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Feasibility Study of Bayuda's Sand for Possible Use as Proppant in Oil Field

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Abstract

Natural white and brown sand have widely been used for hydraulic fracturing and gravel packing operations; the main supplier country for these types of sand is United States, other efforts were presented to produce the sand from other countries. The wide area of deserts and the large amount of sandstone formation in Sudan offer abundant amount of natural silica sand; which is devoted mainly to construction industry. Recently, no studies were conducted to evaluate the use of the Sudanese as Frac sand; this study however evaluates Bayuda desert's sand to be used as proppant agents in hydraulic fracturing operations based on standarad practice. Three different samples were obtained from Bayuda desert near Al-Dabbah Province in the north of the Republic of Sudan. Chemical and physical characteristics of the sand samples were studied including Sieve Analysis, Bulk Density, Sphericity and Roundness, Acid Solubility, Turbidity and Crush Resistance; the evaluation tests and procedures were conducted following American Petroleum Institute Recommended Practice 19C (API RP 19C).

The results presented that the three samples has a bulk density of 1.62~1.68 g/cm³; with Sphericity and Roundness of 0.6 to 0.7. The Acid Solubility was found in the range of 0.14 to 0.68%; while the Turbidity ranging between 21 to 80 Formazin Turbidity Unit (FTU). Finally, the strength of the three samples was found in the range of 2000-3000 Psi. Comparison of these results with the reference value presented by API RP 19C indicates that the three samples are compatible with the requirements for sand proppant regard to Bulk Density, Sphericity and Roundness, Acid Solubility and Turbidity. However, limitations were faced regard to sand strength; for formation stresses of greater than 2000 Psi, resin may need to modify sand strength.

Keywords: Hydraulic fracturing; Proppant agents; Sand; Strength; Sphericity and roundness

Introduction

Hydraulic fracturing has been used as stimulation technique to improve the productivity and injectifity of oil and gas wells for more than 60 years. The technique was introduced to the petroleum industry on 1948; and the first two commercial jobs were performed on March 17, 1949 in Texas. Recently, more than 100,000 individual treatments was performed around the world [1]. With the increasing of the unconventional resources exploration, the use of the technique become more advance and large amount of materials are required. The operation can be performed in two steps: Injection of liquid with high pressure to break the formation, and packing the cracked formation with special materials (known as Proppant) to hold the fracture open. These proppant are solids substance with specific characteristics, used to support low permeability fracture and to achieve the required fracture conductivity and improve the flow; another important uses for proppant that the technique can be used to control sand from unconsolidated formation with the techniques called Frac-Packing. The proppant agent need to satisfying a minimum requirements presented by ISO (2006)or API RP 19C for its properties such as Uniform size distribution; High degree of Sphericity and roundness; Low solubility in acid and reservoir fluid; Crush resistance and Stability in reservoir temperature; therefore, serious of tests are required under spatial conditions (standards) to address the proppant performance. The economic benefits of these jobs is mainly depends on the selection of the best proppant size and type for the working closer stress. Generally, two types of proppant are available, natural materials (Frac Sand) or artificial (Ceramic material). Frac sand is special sand mostly made of quartz and feldspar; it has high-silica-content (98% or more). It is the first material used since the late 1940s. Because of its relative low cost, sand is the most commonly used proppant, especially in wells with low closure stress. Depending on their physical properties, Frac-sand can be subdivided into groups of excellent "White sand", good "Brown sand", and substandard grades. The artificial proppant are mainly two types: the Ceramic ((Intermediate-Strength Proppants) and Sintered bauxite (High-Strength Proppants). Ceramic sintered from bauxite mixed with other additives with specific gravity of 2.7 to 3.3; the mineral composition of ceramic proppant includes aluminum oxide, silicate and titanium oxide. It has uniform shape and higher strength than sand; therefore, it is suitable for deep wells with high closure pressure; it can be divided into Light weight proppant (LWP) and Middle strength proppant (MSP). On the other hand, the Sintered bauxite (HSP) are high-strength propping agents with a specific gravity of about 3.4 or greater; it contain large amounts of corundum and zirconium oxide Because of their greater cost, they are generally limited to wells with very high closure stresses greater than 10,000 psi. Due to the wide variety of proppants, the American Petroleum Institute has established test procedures for several proppant properties to distinguish the quality and usefulness of each proppant (API-1983; API-1987; API-1989). The high proppant quality is only founded in USA which known as premium sand (Northern White); however, the huge spike in demand caused by the natural gas and shale oil boom has motivated many companies to provide Silica sand proppant; and the

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use of non-traditional frac sand (specifically sands that readily do not meet all API/ISO standards) was considered to minimize completion costs [2]. Evaluate two samples of Malaysian sand with a Commercial proppant. They found that the Sphericity and roundness for both local sand sample have the same range of 0.5-0.7, the density and the turbidity agree with the density and the turbidity of the commercial proppant, both local sand start to produce more than 10% fine under the pressure of 1000 psi and above and that the conductivity of local sand is 16-20% lower than the commercial proppant [3]. Evaluate six samples of Malaysian sand with a Ceramic proppant, Ottawa sand and Jordan sand. They found that The Malaysian sand samples possess some of the required proppant characteristics to withstand crush resistance in maintaining desired permeability and meet API standards which require 90% of the sample to be retained within a designated size range with greatly uniform. The grain-size distribution is within the range of 0.425-0.212 mm. The bulk density of Malaysian sand is less if comparing with Ottawa, ceramic proppant and Jordan. Malaysian sand samples meet the Sphericity specification, but fail to meet the roundness specification of API minimum of 0.6 with values of about 0.52. However, the minimum roundness for Non-API standards consideration is 0.5. The turbidity of Malaysian sands agrees with the turbidity of the proppant ceramic proppant, US silica sand and API RP 56 standards. On the basis of chemical composition, Iron and alumina content in Malaysian sands have far exceeded the requirement for high grade silica sand [4]. Measured several physical and chemical characteristics of sand in Colorado state (USA) to evaluate their suitability as frac sand. He found that all samples met the minimum requirements for Sphericity and roundness and possessed grain sizes that could be screened and sorted to meet the size designations for proppant sand specifications. The wide area of deserts in Sudan and the large content of sandstone formation offer abundant amount of natural silica sand; which is devoted mainly to construction industry. Until today, a few researches have been conducted to evaluate the properties of these sands with respect to sand proppant and no local proppant producer or supplier was found [5]. This work however, studies the physical and chemical characteristics of local sand to present the Bulk density, Grain size and shape, Turbidity, acid solubility and crush resistance of three sand samples obtained from Bayuda desert-Dabbah Province in the north of the Republic of Sudan.

Experimental Works

Sample preparation

A serial of tests and experimental works have been conducted according to API Recommended Practice 19 C (API RP 19 C) on three different samples obtained from Bayuda desert near Al Dabbah Province in north of the Republic of Sudan. Using Global Positioning System unit (GPS - GARMIN GPSMAP 64s), the samples were collected from different depths using man-made wells. Each sample weighting about 5 kilograms.

Sieve analysis

Sieve Analysis test has been conducted to determine Grain size for the different samples using JEL 200 mechanical shaker; with USA Standard Sieve Series starting from Sieve Size of 40/60 to 6/112. After washing, samples were poured onto the top sieve and agitated for 10 minutes. Then the retained mass on each sieves were recorded and the percentages were calculated to estimate the cumulative mass and sieve distribution graph have been plotted [6].

Bulk density

Normal weight balance and Calibrated cylinder with given volume (V_C) have been used to estimate the bulk density of different samples. Samples were passed onto the cylinder then the filled cylinder was weighed and the mass record as m_s. The bulk density was calculated as the ratio of measured cylinder mass to the measured cylinder volume (V_C/m_s).

Sphericity and roundness

Sphericity is a measure of how close a proppant particle approaches the shape of a sphere. Roundness is a measure of the relative sharpness of corners or of curvature. Particles shape has been evaluated for different sieve sizes by visual estimation using normal microscope and Krumbein/Sloss chart (Figure 1). 20 particles have been selected randomly for each sieve sizes and the Sphericity and roundness of each selected particle was estimated visually for the different sieve sizes under different magnifications as recommended by API RP 19 C (Figure 2); then the shape was compared to Krumbein/Sloss chart [7].

Acid solubility

Acid Solubility were measured for different sieved samples using a mixture of HCL12% with HF 3%, weight balance of 0.0001 g accuracy. First the sample was dried at 105°C in oven and 5.0 g was placed in 100 ml of the above mentioned acid mixture and the mixture was kept under temperature of 66°C for 30 min as recommended by API PR 19 C. The mixture was flowed onto pre-weighted filter paper to remove the acid; then the samples was washed by distilled water to insure the removing of any remaining solids. Finally, retained sample was dried at 105°C until a constant weight was obtained then the mass was recorded (W_C) and acid solubility was calculated as follows:

$$\frac{5 - \text{Retained sample Weight}\,(W_C)}{5}$$

Turbidity

This test has been conduct on sieved samples before washing it to determine the amount of suspended particles using visual estimation and manual measurements. 20 ml of sample was placed in 100 ml of water for 30 min, and then shaken for 30 s, the fluid was then compared with known turbid fluids to estimate the turbidity.

Crush resistance

Crush resistance tests uses to evaluate the Grain strength; tests have been conduct on sieved samples to determine the highest stress level which the sand can resist, using controls crushing machine and API Crush Resistance Specifications. 100 g of each sieved sample was placed on cylinder of 2 inches diameter; then different pressures has been applied to the cylinder for 2 min; after the load was removed the pressurized sample was sieved again and the percentage of crushed pressurized sample was calculated under different loads (Figures 1 and 2).

Results and Discussions

Following the experimental works described in section 2, the following results were obtained:

Grain size analysis

Figure 3 presented the particle size distribution for the three samples; according to the particle size distribution, all the remaining experiments were conducted on the designation 20/40 and 12/20. Figure 2 shows the percentage of each designation from the total

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sieved sample. Depending on the figure, all the remaining experiments conducted on 12/20 and 20/40 for each sample; both are equal 67.9% from sample 1, 57.7% from sample 2 and 64.7% from Figures 3 and 4.

Acid solubility

The result of acid solubility of different sieve size for the different samples was presented in Figure 2. As presented in the table the acid solubility varying from 0.14-0.68% these results present that the amount of soluble materials (i.e. carbonates, feldspars, iron oxides, clays, etc.) were less than the amount recommended by the API RP 19 C which require that the acid solubility should not exceed 2.0% for sand prop

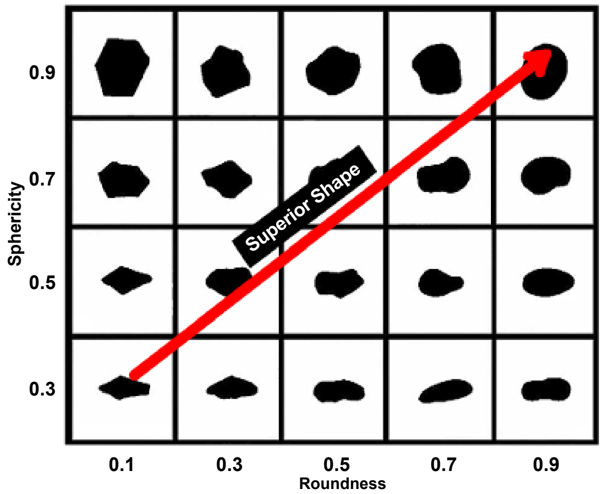

Figure 1: Krumbein/Sloss chart for sphericity roundness.

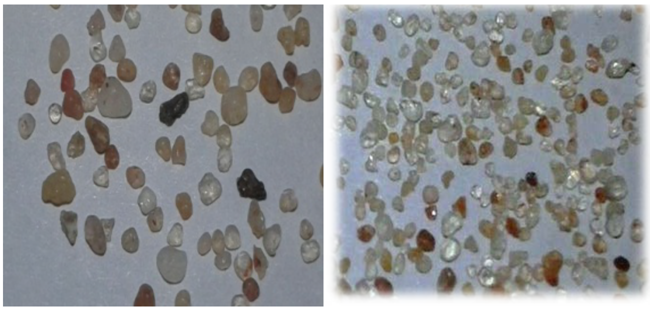

Figure 2: Magnified Picture (*15 Times) of Sample 1.

pant larger than or equal to 30/50 and 3.0 for samples smaller than 30/50) (Tables 1 and 2).

Bulk density

The density of all samples was found to be in the range of 1.62-1.68 g/cm^3 as presented in Table 3. The bulk density was found to satisfying API PR 19C.

Turbidity

The amount of suspended particles was presented in Table 4 for the different samples; the table presented that the turbidity varies from 21-80 FTU, which is less than the amount of suspended particles recommended by API (should not exceed 250 FTU for all types of proppant).

Sphericity and roundness

The Sphericity and roundness for the different sample and size was presented in Table 5 it is clear that all samples varies from 0.6-0.7 for both Sphericity and roundness; the API recommended that Sphericity and roundness should not be less than 0.6.

Crush resistance

Table 6 presents the percentages of the crushed materials at 1000, 2000 and 3000 Psi for different samples sizes and types. The crushed material weight% varies from 2 to 6% for applied stress of 1000 Psi, and at 6 to 10% at 2000 psi and reached more than 10% at 3000 Psi. When compared to the recommend practice API Pr 19 C, the study presented that this type of sand cannot use for stress greater than 2000 Psi without coating with resin. From the previous results, all samples has a potential to work as proppant with certain strength limitations, the following is the evaluation of each sample. For sample No. 1 the size 12/20, the amount of softer and less desirable cementations minerals is 0.22% with turbidity of 21 FTU; the shape of the sample is 0.7 Sphericity and 0.6 roundness while the crush resistance test for this sample presented that at 3000 psi more than 10% of crushed particles has produced. According to API this sample can be used as a proppant at pressure up to 3000 psi. For sample 1 with 20/40 size, the Acid solubility test shows that the amount of the less desirable cementation minerals is 0.24% with a turbidity of 24 FTU; the density of this sample is 1.65 g/cm^3, and the shape of this sample is 0.7 and 0.6 for Sphericity and roundness respectively; while the crush resistance test presented that more than 10% crushed particles was produced at 3000 psi. For Sample 2 with 12/20 size, acid solubility test shows that the amount of less desirable cementations minerals is 0.32% with turbidity is 80 FTU; the density of this sample is 1.62 g/cm^3, the shape of this sample is 0.7

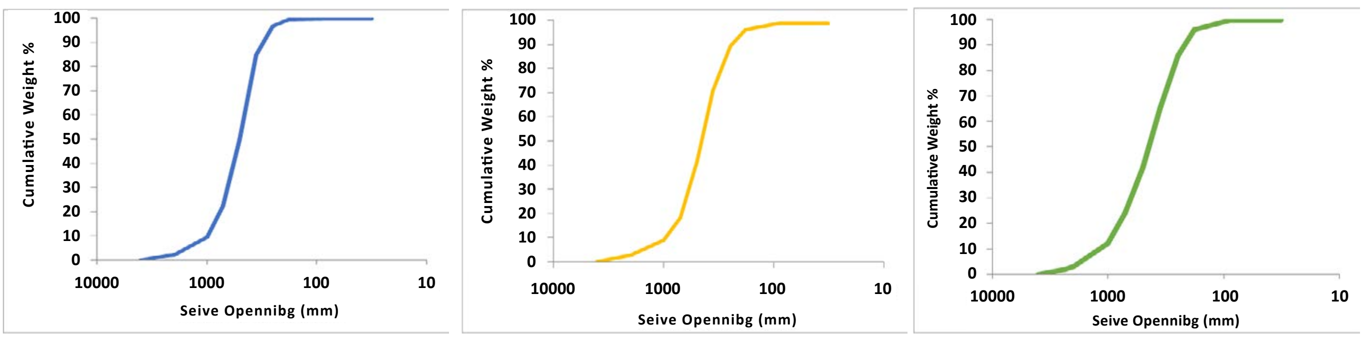

Figure 3: Particle size distribution for the different samples.

Sample No	Latitude	Longitude	Elevation from sea level	Depth	Description
1	18°03.082'	030°57.207'	238 m	1.5 m	Coarse sand, moderately-well sorted, coarse skewed
2	18°03.488'	030°58.510'	254 m	4 m	Medium sand, moderately sorted, Near-symmetrical
3	18°02.705'	030°57.466'	242 m	4.5 m	Medium sand, moderately sorted, Near-symmetrical

Table 1: Samples locations and descriptions.

Sample No	Designation					
	12/20			20/40		
	Weight before (g)	Weight after (g)	Solubility%	Weight before (g)	Weight after (g)	Solubility%
1	4.999	4.988	0.22	5.001	4.989	0.24
2	4.993	4.977	0.32	4.999	4.965	0.68
3	5.001	4.978	0.46	4.999	4.992	0.14

Table 2: Acid solubility results.

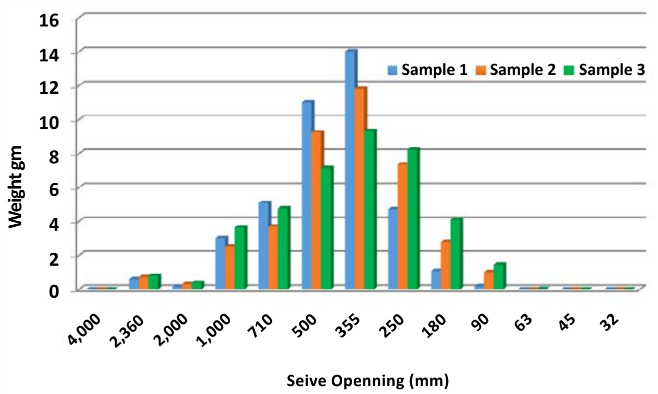

Figure 4: Mesh size vs. Weight for the three samples.

Sample No	Designation	
	12/20	20/40
1	1.66	1.65
2	1.62	1.66
3	1.68	1.66

Table 3: Sample's density.

Sample No	Designation FTU	
	12/20	20/40
1	21	24
2	80	77
3	31	36

Table 4: Turbidity results.

for Sphericity and roundness; the crush resistance test for this sample presented that at 2000 psi 10% of crushed particles has produced. hence this sample can be used as a prop pant at pressure up to 2000 psi. on the other hand sample 2 with 20/40 size, the sample can be used at pressure up to 3000 psi. Sample 3 by the same way can be used at pressure up to 3000 Psi for the two sizes.

Sample No	Designation			
	12/20		20/40	
	Sphericity	Roundness	Sphericity	Roundness
1	0.7	0.6	0.7	0.6
2	0.7	0.7	0.7	0.7
3	0.7	0.6	0.7	0.6

Table 5: Grain shape.

sample No.	Crushed%	@ 1000 psi	@ 2000 psi	@ 3000 psi
1	12/20	3%	6%	9%
	20/40	4%	9%	>10%
2	12/20	6%	10%	>10%
	20/40	3%	8%	>10%
3	12/20	3%	7%	9%
	20/40	2%	6%	8%

Table 6: Samples crushed per cent.

Conclusion

The Cchemical and physical properties of three different samples obtained from Bayuda desert in the north of the Republic of Sudan was presented with recpect to frac sand. Sieve Analysis, Bulk Density, Sphericity and Roundness, Acid Solubility, Turbidity and Crush Resistance; were evaluated tests following API RP 19C. The three samples has a bulk density of 1.62 ~1.68 g/cm^3; with Sphericity and Roundness of 0.6 to 0.7. The Acid Solubility was found in the range of 0.14 to 0.68%; while the Turbidity ranging between 21 to 80FTU; samples strength was varying from 2000-3000 Psi. Comparison of these results with the reference value presented by API RP 19C indicates that the three samples are compatible with the requirements for sand proppant regard to Bulk Density, Sphericity and roundness, Acid Solubility and Turbidity. However, limitations were faced regard to sand strength; for formation stresses of greater than 2000 Psi, resin may need to modify sand strength. The results presented that the density of samples is in range from 1.62 to 1.68 g/cm^3.

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