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Distributed fiber optic temperature and strain sensing in a cement specimen

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Injection of CO2 induces the increasing of pore pressure in a reservoir, leading to the uplift of ground level around an injection well. Cracks might appear in the ground if geological layers deform largely. This decreases the reliability of safety sequestration of CO2. Therefore, it is important to evaluate the stability of the geological layers by monitoring the amount of the deformation.

The stability evaluation requires the monitoring of the deformation of whole geological layers form reservoir to ground level. Displacement meters buried in the ground can measure the deformation of geological layers. However, displacement meters are not suitable to successive monitoring due to inadequate numbers of the meters that are buried in the ground. We have therefore researched fiber optic sensing technology that is used in oil and gas development field to apply it to CCS field. Fiber optic sensing technology was initially used as a temperature sensor to monitor the distribution of temperature in a well over several kilometers. The technology has now been used to measure even the deformation of casing pipes. Monitoring of the deformation of casing pipes measures the strain of the pipes. If the strain of geological layers can be measured successfully, we can monitor the stability of the layers.

Fiber optic sensing technology is divided into two categories in terms of the alignment of sensors: point sensor system and distributed sensor system. Point sensor system is the most popular in fiber optic sensing technology that has high sensitivity and accuracy in data acquisition at measurement points printed on optical fibers. Fiber Bragg Grating (FBG) sensor system is a typical one. Some studies on measurements of the deformation of the ground have adopted this system. However, the point sensor system has fewer number of measuring points compared to the distributed sensor system because optical power losses at every measuring point in this system. Optical fiber itself works as sensors without any processes in the distributed sensor system, and thus the number of measuring point is infinite (the number of measuring point depends on a measuring equipment). In recent years, the maximum resolution of temperature and strain has been reached to 0.0096 deg C and 0.078 me respectively due to the improvement of measuring equipments. The resolutions are almost as high as those of FBG. Therefore, the distributed sensor system is coming to the front as a new monitoring method compensating for the defects of the point sensor system such as expensiveness relating to printing sensors and the limitation of the number of measuring point.

Our previous laboratory experiments revealed that the distributed sensor system successfully measures the strain of rocks as accurate as strain gauge during compressive and dilatational process. Fiber optic cables will be installed in cement slurry along a casing pipe if they are put into practical use. Therefore, the cables should have enough strength against cementing, and should be sensitive to measure strain. An existing fiber optic cable for the use in wells is made to measure temperature change. Three layers of stainless steel wire enforce one optical fiber which is set at the center of the cable. Therefore, this cable may fail to measure strain of geological layers due to the protection structure.

Laboratory experiments were conducted to assess the validity of strain measurement using the existing fiber optic cable mimicking the installation along a well. The results show that the cable measures strain during the change of confining pressure. We report the details of the results obtained from the experiments.

Keywords: optical fiber, distributed sensor, temperature and strain measurement