Characteristics & Erosion Study of Uncoated Sand Proppant Under Flowback Condition

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***Abstract*—United States is the main supplier country for brown and natural white sand that have widely been used for hydraulic fracturing. The large amount of sandstone formation in Malaysia offer abundant amount of silica sand that be high potential to develop. Eight different samples were collected from Terengganu coastal area in the east of Peninsular Malaysia. The procedures and evaluation test of the sand samples were performed following ISO 13503-2 such as sieve analysis, roundness and sphericity, acid solubility, turbidity and crush resistance. During well stimulation treatments, proppant in slurries may damage pumping equipment and have been shown to erode perforation tunnels. This paper also will examine the erosion mechanisms of the samples toward two types of metal target, 6061 aluminium and mild steel by using impingement test. The results presented that the eight samples has a bulk density of 1.47 ~ 1.56 g/cc with roundness and sphericity of 0.32 to 0.72. The acid solubility was found in the range of 2.79 to 12.20% while the turbidity ranging between 14 to 39 Formazin Turbidity Unit (FTU). The sieve analysis showed the samples were larger or equal to 16/20 and the strength of sand samples was found Sample 2 and Sample 3 were the highest K-value around 2000 – 2500 psi. For erosion analysis, the 6061 aluminium showed good resistance of metal loss compared to mild steel.**

Keywords— Hydraulic fracturing, sand proppant, ISO 13503-2, particle size distribution, roundness and sphericity, acid solubility, turbidity, crush resistance, erosion.

I. INTRODUCTION

Nowadays, demand for hydraulic fracturing has increased in decade ago as thousands of oil and natural gas wells are stimulated. Statistic showed that up to 90 percent of the wells have been fractured and more again in the future [1]. Hydraulic fracturing is one of well stimulation that used enhanced productivity by increasing the flow of hydrocarbons from reservoir rocks to wellbore. Hydraulic fracturing is a process of pumping fluid down the well at above fracture pressure. The fracturing fluid contains propping agent as function to hold fractures open once pumping is stopped and the pressured decreased. Proppants is a solid material made of silica sand, resin-coated sand, or ceramic proppants.

For identify the best specification of proppant, the sand must undergo certain standard and code such ISO 13503-2. The sand should meet requirements like low solubility, high sphericity & roundness, high crush resistance, consistent grain size and low turbidity. However, inconsistent grain size will give a low conductivity of the fracture while the proppant sizes itself will affect the permeability of pack. The natural sand usually have different grain sizes that should be consider before use as a proppant in hydraulic fracturing. The angularity shape of proppant will negatively impact on pack porosity which also leading to bad conductivity of the proppant. This also will impact proppant strength in high closure stress and increase erosion rate on production equipment [2].

Different types of proppant will give various reaction when contact with acidic fluid such as Hydrochloric acid (HCL) and Hydrofluoric acid (HF) inside the perforation channels [3]. For recognize the natural sand as good proppant, it should show low reaction with acidic fluid and at a same time, decrease dissolution part of particles. Raw natural sand usually have impurity materials that introduced by environmental effect [4]. The scale precipitation within the natural sand will cause turbidity effect. So, the turbidity level must be pass the standard requirement to prevent produced fluid contaminated and precipitate on the production string [5]. A proppant is exposed to varying stress levels from the formation. The natural sand should be strength enough to withstand with higher pressure from crushing [6]. The crushing particles will blockage the permeability of rock and reduce well conductivity. Unfortunately, the usage of the sand as a proppant also has negative effect. Sand will collide with production equipment during slurry injection and flowback condition which cause the erosion. There are several factors that can be influenced by proppant selection such as velocity or trajectory of particles, concentration of particles and size of particles.

The ISO 13503-2 was used as a procedure in achieve the standard quality of proppants. A sieve analysis was conducted to determine particle size distribution of proppant sample collected from different beaches in Malaysia. The Terengganu beaches were selected because the good performance of sand in term of chemical and physical characteristics [1]. For sphericity and roundness procedure, Krumbien/Sloss chart as a reference in decide whether the proppants achieve the average shape of spherical and roundness. In measuring the solubility of proppants, the acid solubility test must be conducted. A solution of 12:3 HCL:HF was used in observation of the reaction between acid and proppants. Percentage of scale formation can be perceiving by turbidity procedure using turbidimeter. It measures an optical impurities of a suspension in the wetting fluid. For the final test in ISO 13503-2 procedure, crush resistance test must be conducted to define the failure stress of proppant. Proppants that fully succeed all the requirements will go through erosion study using impingement test in term dependent on the impacting particle properties (density, hardness, size and shape), target materials, particle feed rate, temperature and impact angle. The purpose of this study was to compare real sand and commercial sand in term of quality of proppant followed ISO 13503-2 standards follow with evaluation of evaluate the erosion effect of sand on production equipment using impingement test.

II. METHODOLOGY

A. *Sand Sampling*

Sand samples were collected at certain places in Terengganu coastal area. The typical sand layer thickness is from 0.3 meter to 3.5 meters while the average thickness was about 1.4 meters. Sand samples were collected from 0.6 meter to 1.0 meter depth from surface and 3.0 meter from the shoreline. Another one sand sample was collected from mining site in Perak. All the samples were going certain standard procedures, ISO 13503-2 for characteristic test. All samples were labelled as below :-

Table 1 : List of Proppants

Location	Label
Pantai Teluk Ketapang, Terengganu (Malaysia)	Sample 1
Pantai Seberang Takir, Terengganu (Malaysia)	Sample 2
Pantai Seberang Takir, Terengganu (Malaysia)	Sample 3
Pantai Marang, Terengganu (Malaysia)	Sample 4
Pantai Marang, Terengganu (Malaysia)	Sample 5
Pantai Rusila, Terengganu (Malaysia)	Sample 6
Pantai Batu Buruk, Terengganu (Malaysia)	Sample 7
Lombong, Perak (Malaysia)	Sample 8

B. *Sieve Distribution and Grain Size*

The Endecotts Octagon 2000 Digital Sieve Shaker was used in conducted the test. Suitable sieve sizes in range 150 to 1700 microns were stacked in order of decreasing sieve-opening sizes from top to bottom. The sample was poured onto the top sieve and placed the stack of sieves plus pan together with lid in testing sieve shaker. The sieve shaker were then agitated for 10 minutes. The samples that retained on each of the sieves and in the pan were weighted and recorded. The distribution graph was plotted for further analysis.

C. *Bulk Density*

A 100ml measuring cylinder and an analytical balance were used in this experiment. An empty 100ml measuring cylinder was weighted on the analytical balance and recorded. Sand sample was filled into the measuring cylinder until the reading was 100 ml. The reading was taken and bulk density was calculated from Equation (1) :

$$Bulk\ density = \frac{volume\ of\ dry\ sand\ (g)}{volume\ of\ dry\ sand\ (cc)} \qquad 1$$

D. *Roundness and Sphericity Test*

For roundness and sphericity test, the particle shape of proppant was evaluated by visualization method. Microscope were used to conduct the test in magnification of 4x. The sphericity and roundness were recorded and an average of two parameters were obtained. The results were then compared with the Krumbein and Sloss Chart which an average value to meet the ISO 13503-2 specifications is 0.6 or more.

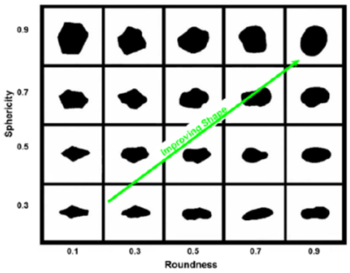


Figure 1 : Krumbein and Sloss Chart (ISO 13503-2:2016)

E. *Acid Solubility*

Experiment was conducted using a solution of 12:3 HCL:HF. 5 grams of proppant was added into beaker that filled with 100 ml of the acid solution. Next, the beaker was placed in a water bath at 66°C for 30 minutes. Filtered the sample and acid mixture by using funnel and filter paper. The sample was washed in the filtering apparatus with distilled water. Lastly, the filter and retained sample were weighted after dried at 105° for 1 hour. The reading was taken and acid solubility, *S* was calculated as Equation (2) :

$$S = \frac{m_s + m_F + m_{fs}}{m_s} \times 100 \qquad 2$$

F. *Turbidity Test*

5 grams of sample was filled in the sample cell following by 15 ml of distilled water. Then, the cell was capped and shaken vigorously for 30 seconds for suspend the particles that contaminated in the sample. The suspended particle sample was placed in a calibrated turbidity meter for measurement. The reading was taken in FTU (NTU).

G. *Crush Resistance Test*

The special requirement was needed in sample preparation for sieve test. The sample size between 80 to 120 grams was prepared by stacked only of the first and the second primary sieves. Only the sample retained on the second primary sieve is used in the crush test. The mass needed in a test cell is 5 gram. The samples were applied 1000, 1500, 2000 and 2500 psi. The content of the cell was transferred into the same sieve stack used before. The crushed material in the pan was weighed and recorded. The amount of crushed material as a percentage was calculated as Equation (3) :

$$m'_{pan} = \frac{m_{pan}}{m_s} \times 100 \qquad 3$$

H. *Erosion Test*

A test facility has been developed by using a jet impingement. The transporting fluid that was used is air. Multiple variables were evaluated to analyse the causes of erosion as target material properties, impingement angle, fluid velocity, test duration and proppant type, size and concentration. By used a compressed air stream, proppants were projected toward a metal target, 6061 aluminium and mild steel with a 90 degree impingement angle. 250 grams of proppant was released with 10 slugs of 25 grams in one minute interval. Inlet air pressure was adjusted to 50 psi for the velocity testing. The test was conducted with a two inch separation between the nozzle and the target. The erosion pattern on tested material was analysed and metal loss from the target was evaluated by weighing the target after testing.

RESULTS AND DISCUSSION

A. Sieve Analysis

The Table 2 below shown the results from sieve test for 70/140 mesh size. Each samples were sieved based on typical proppant size designations in ISO 13503-2. The results for all samples indicated same pattern in highest percentage retained on top sieve which is more than 90%. According ISO 13503-2, the samples supposedly less than or equal 0.1 to pass the test at first sieve otherwise the results showed differ outcome. The result of Sample 3 presented no mass retained between 0.125 – 0.150 mm while below 0.075 mm until 0.125 had a product. It point out that inconsistency in decrease size of sand at Pantai Seberang Takir 2. Sample 6 and Sample 8 represent no output less than 0.150 mm and the data clearly stated that percentage in size far from the requirement. The samples were classified as not a 70/140 product.

Table 2 : Percentage Retained on 70/140 Mesh Size

Mesh Size, mm	0.300	0.150	0.125	0.075	Pan	Final Total	% in Size
ISO 13503-2	≤ 0.1				≤ 1.0		≥ 90
Sample 1	93.75	5.90	0.24	0.11	0.00	100	6.25
Sample 2	91.57	7.88	0.29	0.23	0.03	100	8.40
Sample 3	94.42	5.47	0.00	0.11	0.00	100	5.58
Sample 4	92.74	6.87	0.20	0.19	0.00	100	7.26
Sample 5	97.43	2.53	0.04	0.00	0.00	100	2.57
Sample 6	99.98	0.02	0.00	0.00	0.00	100	0.02
Sample 7	97.32	2.63	0.05	0.00	0.00	100	2.68
Sample 8	99.37	0.63	0.00	0.00	0.00	100	0.63

The samples were repeated with different mesh size for 40/70 product as shown as Table 3. The configuration of result showed likely same with the previous one. Percentage in size were slightly increase but still insufficient to reach the target. From analysis Table 2 and Table 3 conclude that the samples were not categorized as 70/140 and 40/70 product.

Table 3 : Percentage Retained on 40/70 Mesh Size

Mesh Size, mm	0.355	0.300	0.150	Pan	Final Total	% in Size
ISO 13503-2	≤ 0.1			≤1.0		≥ 90
Sample 1	90.64	1.81	6.50	1.05	100	8.31
Sample 2	87.18	6.39	2.68	3.75	100	9.07
Sample 3	89.72	4.84	2.81	2.63	100	7.65
Sample 4	95.29	3.81	0.90	0.00	100	4.71
Sample 5	92.61	4.08	3.31	0.00	100	7.39
Sample 6	96.27	1.81	1.92	0.00	100	3.73
Sample 7	85.97	4.31	9.72	0.00	100	14.03
Sample 8	83.89	13.67	2.44	0.00	100	16.11

Figure 2 and Figure 3 summarized about the largest gap on particle size distribution between first sieve and second sieve. It can be related that majority percentage of sample not passed first sieve due to incompatible size.

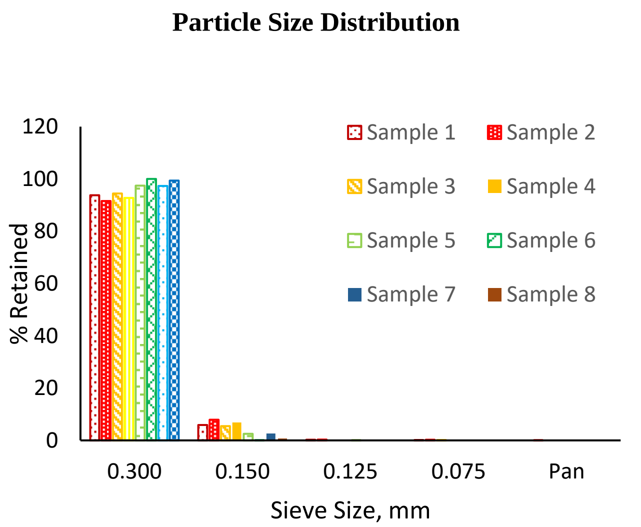


Figure 2 : Particle Size Distribution on 70/140 Mesh Size

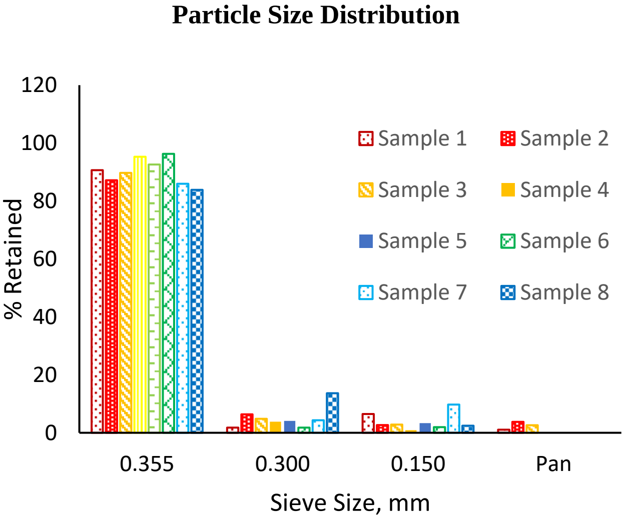


Figure 3 : Particle Size Distribution on 40/70 Mesh Size

The sieve test were carried out with another two proppant size designation,20/40 and 16/20 mesh size as shown in Table 4 and Table 5. There were once again inconsistently results where all the samples showed lower percentage at range 0.850 – 1.000 mm compared to 0.500 – 0.850 mm. Sample 7 and Sample 8 showed highly remarkable from 20% to nearly 70% of sand fall in the designated sieves while Sample 2 until Sample 3 were constantly gross. Sample 6 was the only one sample that passed the recommended criteria with 98% which is indicates it was 16/20 product. The numbers of Sample 1 was signified that it maybe considered as a grain size.

Table 4 : Percentage Retained on 20/40 Mesh Size

Mesh Size, mm	0.710	0.500	0.300	Pan	Final Total	% in Size
ISO 13503-2	≤ 0.1			≤ 1.0		≥ 90
Sample 1	75.35	6.86	6.97	10.82	100.00	13.83
Sample 2	43.07	29.91	22.01	5.01	100.00	51.92
Sample 3	50.45	27.61	17.61	4.33	100.00	45.22
Sample 4	44.31	29.32	20.15	6.22	100.00	49.47
Sample 5	53.65	25.53	17.03	3.79	100.00	42.56
Sample 6	46.29	37.82	13.09	2.80	100.00	50.91
Sample 7	69.97	11.99	10.39	7.65	100.00	22.38
Sample 8	69.01	13.87	10.14	6.98	100.00	24.01

Table 5 : Percentage Retained on 16/20 Mesh Size

Mesh Size, mm	2.000	1.000	0.850	0.500	Pan	Final Total	% in Size
ISO 13503-2	≤ 0.1				≤ 1.0		≥ 90
Sample 1	22.88	33.38	4.21	12.74	26.79	100	50.33
Sample 2	0.67	18.32	9.96	42.20	28.85	100	70.48
Sample 3	0.57	19.35	10.79	41.81	27.48	100	71.95
Sample 4	2.22	25.54	13.17	41.13	17.94	100	79.84
Sample 5	1.71	22.68	9.72	38.45	27.44	100	70.85
Sample 6	0.61	22.57	16.26	60.09	0.47	100	98.92
Sample 7	9.19	32.98	8.71	28.45	20.67	100	70.14
Sample 8	5.59	33.87	7.79	22.81	29.94	100	64.47

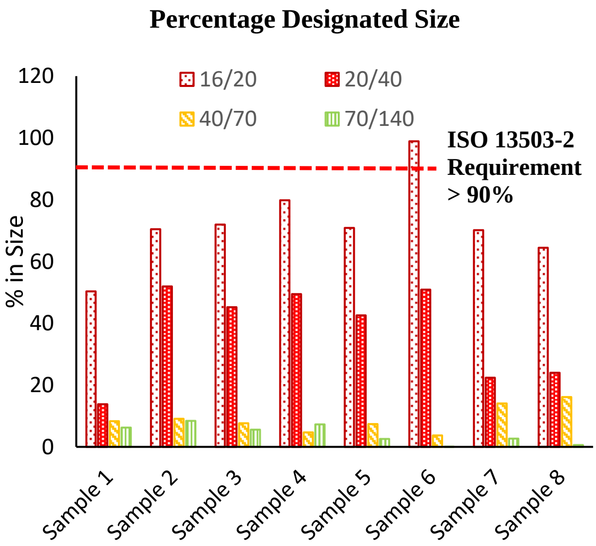


Figure 4 : Percentage Designated Size

Figure 4 showed that all the samples were drastically increased in percentage sand falls between the specified sizes from 70/140 to 16/20. Malaysian sands belong to larger proppant since the diameter range from 16/20. Generally, particle size distribution is more concentrated which can increase the conductivity. Huckabee et al., 2005 stated that grain size distribution was specified based on characteristics of the reservoir which include depth, pressure, and temperature of the well.

B. Bulk Density

Table 6 : Bulk Density of Sand Sample

Sample	Density (g/cc)
Sample 1	1.53
Sample 2	1.54
Sample 3	1.47
Sample 4	1.54
Sample 5	1.56
Sample 6	1.51
Sample 7	1.51
Sample 8	1.53

Bulk density is the mass of proppant that fills a unit volume that includes proppant and porosity. The purpose of bulk density in this analysis is to determine the mass of proppant needed to fill a fracture. Result in Table 6 shows the bulk densities of all sand samples. The highest density is a Sample 5 with 1.56 g/cc while the Sample 6 and Sample 7 shared the lowest values, 1.51 g/cc. The density of the proppant will cause remarkably affect the achieved fracture width.

C. Proppant Roundness & Sphericity

Table 7 : Roundness and Sphericity Sand Samples

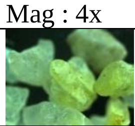
Sample	Mag : 4x	Roundness	Sphericity
Sample 1		0.44	0.72
Sample 2		0.50	0.70
Sample 3		0.41	0.57
Sample 4		0.62	0.63
Sample 5		0.54	0.60
Sample 6		0.32	0.65
Sample 7		0.49	0.72
Sample 8		0.42	0.67

Table 7 showed evaluation of the samples based on physical appearance. The results was compared with Krumbein and Sloss chart to determine whether it achieve the ISO 13502-3 standard. Sample 3 was failed to meet the requirement for both condition where the values not exceed 0.6. The good result came from Sample 4 with the value 0.62 for roundness and 0.63 for sphericity. The rest of the samples were met the sphericity specification but failed to meet the roundness specification. Figure 5 showed that fracturing sand can be considered by met the minimum B500 (Non ISO 13503-2) which is 0.5 [7] . There were three samples that passed the Non ISO 13503-2 standard, Sample 2, Sample 5 and Sample 7.

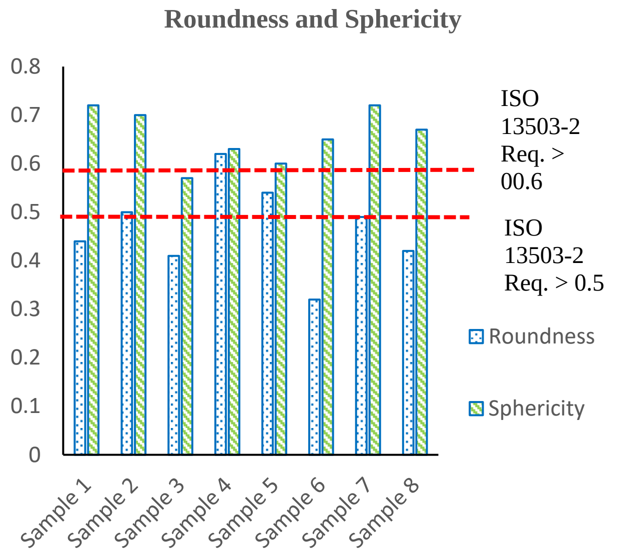


Figure 5 : Roundness and Sphericity Graph

D.Acid Solubility

Acid solubility is a physical property that is important to the durability of proppant especially in extreme conditions [8]. The test involves exposure to 12:3 HCL:HF at a certain condition. The differences between sample mass in early and final were used to determine percent solubility as shown in Table 7. Sample 1 showed the greatest solubility with 12.20%. Sample 2 and Sample 3 had solubility of 7.39% and 9.25% respectively. These two results were equivalent cause the samples taken from same place. The similar situation happened to Sample 4 and Sample 5 with 6.18% and 4.14% solubility. The standard ISO 13503-2 stated that sand proppant larger or equal to 30/50 should not exceed 2% for acid solubility. Due to all the samples were classified as greater or equal to 16/20, only Sample 6 nearly required the standard with 2.79% of solubility.

All the samples is a silica sand that made of high purity quartz sand. [3] proved that temperature, soaking time and static and dynamic conditions of mud acid were factors in dissolve of proppants. (Reed 1980; Weaver & Knox 1992) also stated formation fluids at higher temperature will increased solubility of quartz. In addition, pH plays main element in quartz dissolution process.

Table 8 : Percentage of Acid Solubility

Sample	Sample mass, g	Filter mass, g	Dried sample and filter,g	Acid solubility,%	ISO 13503-2
Sample 1	5.08	1.01	5.47	12.20	2% max
Sample 2	5.01	1.01	5.65	7.39	
Sample 3	5.08	1.01	5.62	9.25	
Sample 4	5.02	1.02	5.73	6.18	
Sample 5	5.06	1.00	5.85	4.15	
Sample 6	5.02	1.00	5.88	2.79	
Sample 7	5.02	1.02	5.81	4.58	
Sample 8	5.04	1.00	5.85	3.77	

E. Turbidity Analysis

The amount of suspended particles was presented in Figure 6 for the different samples. Sample 4 and Sample 1 were showed the highest value of turbidity with 39 and 37 FTU. Sample 6 with 14 FTU was the lowest amount of suspended particles. However, all the samples were passed the API recommended which is all types of proppant should not exceed 250 FTU. Same goes to [9] which is the turbidity ranging between 21 to 80 FTU for three samples obtained from Bayuda desert near Al Dabbah Province in north of the Republic of Sudan.

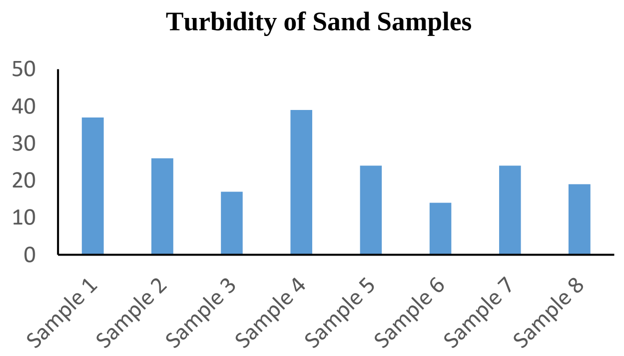


Figure 6 : Turbidity of Sand Samples

F. Crush Resistance Analysis

Table 9 : Percentage of Crushed Sample

Sample	1000 psi	1500 psi	2000 psi	2500 psi
Sample 1	5.60	6.73	19.12	23.57
Sample 2	2.50	8.65	9.25	14.91
Sample 3	6.67	8.68	8.82	10.56
Sample 4	8.18	12.94	13.21	15.69
Sample 5	8.43	11.96	13.41	16.15
Sample 6	10.60	14.12	17.19	18.42
Sample 7	8.52	15.27	16.44	19.54
Sample 8	12.20	15.00	19.20	20.20

The compressive strength of proppant was tested in accordance with ISO 13502-3. Crush resistance was performed by applied various stresses such as 1000, 1500, 2000 and 2500 psi as shown in Table 8. The purpose of the test is to determine K-value which is the closure stress under which 10% of the proppant will crush and become fines. Sample 2 and Sample 3 were showed the highest strength of proppant with K-value around 2000 – 2500 psi. Sample 1 was considered as intermediate strength proppant by 10% of crush in a range 1500 – 2000 psi. There are three samples with the K-value approximately in 1000 – 1500 psi which is Sample 4, Sample 5 and Sample 7. The data of Sample 6 indicated 10% of the proppant will crush at 1000 psi while Sample 8 showed the lowest proppant strength with below 1000 psi.

Figure 7 show a minimal loss of proppant integrity or amount of proppant crushing. However, [10] proved that the coated proppant shows a lower amount of crushing compared with the uncoated proppant. This could be the result of lack of static friction led to additional movement in the uncoated proppant or adhesion provided by the resin coating of the coated proppant.

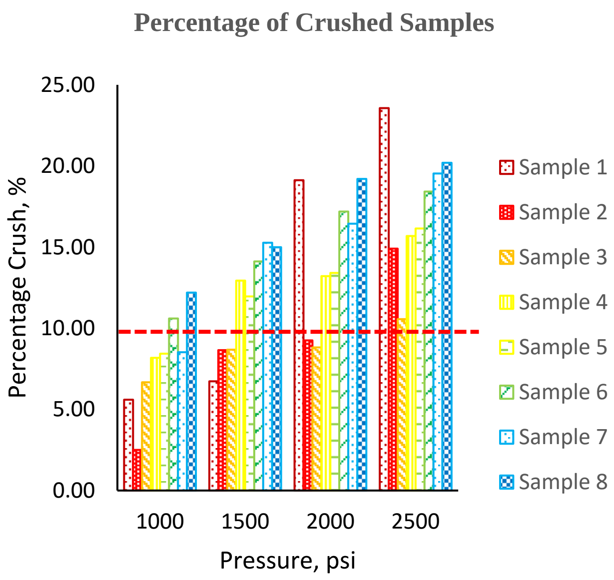


Figure 7 : Percentage of Crushed Sample Grap

[11] were determined sensitivity of the measurement of manual and automatic load application. Variance in proppant crush resistance is high influenced by proppant material, operator, cell size and load frame. [12] supported the above statement that an operator evaluating a proppant sample would obtain different crush values by different laboratories and leading to fault in determination of proppant suitability.

[13] presented that different behaviour of proppant packs over a wide range of pressures. There are three distinct regions in the trend of pressure derivative with time. First region with an increase in graph that represent the time during particles rearranged within the fracture. Second region with a constant that indicates the particles are undergoing compaction or supporting the load. Third region with a larger increase in pressure derivative than the initial rise in first region. Third region shows rearrangement occurs as grains break during the compaction process in second region. [12] categorized particles as interior or exterior grains when proppant are loaded into a crush cell. Grains in interior of the pack experience uniform stress distribution while exterior grains with greater force magnification. Thus, exterior grains experience greater damage in the crush cell. Therefore, decrease in proppant concentration led to crush increases.

G. Erosion Analysis

In Figure 8, it is possible to observe the wear scars obtained for three samples at different tested materials. A circular shape is observed at impact angle 90° for both tested materials. At the central part of the stream showed the concentrated plume of abrasive particles. The 6061 aluminium and mild steel showed clearly the halo effect which is indicated by a secondary erosion damage zone.

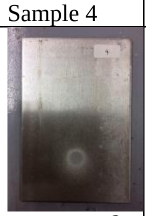
Material	Sample 4	Sample 6	Sample 8
6061 aluminium	 $113\ mm^2$	 $113\ mm^2$	 $154\ mm^2$
Mild steel	 $154\ mm^2$	 $154\ mm^2$	 $201\ mm^2$

Figure 8 : Erosion Damage on Tested Materials

[14] presented the damaged incurred on 6061 aluminium. The subsequent impacts of abrasive particles created particles of aluminium debris and lips around the craters. In addition, striations, craters and pitting are detected on the specimen surface. [15] stated that most of abrasive particles kinetic energy is used to penetrate the specimen resulting in embedded materials particles and dimple formation at high impact angle and low particle velocity. The process of metal removal is often observed at high velocity where metal is squeezed out of dimples to form ridges. Then, metal is removed by fracture due to flattening of ridges around dimples and plastic deformation.

Table 10 : Mass Loss of Tested Materials

Material	Sample 4	Sample 6	Sample 8
6061 aluminium	0.02	0.01	0.02
Mild steel	0.02	0.02	0.03

Table 10 presents the results obtained of the mass loss at all the three samples. Results indicate that Sample 8 was most erosive compared than Sample 4 and Sample 8. As this effect was interpreted to be due to erosion increased with the larger proppants. Deep of particles penetrates the surface depend on angularity of the particle and the sharpness of the asperities will cause on the removed material volume.

H.X-Ray Diffraction Test

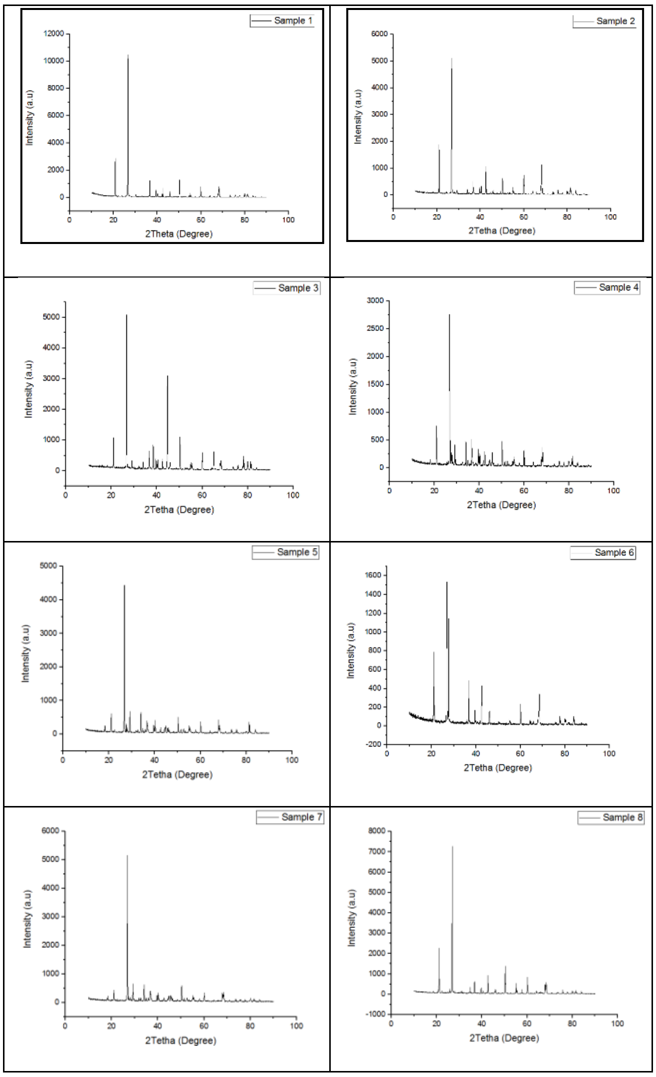


Figure 9 : XRD Analysis of Sand Samples

Characterizing the mineralogy of the particles can be performed in different interpretation. X-ray diffraction is to determines the minerals present in powdered specimens such as micro fines and presence or absence of clay. The mechanism of x-ray diffraction is lattice spacing of the elements present in the material due to pattern of atoms. When the x-rays are in phase, constructive interference occur and produce a wavelength peak. The inter planar spacing of the material was found by measuring the x-ray wavelength with various of angles. [16] stated that a diffractometer and a list of interplanar spacing are used in the powder diffraction pattern analysis. The intensities are prepared in order to identify an unknown substance and compared with the standard line patterns in the Powder Diffraction File (PDF) database. Figure 9 shows the XRD of Sample 1 until Sample 7. For Sample 1, the highest peak at 27° with the 10,000 a.u. Same goes to XRD for natural sand but a bit different with value of intensity. The natural sand and the samples was primarily composed of quartz along with the presence of calcite. The smallest particles such as clays and other deleterious products formed regularly.

III. CONCLUSION

The typical proppant sizes used in industrial is a Grade 20/40, Grade 30/50 and Grade 40/70 while all sand samples indicates lower than Grade 16/20. The suitability grain size distribution not only depends on proppant size itself but also include factor of compatible with the characteristics of the reservoir. Malaysian sand shows the lower evaluation in physical appearance with only one sample passed the roundness and sphericity which is Sample 4. The others were fulfilled the sphericity specification but failed meet the roundness requirement. The ideal proppant shape should provide a good pack porosity, thereby leading to better conductivity of proppant. For acid solubility test, only Sample 6 nearly achieved the standard while the others exceed the maximum 2% for sand proppant larger than or equal to 30/50. When proppant contact with mud acid or reservoir fluid, it should be not react to preserve the integrity of proppant. . The turbidity of the all samples agrees with the turbidity of ISO 13503-2 standard. In term of closure stress, the proppant must withstand the higher pressure in reservoir. Sample 2 and Sample 3 shows impressed result with the highest of K-value at 2000-2500 psi. For erosion test, the alloy material show good resistance of metal loss. Based on the results, it is possible for Malaysia to produce our own local proppant with some modifications through coating with suitable resin materials such as epoxy.

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