Gas Flow Quantity Measuring Technique to Rock Permeability Using Throttling Capillary P-Q Regression

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Abstract This paper introduces the technical status of rock permeability measuring technique to gas flow quantity measurement at home and abroad.Aiming to the problems of rock gas permeability measurement in the exploration and development process of oil/gas reservoir of low permeability,a set of automatic measuring device of throttling capillary gas flow quantity was developed,the throttling capillary P(Pressure)-Q(Quantity) regression measuring approach of rock permeability was set up.The approach,which is fast to measuring speed of the gas passing through rock,high to measuring accuracy,and high to automatizing degree,is a great breakthrough to measuring technique of rock gas permeability,The throttling capillary gas flow measuring device introduced in the paper granted the patent of invention in China,the patent No.is ZL-01278258.0.

Keywords: throttling capillary, gas flow quantity, measurement, rock permeability, P-Q regression

1. Introduction

Rock gas permeability means the ability of gas passing through the porous rock medium under certain pressure. The measurement of the gas flow follows Darcy flow law. We commonly use soap bubble flow meter gas flow quantity measurement technology at home and abroad, the exploration and development of Chinese oil/gas fields have entered a new stage since 1990s. "Three-low", (that is permeability$<10\times10^{-3}\mu m^2$, porosity<1%, reserve abundant degree$<50\times10^4 t/km^2$) oil/gas reservoirs are put into exploration and development successively. As for rock permeability testing technology, the accuracy and quick measuring are its technical difficult points. In order to meet the needs of the research into low reservoir of permeability, throttling capillary gas flow quantity was developed on the basis of traditional rock permeability gas flow quantity measurement technique; new technology of rock gas permeability testing was set up by using P(pressure)-Q(quantity) regression measuring approach, this greatly improved the analysis work efficiency and analysis quality of rock gas permeability. The throttling capillary gas flow measuring device has granted the patent of practical new style invention in China, the testing method has applied for the patent of invention in April, 2002 in China.

2. The problem of rock gas permeability measuring technique to gas flow quantity measurement of reservoir of low permeability

The exploration and development of "three-low" (that is low porosity, low permeability and low abundant degree) oil/gas reservoirs are the technical difficult points at present's exploration and development of oil/gas fields. Because the colloid of this kind of reservoir rocks is very compact, it gives the great difficulty in rock physical nature parameter measurement. During the former rock permeability measuring work of oil/gas reservoir of low permeability, we use classical measurement mostly at home and abroad, that is measuring the ability of gas passing through rock by using soap bubble flow meter,

this gas flow quantity measuring approach mainly exists following problems.

2.1. Rock permeability

The size of rock permeability and the quantity of gas passing through the core are direct ratio, which reflecting on gas flow quantity measurement of soap bubble flow meter is: the better the permeability, the faster the speed of the gas flow in a unit of volume; the worse the rock permeability, the slower the speed of gas flow.

2.2. Rock permeability measurement calculating formula

$$K = \frac{Q \cdot \mu \cdot L}{A \cdot \Delta P} \times 1000$$

where K is rock sample permeability, Q is gas flow quantity, μ is gas adhesion, L is the length of the rock sample, A is section area of the rock sample, Δ P is the difference of two ending sections of the measured rock sample

According to this formula, the bigger the rock permeability, the smaller the pressure difference of two endings of rock measurement section. From this we can know it takes rather a long time for soap bubble flow meter to steady when measuring the ability of gas passing through super low permeability core, it doesn't only lack the installation of improving gas the steadiness of gas flow quantity, but also lack the precise meter which can steadily display the changes of the pressure in traditional measuring approaches, which made the analyzing members spent several hours in measuring each samples of low permeability, heavy in intensity of labor and low in working efficiency.

As we use soap bubble flow meter as the measurement of gas flow quantity, and use the original handmade stopwatch to time the soap bubble passing through the flow pipe, as for this flow quantity measurement, one is the big man-made error, the other is analyzing members' heavy intensity of labor. Because the backward gas flow quantity measuring approach, the rock permeability measuring work becomes complicated, labor consuming, needing great effort and taking time.

The data collected by men has to convert to international used units by hand, not only slow in speed, but also high in error rate, it is urged to accomplish the computerization of calculating the flow quantity data collection.

As for the reasons above, we developed the throttling capillary gas flow measuring technique on the basis of traditional rock permeability measuring technique, to improve the analysis work efficiency and the analysis quality of rock permeability of low permeability reservoir and meet the need of the exploration and development of oil/gas fields.

3. Automatic measuring device of throttling capillary gas flow quantity measurement

Automatic measuring device of throttling capillary gas flow quantity measurement is composed of throttling capillary, pressure conducting device, digital display and computer, to put it specifically, join one more set of pressure conducting device and the display at both sides of the throttling capillary to the computer.

The throttling capillary is a glass pipe whose inner diameter is from 0.05mm to 0.07mm and varies in length from 40mm to 70mm. We need to install the throttling capillary in rubber tube set when measuring the flow quantity of gas passing through the rock.

When we use throttling capillary measuring system to test the ability of gas that is allowed to pass through the rock under certain pressure, we must make sure that all the measured gas is flown out through glass capillary, no gas leaking.

4. The approach and the principle of throttling capillary gas flow quantity measurement

This measuring technique accomplishes it based on the following principles. It is the classical approach of rock permeability measurement by using soap bubble flow meter to measure the ability of gas passing through the rock. This installation uses soap bubble flow meter as the original meter on gas flow quantity measurement, employing P(pressure) and Q(quantity) regression technique, and using throttling capillary taking place of soap bubble flow meter. Specific craft technological process and measuring principles are as follows:

4.1. Measuring rock samples using soap bubble flow meter

By using soap bubble flow meter to measure a group of rock samples, we can get this sample's gas flow quantity data under certain pressure, that is, each sample has a P-Q corresponding value.

4.2. Measuring rock samples using throttling capillary

Using throttling capillary instead to measure the same group of rock samples as measured by soap bubble flow meter, now we can think this sample's Q(quantity) is known, there will be a pressure figure value on the digital display of measured sample through the pressure conducting device, and we can get the corresponding relationship of P(pressure) and Q(quantity) under the measuring condition of throttling capillary through this group of samples.

Because of the gas sliding off effect when using the throttling capillary to measure the quantity of gas passing through rock porosity, throttling capillary of different inner hole diameter should be chosen in rock samples of different sections of permeability measurement. In the section where the air permeability is from $0.0001 \times 10^{-3}\ \mu\ m^2$ to $5000 \times 10^{-3}\ \mu\ m^2$, we choose level 4 throttling capillary, Chart 1 is the P-Q regression curve made when chose Level 2 throttling capillary.

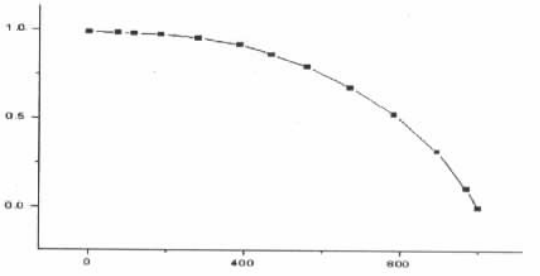

Chart1 Level 2 throttling capillary P-Q regression curve

4.3. To make P-Q regression curve

Proofreading the regression curve by using standard materials of National level 2, and then set up a standard P-Q corresponding curve to measure the ability of reappearance and corresponding error of the analysis outcomes of the samples. Table 1 is the stability and the ability of reappearance of throttling capillary measurement approach; Table 2 is the data outcome contrast of manual soap bubble flow meter approach and capillary approach.

Table 1 The stability and the ability of reappearance of throttling capillary measurement approach

Sample No.	Permeability / $10^{-3}\ \mu\ m^2$			Standard deviation $10^{-3}\ \mu\ m^2$
	April 18th	morning of May 19th	afternoon of May 19th	
1-5-1	0.0276	0.0265	0.0261	0.0008
	0.0299	0.0292	0.0287	0.0006
	0.0332	0.0345	0.0328	0.0009
	0.0375	0.0398	0.0392	0.0012
2-1-2	0.0307	0.0289	0.0311	0.0011
	0.0337	0.0355	0.0346	0.0009
	0.0378	0.0408	0.0402	0.0016
	0.0451	0.0475	0.0468	0.0012
1-4-1	0.0626	0.0609	0.0616	0.0008
	0.0690	0.0665	0.0656	0.0018
	0.0777	0.070	0.0747	0.0020
	0.0888	0.0864	0.0865	0.0013
2-5-2	0.0705	0.0676	0.0671	0.0018
	0.0781	0.0740	0.0746	0.0022
	0.0878	0.0852	0.0848	0.0016

	0.1009	0.0978	0.0987	0.0016
1-2-3	0.2388	0.2345	0.2383	0.0024
	0.2553	0.2548	0.2608	0.0033
	0.2915	0.2766	0.2909	0.0084
	0.3356	0.3060	0.3281	0.0154
1-1-3	0.3908	0.3873	0.3900	0.0018
	0.4515	0.4210	0.4250	0.0166
	0.4664	0.4596	0.4706	0.0055
	0.5172	0.5096	0.5232	0.0068
2-1-5	0.7192	0.7172	0.7147	0.0022
	0.7718	0.7665	0.7666	0.0030
	0.8439	0.8333	0.8294	0.0075
	0.9233	0.9086	0.9079	0.0087
2-5-4	0.9372	0.9322	0.9195	0.0091
	0.9960	0.9974	0.9868	0.0057
	1.0768	1.0715	1.0626	0.0072
	1.1648	1.1679	1.1573	0.0054

Table 2 The data outcome contrast of manual soap bubble flow meter approach and capillary approach

Sample No.	Length cm	Diameter cm	capillary flow quantity ml/s	permeability 10^{-3} μ m^2	manual flow quantity ml/s	permeability 10^{-3} μ m^2	coresponding deviation %	related parameter of capillary approach	elated parameter of manual approach
1-5-1	9.88	6.90	0.09312	0.0265	0.0915	0.0260	0.88	0.998	0.965
	9.88	6.90	0.08553	0.0292	0.0807	0.0275	2.91		
2-1-2	9.99	6.80	0.09667	0.0289	0.107	0.0320	-0.90	0.994	0.991
	9.99	6.80	0.09895	0.0355	0.094	0.0337	2.57		
1-4-1	9.82	6.93	0.19994	0.0609	0.202	0.0615	-0.51	0.998	0.989
	9.82	6.93	0.18273	0.0665	0.1779	0.0648	1.34		
2-5-2	10.09	6.83	0.20854	0.0676	0.2141	0.0694	-1.32	0.999	0.998
	10.09	6.83	0.19082	0.0740	0.1855	0.0719	1.41		
1-2-3	10.28	6.72	0.7728	0.2345	0.771	0.2339	0.12	1.000	0.966
	10.28	6.72	0.70274	0.2548	0.653	0.2367	3.67		
1-1-3	10.46	6.95	1.28813	0.3873	1.335	0.4014	-1.79	1.000	0.996
	10.46	6.95	1.17483	0.4210	1.139	0.4081	1.55		
2-1-5	10.20	6.90	2.17431	0.7172	2.226	0.7343	-1.17	1.000	0.996
	10.20	6.90	1.96794	0.7665	1.918	0.7470	1.29		
2-5-4	9.42	6.88	2.75565	0.9322	2.825	0.9557	-1.24	1.000	0.977
	9.42	6.88	2.51287	0.9974	2.441	0.9688	1.45		

4.4. Disposing by computer program

Input the standard P-Q regression curve into the computer, work out corresponding data disposal software, and use throttling capillary to measure the gas flow quantity passing through the rock under certain pressure automatically according to this P-Q corresponding relationship.

5. Using effect of measuring technique to throttling capillary gas flow quantity

Measuring technique to throttling capillary gas flow quantity and automatic measuring device have the advantages of simple in structure, convenient in operating, good measuring ability of reappearance and fast in measuring speed. It made the gas flow quantity measurement of rock permeability fare wares the manual operation completely, and its measuring principles are advanced. The measuring outcome has good ability of reappearance through testing by many groups of National Level 2 Standard materials; measuring relative deviation is controlled in the scope

of China Petroleum Trade Standard (SY/T 5336-1996 Core conventional Analysis Approach) and it can meet the need of the measuring work of rock permeability of different specifications.

From 2001 to 2002, we've tested the rock permeability of about 25,000 various samples by using automatic measuring device of throttling capillary gas flow quantity, the quality of analysis all meet the requirement stipulated by the trade standard in SY/T 5336-1996 Core Conventional Analysis Approach. The main technical index of this measuring technique is:

Measuring scope: air permeability from 0.0001×10^{-3} μm^2 to 5000 $\times 10^{-3}$ μm^2

Measuring deviation: when the rock permeability is under 10×10^{-3} μm^2, relative deviation rises to controlled within 5% form original controlled within 10%.

6. Conclusion

There are three breakthroughs of measuring technique to throttling capillary gas flow quantity of rock permeability on rock permeability measuring craft.

5.1. Measuring technique of reservoir of super low permeability

Of measuring technique of rock permeability, by developing the measuring approach of throttling capillary, we've solved the problems of long time measuring and the reappearance of the measuring outcome of core permeability of super compact reservoir, and surmounted the technical difficulties of rock permeability of super low reservoir.

5.2. Automation of the measuring process

Installation and measuring process have accomplished the automation, which raise the analysis quality and working efficiency. The analysis time has been shortened to within 20 minutes from original 40 minutes per block or 60 minutes per block of the rock sample of low permeability, and it has reduced the deviation brought by manual collected data and calculating, rational in installation and advanced in measuring approach.

5.3. Technological creation

This technology is a creative one. Automatic measuring device of throttling capillary gas flow quantity has granted the patent of national practical new style in China. The throttling capillary P-Q regression measuring approach of rock permeability has applied for the patent of the approach invention in China, and it has better expanding use value.

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