

Petrography Analysis of Northern White and Texas Brown Sands to Understand Its Crush Resistance Behavior for Hydraulic Fracturing Operations

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Proppant such as sand and ceramic particles are used in hydraulic fracturing (HF) operations to keep the fractures open allowing a permeable channel for hydrocarbon production [1]. Proppants are carefully selected for its size, shape, and grain strength so that it can withstand the reservoir closure stresses. Sand is preferred over ceramics due to its low cost and abundance though it has relatively lower crush strength [2]. Sand, being a natural material, exhibits a large variation in its texture, composition, maturity, and crystallinity depending upon the depositional environments and provenance.

In this work, two of the most commonly used sands in HF operations- namely, Northern white (NW) and Texas brown (TB) sands were investigated. As received sands were evaluated by (1) petrographic or polarized light microscopy (PLM), (2) single grain crush test, and (3) ISO standard proppant crush resistance test [4]. NW sand is composed of quartz-rich, mono-crystalline, geologically mature grains with high sphericity and roundness resulting in higher crush strength [3]. Thin sections of NW (Fig. 1a, 1b) and TB (Fig. 1c, 1d) sands (diameter ~0.3-0.6 mm), analyzed by PLM, reveals the nature of crystallinity as well as the inner fractures and crystal boundaries as observed by the color contrasts under the plane polarized light. Polycrystalline, metamorphic quartz with cementation were common for poorly sorted TB sands compared to abundance of monocrystalline and plutonic quartz in well sorted NW sands. Table 1 compares the characteristics of NW and TB sands including X-ray fluorescence data quantifying the mineral contents.

The effect of particle angularity on its load bearing capacity was investigated by single grain crush test. Fig. 1e, and 1f show a spherical and angular sand grain, respectively, loaded in diametrical compression mode. The onset of crush was recorded by a high-speed camera (at 90,000 frames per second) simultaneously with the load-displacement plot. As calculated, the spherical grain sustained ~3x higher load and absorbed ~8x higher energy due to more uniform stress distribution across the grain compared to the angular one. The inset image in Fig. 2 (left) captured the moment of parting of the angular sand grain immediately after exceeding the peak load generating the zig saw pattern in the load-displacement plot. The spherical grain abruptly shattered into fine particles when the peak load was reached.

ISO standard crush resistance test measures the amount of crushed particles (size <100 μm) generated when stress is applied on a given mass of sand pack. Fig. 2 (right) shows that NW sand generated 23% less crushed fines at a closure stress of 12,000 psi than that of TB sand. Depending upon the reservoir properties, these fines may reduce or even block the pore space available for hydrocarbon production. A maximum of 10% generated fines are acceptable for a given closure stress to qualify. In summary, two types of sands were investigated and it is concluded that mono-crystalline sand grains with high quartz contents, low impurities, and rounder shape can withstand higher closure stress generating less fines. This makes Northern white sand a better candidate for hydraulic fracturing operation.

References:

- [1] Gallagher et al., J. of Petroleum Technology **63 (04)** (2011), p. 18.
- [2] Liang et al., Petroleum **2 (01)** (2016), p. 26.
- [3] Stephenson et al., SPE Annual Technical Conference & Exhibition, Denver. SPE 84304 (2003), p. 1.
- [4] ISO 13503-2, First edition (2006).

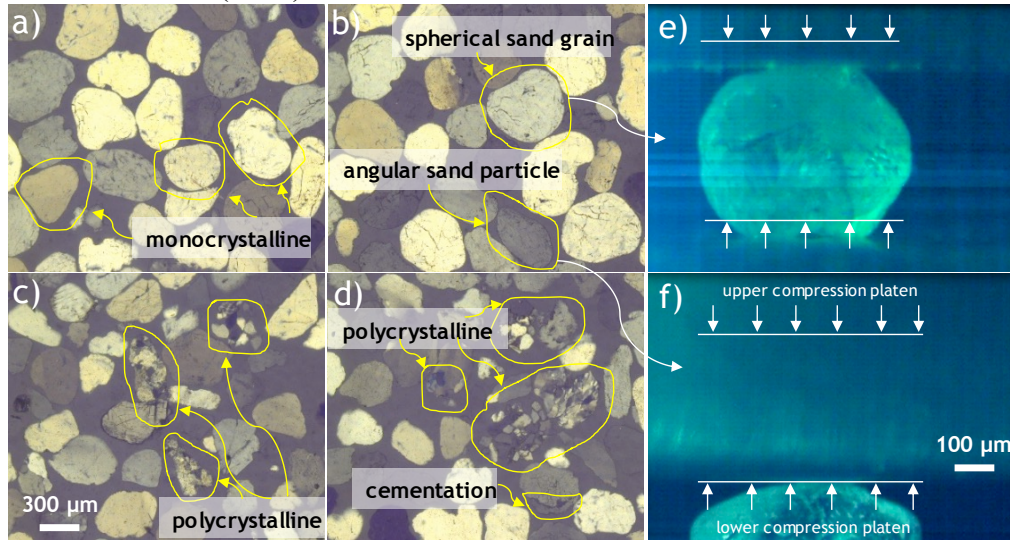


Figure 1. Petrographic microscopic images of Northern white (a, b) and Texas brown (c, d) sands. Optical images of a spherical (e) and angular (f) sand grain loaded in diametrical compression mode.

	Northern White Sand	Texas Brown Sand
Quartz type	plutonic (99.77% quartz)	metamorphic (99.17% quartz)
Crystalline structure	monocrystalline	polycrystalline
Maturity	well sorted	poorly sorted
Impurities	< 0.3% (Fe ₂ O ₃ , CuO)	> 0.7% (Fe ₂ O ₃ , CuO, K ₂ O)
Roundness & Sphericity	high (> 0.6)	low (~ 0.4-0.6)

Table 1. Comparing characteristics of Northern white and Texas brown sands.

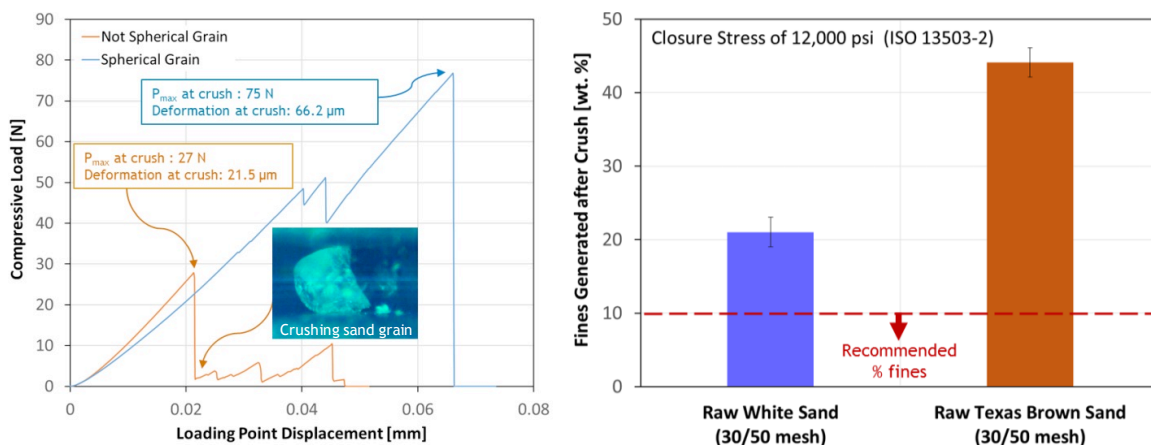


Figure 2. (a) Load-displacement plot of single grain crush test. Inset image shows the moment after crush for the angular grain. (b) ISO standard crush results shows generated fines for NW and TB sands.