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Analysis of Reservoir Fracture Complexity based on Core Brittleness Characteristics

Zilin Zhang

Research Institute of Petroleum Engineering Technology, Sinopec Shengli Oilfield Company, Dongying, Shandong, 257000, China

Abstract

The brittleness index characteristics of reservoir cores are highly related to the post-pressure effect of tight oil, and the research on the influence law of brittleness on fracture complexity of tight reservoirs is significant for process optimization and post-pressure effect evaluation. The brittleness evaluation model of reservoir core based on full stress-strain curve is proposed by comprehensively considering the brittleness characteristics of the whole process of rock damage, i.e. pre-peak and post-peak stages; the accuracy of this model is verified by using uniaxial and triaxial stress-strain curves of rocks with different lithologies and existing brittleness evaluation models. The brittleness evaluation model can comprehensively evaluate the brittleness characteristics exhibited by the whole process of core destruction, and is more sensitive to the brittleness changes of rocks under different surrounding pressures of different lithologies than the traditional brittleness evaluation model; the strength parameters and elastic modulus of cores under different surrounding pressures are negatively correlated with the brittleness index.

Keywords

Reservoir Core; Brittle Characteristics; Total Stress-strain Curve; Brittleness Evaluation Model.

1. Introduction

The rock brittleness characteristics of tight reservoirs are closely related to the effect of reservoir modification in low permeability reservoirs. The quantitative description of rock brittleness characteristics needs to be carried out on the basis of theoretical research and joint field analysis in order to improve the accurate description of brittleness characteristics, which is also a hot issue for scholars at home and abroad. Rickman R [1] proposed the relationship between rock brittleness and fracture extension pattern of hydraulic fracturing in 2008. He concluded that in weakly brittle reservoirs, the fractures are bipartite symmetrical and do not fracture in the vertical direction; in moderately brittle reservoirs, the fractures are bipartite symmetrical multi-branched fractures; and in strongly brittle conditions, the fractures are very complex. Therefore, the rock brittleness magnitude determines the fracture morphology. The initial stage of the mechanical study was limited by experimental conditions and understanding, and only the stress-strain curve of the rock before fracturing and the brittleness under zero-perimeter pressure conditions were investigated. Mogi K et al [2,3] carried out cyclic uniaxial compressive experiments and found that the mineral composition of the rock has a strong influence on the rock brittleness. Perera M S A et al [4] showed that the stress conditions, temperature conditions, and chemical conditions to which the rock is subjected, produce microscopic damage to the rock and have an effect on the brittleness. With the advancement of technology, the stress-strain curves of granite and marble were first obtained by uniaxial compressive experiments in 1965 by Cook N G W [5].Hull D [6] and others carried out physical simulation studies

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to establish the fracture morphology of rock crushing to characterize the brittleness.Hallbauer D K et al [7] mainly studied the relationship between the surrounding pressure and rock damage. Hajiabdolmajid V and Kaiser P et al [8] established the CWFS model by drawing on the experimental results of the Mohr-Cullen criterion analysis, which can better reflect the frictional enhancement and cohesive weakening of the rock during brittle damage.

In order to comprehensively evaluate the brittle characteristics of the whole process of rock failure, the stress-strain state before and after the peak should be considered simultaneously. The author believes that the calculation model of brittle characteristics should have three main controlling factors : (1) the growth rate of stress before peak, the smaller the growth rate, the weaker the brittleness ; (2) After peak stress reduction rate, the smaller the reduction rate, the weaker the brittleness ; (3) The lower the drop level of peak strength, the weaker the brittleness. At present, most of the main research results only consider one or two of them. Therefore, how to use the characteristics of the total stress-strain curve to establish a comprehensive brittleness evaluation method is of great significance for fracturing engineering optimization.Organization of the Text.

2. Calculation Model of Rock Brittleness Index based on Whole Stress-strain Curve

The connotation of rock brittleness is that the rock has undergone slight deformation under external force in a short period of time. At the same time, it generates large stress confrontation values and stores huge energy. When the stress intensity reaches the maximum value, as shown in Fig. 1.ε_p is the peak stress strength of rock. When the stress continues to increase, the rock itself destroys and releases energy, and the stress drops sharply. Therefore, the stress drop ability after peak value is also the main parameter for evaluating rock brittleness.

In this paper, the brittleness calculation method combining the whole stress-strain curves before and after peak is defined as follows : The pre-peak brittleness index B_a and post-peak brittleness index B_b are proposed, and the stress rise rate and stress drop rate before and after the pressure peak are used to evaluate the brittleness of reservoir core.

$$B = B_a + B_b$$

$$B' = B_a \times B_b$$

In the formula:B_a is Pre-peak brittleness index, B_b is Post-peak brittleness index.

Further definition:

$$B_a = \frac{(\sigma_p - \sigma_i)/\sigma_p}{(\varepsilon_p - \varepsilon_i)/\varepsilon_p}$$

$$B_b = \frac{(\sigma_p - \sigma_r)/\sigma_p}{(\varepsilon_r - \varepsilon_p)/\varepsilon_p} \times \frac{\sigma_p - \sigma_r}{\sigma_p}$$

In the formula: σ_i is initial stress, ε_i: initial strain, σ_p: peak compressive strength, σ_r: drop residual strength, ε_p: strain at peak compressive strength, ε_r : drop residual strength, the significance of each parameter in the stress-strain curve is shown in Figure 1.

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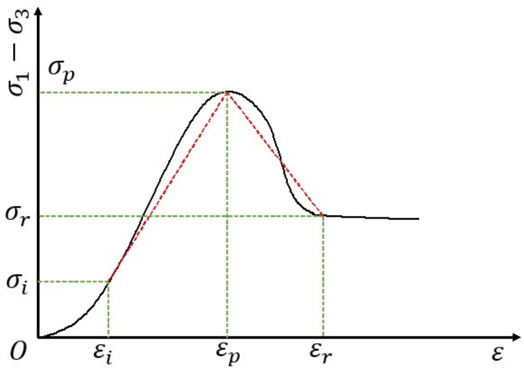

Figure 1. Diagram of brittleness evaluation index

3. Correlation Analysis between Core Mechanical Parameters and Brittleness Index

The initiation stress, peak strength and residual strength of rock are important parameters to characterize the failure strength characteristics of rock. Figure 2 fitted the correlation between the initiation stress, peak strength and residual strength of core and the brittleness index B andB' under different confining pressures. It can be seen from the fitting results that the three strength parameters have good linear correlation with the brittleness index. With the increase of surrounding rock, the initiation stress and peak stress of core in pre-peak stage gradually increase. Brittleness index B and B' decrease gradually, The brittleness of rock mass gradually weakens. For the post-peak stage, the residual strength increases with the increase of confining pressure, the energy released by rock fracture decreases, the brittleness index B and B' gradually decrease, and the brittleness becomes weak.

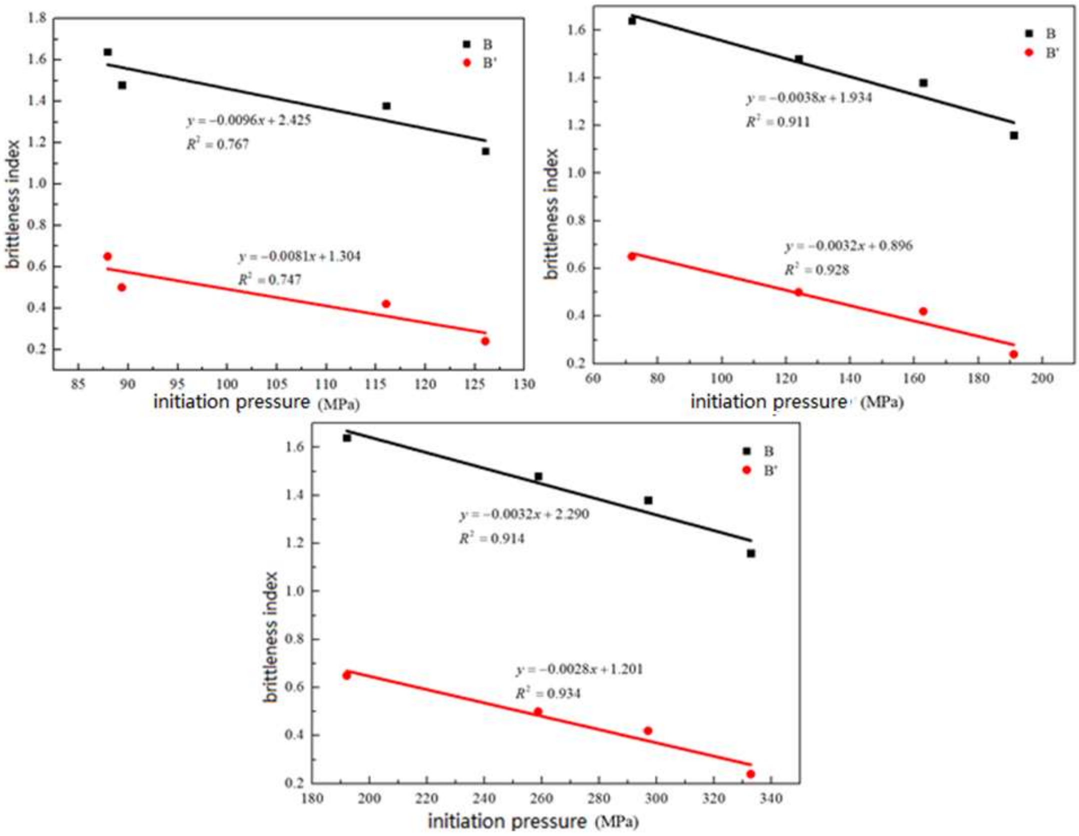

Figure 2. Correlation curve between strength parameters and brittleness index of core under different confining pressures

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Elastic modulus is the main parameter to reflect the elastic deformation resistance of rock under stress. Fig. 3 shows the relationship curve between elastic modulus and brittleness index of core, and elastic modulus is negatively correlated with brittleness index. Therefore, for the fracturing transformation of deep tight reservoirs, the higher confining pressure leads to the decrease of brittleness index. Different from shallow fracturing, it requires higher required fracturing parameters to obtain complex fractures, and the higher the pressure of rock damage, so it is necessary to accurately simulate the influence of brittleness on fracture morphology, and obtain the optimal construction parameters according to the construction ability.

The comprehensive study shows that the core strength parameters and elastic modulus increase with the increase of confining pressure, but the brittleness index decreases with the increase of confining pressure. The core strength parameters and elastic modulus are negatively correlated with the brittleness index under different confining pressures.

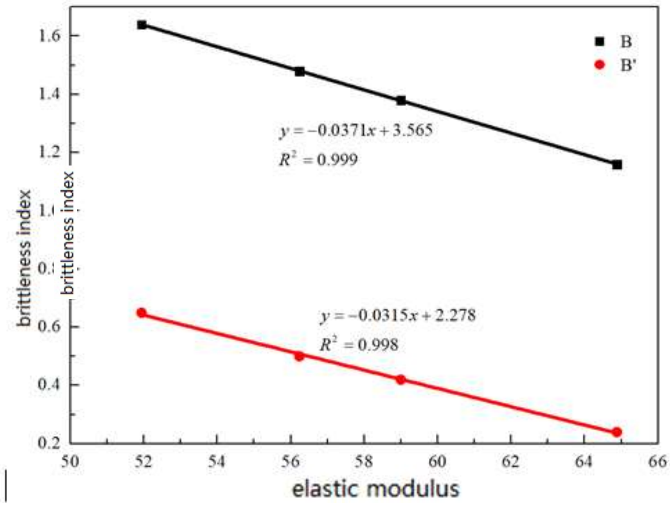

Figure 3. Correlation fitting curve between elastic modulus and brittleness index of core under different confining pressure

4. Conclusion

Based on the in-depth analysis of the calculation methods of rock brittleness index at home and abroad, a calculation method of total stress-strain brittleness index B and B' is proposed, which combines the stress uplift rate and stress drop rate. This method combines the relative variation of three stress states of rock initiation-peak-residue. Compared with the existing brittleness evaluation model, the model has good accuracy and applicability. The core strength parameters and elastic modulus increase with the increase of confining pressure, but the brittleness index decreases with the increase of confining pressure. The core strength parameters and elastic modulus are negatively correlated with the brittleness index under different confining pressures.

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