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Extended Abstract

Numerical Investigation of Total Stresses Change in Oil Reservoirs due to Extraction, Considering Non-linear Behavior for the Rock

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Keywords

**Total Stresses Change,
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Non-Linear Elastic Behavior**

Abstract

As a result of extraction from underground oil and gas reservoirs, the pore pressure in the reservoir decreases and the effective stress increases accordingly. Field measurements in the past two decades have shown that in addition to the change of effective stress, the total horizontal and vertical stress field can also change in and around the reservoir. As a result of the settlement that occurs at the upper part of the reservoir due to the consolidation phenomenon, the stability of this area is reduced and it causes "Stress Redistribution" inside and around the reservoir. The mechanism of stress redistribution is attributed to the "Stress Arching" phenomenon. By the stability reduction at the roof of the reservoir due to the compaction, this area will no longer bear the whole over-burden weight. A part of the over-burden is transferred to more stable areas such as the sides of the reservoir. The current research aims to investigate how the total horizontal and vertical stresses change around oil and gas reservoirs due to the extraction by a fully-coupled hydro-mechanical (HM) simulation. In order to simulate the process of fluid extraction from the reservoir and to consider the effect of production operations on the geo-mechanical properties of the depleting zone, a Non-linear elastic constitutive model has been used. The conducted studies show that in cases which the reservoir has a limited lateral extent, or the reservoir rock has a lower initial stiffness in comparison with that of the surrounding rock, the changes in the total stresses field are significant and it is necessary to consider their effect on various aspects of the production and the development of field.

1. Introduction

In the following of extracting hydrocarbon fluids from underground oil and gas reservoirs, fluids gradually come out through the voids of the porous rock, and the pore fluid pressure is subjected to a decrease in the reservoir and the surrounding rock. Due to the drawdown in pore pressure, the effective stresses tend to increase, and consequently, the well-known phenomenon called Consolidation happens. In addition, there are some other geomechanical occurrences including changes in total stress field which could happen in the exposed-to-production region [1].

One of the key actions in predicting and evaluating the behavior of the reservoir and the surrounding rock during production and field development operations in order to provide an optimal design is to determine the state of the stress field and the changes of it in different time periods of project [2].

Field Measurements in the past two decades have shown that in addition to the change of effective stresses, the total horizontal and vertical stress field can also change in and around depleting reservoirs [3]. As a result of the settlement that occurs at the upper part of the reservoir due to the consolidation phenomenon, the stability of this area is reduced and it causes "Stress Redistribution" between the reservoir and the adjacent surrounding rock. The mechanism of this stress redistribution is partly attributed to the "Stress Arching" Phenomenon. By the stability

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reduction at the roof of the reservoir due to the compaction, this area will no longer bear the whole over-burden weight. A part of the over-burden is transferred to more stable areas including the region near the sides of the reservoir rock in the surroundings [4].

2. Methodology

The main purpose of this research is to investigate the occurrence possibility of changes in total vertical and horizontal stresses in and around the reservoir rock under the effect of depletion, and also assess the effect of elastic contrast and lateral extent of the reservoir on the intensity of such changes.

The extraction operation of an oil reservoir is simulated in a fully-coupled hydro-mechanical manner by considering a single production well and applying the temporal values of exiting fluid flow flux to a part of the mentioned well located at the reservoir level, by means of Abaqus FEA software. The considered constitutive law for the behavior of the porous rock medium is a non-linear poroelastic one. In the implemented constitutive model, the Young Modulus of the porous rock is considered to increase by 10% up to 0.1% Volumetric Strain because of stiffness increase through compaction.

the surrounding rock of three different reservoirs in terms of their width, in different time periods of the production. In the second part, the effect of the difference between the initial stiffness of the reservoir rock and the surrounding medium on the intensity of the stress arching phenomenon are investigated by considering three different types of elastic contrast.

3. Results and Conclusions

In addition to the positive answer for the possibility of occurring significant changes in Total Vertical and Horizontal Stresses, results have shown that some factors such as elastic contrast and lateral extent have an important role in the intensity of these changes. As can be recognized from **Fig. 1**, the amount of decreasing changes in the total vertical stress affecting the upper boundary of the reservoir becomes more intense as the lateral extent of the reservoir rock is more limited. The more intense the drawdown in the amount of the total vertical stress that the roof of the reservoir is burdened with, the more this stress component is redistributed and conveyed to the more stable region near the reservoir edges in the surroundings by the stress arching phenomenon. Regarding **Fig. 2**, it can be seen that by existing a more softer reservoir rock compared

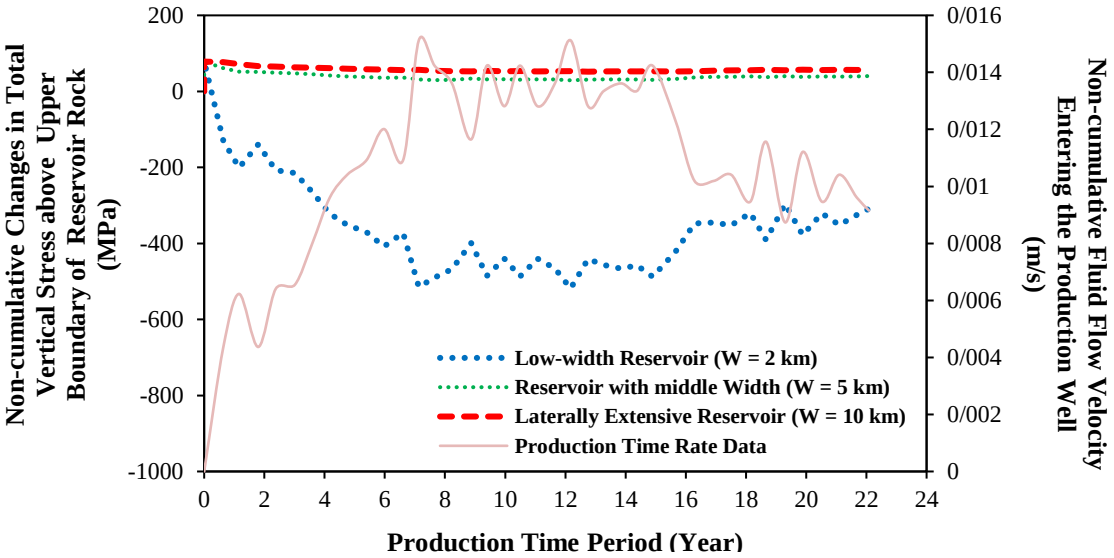

Fig. 1. Comparison of the Non-cumulative Changes in Total Vertical Stress Affecting the Upper Boundary of three reservoirs with Different Widths During 22 years of Production.

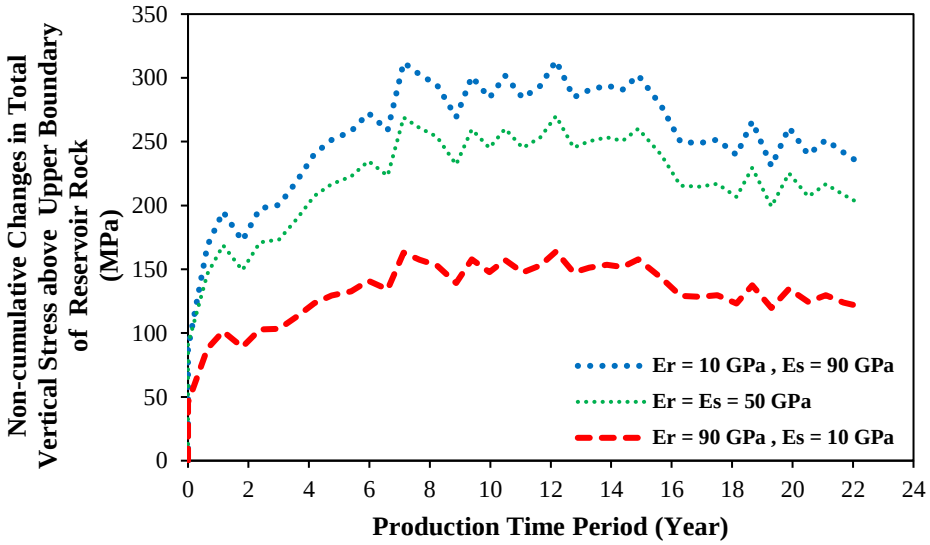

Fig. 2. Differences between Non-cumulative Changes in Total Vertical Stress of Adjacent Area near the Side Boundary of the Reservoir in the Surroundings During 22-year Production.

to the adjacent surrounding medium which has a significant role in terms of absorbing the redistributed stress by the stress arching due to possessing more reliability than the upper boundary of the depleting reservoir, the level of increase in the total vertical stress of the surrounding region adjacent to the edges of the reservoir rock is higher.

The conducted studies show that by the progress of production process, as well as the effective stresses, changes in the total stress field of the affected region are possible. Furthermore, the significance of these changes can be dependent on several factors, in which some characteristics of the reservoir and the surroundings such as the lateral extent of the reservoir and the elastic contrast between the two mentioned media are recognized.

The authors of this article believe that it is necessary to consider the side effects of this geomechanical phenomenon on the response and the performance of the target reservoir rock, and hence, on various aspects of the production and the development of field.

5. References

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