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PETROPHYSICS STUDY OF SAND STONE CORE TO THE ACCURACY OF ULTRASONIC PULSE VELOCITY

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ABSTRACT

Several cores sand stones Malaysian from out croup to determine their petrophysical properties in laboratories. Reservoir rocks are mostly consisting of sedimentary rock. There are few important characteristics of reservoir rocks in petroleum industry that need to be studied for further development. Among them are petrophysical properties such as density, porosity , water saturation and permeability. In this study, tests have been carried out to examine the relationship between petrophysical properties and acoustic velocity using Ultrasonic Pulse Velocity Method (UPVM). Result of the laboratory test have been used to determine physical rock properties from acoustic velocity data.

Keywords: Petrophysics, Ultrasonic Pulse Velocity.

1 INTRODUCTION

Any two characteristic of rock formation , is follow: Physical of rock characteristic, and Mechanical of rock characteristic. The physical rock characteristic follow;density, porosity, saturation, and permeability. The mechanical rock characteristic; compressive strength, shear strength , modulus young, and Poisson ratio.

The parameters of rock physical properties can measured by using two methods, laboratory test and well log analysis. In this paper to study how determined physical rock properties from acoustic velocity tester. As is well know in this tester is non destructive testing, on the other hand core sample is not leak.

Advances in acoustic wave and sonic logging technology have resulted in enhanced formation evaluation capabilities. Acoustic wave velocities in reservoir rocks depend on many parameters, for example , porosity, pore fluid properties and level of saturation, lithology, clay content, pore structure and geometry and other physical characteristics.

The application of acoustic and sonic wave technology in the petroleum industry has ben limited to measurement of compressional and shear waves. Compressional and shear waves correspond respectively to particle vibration parallel and perpendicular to the direction of wave travel. Acoustic wave measurement in the laboratory and in the field have been used for various applications ranging from determination of porosity , interpretation and calibration of sonic logs. identification of lithology , determination of classical elastic rock parameter and formation , enhanced seismic interpretation , micro fracture recognition and formation damage evaluation.

Study of rock properties as long time use of oil and gas industry, because oil and gas is stile of reservoir rock in trap stratigraphy and structure of sedimentary rock. Identification of rock properties can be design of optimization drilling program, specially if can drilling exploration is very difficult to determinate this parameter because not any core and logging. If this oil field the stratigraphy and structure any out croup, correlation of stratigraphy and structure can be held with geological map and seismic exploration.

Acoustic wave from seismic and sonic well log, can be correlation from acoustic wave from ultrasonic data in the laboratory. Ultrasonic tester is non destructive testing, and than core sample is not franc (non destructive), whit use correlation acoustic velocity from data test versus physical rock properties can be determine of characteristic of rock can be drill, stimulation (fracturing), and evaluated of reservoir rock.

M.S. King, M.Shams Khanshir and M.H. Wollington , as study of correlation acoustic with rock properties, as the topic: Petrophysics studies of core from a cross hole seismic test site (1991). Four vertical boreholes of 260 m depth have been drilled through five cyclical sequences of shallow-dipping sandstone, clay stone and lime stone formation.

This study can be predict physical rock properties several sand stone Malaysia from acoustic velocity of rock. Acoustic tools use sound to measured different characteristics of rock and the sonic tool is used in calculate density, porosity, water saturation and permeability.

2 PHYSICAL ROCK PROPERTIES

Rock physical properties that frequently is used in oil industry are density, porosity, saturation and permeability Rock density is measurement of the dimension of mass of a rock.. Density is stated as weight of mass divided by volume unit. Density is frequently stated in unit either gr/cc or Ibm/gal (ppg). Mathematically, density can be written (ρ) as follows. In laboratory , density can be determined using weighting method.The density of stone can be calculate by equation;

$$\rho = \frac{m}{V_b} \quad (1)$$

where ρ = density of sample (g /cm^3), V_b = bulk volume of sample (cm^3) and M = weight of sample (gram).

The porosity of rock depicts the dimension of pore space of a rock filled by fluid, either oil or gas or water or a combination of the fluid. In laboratory, the porosity of a rock can be measured using both porosimeter and weighting method. The porosity of rock can be formulated in dimensionless equation (percent or fraction), that is the ratio between pore volume (V_p) with total volume of a rock (V_b). It can be written mathematically as follows:

$$\phi = \frac{V_p}{V_b} \quad (2)$$

Saturation depict pore space of rock filled by fluid. The saturation is defined as the ratio between pore volume and filled by fluid and total pore volume. |Saturation is frequently stated either percent or fraction. Fluid filling pore space can be either oil or gas or water or a combination of the fluid. If the three fluid occupy pore space of rock then the following equation is applied, $S_w + S_o + S_g = 1$.

In laboratory, water saturation (S_w) can be determined using weighting method. In addition, from well logs, water saturation can be determined from evaluation of well log parameter combination consisting of density, sonic, neutron, gamma ray, and resistivity logs. From weighting method, water saturation can be determined using equation below:

$$S_w = \frac{W_n}{W_w - W_s} \quad (3)$$

Permeability of sandstone ,will be measured by using gas permeameter. The sample will be Put into the rubber sleeve and tighten, inside the core holder, and then put into gas permeameter system. Pressure regulating valve is slowly opened until pressure gauge reading of 0.25, 0.5, or 1 atm, depending on the large, medium or small tube used. The gas flow rate will be taken from gazometer when out let pressure P_2 must be stable. The permeability of sample can be calculated using Equation 2.4.

$$K = \frac{2Qx\mu xLx(P_1 - P_2)}{A} \quad (4)$$

where K = permeability of sample (D), Q = flow rate of gas (cm^3/s), P = viscosity of nitrogen (cp), L = length of sample (cm), P = inlet pressure (atm), P = outlet pressure (atm) and A = cross section of sample (cm^2)

3 THEORY OF ACOUSTIC

The ultrasonic wave include mechanical vibration type is involve to various mechanical forces in transit in a medium of rock. Effect of acoustic wave depend to medium elasticity spreading.

The transit time of rock is the mine , how long necessary of acoustic velocity transit at a rock in length dimension, in µ sec / ft. The transit time the equal reverse with acoustic velocity of wave in the rock. Transit time of rock to determined in mathematical equation as follow:

$$\Delta t \text{ ma} = 1/\text{ Vma} \times 10^6 \quad (5)$$

where Δt ma = transit time, µ sec/ft and V ma = acoustic of velocity wave in the rock, ft/sec.

Any 3 types of ultrasonic wave is basically direction of spreading particles medium with direction spreading wave, as follow; longitudinal wave, transversal wave, and surface wave. In this study is used longitudinal or compressional wave (P wave).

Method of testing for assessing the quality of materials from ultrasonic pulse velocity measurement, it is necessary for this measurement to be of a high order of accuracy. This is done" using an apparatus which generates suitable pulses and accurately measures the time of their transmission (i.e. transit time) through the material tested. The distance which the pulses travel in the, material (i.e. the path length) must also be measured to enable the velocity. Path lengths and transit times should each be measured to an accuracy of about 1%.

The instrument indicates the time taken for the earliest part of the pulse to reach the receiving transducer measured from the time it leaves the transmitting transducer when these transducers are placed at suitable points on the surface of the material . In this research of ultrasonic method can be determine, is direct method , when the surface of the specimens tasted direct contact whit transducer.

The direct transmission arrangement is the most satisfactory one since the longitudinal pulses I leaving the transmitter are propagated mainly in the direction normal to the transducer face.

4 ACOUSTIC VELOCITY MEASUREMENTS

Analysis condition is a material with ultrasonic wave is Non Destructive Test (NDT) Test. Principal is work as: electrical wave energy from generator pulse to transfer from transducer (Tx) as mechanical wave, and than can spreading in sample of rock (material). After reaching the receiver transducer (Rx), the wave energy can be retransformed to electrical wave by transducer (Rx) and then it is spread through booster and finally to determined time transit by digital numerical or oscilloscope.

The P wave transducers are each switched sequentially to produce and detect pulses of either type of wave. The pulse train bandwidths are as follows: P-wave, 54 kHz to 150 kHz;. The time-of-flight method is used to determine the P wave velocities. Either transit time of is displayed on PUNDIT screen and time Δtp, is then recorded for each of the P wave pulses.

From these values have to be subtratcted the times, Atp, required for the P wave pulses just to traverse the transducer holders and brass end pieces them selves. These values are obtained prior to the tests with rock specimens, by placing. the transducer holders and end pieces in face-to-face contact with a disc of lead foil between them and. establishing the times of flight, Δ tp for P waves. The velocities are calculated by dividing the length of the specimen, L, by the appropriate pulse time-of-flight, corrected for Δtp.

5 SAMPLE PREPARATION AND ASSEMBLY

Sample sand stone Malaysia of 1 inch diameter and length 1 inch were cored in the laboratory from out croup from the preserved core, The samples is conditioning to oven at 60 ° C during 8 hours and than sample to test density , porosity, permeability and water saturation versus acoustic compress ional wave velocity with Pundit. This procedure permits the measurement of both P wave velocities for preserved core samples obtained perpendicular to the bedding.

A CNS Electronics "PUNDIT" pulsing unit is used to pulse the transmitting combined P-wave transducers and to provide a trigger pulse. Results may be displayed as screen of Pundit as transit time and velocity is determined from Length of sample per transit time acoustic. The electronic system permits P -wave velocities on 1 inch length specimens of typical sedimentary rocks to be measured with an accuracy of better than ±1% and a precision of +0.5%.

6 RESULT AND DISCUSSION

Studied sand stone have of petrophysical characteristic that as density mean 2.4242 gr/cm^3, average porosity 13.6583%. And the average with mean permeability 13.6583 mD, and with mean water saturation is 44.5156%.

TABLE 1. Acoustic Velocity Vs, Rock Properties

Sample	Velocity (mm/u·sec) 54 KHz	Velocity (mm/u·sec) 150 KHz	Density (gr/cc)	Porosity (%)	Permeability (mD)
A-1	2.0270	2.0833	2.4320	13.67	13.67
A-2	2.3538	2.3181	2.4966	12.65	12.65
A-3	2.5813	1.6276	2.3934	12.83	12.83
A-4	1.6483	1.6483	2.3710	15.83	15.83
A-5	2.0547	2.0040	2.4517	12.60	12.60
A-6	1.9244	1.9188	2.4005	14.37	14.37

6.1 CORELATION OF DENSITY ROCK VERSUS ACOUSTIC VELOCITY

From six samples of sand stone Malaysian the acoustic velocity P wave (150 kHz) range from 1.6276 to 2.3181 mm/u.sec and determined from P wave (54 kHz) from 1.6483 to 2.5813 mm/u.sec. The rock density at sand stone Malaysia from 2.3710 to 2.4966 gr/cc. Correlation as follow is Figure 1.

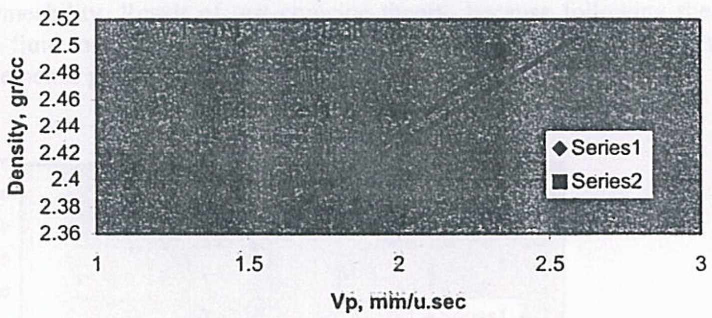

FIGURE 1. Acoustic Velocity (V_p) versus Density

6.2 CORRELATION OF ROCK POROSITY VERSUS ACOUSTIC VELOCITY

Than graph at Figure 2 is following generally it acoustic velocity wave decreasing with acceleration of porosity. This coincide theory that higher velocity wave at low porosity conversely. Specimen heaving assumed high case to have porosity compare low porosity The specimen having assumed with higher porosity to have many air room (pore) compared low porosity specimen. The wave of velocity more slow in air compared of massif material. Therefore more and more slow of air room progressively acoustic velocity waving.

The correlation velocity of P acoustics waves versuso porosity at transducer frequency 54 kHZ, fulfilling equation : y = - 3.183 X + 20.337, and corrective factor of R^2 = 0.6779. Correlation medium acoustics waves velocity to porosity at transducer frequency 150 kHz, fulfilling equation of y = - 3.183 X + 20.337, and corrective factor of R^2 = 0.6779.

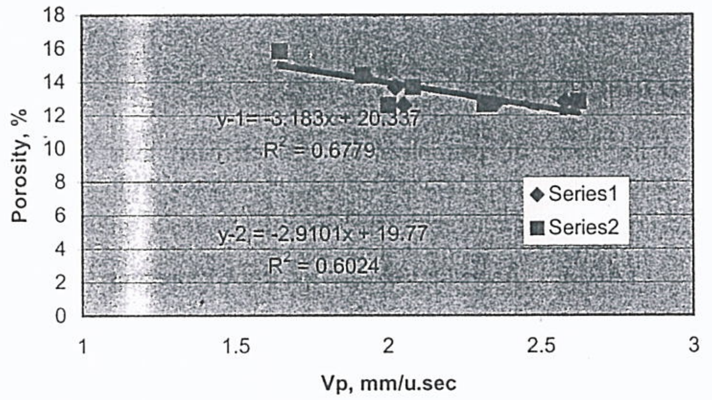

FIGURE 2. Acoustic Velocity (V_p) vs. Porosity of Rock

6.3 CORRELATION PERMEABILITY WITH NATURE OF ACOUSTIC ROCK

Data correlation taken away from ten Malaysia limestone samples from A-1 until A-6, by using Gas Permeameter. Result posed at smallest permeability have value 12.60 mD (A-5) until 15.83 mD (A-4), with mean permeability 13.6583 mD. Correlation level of velocity primary waving value for the frequency of transducer 54 KHZ and 150 KHZ, can be seen at Table and Figure hereunder.

Graph at Figure 3 above showing velocity waving primary fight against permeability of rock taken data predict to have porosity 11 < ϕ< 13 %. Got that velocity waving have rate to continue downwards it assess permeability or permeability grade excelsior progressively low velocity of waving primary. Velocity waving primary mount with degradation of permeability. Result of test coincide theory, because following theory, velocity waving in fluid medium is higher compare air, by that more and more content irrigate in rock cave hence progressively accelerate wave propagation.

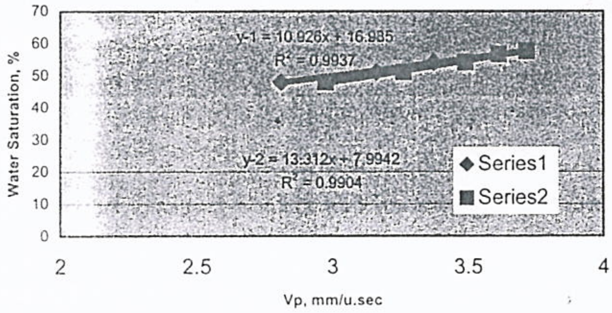

FIGURE 3. Acoustic Velocity (V_p) vs Permeability of Rock

The P wave acoustics velocity correlation to permeability at transducer frequency 54 KHz, fulfilling equation of $y = -9.979x + 30.568$, and corrective factor of $R^2 = 0.7879$. Correlation medium acoustics waves velocity to permeability at transducer frequency 150 KHz, fulfilling equation of $y = -9.4008x + 29.759$, and corrective factor of $R^2 = 0.7687$.

6.4 CORRELATION WATER SATURATION WITH ACOUSTIC VELOCITY OF ROCK

Graph at figure 4 showing velocity waving primary fight against saturation taken data predict to have porosity $12<\phi < 14$. Got that velocity waving have rate to continue with water saturated. Discovered grade excelsior saturation of velocity excelsior waving primary. The velocity waving primary mount with make-up of saturation. Result of test coincide theory, because following theory, velocity of waving in fluid medium is higher compare air, by that more and more content irrigate in rock porosity hence progressively accelerate wave propagation. Schedule and tattoo following will show acoustics waves velocity relation with saturation of sand stone Malaysian sample.

The assumed of dry specimen to have saturation of cipher fluids and value of triaxial compressive strength at maximum value. Reduction strength of rock with accretion of saturation, because do not of interstitial water to make a move free and cause pore pressure becoming burden to specimen mount. At dry specimen is no accretion of burden and this cause he may arrest detain higher of imposed pressure

TABLE 2. Acoustic Velocity vs. Water Saturation

Sample	Velocity (mm/u.sec) 54 KHz,	Velocity (mm/u.sec) 150 KHz	Water Saturation (%)
A-1	2.3070	2.4093	0 (dry sample)
A-2	2.8111	2.9764	47.9321
A-3	3.1625	3.2.627	51.0047
A-4	3.3733	3.4896	54.0773
A-5	3.6142	3,6142	56.5353
A-6	3.7112	3.7181	57.5443

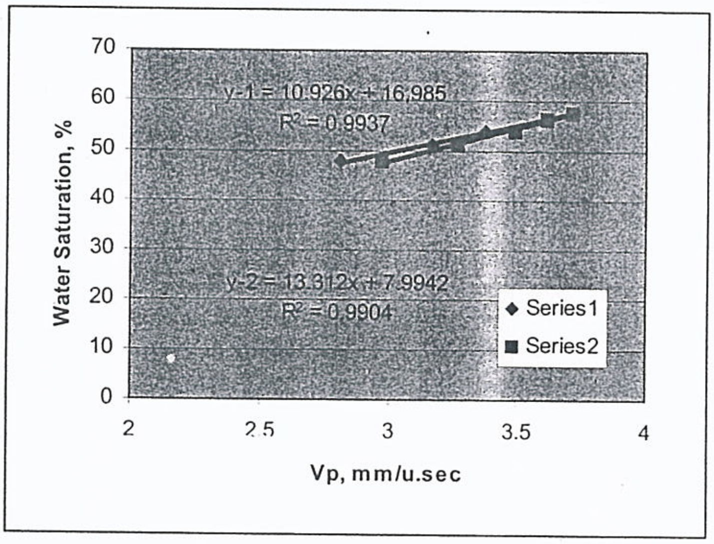

FIGURE 4. Acoustic Velocity (V_p) Vs Water Saturation

The correlation acoustic velocity of P wave by transducer frequency 54 kHZ versus water saturation, fulfilling equation: $y = 10.926X + 16.985$, and corrective factor of $R^2 = 0.9937$. Correlation medium acoustics velocity of waves to saturation at transducer frequency 150 kHZ, fulfilling equation of; $y = 13.281X + 8.1053$, and corrective factor of $R^2 = 0.9902$.

7 CONCLUSION

The result of the study of petrophysical correlation with an acoustic velocity can be outlined as follows: (1) the greater increasing density of rock to effect increasing acoustic velocity; (2) the greater descresing porosity of rock to effect increasing acoustic velocity; (3) the greater descresing permeability of rock to effect increasing acoustic velocity; and (4) the greater increasing water saturation of rock to effect increasing acoustic velocity.

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