Feasibility study of super critical water reservoirs for the next generation of clean and renewable energy sources

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Introduction
Geothermal energy is attracting people in the world for one of the clean and renewable energies. In addition to conventional geothermal energy including EGS, the supercritical water is thought to be as the revolutionary energy source. NEDO is promoting the utilization of the super-critical water as one of the future energies.
Studies
To evaluate the feasibility of super-critical water as the future energy sources, we studied following six subjects.
Geological and other conditions for and super critical water in the world and in Japan.: We reviewed world super-critical geothermal programs. There are many examples to reach to the super-critical conditions (e.g., IDDP-1 and IDDP-2). Kakkonda WD-1a also reached to >500 degrees C, and it was the super critical condition. In Larderello in Italy >500degrees in Celsius also was observed. However, super-critical water in Kakkonda (Muraoka et al., 1998) and Larderello (Bertani et al., 2018) has not been detected. For possible areas of super-critical water, the temperature should be >300degree C and many geothermal areas in the northern Japan reach to this temperature range. In addition, the temperature in Hachobaru in Kyusyu is >300degree C in the brittle zone, and it is similar to Iceland.
Evaluation of heat retrieval: Using WellCAT which is simulation software to evaluate the thermal conditions we evaluated the retrievable power by indirect and direct heat transfers from super-critical zone (Suzuki et al, 2018). If we assume the indirect heat transfer, the retrievable power could be 1.8-6MW /well at maximum. On the other hand, the direct heat transfer could give 27MW/well. Although we assume 200m in diameter x 1000m long for the super-critical reservoir, the size of super-critical water zone is big-issue to study.
Casing-cementing program and hydrofracturing: We proposed casing program for the drilling. We also examined the hydro fracturing method to assist to expand the super critical fluid zone. Casing, cement, packer, explosives for perforation and cooling system of well are future technologies.
Engineering tools for drilling of super-hot and super deep zone: We evaluated casing and cement under super- critical circumstances. We tested various materials including SiC under super critical conditions (500degree C 23MPa, 100hr). SiC was suffered erosion by super-critical water under this circumstance, and the price and making technology for SiC are another big hedge.
Economic studies: We evaluated the indirect and direct heat retrieval in economical viewpoints. If we overcome the engineering difficulties in the direct heart retrieval, this method could reach to the reasonable cost of current electricity generation cost level. In contrast, the indirect heat retrieval could not make this level.
Risk evaluation: We reviewed the induced earthquakes. Because ductile region cannot sustain large strain, the risk of induced earthquakes seems to be very low or none. If we detect any possibility of induced earthquakes, we will sustain the whole works.
Monitoring of super critical reservoirs: We are proposing the geophysical monitoring system using ACROSS borehole source, DAS (Distributed Acoustic Sensor) and waveform inversion. We tested the

quality of data obtained by DAS and concluded that DAS data are equivalent to geophones and it can be used up to 500 degrees in Celsius (Kasahara et al., *2*018a). For imaging of super critical water zone, we developed waveform inversion method (Kasahara et al., 2018b). We can nicely image the location, shape and physical properties (Vp, Vs and density).

Discussion and Conclusions

In conclusion, we think the direct heat retrieval method is feasible by economical viewpoint. However, there are many remaining technologies to be developed. Seismic method could drastically improve successfulness.

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