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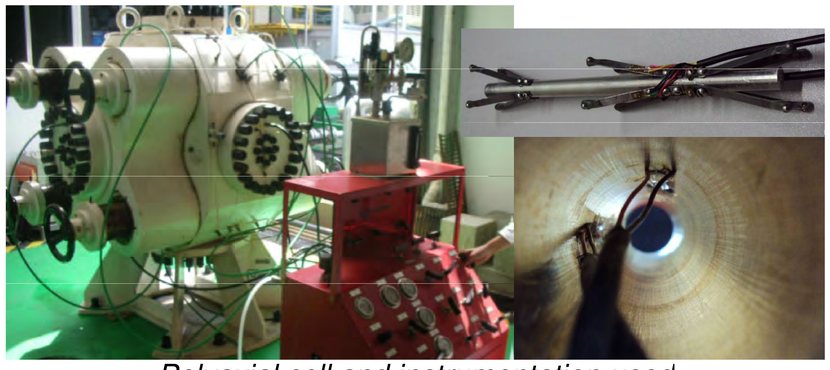
Numerical Analysis of Experiments in Sand Control Measures Using Stand Alone and Open Hole Gravel Pack Completion

Lower completion in a complex environment, such as in a turbiditic reservoir, non-consolidated sandstones and high porosity and permeability reservoirs, usually requires sand control methods to prevent damage in surface and subsurface equipment during high rate oil production. Guidelines to select sand control systems are primarily based on sand exclusion, seeking to optimize balance between oil rate and fines production. However, another important aspect, usually overlooked, is the collapse strength of the system formed by the sand control equipment and the formation, that it will be subjected to different mechanical loadings during production and well construction, especially during well clean up, start up and production platform shut down. Generally, the mechanical loading on the sand control system is predicted from production historical data, using a very conservative approach due to the screen collapse is an economically catastrophic event which results in huge oil-production losses. In order to predict the behavior of the adopted sand production strategy it becomes important to understand the **interaction mechanisms between the formation and the introduced linings/screen**. The present paper presents results of an experimental program aimed at studying these interaction mechanisms. The results obtained in the experimental program were compared to the ones obtained from numerical simulations of the same laboratory experiments. The numerical analyses were carried out using continuum based techniques and discrete elements in order to simulate the behavior of the gravel pack.

Experimental Studies

The polyaxial frame (500tf) used in the study has 6 pistons, independently pressurized and manually controlled. The equipment is presently installed at the Petrobras Research and Development Center – CENPES, and allows a variety of tests on large scale cubic samples (30cm x 30cm x 30cm).



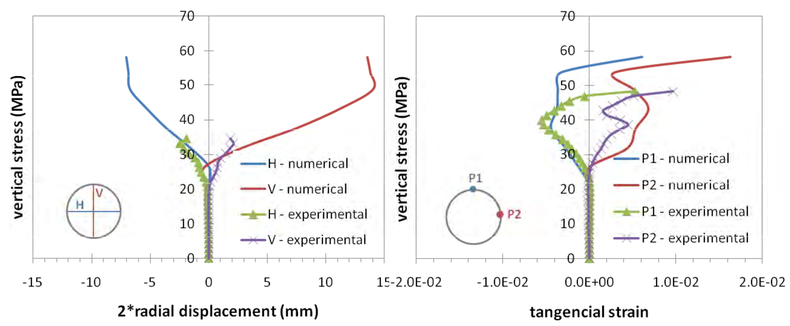
Polyaxial cell and instrumentation used

Experiment configurations

Final configuration for stand alone conditions

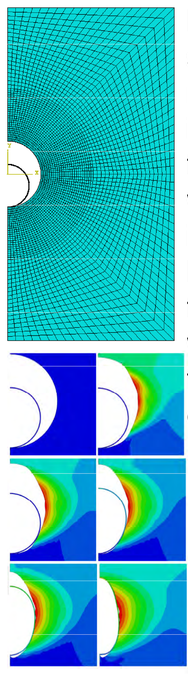
Continuum Modeling

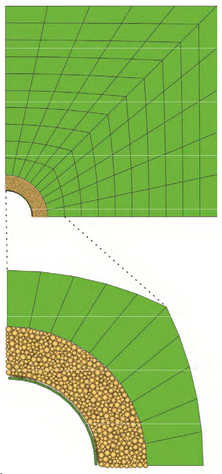
For this type of simulation, the computer code *Abaqus* was used.
The following constitutive models were used to represent the relevant materials:
• *Synthetic sandstone*: Mohr–Coulomb elastoplasticity with softening;
• *Gravel*: Non-linear elasticity assuming stress dependent Young's modulus;
• *Screen*: Perfect elastoplasticity.
In general terms, the numerical simulations using continuum based procedures satisfactorily reproduced the experimentally obtained results.
Regarding the stand alone conditions match between the experimental and numerical simulation results were not as good as for the gravel pack cases. For the stand alone condition, extensive failure of the synthetic sandstone occurred and although large strain conditions were used in the numerical analyses, the failure mechanisms were not correctly simulated.



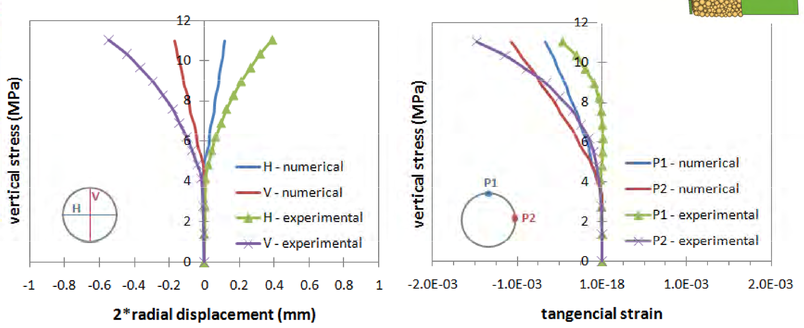
Continuum Modeling: Stand Alone

Continuum-Discrete Modeling

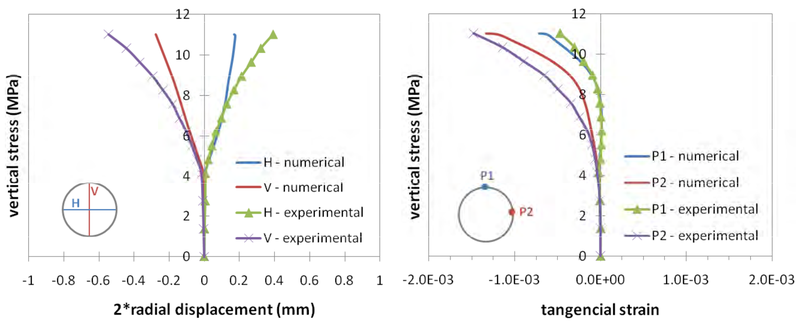




In this type of modeling, the synthetic sandstone and the brass tube (screen) are modeled as continua while the gravel pack is modeled as a discrete medium. In order to achieve that, codes PFC3D and FLAC3D were coupled. The analysis was carried out in 3D.
Regarding the constitutive model used for the gravel, a Hertz type (non linear) contact was used as proved to be representative of the behavior of the (ceramic) particles composing it.



Continuum-Discrete Modeling: Centralized Gravel Pack



Continuum Modeling: Centralized Gravel Pack

Final remarks

The present paper addressed the mechanical interaction between formation rock and sand containment measures such as the use of gravel pack and stand alone techniques. This was carried out by numerically analyzing tests performed on a large polyaxial frame. The two approaches used for the numerical analysis namely continuum only techniques and continuum-discrete ones showed in different degrees a fair match with the experimental results. In general, at this stage of the research, continuum only techniques presented a better match for the two situations under analysis. However, the authors believe that an improvement of contact constitutive model for the discrete part of the model may improve substantially the quality of continuum-discrete model predictions. As a general conclusion, it is possible to state that the techniques involve are indeed able to predict in an acceptable degree the mechanical behavior of the sand containment techniques under study.