THE MANUFACTURE AND USE OF ARTIFICIAL CONSOLIDATED CORE SAMPLES IN CHINA

Q. Jishun
Research Institute of Petroleum Exploration and Development, PetroChina

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ABSTRACT

Artificial core plugs can be used to replace natural reservoir core plugs and outcrop core plugs for the study of oil-water displacement mechanism. As suitable reservoir or outcrop core plugs are not always available, artificial core plugs have been used as alternative porous media for laboratory investigation of the fluid flow in China. In this paper, the design philosophy, manufacture technology and evaluation methods are summarized, and the applications of the artificial core samples are introduced.

INTRODUCTION

Core plug samples are widely used in the core analysis and petrophysical experiments. Presently, there are three types of core samples used in experiment: natural reservoir core samples, outcrop samples and artificial core samples. Artificial cores include consolidated and unconsolidated cores. Since suitable natural core samples are relatively more expensive or may not be available, artificial consolidated core samples can be used to reflect flow characteristics of real natural rock and replace the natural core. So, developing the technology of making artificial consolidated core has practical value and theoretically significance.

It was well-known that Darcy's experiment (1856) was conducted upon some artificial unconsolidated sand packs [1]. Slichfer (1899) had presented the equal diameter spheroid pack rock model, while Graton and Fraser (1935) proved that the porosity of Slichfer's model was related only with the stack of the sand grain. Hawksley summarized up the previous study about unconsolidated core for more than 50 years after Slichfer's work. He pointed that Slichfer's models couldn't be applied because the proper phenomena such as cementation and compaction weren't properly introduced. These were believed the prior proposals about the control condition of artificial cores[2]. Corte (1957) attempted to make consolidated rock. He used the rock granularity constitute as control condition. However, the result was disappointed[3]. Through abundant study work about artificial consolidated core, Masch and Denny (1966) pointed out that there was direct

relation between rock permeability and the particle diameter only under the consolidation condition[4]. Collepardi (1973) and Young (1974) studied the pore structure characteristics of consolidated materials through capillary pressure and proposed that the amount and component of consolidated materials have the ability to control the pore structure[5,6]. Ivensen (1973) made porous media by the abio-consolidation sinter method and studied the material's pore structure through scanning electron microscope[7]. These works deepen the study of artificial consolidated core from macroscopic control to microscopic control.

The petroleum technologists in China began to study and manufacture the artificial consolidated models in the early 1950s. From 1990s, in order to satisfy the need of tertiary oil recovery, the artificial consolidated core plugs were used for the determination of oil water relative permeability and capillary pressure curve under specified condition. It was found the capillary pressure and relative permeability curves of artificial core plugs were close to the natural cores. Therefore, it is regarded as suitable to study oil-water displacement mechanism.

At present, there isn't a set of uniform manufacture standards on artificial consolidated core plugs. The companies and factories usually established laboratory standard according to the specified purpose. To satisfy the need in petrophysical modeling, the manufacture standard of the artificial consolidated core plugs is needed for both static and dynamic parameter. In this paper, the manufacture process of the artificial core plugs will be described and the manufacture standard of the artificial consolidated core plugs with the consideration of geometrical similarity and mechanical similarity will be discussed.

MANUFACTURE OF ARTIFICIAL CORE PLUGS

The artificial consolidated core plugs were designed through similarity principle. The process for manufacture artificial core plugs includes material screening, mixing, moulding, compaction, drilling and trimming.

Material Screening

The materials of the artificial consolidated core mainly include skeleton material and cement material.

(1) Skeleton Material

The basic material of the artificial consolidated core is natural quartz sand. Consider the stability of rock character, the purity natural quartz sand is selected. At present, the

natural quartz sand most used include Shandong Pingdu sand, Beijing Fangshan sand, Sichuan Dongling sand etc. Moreover, when making model, we must consider some character such as particle's surface and sphericity.

(2) Cement

The basic demand of making artificial consolidated core is that the size of core's pore throat and distribute is close to natural core. The merits of organic matter as cement are that it can make core under room temperature. And its disadvantage is that the pore inner surface of the core is smooth (called glass surface); small pore throat or micropore throat is not present. The inorganic cement material include phosphatic aluminum, pottery clay, and porcelain clay. By the use of inorganic cement material, the inner surface of pores become comparatively rough, and there is some microscopic pores and throats. Its disadvantage is that the temperature involved is high and the cement performance is difficult to control.

Fabrication Process

The making method mainly include molding and consolidation craftwork. There are four types about forming method – dry compaction, vibration, hot casting and direct filled sand.

(1) Dry Compaction Method

Dry compaction method can divide into two types –the method with the constant pressure and the method with constant density, which also is called shaping with the constant pressure and with the constant model. The definition of shaping with the constant pressure is that material in the model was exerted to constant pressure so as to ensure that core is compacted and the basic parameters of the same kind of core have the repeatability when artificial core is formed. The definition of the constant model is, according to the shape and size of model, that core is compacted and used in a variety of comparative experiments with no need to be processed again.

(2) Vibrating Method

For the artificial core made by dry compaction method, the process of filling sand produces great effect to the uniform of core. Therefore vibrating method was invented. Its primary method is to dig a pit having certain acreage and depth on the ground. At the bottom of the pit, layer thin sand is filled in advance and flatted by rake, then put the wooden mould into the pit and the place around the mould is filled with thin sand. Meanwhile, the mould is filled with model materials that is smoothed by scraper, then was paved with plastic cloth, and spread with thin sand. Then it take 20~30 minutes to

tamp with compactor, finally model can be taken out. The degree of uniform of the artificial core made with this method is relative well, however, its operation is so complex and the workload is so hard that the method is difficult to popularize.

(3) Casting Method

Casting method is usually adopted in the technology of ceramics. Its advantage is that the formed base his relatively uniform. The material is put into a special suspending liquid with definite proportion, which can turn into colloidal liquid after equable mixing in a certain temperature, then it is poured to model and dealt with high-temperature after it is taken out of the model, finally the artificial core is made.

(4) Filled sand Method

In this method material is directly filled in steal pipe or organic plastic (or plastic) to form core in pattern.

Cement Process

There are primary two types of cementation: low temperature cementation and high temperature cementation.

(1) Cement in Low Temperature

Cement in low temperature is applied for consolidated core made of organic material. It refers to the process that after the semi-finished shaped core is taken out from the model, it is placed in a box in constant temperature and, according to a certain rising temperature process, dried by fire and solidified under the condition less than 100 deg.C. The time is usually within 8~24 hours.

(2) Cement in High Temperature

Cement in high temperature is applied for the artificial core consolidated by inorganic material. It refers to the process that after the semi-finished shaped core is taken out from the model, then, according to a certain rising temperature process, placed in the agglomerative stove and dried by fire and solidified until 800deg.C. The time is usually in 4~6 days.

EVALUATION OF ARTIFICIAL CORE PLUGS

The purpose of evaluation of the artificial core is to appraise the extent of similarity for the core and prototype (natural rock). According to the requirement, the examination for the core mainly include: the basic parameters, such as porosity, permeability, saturation, etc; the characteristic relations of seepage flow, such as capillary pressure curve, relative

permeability curve, displacement curve and wettability etc; mechanics parameters and fluid sensitive parameters of core. In order to examine the stability of core quality; we also need to examine the repeatability and randomness of the basic parameters of core.

The conventional core analysis methods were adopted for examining the basic parameters and repeatability of artificial consolidated core. The special core analysis methods were adopted for examining the characteristic relations of capillary pressure curve, etc. All the above-mentioned methods are carried out in accordance to industry standard.

Table 1 is a comparative table about the characteristic parameters data of pore structure of GM and nature core. Figure 1 and Figure 2 are comparative charts of capillary pressure curve and relative permeability curve of GM and natural core made in the geological institute of Shengli Oilfield Company, China. From the comparison, as shown in Table 1 and Figures, we may conclude that the artificial consolidated core has achieved high similarity to natural core plugs in the basic parameters and seepage flow behavior.

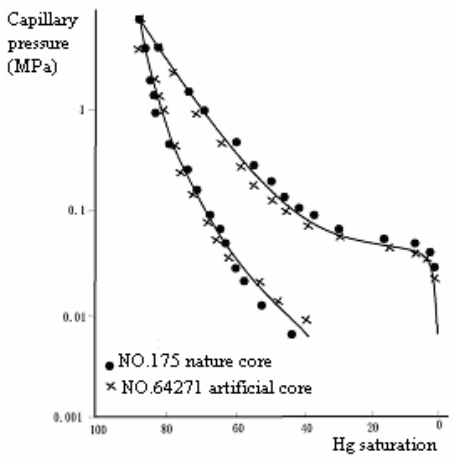

Figure 1.Capillary force correlation curve

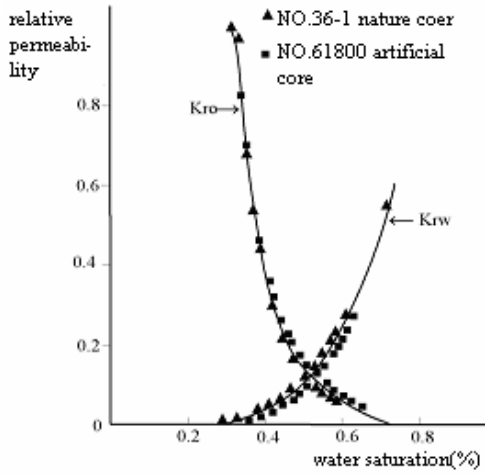

Figure 2. Relative permeability correlation curve

Table 1 characteristic parameter data of pore structure for GM and natural core plugs (Tang Renqi, 1994.)

Constitute	I		II	
Sample No.	175	64271	149	64261
Type of core sample	Nature	GM	Nature	GM
Air Permeability(μm^2)	0.453	0.466	1.097	1.070
Porosity (%)	26.1	26.2	26.2	28.1
Mean radius(μm)	7.5	8.8	9.7	11.3
Variance coefficient	0.91	0.83	0.78	0.77
Homogeneous coefficient	0.38	0.40	0.38	0.39

Lithologic coefficient	0.20	0.16	0.28	0.21
Maximum radius(μm)	19.2	21.4	25.30	28.6
Maximum Hg-bearing porosity (%)	80.1	87.2	89.7	88.0

CONCLUSION

The technology of artificial consolidated core in China has been studied and explored over 40 years and the technology has achieved a high level. The study of artificial consolidated core and the formation have developed from the similarity principle. At present, a complete set of advanced crafts and methods of artificial core have been formulated from the formula design, mould and consolidation to the quality examination. The technology satisfies the basic requirements of petroleum scientific colleges and universities, for fundamental core analysis experiments and EOR investigations.

Based on the review of the study of artificial cores, the strength of artificial core is different from the index of stability and pore structure etc. Therefore, searching for more ideal consolidation is important in the future study of artificial core. In view of the manufacture technology of artificial core, the uniformity and repeatability of artificial core made by hand or formed by shaped model at is still not ideal. Therefore there is a need for improving and developing the manufacture technology. Artificial limestone with fissures is still unavailable, hence making such artificial core needs to be further investigated. Establishing a set of industry standards of artificial core is recommended.

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