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Experimental investigation of particle suspension injection and permeability impairment in porous media

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HIGHLIGHTS

- An experimental study is performed to explore the effect of the produced water reinjection in oil reservoirs.
- The effect of various parameters on the permeability impairment is explored.
- A clogged area of a few centimetres is formed at the column inlet even with a very low particles concentration.

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ABSTRACT

Damage and clogging of the granular structure of reservoirs are commonly observed during the re-injection of produced water containing solid particles and oil droplets. These phenomena can lead to a significant decrease of the reservoir permeability around the injectors and affect the injectivity of these wells. In this paper an experimental study on the transport and deposition of silica particles in a porous medium subjected to flow is presented. The study is performed on two different devices; the first one is an injection column 1 m long in which a sand pack with controlled density using the pluviation technique has been placed and the second one is an injection cell in which a cylindrical sand specimen (height 80 mm, diameter 80 mm) is put under isotropic stress. Water containing a low concentration of fine particles (diameter of few microns) is injected at a constant flow rate. The evolutions of the sample mass and of the injection pressure are recorded. The experimental results show an increase of particles mass retained inside the sample during the injection and an increase of the injection pressure attributed to a decrease of the permeability of the sample. They also show that despite the low concentration of particles of the injected fluid, a clogged area of a few centimetres forms at the column inlet. The analysis of this area by mercury porosimetry showed a significant decrease of the porosity and of the pore size and the formation of a new family of pores by the agglomerated particles. This study focuses on the impact of various parameters (diameter of the injected particles, pore size distribution of the porous medium, concentration of particles in the injected water, injection flow rate and surface roughness of the grains) on the reduction of the permeability.

1. Introduction

When hydrocarbons are produced from a reservoir, a significant amount of water may also be produced. It is estimated that up to three barrels of water are produced

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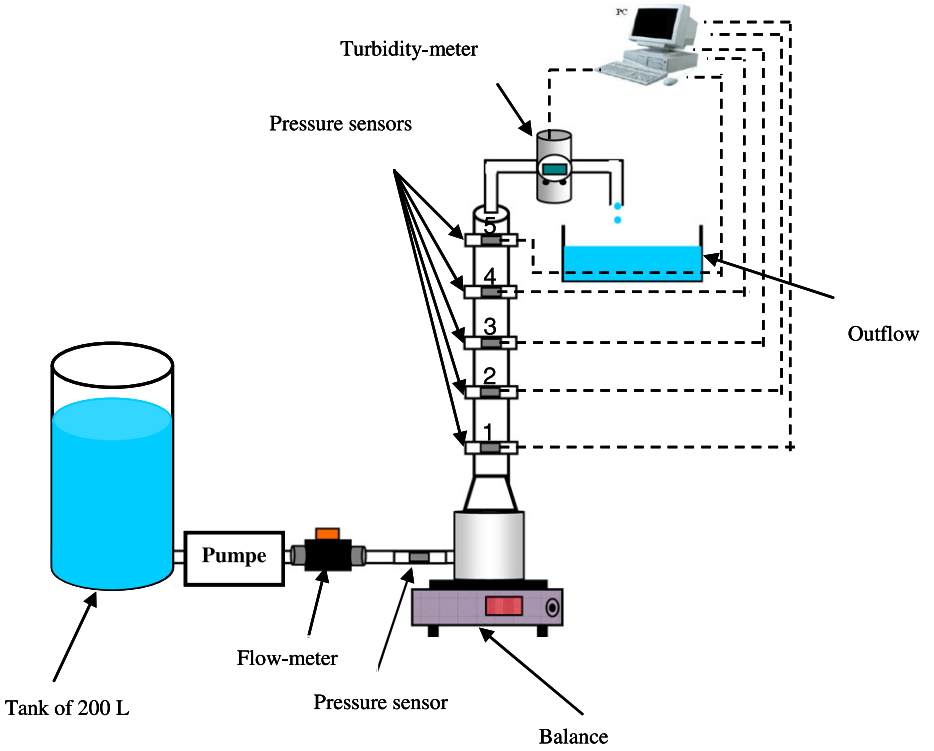

Fig. 1. Schematic diagram of the column injection test.

for every barrel of oil produced worldwide.[1,2] A solution commonly used to manage this water, which cannot be discharged in the natural environment, is to re-inject it into the reservoir. This technique, called "Produced Water reinjection" (PWRI),[3,4,2,5–7] contributes also to maintain the pore pressure in the reservoir and to stimulate the production. However, some difficulties can be encountered in application of this technique due to the fact that the produced water contains impurities such as oil droplets and solid particles. Despite the filtration of the produced water before re-injection, a small amount of particles always remain in the water.[8,9] These particles are exogenous particles generated by the fluid in the injection circuit and endogenous or *in situ* particles which coat the rock matrix like clays and other minerals.[10] These particles can be deposited in the reservoir and may consequently lead to a decrease of the reservoir permeability around the injection wells, and affect the injectivity of these wells.[11,12] During the injection at an imposed flow rate, this may lead to an increase of the injection pressure beyond the capacity of the pumps. Therefore, good knowledge of the mechanisms of transport and deposition of solid particles in a porous medium and their consequences in terms of permeability change is a key issue for a robust control of PWRI technique.

Four mechanisms, i.e. external and internal filter cakes, wellbore fill-up and perforation plugging are responsible for decline in well injectivity.[3] Pang and Sharma[13] stated that internal and external filter cake formations are the dominant mechanisms. The degree of impairment of porous medium over a period of time depends on the concentration of suspended solids in the injected water, the injection flow rate, the porous rock formation and particles characteristics (types of minerals, grain size, pore access size), and the nature of the interaction between the injected particles and the reservoir rock.[14,7]

In this paper, we present an experimental study on the process of transport and deposition of particles in porous media. The effect of various parameters (such as the size of the injected particles, the pore access size of the medium, the injection flow rate, the concentration of particles and the surface roughness of the grains of the porous medium) on the particles deposition and permeability reduction is explored on the basis of injection experiments performed in the laboratory. The experiments are performed on sand samples in which water (containing a small quantity of solid particles in suspension) is injected.

2. Experimental programme

2.1. Experimental setup and specimen preparation

Two different experimental setups have been used; the first one is an "injection column" (1 m height) which permits to obtain the profiles of permeability and mass deposition along the column and to study the heterogeneity of the clogging process.[15] A schematic view of the injection column system is presented in Fig. 1: it consists of a plexiglas tube with an inner diameter of 8 cm, a thickness of 0.5 cm and a height of 113 cm. Pore pressure sensors are installed at five different points 20 cm apart along the column. At each side of the column, above and below the