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Extended Abstract

Design of Instrument to Measure Capillary pressure and Resistivity Index (CAPRI) for a Reservoir Rock

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Abstract

Capillary pressure plays a crucial role in extracting oil from underground reservoirs. The simultaneous measurement of capillary pressure and the electrical resistivity index of rock allows for the determination of connate water saturation, which is essential for calculating the in-situ oil volume. Since laboratory analysis of core samples is the only direct method to obtain reservoir parameters, the results of electrical resistance measurements are also utilized to calibrate the electrical resistance log. Another outcome of measuring capillary pressure and resistivity index is the ability to determine the height of the transition zone. Additionally, oil displacement modeling can be performed by measuring capillary pressure at various degrees of water saturation, which aids in assessing the effectiveness of immiscible injection methods for enhancing oil recovery. The objective of this study is to design a device that measures capillary pressure and electrical resistivity index as a function of saturation percentage. Developing such a device, which encompasses a wide range of laboratory operations, can lead to significant cost reductions, as importing a foreign sample of this device is prohibitively expensive. In this research, leveraging knowledge from petroleum engineering along with principles of mechanical and electrical design, we have designed a device for the simultaneous measurement of capillary pressure and rock resistivity index. Efforts have been made to enhance the capabilities of this device compared to its predecessors, allowing for more accurate testing.

1. Introduction

The laboratory conditions required to measure capillary pressure and the electrical characteristics of reservoir rock are somewhat similar. Additionally, the time it takes for a core sample to reach equilibrium in the capillary pressure test can be accurately determined by monitoring the electrical resistance of the core sample. Therefore, the simultaneous measurement of these two parameters leads to a significant reduction in both the cost and time of the test, as well as an increase in accuracy.

In this research, we examine various methods for measuring the two parameters capillary pressure and electrical resistance of reservoir rock samples, ultimately designing a suitable measurement process. We then outline the equipment needed to perform the tests and provide a detailed design for each component. Using the complete design of the components of the CAPRI device, we present a roadmap for constructing this device. Our approach aims to bring the test conditions closer to those governing the core sample in the reservoir, resulting in a CAPRI device designed for maximum capability and accuracy.

2. Methodology

After examining the theoretical foundations of capillary pressure parameters and the electrical characteristics of the core, the next step in the research is to find a suitable method for the simultaneous measurement of capillary pressure and the specific resistance index. Following the design of an appropriate process for measuring

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these parameters, a device was created that can simultaneously measure capillary pressure and rock resistance index. The required components were identified and arranged accordingly.

Static and thermal analyses were conducted on the various components of the device to ensure their performance during testing. Each component was then designed in detail, specifying characteristics such as type, dimensions, and operating range, utilizing CATIA software, which is one of the most powerful design tools available.

The core holder, capable of simultaneously measuring capillary pressure and electrical resistance, was designed and modeled using CATIA. After conducting static and thermal analyses, it was structurally optimized. All valves, as well as hydraulic and electrical connections, were designed with regard to both process and mechanics. The pumps for the device were designed considering their functionality, and a control cycle was implemented to adjust the pressure and flow rate.

CAPRI's oven was thoroughly investigated, and an appropriate control cycle was developed to regulate its temperature. Finally, the output parameters from the measuring device were analyzed using Excel software.

3. Results and Conclusions

In this section, the results of the mechanical and process design of the CAPRI device are presented. An LCR meter with a working range of 0.01 ohm·m to 1000 ohm·m is required. However, under certain test conditions and due to improper connections of the electrodes to the core sample, the measured electrical resistance may be artificially reported as much higher than its actual value. Therefore, it is necessary for the measurement interval of the LCR meter to include a safety factor. Consequently, it is preferable for this device to be capable of measuring up to a range of 2000 ohm·m.

The wall thickness is chosen to be $\frac{2}{16}$ in. Therefore, for the pipelines used in the capri device, H-grade stainless steel pipes with an internal diameter of $\frac{1}{8}$ in and an external diameter of $\frac{4}{16}$in are used. The standard used for the CAPRI device is API 6A. This standard has several working classes, each of these classes represents the working pressure at a temperature of 100 degrees Fahrenheit. 10000 psi working class is a prudent and safe choice for CAPRI valves, flanges, and fittings.

Considering the volume of the piston equivalent to 100 ml for the syringe pump and a stroke length of 6 cm, and assuming the maximum flow rate of the CAPRI device pump is 50 cc/min, the required force that the motor shaft must apply to the syringe is calculated to be 7324.456 lbf. The maximum required pressure for the CAPRI injection pumps designed in this research is 7000 psi, with a maximum flow rate of approximately 50 cc/min. Therefore, assuming a mechanical efficiency of 0.85 for the ball screw mechanism used in CAPRI pumps, the required power of the pump is calculated to be 3.752 hp.

The optimum dimensions of the core holder parts are listed in Table 1. The symbol (min) denotes the minimum diameter, while (max) denotes the maximum diameter.

An examination of the heat requirements for the electric oven indicates that a maximum of 3600 kilowatts of electric power is needed. PIDs play an important role in the maintenance and repair of the processes they describe. It is crucial to illustrate the physical sequence of equipment and systems, as well as their connections and interactions. Figure 1 presents the PID map of the CAPRI device.

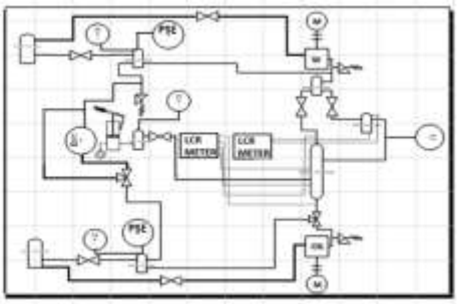

Fig. 1. Pipelines and instrumentation Map of CAPRI device

Finally, Figure 2 illustrates the fully designed device created using CATIA software.

Based on the validations conducted at each stage of the design process in this research, the results can be confidently utilized for the precise construction of the CAPRI device.

Table 1. The optimum dimensions of core holder parts

outer thread length	Inner thread length	thickness	diameter (min) / (max)	inner diameter	outer diameter	height	name
-	-	5 mm	4 cm (max)	6 cm	-	15Cm	**sleeve**
-	-	2 cm	10 cm (max)	6 cm	10 cm	6Cm	**Ferrule1**
3.3	-	2 cm	10 cm (max)	6 cm	10 cm	16 cm	**Ferrule2**
-	-	0.9 cm	3.81 cm (max)	3.175 mm	3.81 cm	1 cm	**Distribution plug**
3.5 cm	5 cm	2 cm	14 cm (max)	6 cm	11 cm	5 cm	**end plug**
-	-	0.5 cm	-	9.5 cm	10 cm	0.5 cm	**o-ring seal**
4.5 cm	13 cm	2 cm	8 cm	2 cm	6 cm	13 cm	**retainer**
-	4.5 cm , 4.8 cm	2.5 cm	10 cm (max)	10 cm	14 cm	28 cm	**Body of core holder**
-	-	-	-	-	3.81 cm	1 cm	**Porous plate**
-	-	2.75 cm	-	0.5 cm	6 cm	12 cm	**moveable plug**
-	2 cm	2.7 cm	6 cm (max) 4.4 cm (min)	0.5	6 cm	8.5 cm	**End plug**
4.8 cm	-	1.5 cm	14 cm (max)	9 cm	12 cm	7 cm	**Hollow plug**
-	3.3 cm	1.2 cm	5 cm (min)	9.5 cm	12 cm	5.5 cm	**End cap**
-	-	0.16 cm	-	0.3175 cm	0.476 cm	6.8 cm	**tubing**
2 cm	-	0.9 cm	3.3 cm (max)	0.48 cm	2.25 cm	2.5 cm	**Tubing plug**
-	-		-		8 cm	10 cm	**Rw cell**
-	-	-	-	3.175 mm	3.81 cm	0.5 cm	**Current electrode**
-	-	-	-	3.8 cm	4.81 cm	1 cm	**Potential electrode**

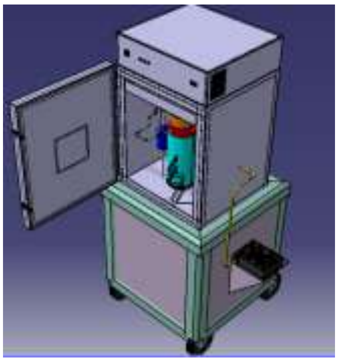

Fig. 2. CAPRI system designed in Catia software

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