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An Integrated Approach to Characterize Fracturing Sand

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SUMMARY

The increase in exploration and development of unconventional and tight reservoirs worldwide has led to increased hydraulic fracturing activities and, as a consequence, increased demand for hydraulic fracturing sand. Hydraulic fracturing uses specially engineered fracturing fluid containing propping agent or silica sand that can withstand reservoir stresses and keep induced fractures open to help optimize hydrocarbon production. Sand used in hydraulic fracturing must be aligned with quality standards outlined by the International Organization for Standardization (ISO) and the American Petroleum Institute (API).

This paper discusses the design of a systematic workflow to characterize the geomechanical and geochemical properties of silica-rich formation from an outcrop to laboratory scale. This workflow includes processing, morphological and mineralogical studies by thin section and X-ray diffraction (XRD), and elemental analysis by X-ray fluorescence (XRF). In addition, the physical geomechanical properties are investigated for a complete analysis and to determine the sand's compatibility in specific hydraulic fracturing applications.

This workflow helps operation and service companies determine the type of sand that best suits the targeted reservoir formation, which can help optimize reservoir productivity. Understanding the properties of the reservoir is important for designing and implementing the appropriate propping agent and hydraulic fracturing solution.

Introduction

Post-mining processes are primarily responsible for decreasing turbidity and removing heavy minerals present in mined sand. Clay particles and heavy minerals affect fracturing fluid efficiency and coating performance and can block pores in unconventional tight formations. The normal process, which is inexpensive and cost-effective, is to clean fracturing sand with water. This removes clay slimes and disintegrated agglomerated sand and makes sand effective for resin coating and/or for direct application into a reservoir. This process involves the interaction of sand with water in a swirling environment, known as hydro-cyclones and hydro-classifiers, for desliming. It is sufficient for loosening clays and/or fines particles smaller than 100 microns, which are then removed. In some cases, if sand grains are agglomerated with clays or silt particles, attrition scrubbing is used. Unwanted iron-bearing minerals are removed by rare earth roll (RER) magnetic separation methods. Sand acquired in bulk and by uniform sand sampling requires testing before it can be used in a tight reservoir. This paper describes the detailed laboratory tests used to determine the best type of sand for specific reservoir conditions.

Workflow

Splitters and reducers are used to obtain representative sand samples. A series of tests are then performed on these samples.

The first test performed is sieve analysis using a sieve shaker with a specific arrangement of sieves that corresponds to sand sizes. The goal of this particle size distribution is to acquire a uniform grain size because different sizes can impart differing physical properties, such as bulk density, surface area/reaction, miscibility, and conductivity. As per the API/ISO selection criteria, 90% of sand particles should fall within a designated range.

After passing sieve analysis, morphology tests are performed. The morphology of a fracturing sand is defined as its sphericity and roundness, which are greatly affected by the paleo-depositional environment and nature of the provenance rocks—older formations produce well-rounded and more-spherical grains. Sphericity defines the spherical shape of grains while roundness is a measure of gentle edges, which can be studied using a simple microscope. These two parameters (sphericity and roundness) are affected by the transportation distance from the provenance to the depositional basin. If the provenance rock type and location vary, then morphology, mineralogy, and mechanical properties can vary greatly. As such, reducers and splitters are used to produce uniform grains in terms of size, sphericity, and roundness to represent the sand in bulk. Well-rounded/spherical sand is defined by API specifications as having 0.6 sphericity and roundness.

Quartz, which is chemically inert and passive, is a highly abundant and resistant mineral with great importance in the petroleum industry. Fracturing sand contains large amounts of pure quartz with little surface defects (Fig.1). XRD is used to study the purity of sand grains and is performed on ground samples of sand to determine the mineralogical composition. Analysis is performed using the semi-quantitative method and an International Centre for Diffraction Data (ICDD) database. XRF is also performed on fracturing sand to reinforce the XRD findings.

Figure 1 (a) Poorly sorted, highly fractured, moderately- to well-rounded sand sample from one vendor; (b) well-sorted and well-rounded sand from another vendor with no fractures on the surface of grains.

Well-rounded and spherical sand can help reduce turbulence compared to highly angular-shaped grains. Moreover, angular grains can negatively impact the performance of hydraulic fracturing equipment, causing wear to the pump, flow lines, and other important parts. Compatibility between the sand density and fluid viscosity is very important for keeping the grains in suspension and to help settling occur at the desired location. The quantity of sand required to fill fractured surfaces can be determined from the density of the fracturing sand. Bulk density is also important for determining the volume/space required for sand storage.

Unwanted minerals, such as carbonates (including calcite and dolomite), feldspars, iron-bearing minerals, and clays can decrease the performance of fracturing fluid and fracturing sand when they come in contact with acid environments. As per ISO/API criteria, sand is tested with 12:3 hydrochloric (HCl): hydrofluoric (HF) acids (i.e., 12% HCl acid and 3% HF acid by mass). The acceptance range of solubility is less than 2%. If this value increases, the percentage of acid-soluble minerals increases, and ultimately the sand will fail the acid-solubility test. Moreover, the mechanical strength of acid-soluble minerals is very low, producing a higher percentage of fines at higher stress levels.

Reservoir petrophysical properties and fracturing fluid performance are sensitive to fines migration; turbidity is a measurement of the silt and clay material suspended in fluid. Sand grains are sometimes contaminated by fines attaching to them. The turbidity of fracturing sand is measured using ultraviolet (UV) equipment. High concentrations of fines result in a higher turbidity number; less than 250 FTU and/or NTU is qualifying criteria for sand. Most mines wash sand before packing it into bags to improve the sand quality.

Among the ISO/API tests, the crush-resistance test is very important. A crush test measures the geomechanical strength of the sand grains at a certain stress level. Stronger sand grains can sustain higher in-situ stresses under reservoir conditions, which allows them to be used to prop open fractures. Moreover, stronger sand generates fewer fines.

The performance of the fracturing sand with the fracturing fluid under reservoir conditions should also be considered for choosing the proper sand to use.

Conclusions

This workflow helps operation and service companies determine and understand the type of sand that best suits the targeted reservoir formation, which can help optimize reservoir productivity. ISO parameters, such as solubility, turbidity, and grain size (sieving), can be controlled by providing instructions or modifying sand vendor procedures. Other ISO parameters, such as bulk density, crush resistance, and morphology are uncontrolled; these are natural phenomena that develop over thousands of years. Well-rounded and spherical quartz grains with less surface defects (i.e., microfracture and micropores) are highly recommended for fracturing applications. Understanding reservoir closure stresses is important for designing and implementing the appropriate hydraulic fracturing sand that is compatible with the hydraulic fracturing fluid properties.

References

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