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Experiment of Fluid Driven Rotational Device for Scaling Removal Inside the Geothermal Well

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ABSTRACT

The purpose of this study is to design and develop a fluid-driven down-hole scraper including the rotation sensor to remove scaling inside the wellbore (patent pending).The experiments include artificial channel tests, horizontal production pipe tests and down-hole casing tests. The study conducts the scraper into the horizontal production pipe in IC-13 and the down-hole casing for the test of removing scaling in IC-19 and IC-21, Chingshui geothermal site. Furthermore, for the purpose of understanding results of test, we install the rotation sensing and photometer to detect the rotating speed of impeller and the production brine of turbidity. The sensor and photometer assist the techanicians in evaluating the working status of the downhole rotational device driven by flowing fluid. The laboratory tests show that the rotating speed of impeller goes up to 60 RPM as the fluid rate of 0.43m/s and the normal force is 0.4N. The horizontal production pipe test show that the thickness of scrape about 2mm as the flow rate is 2.62 ton/hr. The down-hole casing tests show that scraper rotation can achieve 120 rpm while the production rate is around 4.8~4.9 ton/hour. On site tests confirm that the scraper can be rotated fluid-driven via the signal of magnetic sensor and turbidity sampling. This study extended from the laboratory tests to on site test. In this paper, we mainly focus on the down-hole scraper casing test.

1. INTRODUCTION

Geothermal resource is the renewable energy that store in the deep stratum. Taiwan, which sits on the West Pacific Ring of Fire. So the geothermal energy distribute around the island. In addition, this resource is clean and stable. If we exploit the energy effectively, it can be the one of the base load in Taiwan. The geothermal resource can be divided into the volcanic and the non-volcanic geothermal area in Taiwan. The volcanic type of area include the mountain of Tatun and Turtle island, where the reservoir temperature reach up to 180~290 degrees Celsius, it belong to the vapor type of geothermal resource. The non-volcanic geothermal area included Chingshui, Lushan and Jhihben which distributed in metamorphic and sedimentary geological area. The reservoir temperature goes up to 80~220 degrees Celsius, it belong to the hot water type of geothermal resource. The Chingshui geological is type of metamorphic and alkaline fluid in the reservoir. Scaling in the wellbore caused the declining flow rate after the long time production. Scaling is an assemblage of deposits in geothermal well that result in clogging the wellbore and preventing the fluid flow, thereby causing declined in production rate and pressure. In general, the scaling is removed mechanically, chemical inhibit system and acid processes. However, those methods need more manpower, and moreover, damage of environment. Therefore, this study is developing the down-hole device which can scrape the scaling. The invention will decrease the decline in production rate and investment costs.

2. EXPERIMENT PLANNING AND EQUIPMENT DESIGN

2.1 System Introduction

The $CaCO_3$ (scaling) deposited at the inner surface of pipe. It was not so hard and solid as you might thing. It was weakest and softest than that composited for a long time (Referring to FIG.1 and FIG.2). The chemical formula for this scaling reaction is:

$$Ca^{++} + 2HCO_3^- = CaCO_3 \downarrow + CO_2 \quad (1)$$

If the scaling deposit in short time, it is easier to remove by the scraper immediately. This study according the principle of “rolling stone gathers no moss”, and design the equipment which fluid driven the impeller that cause the scraper rotation and remove the scaling inside the wellbore. The scaling is just formed and removed immediately. It can extend the life of each geothermal well. This operation in concert with winch that rolling the cable up and down that in order to remove the scaling at different depth (Referring to FIG.3).

Figure 1: The scaling deposited recently

Figure 2: The scaling deposited for a long time

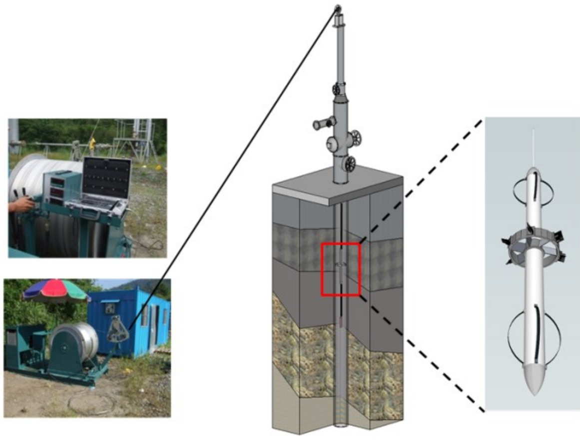

Figure 3: The system of down-hole scraper

2.2 Evaluate and Plan the Test Site

<u>2.2.1 The Test Site Introduction</u>

Chingshui is located at the north of Taiwan, which is Sodium bicarbonate hot spring and the pH value is around 9. The precipitation in the wellbore during the production has been proven, so we choose this place to the test site. As early as 1970s to 1980s, the Industrial Technology Research Institute (ITRI) and Chinese Petroleum Corp. (CPC) are co-engaged in exploration, drilling, geological, geochemical and geophysics testing at this site. The deepest of geothermal well is around 3,000 meters and the total of drilling well is 19 (Referring to FIG.4).

The Taiwan power company (TPC) also participated in the group in 1981s. They built the 3MWe single flash pretrial geothermal power plant and altogether run for about 12 years. Because of the scaling problem, it stopped generation in 1993s. ITRI is entrusted to develop the technology that resolved the problem of declined in production rate by the Bureau of Energy (BOE). This project implemented the old well recovering and the new well of IC-21 drilling. IC-19 provided the hot spring to the visitor center where people can boil eggs, sweet potato, etc. The depth of IC-21 is 1158 meters and completed in 2011s. The hot spring provide to the 50kW generator of Organic Ranking Cycle (ORC) system. So the study decides to choose those two wells for the down-hole test.

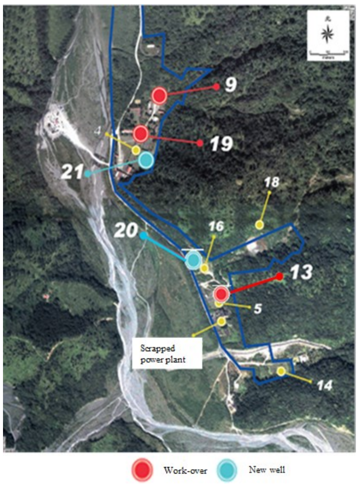

Figure 4: The well distribution in Chingshui

2.2.2 Plan of the On-Site Test

This experience is logging the down-hole scraper into the geothermal well. To prevent the logging device choke. In the first, we must know the scales of down-hole casing. In the test, we set the first level of down-hole casing for the target which the inner diameter is 22.5 centimeters. The scraper device utilizes the power of production rate which drive the impeller rotation. A rotating mechanism causes the scaling collapsed. In order to confirm this experiment, we sampled the water for turbidity sampling during the experiment period.

2.3 Design the Fluid DRIVEN rotationAL DEVICE

2.3.1 Mechanical Construction

The cleaning device for the wellbore was shown in FIG.5, which includes a mandrel, an impeller, a plurality of bristle members, two centralizers and a bearing assembly. The impeller is composed of an inner ring, a plurality of blades and an outer ring. The blades encircle the hub, and the outer ring is connected to the distal ends of the blades. The bristle members are disposed on the outer side of the outer ring. Along the longitudinal direction of the mandrel, the centralizers are respectively deployed on the opposite sides of the impeller. The bearing assembly connects to the mandrel and the inner ring, so that the mandrel can be rotated by the impeller. The rotating impeller is driven by the production of fluid; meanwhile, it cleans the scaling on the wall surface.

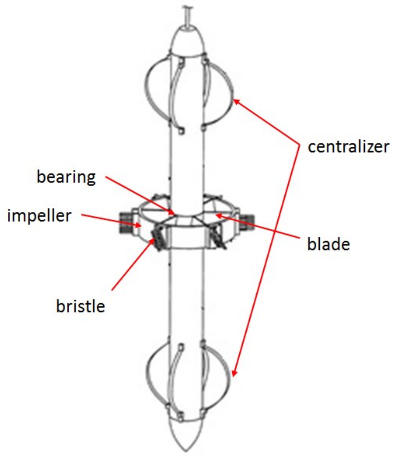

Figure 5: The cleaning device (patent pending)

2.3.2 The Centralizer

Since the casing diameter is inverse proportional to the depth of the well, we design a centralizer, which has flexibility to the varying lengths. Thus, the device is capable of operating at different depth. As shown in FIG.6, this device is mainly composed of centralizer, transmission rod, cam, bearing assembly and spring. As the lower centralizer reaches casing wall or scaling, the cam changes its position, and then the bristles shifts. This design and experiment of this equipment are not shown in this paper but this design concept are patent pending.

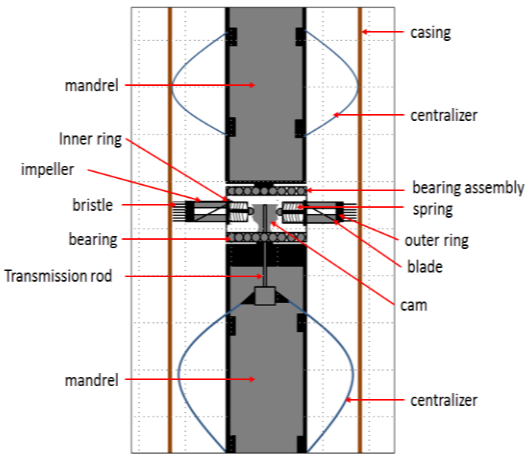

Figure 6: The cross-sectional view of cleaning device (patent pending)

2.3.3 The Bristle

As a result of the temperature goes up to 180~220 degrees Celsius, we choose the steel wire to bristles. The impeller make up by two-group of bristles. In order to add the friction and scraper extent, each bristle constitute by plural bundle of steel wires which length is about 4.5 centimeters (Referring to FIG.7).

Figure 7: The impeller and bristles

2.3.4 Rotation Sensor

This study design the rotation sensor because of this experiment is non-visualized. All of the mechanical actuation is under-ground thus we cannot differentiate the circumstances of the rotation scraper. This design included power supply, oscilloscope and magnetic sensor (reed switch) (Referring to FIG.8). This material of signal wire is Teflon type because of the down-hole temperature goes up to 200 degrees Celsius. This signal wire connects the surface power supply with the down-hole sensor. The neodymium magnet (NdFeB) fixed at the center bearing. The rotation impeller induced the voltage change that we could receive and distinguish the circumstances or the rotation speed.

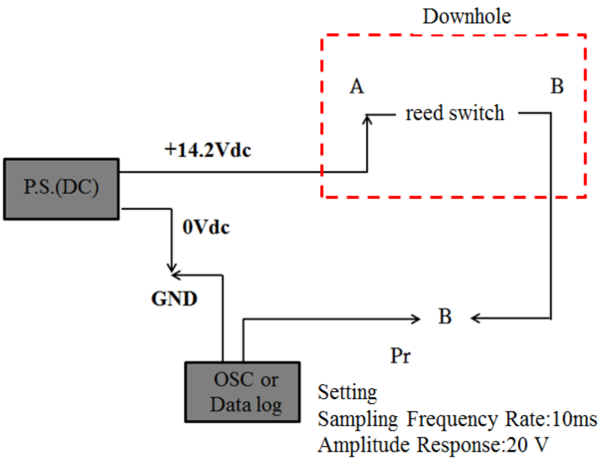

Figure 8: Field deployment of rotational sensors

2.4 Wellbore Clean Test in Chingshui

The wellbore clean test using scraper in Chingshui IC-19 and IC-21 was discussed. The scraper was hung into the geothermal well by the crane. The signal wire combined steel wire and connected between scraper and winch are put in down-hole through the pulley and blowout preventer (Referring to Fig.9). The rolling speed and depth of winch are controlled by the hydraulic system. Carefully keep signal wire and steel wire smooth to avoid the two wires twine each other.

Figure 9: Logging process

2.4.1 Down-hole Test at IC-19

The production rate of IC-19 is 4.26 ton/hour that provide to the tourist center. The well gage pressure is 7 kg/cm^2 and the wellhead temperature is 160 degrees Celsius. We utilize the power of production rate which drive the impeller rotation.

The twice logging tests that we still cannot receive the signal. Those reasons for failure include the strength of signal wire and the entry friction. We improve those elements design after the twice tests. As well as we increase the weight of the heavier guide rod (total weight is 36 kg). The impeller rotation when open the valve immediately, but only maintained few seconds during logging process (Referred to FIG.10). We decide to open the side valve of pipe thus increase the production rate. The sensor is no reaction after opening the side valve. We pull the device up to the ground and check the weir, impeller and sensor. Those elements are all right. We infer that the scaling is hard and solid so scraper can't operate. We change the test well to IC-21 because the triple tests that cannot receive the signal effectively.

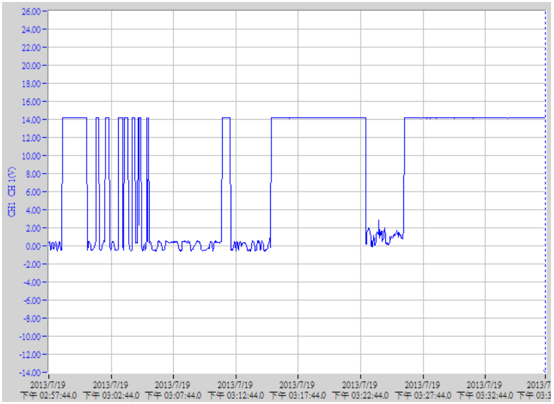

Figure 10: Logging signals at IC-19

2.4.2 Down-hole Test at IC-21

We log the device to 20 meters depth of well IC-21 and control the different production rate for tests **(**Referring to FIG.11 and FIG.12). IC-21 is in good condition that this casing covering with less hard and solid of scaling because of this well complete at 2011s. The production rate changed from 3.3~3.4 to 3.9~4.1 ton/hour and keep in a stable condition. We record the signal continually and changed the production rate to 4.8~4.9ton/hour. Figure 12 show us that each square wave represents the impeller make one revolution round the mandrel.

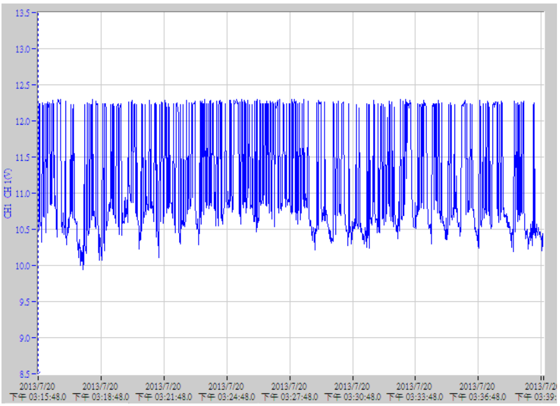

Figure 11: Logging signals at IC-21

3. RESULT AND DISCUSSION

We design and develop a fluid-driven down-hole scraper to remove the pipe scaling. A well bore cleaning device is provided, which includes a mandrel, an impeller, a plurality of bristle members, two centralizers and a bearing assembly. The impeller includes an inner ring, a plurality of blades and an outer ring.

We also design the sensing device which included power supply, oscilloscope and magnetic sensor. The sensing device helped us to differentiate the circumstances of the rotation scraper in the down-hole well. Due to the down-hole condition the sensing device must bear the high temperature and waterproof treat and ensure the signal quality.

We confirm that the scraper can be rotated fluid-driven via the signal of magnetic sensor and turbidity sampling.

The signal is generated by the magnetic sensor. This test shows us that the signal is not a clear square wave because of the magnet N-S poles of the magnetic field lines affected that causing the degradation of magnetic induction.

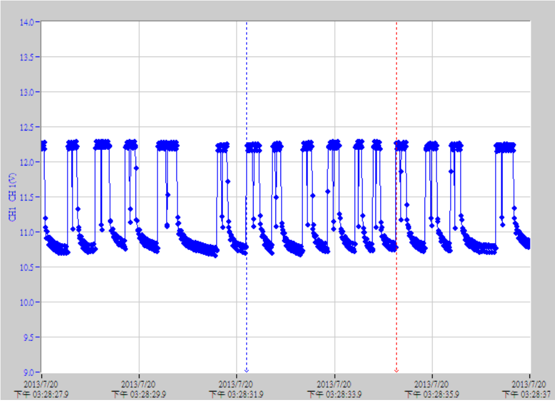

Figure 12: Detail logging signals at IC-21

4. CONCLUSION

On site tests show that the older well have the more problems with scaling in Chingshui. Those scaling is hard and solid that can't scraper it easily. Therefore this device must install in the new well which scaling is in lower hardness and weaker than old one.

The production rate can drive this device when it goes up to 3.3~3.4ton/hour and the maximum rotation speed goes up to 120 RPM as the fluid rate of 4.8~4.9ton/hour at IC-21.

The turbidity sampling shows us that it change from 2 FAU to 20 FAU by the disturbance of down-hole scraper duration the logging process.

The magnetic sensor and turbidity sampling that confirm the scraper can be rotated fluid-driven. This is a good way to clean the down-hole scaling which is more economic and environmentally friendly than the traditional methods.

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