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Combine the capillary pressure curve data with the porosity to improve the prediction precision of permeability of sandstone reservoir

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ABSTRACT

Permeability is a critical parameter that reflects the nature of reservoir, playing a crucial role in the development of oil field. It is difficult to accurately calculate the permeability parameter in reservoir evaluation. Capillary pressure curve represents pore-throat size and distribution of reservoir rocks, and as for the porous sandstone, absolute permeability of rock depends primarily on the pore throat distribution. This paper has improved the estimation model for permeability established by Swanson, adding porosity factor, and has successfully established the absolute permeability estimation model for sandstone using Capillary-Parachor parameters. The permeability of 30 rock samples is estimated by using the above-described two kinds of model respectively. The result shows that the permeability estimated by the improved model is in good agreement with the value of permeability of core testing, and has made some improvement in the precision when compared to the permeability estimation model established by Swanson.

1. Introduction

Capillary pressure curve may derived by mercury injection into rock samples, and is an important data for studying reservoir pore structure (Leverett, 1941; León and León, 1998). Scholars have carried out a lot of researches on the estimation of the absolute permeability using capillary pressure data, and meanwhile, these are indispensable work to find out the relationship between pore structure parameters and absolute permeability (Tiab and Donaldson, 1996; Hasan et al., 2014). Permeability is one of the most important parameters of the reservoir. Using mercury injection curve to estimate formation permeability is of great significance.

2. The capillary pressure curve analysis

Thomeer (1960) found that when the capillary pressure and saturation data are plotted on a log–log scale, a smooth curve best fitting the points approximates a hyperbola which is mathematically expressed as follows:

$$\lg\left(\frac{p_c}{p_d}\right) \times \lg\left(\frac{S_{Hg}}{S_{Hg\infty}}\right) = -C^2 \quad (1)$$

Where P_c is the pressure of mercury intrusion, Mpa; P_d is displacement pressure, MPa; S_{Hg} is the saturation of mercury intrusion,%; $S_{Hg\infty}$ is the saturation of mercury intrusion at infinite capillary pressure; C^2 is the pore geometry factor.

The inflection point A in the above capillary pressure curve of Fig. 1 is essentially the vertex of hyperbola on the log–log scale. It is closely related to the condition when non-wetting phase fully occupies that part of effective pore space that can effectively control fluid flow in the rock pore system.

The value of $(S_{Hg}/P_C)_A$ of point A is called Swanson parameter (Swanson, 1981). Guo et al. (2004) has decomposed Eq. (1) in a stable state, and has found that if a figure is drawn taking S_{Hg} as abscissa and S_{Hg}/P_C^2 as ordinate, the highest point (S_{Hg}/P_C^2) max is called Capillary-Parachor parameter which can also reflect the pore structure of reservoir. The Fig. 2 shows a typical diagram of curve of relation of S_{Hg}/P_C, S_{Hg}/P_C^2 versus saturation of mercury intrusion S_{Hg}, and it can be seen that both are similar to parabolic curves with a maximum existed.

3. The analysis of Swanson parameter and Capillary-Parachor parameter

There are a lot of parameters in the capillary pressure data that

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0920-4105/

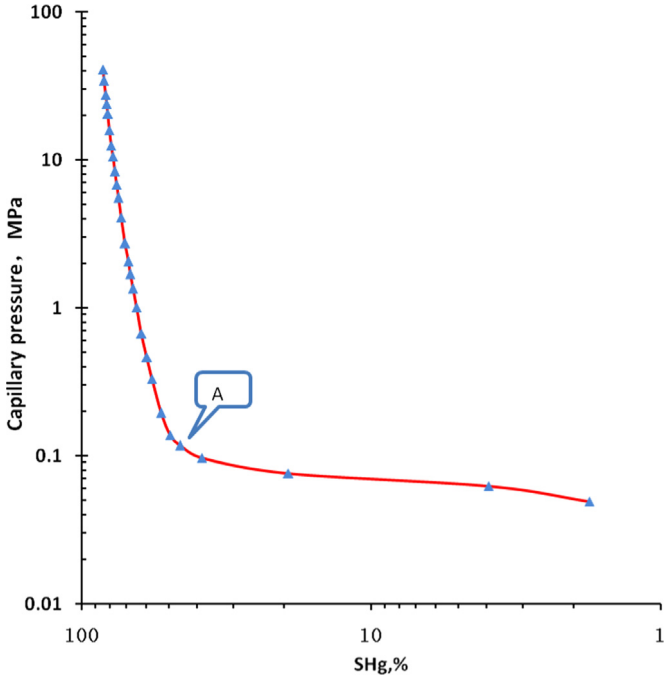

Fig. 1. Mercury-injection capillary pressure curve on the log-log scale.

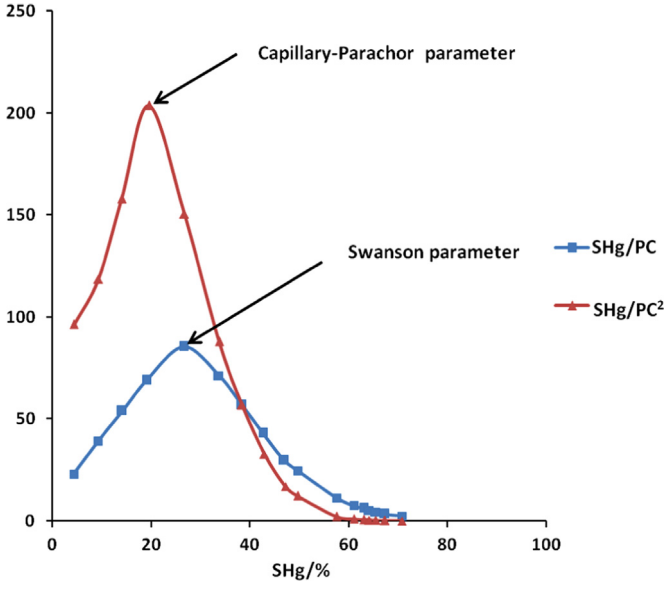

Fig. 2. Curve relations among S_{Hg}/P_C and S_{Hg}/P_C^2 vs. S_{Hg}.

reflect pore structure, such as quality coefficient of reservoir, displacement pressure P_d, capillary pressure mid-value P_{C50} and mean value of pore throat radius Rm, etc., and they all can characterize seepage capacity of pore. Displacement pressure P_d is the capillary pressure corresponding to the maximum interconnected pore throat in pore system, and it is significantly related to rock permeability. The higher permeability the rock sample is, the lower the value of displacement pressure will be, and vice versa. It is one of the main indicators classfying reservoir property of reservoir rocks. The P_{C50} is the median capillary pressure when the mercury saturation reaches 50% and it is a measure of the capillary pressure distribution trend. Mean value of pore throat radius is the measurement of the overall average of pore throat size (Ritter and Drake, 1945; Donaldson et al., 1991; and Tiab and