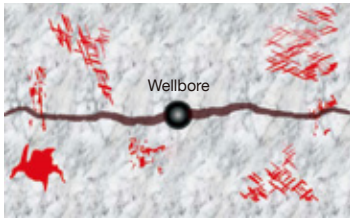


Diverting Acid Fracturing for Carbonate Reservoirs

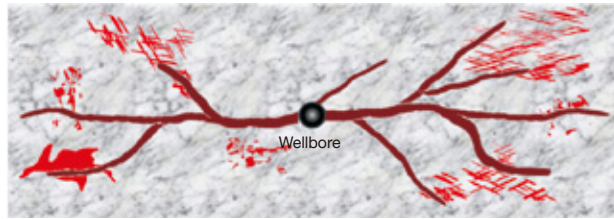
China National Petroleum Corporation



Conventional acid fracturing generally creates fractures only along the direction of maximum horizontal stress, resulting in partial connection among fissures and vugs, small swept volume by acid fluid, and limited yield increase. Diverting acid fracturing is proved to be an effective solution to create multiple fractures, increase connectivity of fissures and vugs, enlarge swept volume, and hence substantially improve stimulation efficiency.



Single fracture created by conventional acid fracturing

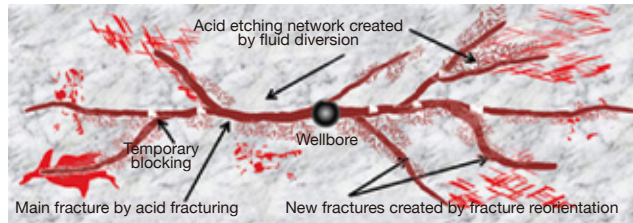


Multi-fractures created by diverting acid fracturing

1. Technical principle and simulated experiment apparatus & method

✓ Diverting acid fracturing treatment combining fluid diversion and fracture reorientation

By temporarily block exited fracture to increase inside pressure, more fractures are induced in new places and new directions, which link up more storage space of fissures and vugs. Meanwhile, by increasing the viscosity of acidizing fluid inside the fracture, the fluid will divert from high permeability zone to low permeability zone, creating an acid etching network and enlarging the swept volume, to maximize the oil and gas flow channels.

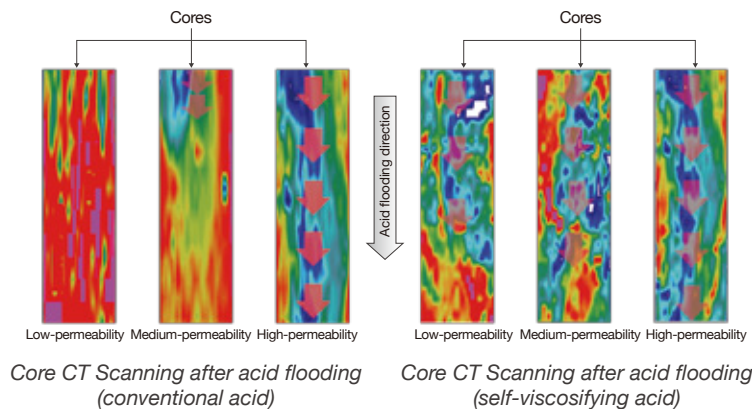


✓ Diversion by blocking the fracture temporarily

Blocking up the existing fracture temporarily with high strength can force it to divert and create new fractures. The minimum blocking strength required for fracture diversion, under different horizontal differential stresses and included angles between horizontal principle stress and natural fracture azimuth, has been worked out.

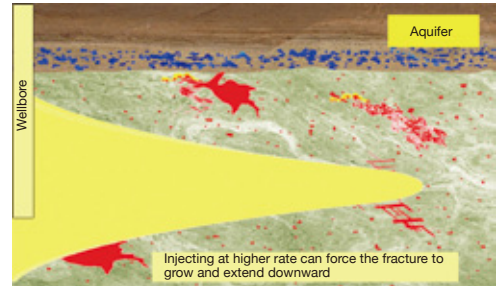
✓ Diversion of self-viscosifying acidizing fluid

Acid flooding test on parallel cores has proved that, after self-viscosifying, the acidizing fluid may divert its flow from high permeability core to medium-low permeability core, resulting in enlarged swept volume.

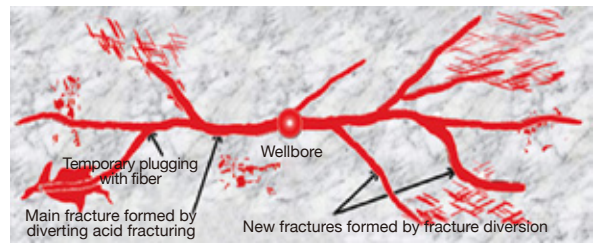


2. Fracture diverting materials: communicate reservoir vertically and create multiple fractures horizontally by temporarily blocking existing fractures

Floating screening material: It can force the fracture to extend downward to link up the reservoir below acid fractured interval, or avoid penetrating the above aquifer. The material is made mainly from silicate powder, aluminum powder and nano calcium carbonate through melting, spraying and cooling, with a density of only 0.37g/cm³ and pressure-bearing up to 124MPa.

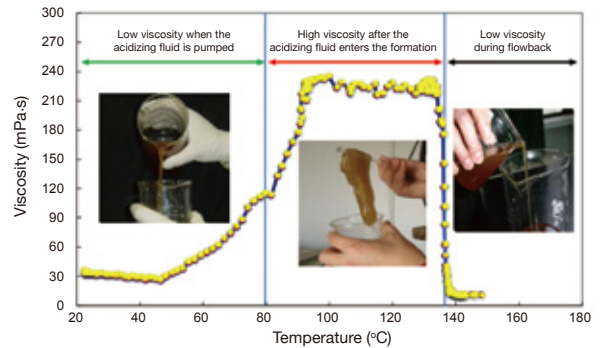


Temporary plugging material of degradable fiber: Used to block existing fracture temporarily to force it to divert and create multiple new fractures. The fiber can be degraded automatically after the treatment, restoring all the oil and gas channels formed by acid fracturing. It has a shut-off capacity of over 20MPa, degradation rate of over 99%, and is suitable for reservoirs at temperature of 60°C-160°C.

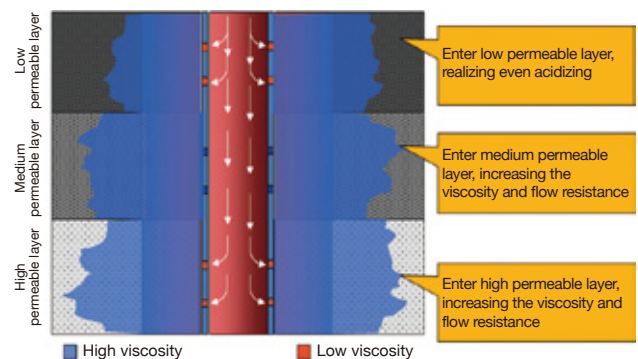


3. Self-viscosifying acidizing fluid diverting systems: allow in-depth fluid diversion and intelligent diversion to form acid etching network and expand swept volume

Temperature control diverting system: It enables flow diversion by self-viscosifying. With a viscosity of less than 30mPa·s and the friction resistance of 30% of water at ambient temperature, it is easy to be injected. Its viscosity can reach over 220mPa·s due to polymerization reaction in the reservoir, enabling diversion in depth. The viscosity of degraded acidizing fluid is below 10mPa·s, making it easy to flowback.

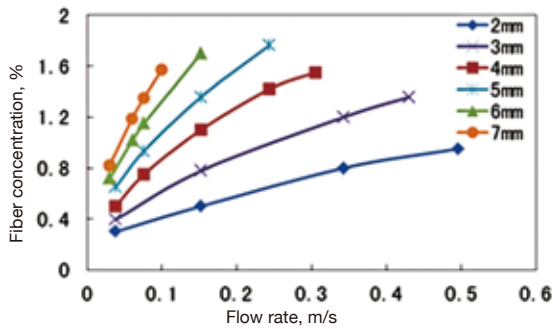


Acidity control diverting system: Special viscoelasticity prevents the surfactant from forming reticular micelle under acidic condition. It can work at a temperature of 150°C, and enlarge the acid etching network volume by 3.1-7.2 times than by conventional acid. During acid fracturing, the acidizing fluid will first enter high permeable layer where the acid-rock reaction causes fluid viscosity increase, forcing the follow-up acidizing fluid to enter medium to low permeable layers, thus realizing intelligent diversion of plugging high permeable layer and acidizing low permeable layer.

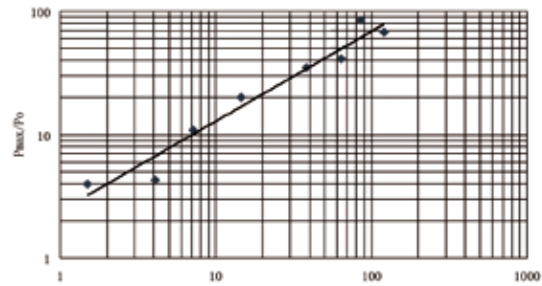


Schematic diagram of intelligent diversion

4. Design optimization software and matching equipment and tools for diverting acid fracturing: ensure safe operation at high temperature and under high pressure



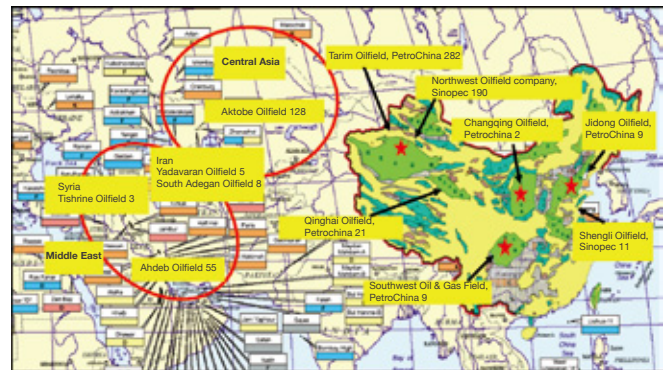
Parameter optimizing plate for fracture blocking



Diversion pressure optimization plate

Industrial Application

Diverting acid fracturing has been applied 677 well-times for carbonate reservoirs in 10 oil and gas fields in China, including Tarim, Changqing, Huabei, Jidong, Dagang, Southwest, Qinghai, Northwest, Southwest, and Shengli. This technology has also been applied for 244 well-times in 7 overseas oil and gas fields, namely Aktobe in Kazakhstan, Amu Darya in Turkmenistan, Ahdab and Halfaya in Iraq, Yadavaran and South Adegan in Iran, and Tishrine in Syria. Field application has been proved fruitful, as evidenced by a cumulative oil production increment of 2.842 million tons and gas output increment of 1.49 billion cubic meters over the past three years.



Case Study

High-yield gas flow obtained from Well Dabei 302 in Tarim Basin by diverting acid fracturing stimulation.

Treatment: 1) Large amount of slickwater injecting to expand natural fractures; 2) HCl-based acidizing fluid to communicate natural fracture system; 3) Fiber assisted inner-fracture diversion to intensify the creating of fracture network and the distributing of acidizing fluid.

Before stimulation: 5mm nozzle with daily gas output of 210,000 cubic meters and flow pressure at 61MPa, but unstable.

After stimulation: 8mm nozzle with daily gas output of 780,000 cubic meters and flow pressure at 87.7MPa; 10mm nozzle with daily gas output of 1,167,000 cubic meters and flow pressure at 78.6MPa.