AN EXPERIMENT STUDY ON INFLUECING FACTOR ON ROCK PERMEABILITY FOR TEMPERATURE

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ABSTRACT

By means of CUMT "211" project: 20MN servo control High temperature Triaxial pressure rock testing machine, feldspar fine sandstone permeability were observed on the condition of temperature and pressure on real time. It was observed that permeability of feldspar fine sandstone appears five phases on condition of invariable triaxial pressure and temperature rising: I, low temperature phase, feldspar fine sandstone permeability declines with temperature's rising. II, fore-phase of threshold temperature, feldspar fine sandstone permeability acutely rises, adds to 65 times more than that of in room temperature. III, back-phase of threshold temperature, feldspar fine sandstone permeability declines with temperature continuously rising. IV, stable phase, feldspar fine sandstone permeability fluctuates opposite state up to a high level, reaches to 8 times comparing to original state (room temperature). V, high temperature phase, permeability of feldspar fine sandstone rises again when feldspar fine sandstone temperature reaches to 450-600°C.

Key words: Feldspar fine sandstone, permeability, temperature, triaxial pressure.

INTRODUCTION

During rock forming course, environment affections and physical or chemical actions among rock minerals grains form rock configuration with some interspaces and crannies. Rock permeability is an important parameter that shows rock inner configuration state; there is compact correlation between rock permeability and rock configuration. Rock permeability researches have been a hot point of rock mechanics. There is a well application future in engineering fields suck as terrestrial heat exploitation, nuclear waste underground set, oil exploitation and so on.

Somerton researches rock permeability on temperature effect. Morrow simulates seep experiment in nuclear waste phenomenon, he indicates that permeability declines with temperature rising, he thought the main reason is the granite minerals fusibility enhanced in

high temperature, fusibility declined and thermal swell in low temperature. Chen yong researches carbonate rock(DongYing), he indicated that carbonate rock has threshold permeability, permeability over this value will rise 8-10 times up to that of original state. Weinbrandt[8] researches boyis sandstone permeability on temperature effect. He thinks that thermal mechanical stress changes permeability but no rock fluid-interface force. Gobran[9] indicates that there is no effect of temperature to permeability. Casse[10] and Ramey's research shows that the effect of temperature to permeability is correlation with saturated fluid character. Saturated fluid rock permeability declines with temperature rising. Permeability declines 65% during temperature rises to 163°C from 21°C, on the other hand, gas permeability has no correlation with temperature. Rock thermal scathe character is an irreversible course. Former researcher usually adopt cooling high temperature specimen to room temperature and measuring permeability in permeability research. The permeability measured by this method is not real rock permeability, and can't show real character of rock thermal scathe.

Figure 1.: 20MN servo control High temperature Triaxial pressure rock testing machine

This experiment researches feldspar fine sandstone permeability on condition of differ-temperature and invariable triaxial pressure, using CUMT 211 project: 20MN servo control High temperature Triaxial pressure rock testing machine.

APPARATUS AND SPECIMEN

Apparatus

The experiment apparatus is China University of Mining Technology 211 project: 20MN servo control High temperature Triaxial pressure rock testing machine. Testing machine is composed of pressure control system and temperature control system. Pressure control system is composed of two parts: assistant machine system and main machine system.

Assistant machine system is composed of assistant pressure machine and control console. Main machine system is composed of main machine control system and experiment testing system. Main machine system operation mode is controlled by computer and console buttons. Experiment course is controlled by computer program; main machine action is controlled by console buttons. Testing function is mainly focus on experiment temperature, experiment pressure value, others testing parameters. Axial pressure and lateral pressure are absolute. Temperature control system can keep specimen constant temperature or control specimen temperature reaching to 600°C from room temperature by definite temperature pace, rock permeability is been tested during temperature rising. Testing gas is provided by high pressure nitrogen gas. Nitrogen gas pressure is controlled by high pressure valve and high precision barometer. The outlet gas flux is measured by soap-film flowmeter. The temperature pace is 1°C /10min. High temperature and high pressure (HTHP) chamber is airproofed by anti-high temperature glue water, soft gold mica ply, pure copper ring.

Figure 2.: Surface of feldspar fine sandstone.

Specimen

Specimen is feldspar fine sandstone collected from YongCheng city in province HeNan. Rock original state is well; machining a cylinder Φ200×400mm. Surface clearing is done, wax enveloping to prevent oxidation.
Specimen machining precision:
(1) Parallelism ≤0.002mm
(2) Verticality ≤0.01mm/1000mm
(3) Roughness ≤±0.1mm/100mm

Testing method

(1) Putting specimen in HTHP chamber, specimen and pressure transmission medium impacted tightness by assistant machine.
(2) Check circuit insulating and the whole apparatus normal operation.
(3) Before experiment, turn on cool water system and keeping the system normal operation.

(4) Ventilating, measuring specimen permeability on condition of room temperature and normal pressure, and taking this experiment as preliminary operation.
(5) Adjusting pressure buttons, little axial pressure first, little lateral pressure next, control the pace of pressure.
(6) Adjusting the temperature buttons to required value, when pressure comes to experiment, keeping temperature stable.
(7) Ventilating Nitrogen gas, measuring inlet gas pressure and outlet gas flux, do six times.
(8) Turn off gas.
(9) Repeating sixth-eighth pace, measuring the parameters of specimen on different temperature, computing specimen corresponding permeability.

EXPERIMENT RESULTS AND ANALYSIS

The measurement on feldspar fine sandstone permeability was done on real time in this experiment. Keeps system stable pressure (axial pressure 6MPa, lateral pressure 5MPa), and keeps porous pressure 1.0MPa, permeability of feldspar fine sandstone see table 1.

The experiment shows that feldspar fine sandstone permeability changes acutely on effect of temperature. From table 1., in 25°C-100°C, feldspar fine sandstone permeability declines, sandstone permeability decreases 23% at 100°C comparing to that of at 25°C, the reason is thermal expanding action among feldspar fine sandstone mineral grains, squeezes and obturates original hole and cracks in fine sandstone. Cracks width is diminishing during this action course, although new cracks come into being. Overall valid connection channel is reduced instead of increased, gas channel crowding, resistance increasing. Feldspar sandstone permeability declines in macro therefore.

Table 1.: Feldspar sandstone permeability K and M_k

Temperature °C	Permeability $10^{-3}\mu m^2$	M_k	Temperature °C	Permeability $10^{-3}\mu m^2$	M_k
25	0.0732490	0	350	1.478207	-0.04221
50	0.0688065	-0.00018	400	0.733948	-0.01489
100	0.0566429	-0.00024	450	0.631996	-0.00204
150	0.0817288	0.000502	500	1.267043	0.012701
200	4.3356460	0.085078	550	2.043239	0.015524
250	4.7522420	0.008332	600	2.843283	0.016001
300	3.5884930	-0.02327			

When temperature researches to 100°C-250°C, feldspar sandstone permeability acutely rises, this phenomenon shows that there is a threshold temperature. Sandstone permeability acutely increases at the threshold temperature. Sandstone permeability increases to $4.752242\times10^{-3}\mu m^2$ from $0.073249\times10^{-3}\mu m^2$ (original state), increases 65 times. After this, feldspar sandstone permeability declines with temperature rising, the lowest value of

permeability increases 7 times more than that of original state, this phenomenon shows feldspar sandstone permeability keeps a high level through thermal cracks course.

Analyze sandstone permeability rule. Select parameter: M_k (permeability ratio on effect of temperature).

$$M_K = \frac{K_{n+1} - K_n}{T_{n+1} - T_n}$$ n: temperature measure point, natural number

M_k: permeability margin-temperature margin ratio of temperature point n+1 to n, M_k is 0 at 25°C.

Analyses permeability and parameter M_k, there are five phases for sandstone permeability on effect of temperature:

- Low temperature phase(25-100°C: permeability declines, M_k<0),
- fore phase of threshold temperature(100-250°C: permeability rises quickly, M_k>0);
- back phase of threshold temperature(250-350°C: permeability declines, M_k<0);
- stabile phase (350-450°C: permeability stabilizes (M_k<0, close to 0);
- high temperature phase (Temperature>450°C : permeability rises again, M_k<0).

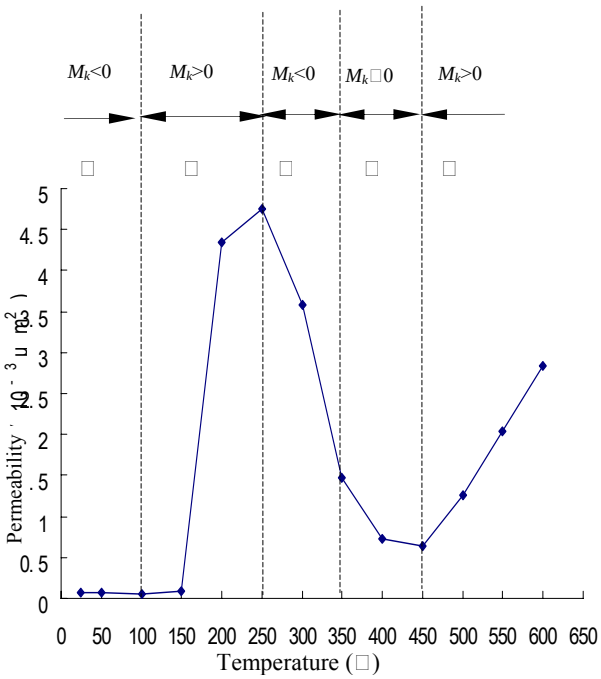

Figure 3.: Permeability change with temperature.

The turning point of sandstone permeability is corresponding to the threshold temperature of sandstone thermal cracking. In the opinion of material mechanics points, materials

destroy will happen in outside force reaching to a limitation. Lots of researches appear that new cracks in rock are corresponding to thermal swell among minerals grains and thermal stress centralizing for thermal swell anisotropy. The temperature decides thermal stress in rock. There will be new cracks germinating in rock when thermal stress centralizing more than rock tensile strength at some temperature. This phenomenon will bring some change about rock permeability.

There are two interesting phases in the course that sandstone permeability declines in experiment:

1) 20-100°C, the reason is that, feldspar fine sandstone minerals grains expand on thermal affection, this expanding phenomenon obturates the cracks among minerals grains, closes the original cranny, and decreases the valid channel.
2) 250-400°C, permeability declines, I will explain this phenomena from macro and micro sides.

(1) Macro analyzing: Number of cracks in sandstone reaches to peak value at threshold temperature on the coupling effect of thermal and pressure, and forms perforation cracks web. Number and openness of cracks is the most value. Rock permeability reaches to peak value too. Number of cracks is stable with temperature rising in this temperature interval; this phenomenon can be proved by Acoustics Emission phenomenon. Rock elastic module declines, which enhances rock distortion. Rock openness declines. Rock permeability is controlled by number and openness of cracks. Cracks number stabilizes, cracks openness diminishes, two phenomena weaken circulating capable of cracks web in rock specimen, diminish specimen permeability.

(2) Micro analyzing: In original temperature rising phase. Rock specimen inner cracks distribute among rock minerals grains. Minerals grains inner transgranular cracks initiate and split for minerals grains inner nonuniformity, these actions reduce to cracks openness among minerals grains, and therefore reduce to intergranular cracks space, and diminish circulating channel, weaken inhere cracks web, decline rock permeability. Before thermal stress destroys rock configuration, swell of minerals grains take up original parts of cracks space, diminishes pore diameter, diminishes flux channel, and declines rock permeability. Some minerals chippings are brought from minerals grains crystal surface which come into cracks and holes of rock at high temperature, this action drops feldspar fine sandstone permeability.

CONCLUSIONS

1) At the range of room temperature to 600°C, feldspar fine sandstone permeability basically increases with temperature rising, keeps ascending tendency.
2) There is a threshold temperature for feldspar fine sandstone permeability; feldspar fine sandstone permeability will acutely increase at temperature reaching to threshold.
3) Feldspar fine sandstone permeability will increase 65 times comparing to original state for thermal action.

4) Feldspar fine sandstone permeability appears five phase on condition of invariable triaxial pressure and temperature: low temperature phase, fore-phase of threshold temperature, back-phase of threshold temperature, stability phase, high temperature phase.
5) The rule of feldspar fine sandstone permeability relates to cracks among minerals grains and local thermal stress centralizing during calefaction.

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