservoir causes oil to flows out.
However, in low permeability carbonate reservoirs, oil is trapped on the rock and is unable to be extracted by the initial drilling. In this case, well stimulation techniques such as acidizing is used to increase the formation permeability in the vicinity of the wellbore.
Two ways of well stimulation are fracturing and matrix acidizing. In fracturing stimulation, fluid is injected in higher pressure than fracturing pressure, which leads to opening of new channels. In the matrix acidizing, acid is injected at a lower pressure than the required pressure for the fracturing method. In this method acid reacts with the carbonate rock, dissolves portion of it and opens up the existing pore spaces that leads to a less restrictive pattern for oil to flow so enhancement of oil recovery. Well stimulation by the acid is getting increasingly important to make drilling more economical. However, it is important to know that rock dissolution by acid does not always improve the oil productivity from the reservoir.

Various factors such as the acid injection rate, diffusion coefficient of the acid species, concentration of acid, temperature and heterogeneity of the formation influence the dissolution pattern and affects the production rate and stability of the well-bore. These dissolution patterns are divided to face dissolution, wormholing, and uniform dissolution. If the large portion close to the well is completely dissolved, it is called face dissolution; conversely, if too much of the rock is removed by dissolution, it is called uniform dissolution. There is an optimum condition at which long channels will be formed. Acid etches the wall of the pores, opens their walls and creates channels that go through the chalk like a worm, hence the name “wormhole”. Creation of wormhole pattern increases oil production, because it has the best penetration depth for the same volume of injected acid.

Counter to the increasing oil production and oil recovery due to the acidizing, is the increased risk of rock breaking down. The stress states of the rock is changed in the area where the wormholes and fractures are formed and this influences the resulting effectiveness of the acid treatment. From the above discussion, in order to have a successful acid fracturing, it is important to investigate the effect of the presence of fractures and wormholes on the rock strength and consequently on the oil production.

2: Objective

In order to understand the physical behavior of the stimulation process, a computer simulation is used.
The objective of this thesis is:

- Presenting a simulation approach that treats the subject efficiently and in accordance with physics.
- Predicting risk of the rock failure due to the presence of the wormhole and fractures.
- Understanding the interaction between the acid injection and the formed dissolution pattern and the stress states of the rock

3: Method

The case study simulated in this thesis is a core sample representing the near well bore area of the chalk reservoirs. The core sample includes pre-existing fractures.

These fractures can be natural fractures in the chalk or fractures created by hydraulic fracturing or other stimulation treatments such as previous acid injection. The fluid flow and acid transport in the core sample is modeled by the flow in the fractured porous media on a Darcy scale. The prediction of the chalk failure, wormhole and damage of the fractures has been done by using a continuum approach and applying an equivalent constitutive model, which considers both chalk and fracture deformations. This work is divided into three main parts:

- The fluid flow model including the acid transport and the chalk dissolution.
- The geomechanical or solid model including elasto-plastic behavior of the chalk and irreversible damage of fractures.
- The coupling method between the flow and geomechancial model.

4: Conclusion of Results

The results indicate that in a chalk core sample with a vertical fracture plane, which is orientated parallel to the plane between the inlet and the core, the injected acid has the best penetration depth through the core sample. However, the vertical fracture leads to high shear stresses in the core, which result an earlier failure of the material, thus a negative effect on the oil recovery. In addition, results show that the wormhole's walls failure risk is higher if the natural fractures are oriented along the wormhole; furthermore, natural fractures with larger dip angles and higher inclinations with respect to the wormhole increase the risk of the chalk failure. The increased fluid production from the wormhole, which can be the result of the further acid treatments, develops damage of natural fractures in addition to increasing the wormhole's wall deformation; this eventually leads to the wormhole's occlusion.