Field Application of A Method for Waterflooding

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Received: 17 August 1999; accepted: 02 January 2000

A field investigation, developed from laboratory test, conducted to identify and understand magnetic effects on oil recovery during waterflooding process at several oilfields in Azerbaijan. Results of the initial field testing of this improved oil recovery (IOR) method show, that magnetisation increases rock wettability, injectivity, as well as the flow capacity of porous media and favours degassing of water. The additional oil produced is attributed to the above factors and buoyant oil flow created by suction force of the magnetic type. Pressure stabilises easily during pressure buildup, scaling from formation water reduced by 80-97 per cent, downhole corrosion reduce by 35-40 per cent and clay swelling minimise by the constant transverse magnetic field. The results reveal that the method is novel are useful for studying magnetic fields.

Introduction

Enhanced oil recovery (EOR) techniques are in a continual state of development. Among traditional EOR methods, carbon dioxide flooding and thermal methods generate great interest\(^1\). Recovery factor is estimated from geology, reservoir development, and reservoir management strategies\(^2\). It is important to investigate new methods of increasing recovery. Waterflooding is a powerful and cheap secondary method that holds lot of potential if properly managed. The volume of oil recovered is equivalent to the volume of water imbibed by the rock\(^3\). The innovations are geared towards recovering more oil from the depleted reservoirs, which still contain as much as 50 percent of the original oil\(^4\). Physical methods of improved oil recovery mainly involve using electrical, electromagnetic and baro-fields or vibrostimulation\(^5\). Unlike these methods, the magnetic application has an indirect effect on the region around the wellbore.

Magnetic flux method has had wide applications in the petroleum industry. The major use has been restricted to prospecting, where its effects have led to discovery of large deposits, and metal corrosion studies such as magnetic flux linkage, MFL\(^6\). Recently, some works have been done regarding use of magnetised water for secondary oil production\(^7\). Here, the problem of increasing oil recovery in a pressure-depleted field with magnetised workflow is addressed understanding the different effects of magnetism results in more economical and speedier oil production.

Magnetised Fluid

Lack of theory in all the earlier works, to explain the magnetic process, has been source of great concern. The laboratory aspect of this work showed that water as the magnetised fluid is subjected to a magnetic field. The water experienced a force from the field. It creates suction force of the magnetic type and buoyant flow, thereby affecting the buoyancy of the oil. Concepts involved in characterising the phenomenon related to the physical properties of the water and crude oil are the magnetic susceptibility, tensor, fluids permittivity, and the magnetic Reynolds’s number related to the Hartman’s number. From the tensor, the curl is not zero hence the change in the field produces motion. The rock-fluid system reacts in such a manner that there is curie temperature effect which involves energy interaction. This could be responsible for the increased wettability observed in different rocks and reduced salt crystallisation. The induced magnetic field is uniform from the constant magnetic field point of view. The magnetised water has limited air bubbles, which gives it dilactant properties because of degassing. The current understanding is a step forward in modelling the process. The normal magnetic field on the earth’s surface and on a horizontally layered medium above this surface is absent (within the quasi-
Experiment and Field Trial

Although new to waterflooding, hundreds of these treatments have been performed during the last few years in the laboratory. The objective of earlier programmes was to determine how magnetic field affected well injectivity and degassing in porous media. The present study examines the effects of magnetism on waterflooding and oil recovery factor. Attention was paid to the laboratory aspects as the Mamed-zade et al. runs were repeated in a glass setup. The flooding process was observed in the see-through glassware to have better insight into the displacement mechanism. Linear and radial physical models, similar to the, Boubroum et al., for fine migration studies were used to simulate field conditions.

Field surveys were carried out with preformed magnetised water at the wellhead. Multi-positioned magnets help to take a series of readings. Five magnets, of 40 mm diam, arranged in series, were the main parts of the apparatus design. No special device is required and the number of magnets depends on well injectivity. In this study, two types of tests were performed. One set tested magnetised-water effect on recovery factor / the other tested conventional waterflood. A series of floods were made in the fields for different injection rates (8-15 Bbl/min) and water temperatures (35-45°C) using water pump and rheostat. Special emphasis was laid on improved recovery and minimisation of formation deterioration by the water. The usual 3-, 4-spot flooding configurations were maintained with magnets at equal distances one from the other, held in place with bolts and separated by bushings in a non-magnetic mandrel to avoid magnetic interference. The magnetic strength H=550-800 Webers each and a total flux density of 4000 Webers/m² were applied to account for losses, since the bubble point is increased, at this intensity, by 2 to 5-times for different under-saturated porous systems. The magnetic field induces an eddy or ground loop current similar to that obtained in induction tools during well logging. The voltage across the monitoring electrodes, read from the potentiometer, is adjusted to almost zero like in focusing electrode log. The induced water potential is equal to that of the porous formation (porous medium). The injectivity increases by about 20 per cent over a period of six months. The value before magnetised water flooding was 1902 m³/d and six months after injection / the average injectivity was 2400 m³/d. The injectivity, production rates, and pressure data were measures of flooding performance.

Results and Discussion

Production data obtained before and after magnetised waterflood in 40 wells are shown in Table 1. Magnetic fields have pronounced effects on well productivity. This could be explained by the fact that near wellbore permeability is improved (in the range of 1.02 to 1.76 x 10⁻¹² m²) through improved injectivity. According to the field observations / the best results were obtained from flooding shaly oil sands with a transverse magnetic field. As noted earlier the magnets may be placed at the injection wellhead but this work shows that they produce best results at the entry of a group pumping station. In this situation/ the number of magnets should not be less than 5. Formation formed was re-injected to the field to ensure compatibility with reservoir water, non-contamination and to reduce corrosion.

Well injectivity increased because the magnetised water changes the degree of system equilibrium (unsteady state) and creates favourable conditions for reduction of gas bubbles from water. The diluant properties of the degassed water, enable the displacement front to level-up, thereby creating greater energy of the moving front. Gas anchors were installed in all the wells to trap evolved and associated gas.

Magnetisation increases the water wetability of different rocks and improves the permeability of shaly formations. These effects are expressed in terms of reduced pressure stabilisation period in pressure buildup analysis, increased injectivity of injection wells, reduced scale formation by 82-97 per cent, corrosion rate dropped by 35-40 per cent and reduced clay swelling.

Increase in production from 1.0 to 2.2 m³/d, as shown in Table 1, may seem meagre. Judged against the background of the pressure depletion and water-cut above 65 per cent, an increase of 0.6 m³/d is significant. The project economics gives the payout period as 0.5 yr, while the financial benefit stands at $500 / well. The average workover lives with and without magnetisation were 125 and 84 d respectively, while increase in oil production and decrease in water-oil-ratio (WOR) were noted. The magnets were surface based to help control water properties and downhole problems such as hole plugging from scales and mechanical impurities. Downhole magnets, like downhole chokes (beans), may not be popular because of the need to regularly change them. This has cost implications such as down-time, to pull out of hole,
The life of the magnets depends on the reservoir fluids characteristics. Sour crude and reservoir water containing chloride ions readily corrode the magnets. One of the major obstacles to the widespread use of downhole magnets is the possibility of magnetic field interference in the tubings (metal).

This work has great potential in providing useful insights into how and why magnetised waterflooded wells behave the way they do. It incorporates the results of laboratory and field investigations.

### Conclusions

The experimental observations and field application of magnetised waterfloods to evaluate the use of magnetic field in improving oil production technology indicate that:

i. Magnetic field has been used effectively to improve oil production through increased injection efficiency and degased crude oil, during waterflood.

ii. This method of waterflooding works best in shaly sands. Scale deposition is reduced by about 90 per cent and corrosion rate by about 40 per cent.

iii. Experience shows that magnetised waterflooding is an emerging technology that holds promise in the future. Recognition of its value in production operations has improved oil recovery from pressure depleted reservoirs.

iv. Mathematical modelling of the forces involved in magnetised water interaction with petroleum rock is being carried out to help gain more insight into the displacement process.

### References

7. Porter P C, The Application of New Technology to the Inspect-
APPAH: METHOD FOR WATER FLOODING


