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Preliminary Analysis of Thermal Expansion of a Geothermal Well

Norio TENMA*, Hirokazu KARASAWA*, Sumio SAKUMA2* and Kazuo HAYASHI3*

*;16-1, Onogawa, Tsukuba Ibaraki, 305-8569, Japan, National Institute of Advanced Industrial Science and Technology (AIST)

2*:Geothermal Engineering Co., Ltd, 3*; Tohoku University

tenma-n@aist.go.jp

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ABSTRACT

The influence of the thermal stress caused by the temperature difference is great in the geothermal wells. To estimate the lifetime of a geothermal well, it is important to understand the influence of the thermal stress on certain components (casing, cement and formation). In order to develop simulator code to estimate the lifetime of a geothermal well, the thermal stress of the geothermal well must first be studied.

1. INTRODUCTION

In geothermal power plants, the temperature in geothermal wells is high during the production of steam and low during PTS logging for maintenance. Thus, it is assumed that the influence of the thermal stress caused by this temperature difference is great in geothermal wells. Geothermal wells consist of several components (casing, cement and rock), as shown in Figure 1.

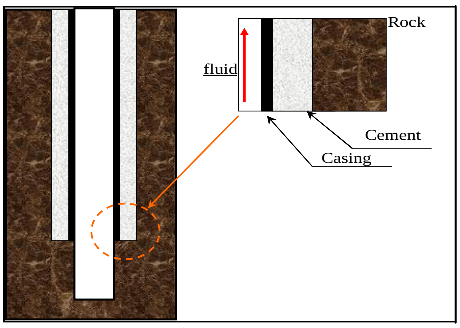

Figure 1: Components of a geothermal well.

To estimate the lifetime of a geothermal well, it is important to understand the influence of the thermal stress on the compound parts. The analyses of the steel casing, cements, and the surrounding formation are reported in several papers using 2D model (horizontal direction), which employs FEM methods (Philippacopouls and Berndt, 2002). However, the estimation of the geothermal well in the vertical direction with respect to the thermal stress is sparse in the literature. Before aiming the development of the simulator code to estimate the lifetime of geothermal wells and include the influence of the thermal stress, the stress of the geothermal well was studied.

In this paper, the thermal stress in the casing is estimated using the field data of the Hijiori HDR project (Tenma et al. 2008).

2. HIJIORI TEST SITE

From 1986 to 2002, a Hot Dry Rock (HDR) geothermal energy R&D project was carried out at Hijiori in the Yamagata Prefecture of Japan. The Hijiori HDR system has two reservoirs (a shallow reservoir and a deep reservoir) and four wells (SKG-2, HDR-1, HDR-2a and HDR-3) completed in the high temperature granite at the site. Injection well SGK-2 was completed in the shallow reservoir and was located at a depth of about 1800 m. Injection well HDR-1 was completed in the deep reservoir, which was located at a depth of about 2200 m. Both reservoirs were intercepted by production wells HDR-2a and HDR-3.

A Long-Term Circulation Test (LTCT, Term 2 and 3) was conducted from December 23, 2001 to August 31, 2002. The test included injection wells SKG-2 and HDR-1 and production wells HDR-2a and HDR-3. In this test, water was injected into injection well SKG-2, as shown in Figure 2. The top of the casing of SKG-2 could be seen at the surface, as shown in the photograph in Figure 3. Thus, the displacement of the casing of SKG-2 was measured. The shrinkage of the casing was large when pumping was started, as shown in Figure 4. Thus, this data thought to be is useful in the estimation of the thermal influence of the geothermal well.

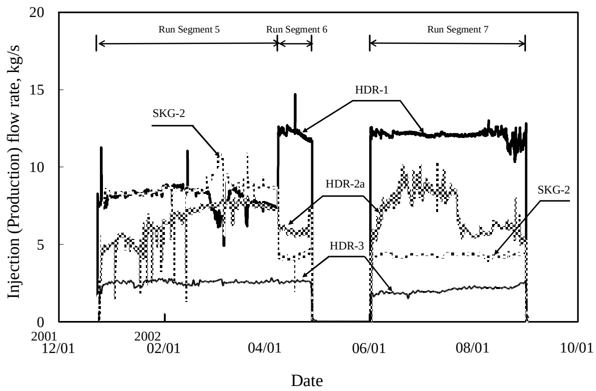

Figure 2: History of injection (HDR-1 and SKG-2)/ production (HDR-2a and HDR-3) rates during the LTCT.

Figure 3: The top of SKG-2 on the Hijiori HDR test site.

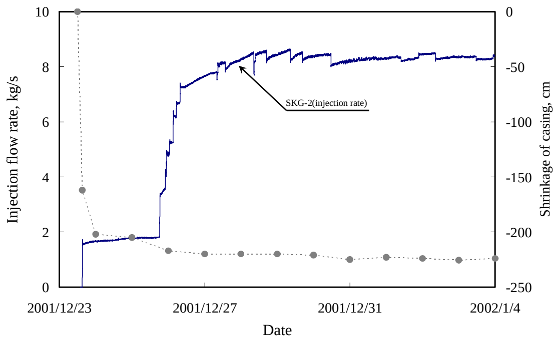

Figure 4: History of the shrinkage of the casing of well SKG-2

3. STEP FOR THE ESTIMATION OF THE THERMAL INFLUNENCE OF THE GEOTHERMAL WELL

The displacement of the borehole is given by Equation 1:

$$\lambda = \int_0^l d\lambda = \int_0^l \left(\varepsilon_{thermal} - \varepsilon_{body\_force}\right) dx$$
$$= \int_0^l \left\{ \alpha (T - T_0) - \frac{\sigma}{\mathrm{E}} \right\} dx \qquad (1)$$

where λ is displacement, ε is strain, σ is stress , E is Young's modulus, and α is the thermal expansion. Also, thermal indicates "thermal stress" and body force denotes "stress based on the casing's weight". Further, the shrinkage of the casing during the LTCT is the difference of the displacements expressed in Equation 2:

$$\lambda_{cir} - \lambda_{init} =$$
$$\int_0^l \left\{ \alpha (T_{cir} - T_0) - \frac{\sigma}{\mathrm{E}} \right\} dx - \int_0^l \left\{ \alpha (T_{init} - T_0) - \frac{\sigma}{\mathrm{E}} \right\} dx \qquad (2)$$
$$= \int_0^l \alpha (T_{cir} - T_{init}) dx$$

Thus, shrinkage is a function of temperature. The temperature of the borehole is calculated in order to estimate the shrinkage.

The following approach was used to estimate the thermal influence of geothermal well.

Calculate the temperature of the borehole during the LTCT using wellbore code (Dash and Zyvoloski, 1982).

1. Obtain the decrease of temperature from initial temperature using by the results of step 1.

2. Calculate the displacement using Equation 2.

3. Estimate the stress of the casing using the displacement in step 3.

4. CALCULATION AND DISCUSSION

The results the calculation are compared to the data measured by PTS logging in the plot in Figure 5. As can be seen in the Figure, the temperature of the borehole deceased quickly following injection. Following this, some temperature was recovered by decreasing the injection flow rate at the end of this test. As illustrated in the Figure, there is good agreement between the measured and calculated temperature data.

The displacement caused by the shrinkage of the casing was calculated using the Equation 2, and the results are shown in Figure 6. The increase of the shrinkage was large when pumping was started, but the calculated shrinkage was found to be smaller than that of the measured data. Also, the injection flow rate and the casing shrinkage both increased on December 25, 2001. However, calculated shrinkage is larger than the measured data after December 25, 2001. The calculated data is close to measured data at the beginning of test, but there was not good agreement between the two for the entire test. This is thought to be due to the mesh size of the model and model properties.

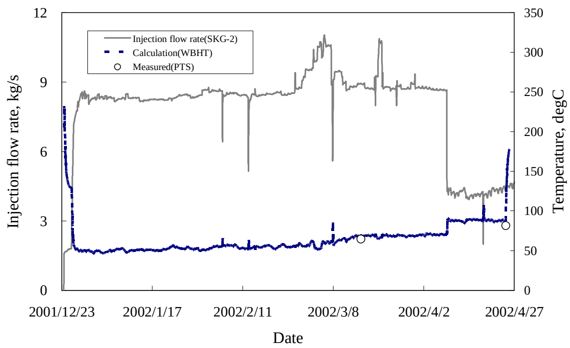

Figure 5: Comparison of calculated and measured (by PTS logging) bottom hole temperatures.

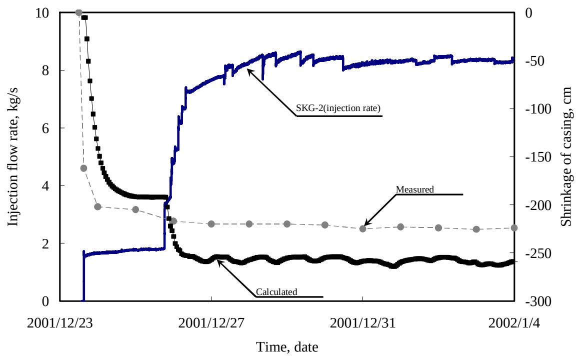

Figure 6: Comparison of the measured and calculated casing shrinkage

5. FUTURE PLANS

It was attempted to calculate the displacement caused by the thermal stress of the casing of the geothermal well. Also, numerical code is being developed for geothermal well. It is planned to estimate the stress of the casing, cement and formation around the geothermal well using this numerical code.

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