INVEST White Paper

Technological development for high temperature measurement in IODP

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Abstract

It is expected that temperature in some of the IODP borehole will exceed 250 deg-C in Phase-2 Projects. Development of high temperature measurement tools, such as LWD/MWD tools, wireline logging tool, and long term monitoring tools is of importance for collection of information around borehole and long-term monitoring. This paper reviews current status of high temperature measurement tools mainly in IODP and oil/gas industries, and describe possible technological developments for IODP. Development of sensors from new principles should be developed especially for long term monitoring in deep IODP borehole. Collaboration with the other industries where high temperature measurement is requested is recommended.

1. Temperature limitation of the existing measurement tools

1.1 Wireline logging/measurement tools

Standard wireline logging tools which have been used in IODP and oil/gas industries have temperature limit at around 175 deg-C. Specially designed logging tools can be operated up to 260 deg-C by protecting the electric circuit with heat isolating cartridge, although such high temperature logging tools has requirements in platform, logging speed and borehole diameter.

Geothermal industries use high temperature logging tools which can be operated under higher temperature (ex. PTF: 370 deg-C, Caliper: 260 deg-C). However, the maximum operating temperature of wireline is limited to 310 deg-C (standard wireline: around 200 deg-C). Cooling of borehole by injecting water is required for logging in higher temperature borehole bringing some risk for the collapse of borehole-wall.

Mechanical borehole tools also have temperature limitation mainly comes from sealing of moving parts. Some of the liquid samplers for geothermal development have designed to be operated at 350 deg-C and have been operated at 300 deg-C. High temperature metal casing packers for minifrac and hydraulic tests can be operated up to 240 deg-C.

1.2 LWD/MWD tools

Most of the LWD/MWD tools provided by service companies in oil/gas exploration/development can be operated temperature under 150 deg-C. Some of the high temperature LWD tools are guaranteed to work up to 175 deg-C.

1.3 Long term monitoring tools

Typical operating temperature of subsea/downhole electromagnetic seismometers is 0 to

60 deg-C. Sensitivity and dumping factor may become incorrect from designed value under higher temperature because of change in physical properties of material. Piezoelectric accelerometer can be operated up to its Curie point which is typically in several hundred deg-C, although necessary electric circuit for preamplifier will be failed under such higher temperature. Some of the downhole seismic detectors in geothermal development can be operated at temperature of 200 deg-C. However, there operating time is in trade-off to the operating temperature (ex. 1 week at 200 deg-C, 1 year at 100 deg-C). Downhole seismic source, such as airgun and sparkers, has operation temperature limit around 60 deg-C.

Temperature monitoring in a borehole can be achieved by an optical fiber sensor. Some of the fiber temperature monitoring system can be operated up to 300 deg-C although its main unit is installed on ground surface.

Long term borehole monitoring system (LTBMS) which has been developing in CDEX was designed to be operated under 125 deg-C environment for 5 years.

2. Technological developments

The followings should be investigated to realize measurement in high temperature IODP boreholes.

- Sensor: Most of the sensors lose designed sensitivity/frequency characteristics under 200 deg-C because of change in physical properties. Therefore, high temperature sensors with new principles should be investigated. Optical downhole sensors combined with seafloor main unit are one of the solutions for long-term passive downhole monitoring.
- Electronics: Typical operating temperature of electrical circuit elements is less than 80 deg-C. In higher temperature, problems in failure, noise, and performance deterioration may occur. Even we can use elements for military/aerospace use, the maximum operating temperature is still less than 200 deg-C. It should be also considered that active circuit element (IC/LSI) radiate some amount of heat while their operation. One of the solutions for high temperature operation is to cool the circuit/sensor using thermoelectric conversion element, although the heat is transferred to formation and some electricity for operation of thermoelectric converter is required. The other possible solution is to design “remote monitoring” system where main unit is installed on seafloor and passive high temperature sensor is deployed in borehole. Optical system can realize such remote monitoring system, and has advantage in noise contamination and transmission loss.
- Mechanics: Development of sealing material is a key to develop high temperature

mechanical tools. PTEF sealing material has a good ability to seal moving parts up to 260 deg-C. Metal seal are used for higher temperature but may not be suitable for sealing of moving parts. Chemical reaction of high temperature water and gas should be considered in development of high temperature mechanics.

- Wireline: The temperature limitation for standard wireline for geophysical exploration should be improved up to 400-500 deg-C. New material for the shell of the cable should be investigated. Technologies in aerospace/aircraft can be imported.

3. Problems and recommendations

- Cost: One of the biggest issues in developing high temperature measurement system for IODP is cost. This is because cost reduction by mass-production can not be expected and new materials/elements for high temperature use are expensive. Recently high temperature or ultra high temperature boreholes are commonly drilled for oil production, and R&D of geothermal energy has been re-activated worldwide. It would be cost and time inefficient to develop high temperature measurement system only within the IODP group, and, therefore, collaboration with oil/gas and geothermal industries is recommended. Collection of information on sensing in aerospace and car industries is also recommended.
- New principles: There are some physical limitations in operating temperature of sensor/circuit elements. In such case, sensors using new principles should be developed. However, it is out of the IODP coverage. Establishment of link to sensor development community and discussion on feasibility of new sensors are recommended.

Reference

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