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AN ELEMENT-BASED FINITE VOLUME METHOD FOR THE SIMULATION OF THE COUPLED FLUID FLOW/COMPACTION PROBLEM IN SEDIMENTARY BASIN

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ABSTRACT

The simulation of sedimentary basin is one most important tool in the process for identifying petroleum reservoir formations. The simulation tries to recover the way sediments were deposited along time in a scale of millions of years. Compaction of sediments is a geomechanical process coupled with the fluid flow inside the porous media. The resulting porosity, a function of the effective tension, is a balance between the load of the sediments and the pore pressure.

When the goal is finding oil accumulation during the deposition of sediments, the geomechanical problem must be solved coupled with the multiphase flow of oil, water and gas and the energy equation for calculating the oil generation components when kerogen rocks are presented.

In the numerical point of view, several key issues arise when simulating sedimentary basins, being the moving mesh one of the critical ones. When moving meshes are employed, extreme care must be exercised in order to enforce the conservation principles for fluids and solids. The usual way of guaranteeing this is obeying the Geometric Conservation Law, in order to avoid sources and sinks of mass, momentum and energy. When finite volume methods are employed the GCL is automatically satisfied.

In this paper it is presented a novel method for simulating the fluid flow/compaction problem using an Element-based Finite Volume Method with moving unstructured grids. The new grid after compaction, that is, for the new time level, is determined considering that the mass of solid is conserved for each control volume. In other words, the volume of the control volume shrinks according to the porosity reduction of the media. In this approach, this is the condition which establishes the new z-coordinate for the new shape of the layer. Recall that using finite-volume methods the mass conservation is always enforced at control volumes at one specified time level, but it is not required that the mass inside each control volume be conserved in subsequent time

levels. The porosity is given as function of the effective tension, given by $\sigma_e = S - p_f$, where S is the load of sediments and p_f the pressure of pore fluid. Therefore, one has several couplings to be handled. The load, for example, depends on porosity, and porosity depends on the effective tension, which, by its turn, depends on the fluid pressure.

This work reports the full procedure for simulating a sedimentary basin with several deposited layer. Attention is also given to the analysis of the coupling between the porosity and sedimentary load calculation. Since this is an iterative procedure inside the full coupling, we may keep the load frozen during a few iterations in order to minimize the computational time.

As an example, Fig. 1 shows the sedimentary load and the fluid pressure obtained with the simulation of a sedimentary basin with 5 layers of different materials. The problem is solved considering all steps of the simulation, including the discrete deposition and the single-phase flow of water being expulsed from the porous media, using a Newton-like method for the solution.

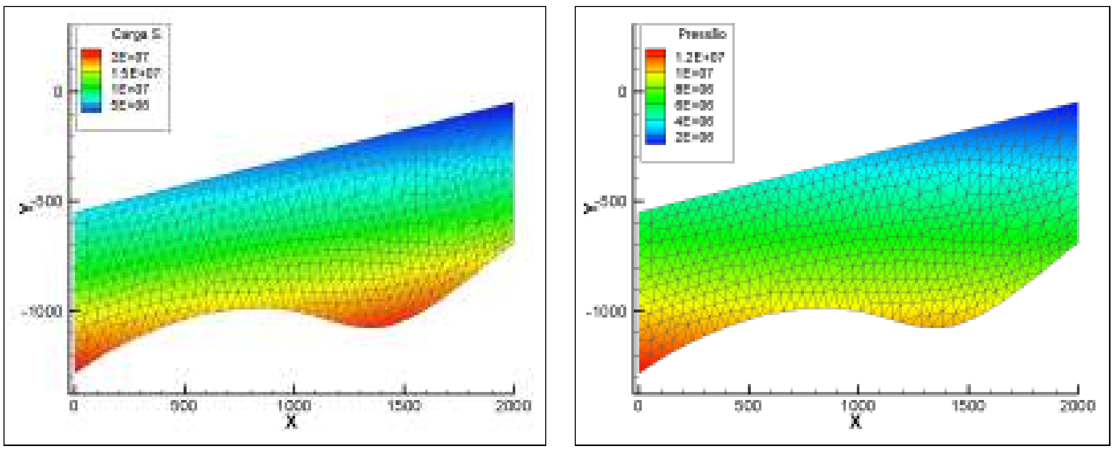

Fig. 1 – Sedimentary load (left) and fluid pressure (right) obtained with the simulation of a basin with 5 layers of different materials.

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