Study on the Acoustic Characteristics of Rocks and Fracability in Wunan Oilfield

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Abstract: The acoustic characteristics under P& S wave velocity of 56 samples from Low Youshashan Formation in Wunan Oilfield were tested by SCMS-E high temperature and high pressure core multi parameter test instrument, the measured velocity ratio of P wave and S wave is 1.32-1.67 and the conversion between the P and S wave velocity of rock sample was established. The corresponding dynamic elastic modulus and Poisson's ratio were obtained on the base of the elastic wave propagation theory formula. So, according to the transformation relationship between static and dynamic mechanical parameters, rock brittleness index is calculated and average value is only equal to 38. Therefore, it is difficult to form a fully developed network model during the hydraulic fracturing. These achievements provide a guiding significance for fracturing development at Low Youshashan Formation in Wunan Oilfield.

1 Research background

The Wunan oil field is a Southeast-northwest plunging anticline with North-west longitudinal nosing structure. The southwest wing of the structure shows a relatively large formation dip while relatively small one of the northeast wing. The burial depth is 1200-2500m, and most of them consist of shore-lacustrine deposit. There were several fault blocks under the action of fault wherein secondary normal faults was developed in the fault block. The formation mostly dips towards north with high and flat-south low and steep-north structure, and the southern fault was well developed with large change in formation occurrence. The physical properties of oil reservoirs vary widely with high plane heterogeneity. A certain effect has been achieved in the practice of fracturing and reconstruction in the ore field, whereas vague understanding of the hydraulic fracture morphology seriously restricts the correctness and guidance of the optimum design for hydraulic fracturing. The research on the acoustic characteristics and fracability of reservoir rocks is very important for guiding the fracturing development of Wunan oilfield.

The acoustic characteristics of rocks are widely used to calculate the rock mechanics parameters, which have been proved to be related to such as lithology, porosity, and shale content [1,2]. Results from a large number of previous studies on the acoustic characteristics of different regions and lithologies [3-5] show that the acoustic characteristics of the rocks are different from each another, reflecting the difference in rock fracability. At present, the interpretation of rock mechanics parameters by logging data is fundamentally calculated by the acoustic characteristics data of rock P& S wave obtained by logging [6-9]. In this paper, 16 groups of rock samples with different buried depth in Wunan oilfield are used to test the acoustic characteristics of rock samples under P& S wave velocity, and the dynamic mechanics parameters are calculated based on the theory of wave propagation, and static and dynamic mechanics parameters are obtained by using the relationship between the two parameters. Various methods are used to calculate the brittleness index of rocks combined with the determinant mode of hydraulic fracture initiation to provide some guidance for fracturing optimization and design for reservoir development in Wunan oilfield.

2 Experimental test on the acoustic characteristics of rocks

The SCMS-E high temperature & pressure core multi-parameter meter is used to measure the acoustic characteristics of rock samples under P& S wave velocity based on the transmission measuring method. The acoustic wave shape of W9-17-1A rock samples is shown in Fig.1. P& S wave time difference and velocity are calculated, and the experimental results of P& S wave velocity of 56 rock samples from Wunan oilfield are shown in Fig.2.

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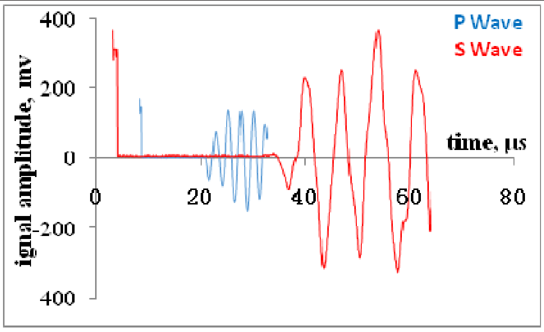


Fig.1 P&S wave shape of W9-17-1A cores

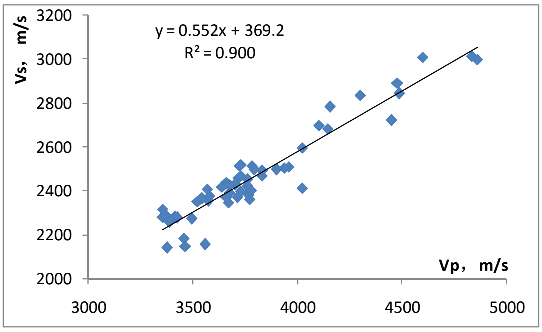
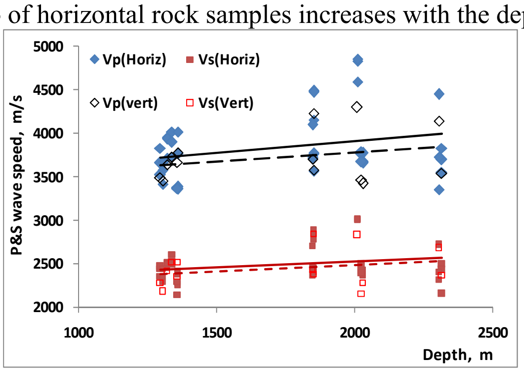


Fig.2 Test results and fitting relation of P& S wave velocity on samples

Results show: (1) P& S wave velocity of rock samples respectively are 2856~4859m/s (mean 3705.7m/s) and 2142~3014m/s (mean 2477.8m/s) with 1.32~1.67(mean 1.49) of velocity ratio; (2) The fitting relationship between P& S wave velocity is Vs=0.552Vp+369 with the correlation coefficient R>0.948, representing a good fitting result.

Furtherly, the acoustic experimental results of vertical and horizontal rock samples are separated and processed as shown in Fig.3. The experimental results show that: (1) Horizontal wave velocity is higher than vertical wave velocity, and has greater influence on P wave. (2) Vertical rock samples basically show a constant in terms of the ratio of P& S wave velocity, while P& S wave velocity ratio of horizontal rock samples increases with the depth.



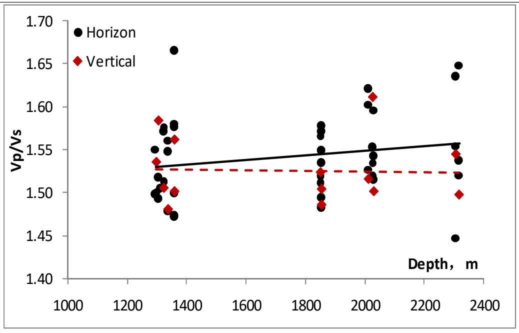


Fig.3 Vertical and horizontal P&S wave velocity, and Results analysis on the ratio test

3 Dynamic mechanics parameters of rocks

Based on the acoustic characteristics of P& S wave velocity, dynamic mechanics parameters of rocks from Wunan oilfield are calculated according to the relationship between elastic parameters and P& S wave velocity of rocks [6]. As shown in Fig.4, Dynamic elastic modulus is 25.8~56.7GPa (mean 34.65GPa) and dynamic Poisson's ratio is 0.082~0.2089 (mean 0.1301). Poisson's ratio and Young's modulus of rocks increase with depth.

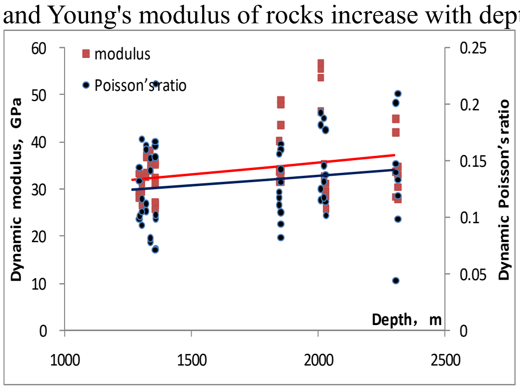


Fig.4 Dynamic mechanics parameters of rocks from Wunan oilfield

4 Fracability research on SRV

With the emergence and rapid development of SRV technology in unconventional reservoirs represented by shale reservoirs, the concept of reservoir fracability characterized by brittleness index is presented. At present, the definition of brittleness is still lacking in a unified view of micro fracture mechanism and comprehensive mechanics property with more than 20 kinds of methods for measuring brittleness [10]. In this paper, the following three methods are used to study the brittleness of rocks:

(1) Using the stress-strain curve for rocks

The stress-strain curve for rocks reflects the whole process from rock deformation, failure to final loss of bearing capacity under external loads. It is the most direct and effective method for qualitative evaluation of the brittleness of rocks [11]. The stress-strain curve of rock samples were tested by the triaxial rock mechanics test device. The deformation characteristics and some typical experimental curves are shown in Fig.5 and Fig.6.

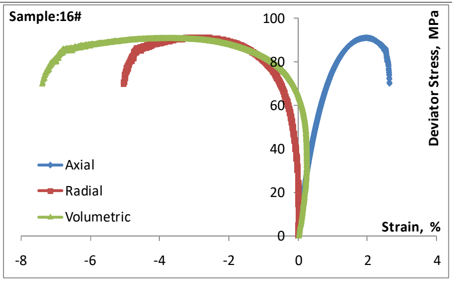


Fig.5 Stress difference-axial strain curve (sample 16#)

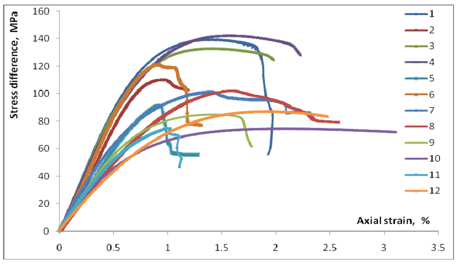


Fig.6 Stress difference-axial strain curve (partial)

The stress-strain curves of rock samples shown in Fig.6 show that there is generally obvious plastic characteristic for rocks.

(2) Evaluation by mechanics parameters

Based on dynamic and static parameters of rock samples obtained by the triaxial stress-strain test and the conversion relationship between the two parameters obtained by laboratory tests [12], the brittleness of rock is calculated according to the Rickman formula [13].

$$Brit = \frac{1}{2}((E-1)/7 + (0.4-\nu)/0.25)\times 100$$

Where, *Brit* — Brittleness index of rocks, dimensionless

E——Elastic modulus of rocks, MPa

ν — — Poisson 's ratio of rocks, dimensionless.

The brittleness index of rocks shows a positive correlation with elastic modulus, and a negative correlation with Poisson's ratio. The brittleness index of the oilfield reservoir is 27.5-48.5, with an average of only 38.

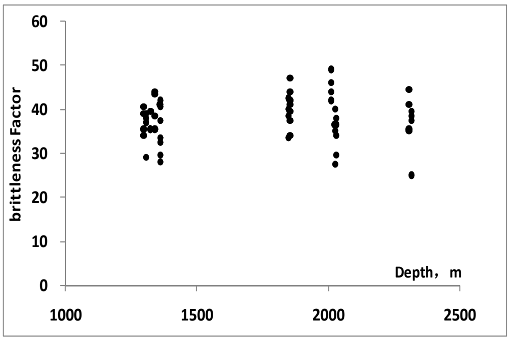


Fig.7 Brittleness index of rocks from Wunan oilfield (Evaluation by mechanics parameters)

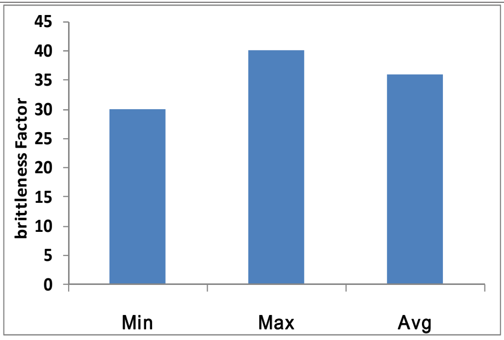


Fig.8 Brittleness index of rocks from Wunan oilfield (Calculation on mineral contents)

(3) Evaluation by calculation on mineral content

In the Wunan oilfield, the content of quartz, feldspar and rock fragment respectively is 30%-40% (mean 36%), 25%-35% (mean 30%) and 30%-38%, (mean 34%). The method of calculating brittleness index based on the content of brittle minerals presented by Jarvie et al. [13] is:

Brittleness index（%）= Content of brittle minerals (quartz)/total mineral content.

The calculated brittleness index is 30-40 (mean 36%) as shown in Tab.1 and Fig.9.

Tab.1 Relationship between brittleness index and hydraulic fracture morphology

Brittleness Index	Fracturing pattern
70	Full network fracture
60	Network fracture
50	Preliminary network fracture
40	Multicracks- network fracture
30	Multicracks
20	Two-wing symmetry fracture
10	Two-wing symmetry fracture

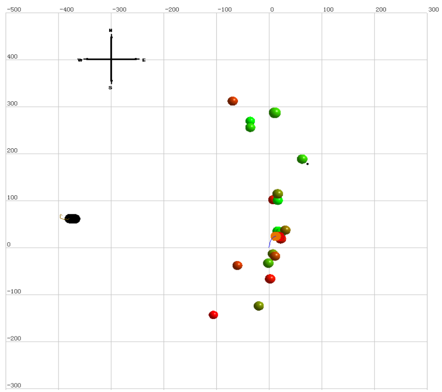


Fig.9 Microseismic monitoring results for well W217 events

5 Hydraulic fracture morphology tested by the microseismic method

The rock stress-strain curve shows that the study area has obvious attribute characteristics, based on the qualitative relationship between brittleness index and hydraulic fracture morphology [15] and above research results on brittleness index. Judging from the average brittleness index (only 36-38) calculated as per the two methods, the morphology is in a transition mode from multicracks to network. Thereby it is difficult to form a complete SRV with complex network.

The results of microseismic monitoring for fracturing in W217 well (black spots denote monitoring wells) are shown in Fig.9. It is proved that hydraulic fractures are multi cracks morphology or inadequate network fractures. The results are in agreement with the theoretical results.

6 Conclusions

The following conclusions by research on the acoustic characteristics and fracability of rock samples from Wunan oilfield are as below:

(1) P& S wave velocity of rock samples respectively are 2856~4859m/s (mean 3705.7m/s) and 2142~3014m/s (mean 2477.8m/s) with 1.32~1.67(mean 1.49) of velocity ratio.

(2) The fitting relationship between P& S wave velocity is Vs=0.552Vp+369 with the correlation coefficient R>0.948, representing a good fitting result.

(3) Based on the acoustic characteristics, the calculated dynamic elastic modulus is 25.8~56.7GPa (mean 34.65GPa) and dynamic Poisson's ratio is 0.082~0.2089 (mean 0.1301), both of which increase with depth.

(4) The rock stress-strain curve shows that the study area has obvious attribute characteristics, judging from the average brittleness index (only 36-38) calculated as per the two methods. It is difficult to form a complete SRV with complex network.

(5) The results of the field micro seismic monitoring confirm that the research results can be used to guide the fracturing optimization design in this area.

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