USE OF SWAGES AS A TUBULAR REPAIR ALTERNATIVE FOR GEOTHERMAL WELLS

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ABSTRACT

Casing deformation is commonly found in geothermal wells, caused by natural or induced forces. Casing damage within geothermal wells may lead to the decline in production, stuck downhole tools, gravel bridge when loaded during well abandonments, reduction in well integrity and numerous other problems that could potentially result in major and expensive remedial works. For this reason, maintaining wellbore integrity is vital throughout the well life cycle.

Swaging is a technique used to open partially collapsed wellbore tubular. This process consists of jarring down a swage tool through the damaged area. Different types and sizes of swages are available to facilitate the casing re-shaping procedure by gradually passing a greater size swage by the collapsed zone. The aim of this paper is to present an overview of how swages have been used as a technique to repair collapsed geothermal wells in New Zealand.

1. A PROBLEM TO BE SOLVED

Geothermal has become a valuable alternative source of energy over the past years. At least 20 countries are now producing energy from underground heat (eart.org, 2021). Geothermal wells allow the extraction of high-temperature resources from sub-surface reservoirs to geothermal power plants for electricity generation. The tubular (i.e. casing and liner) selection for a geothermal well is defined depending on the well diameter, depth and target. As time goes by, tubular integrity gets deteriorated and may affect the normal flow of a well (Teodoriu, 2015)

Tubular failure, mainly caused by poor integrity, is a very undesirable condition to have in a well. This phenomenon primarily happens due to induced fatigue on the well components caused by extreme downhole conditions, areas of subsidence, casing running overloads, vibration and thermal stress during the well's lifespan (Teodoriu, 2015).

As a result, the tubular loses integrity at the point of facing wear, implosion, shear, buckle and even break, restricting the run of downhole tools and the deployment of gravel or cement for abandoning purposes. Herein lies the problem which the paper intends to address.

2. SWAGING

2.1 Overview

Swaging is a restoration technique that brings back the original tubular geometry by mechanically forcing a swage through the deformed section. A swage is a tapered shaped tool, usually made of hard steel, with an orifice on its body. Ideally, a swage with a slightly smaller diameter than the tubular should be passed through the collapsed section.

As swaging operates purely mechanically, it can be performed using slickline or braided line, which makes this technique inexpensive, but with the risk of lost tools leading to a fishing job.

This operation includes one or more jars as part of the tool string to deliver enough force against the restriction and to pass through it with a swage (Edvardsen, Gawel, & Cerasi, 2018)

Figure 1 explains three different scenarios. The scenario on the left shows a tubular with a swage sitting above a restricted section, whilst in the middle case, the tubular has been corrected to its original shape. Last, the illustration on the right side shows no complete clearance on the tubular after been swaged.

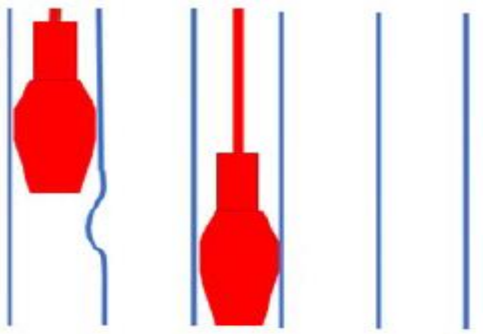

Figure 1: Schematic illustration of a swaging tool run through a collapsed casing/tubing (Edvardsen, Gawel, & Cerasi, 2018)

2.2 Application to Geothermal

In geothermal wells, casing damage represents a significant issue due to the high cost for the repair and abandonment, in conjunction with the reduction in electricity generation and the associated risks that this entails (Zarrouk & McLean, 2019).

External pressure is another and prevalent reason within geothermal wells that leads a casing to collapse. In this case, the casing tends to buckle due to the deficiency of cement surrounding it. When a well presents tubular damage, safety becomes a big concern as poor casing integrity could convert the surface into a hazardous environment (Kaldal, Jónsson, Pálsson, & Karlsdóttir, 2013)

2.3 Test Design and Planning

Western Energy has been in the market of servicing geothermal wells around New Zealand for over a decade.

Dealing with casing damage is a routine situation for Western Energy. By using diverse techniques such as swaging, Western Energy brings a range of solutions to complex scenarios.

Swaging at Western Energy began by manufacturing a set of swages with an outside diameter ranging from 2.4"-3" (See Figure 2). Starting with small size swages was the most viable option as the hard steel material, and labour presented a high cost. The swage tool design was based on the following considerations:

- Swage material selection.
- Max OD & tapered design.
- Fluid behaviour around the swage when used.
- Contingency planning for ease of fishing should it be required.

In addition, swaging needed approval from our client; therefore, trials and successful results were first required to be delivered.

Figure 2: Images of fabricated swages: 2.4in, 2.6in, 2.8in (ODs Left to Right)

In our experience, where we have been opening up restrictions predominately for geothermal well abandonment works (ranging from 2.4" – 3.25"), we have found that having swages stepping up in 0.200" increments has proved most efficient for swaging out damaged casings. This technique has also limited the work/stress being put onto the wireline while carrying out the swaging, therefore reducing the risk of fatigue on the wireline.

The swaging method was decided upon after performing trials in our workshop. A length of the casing was intentionally deformed to simulate a downhole scenario, and swages ran through to see how this performed.

The test pipe was prepared based on the following considerations (see Figure 3):

- Test pipe should be dimensionally similar to the casing in the geothermal wells with known obstructions.
- The test pipe should contain multiple obstructions so that the swages can conduct multiple tests
- The test pipe obstructions should be visible during the trial so that obstruction changes can be measured and monitored.
- The test pipe should be able to be filled with water to more closely simulate downhole conditions.

The test pipe created has the following characteristics:

- 3.5in OD, 3.0in ID.
- 3m long.
- Upper restriction of 2.8in OD (expected 2.3in ID).
- Lower restriction of 2.1in OD (expected 1.6in ID).
    - That is 2.1in OD at narrowest point (Restriction OD Range 2.1-2.8in OD).
- Welded to 4in 900# flange so it can be secured to the test stand and filled with water.
- A test stands is secured to the ground with 8 16mm diameter 100mm long concrete anchor screws.

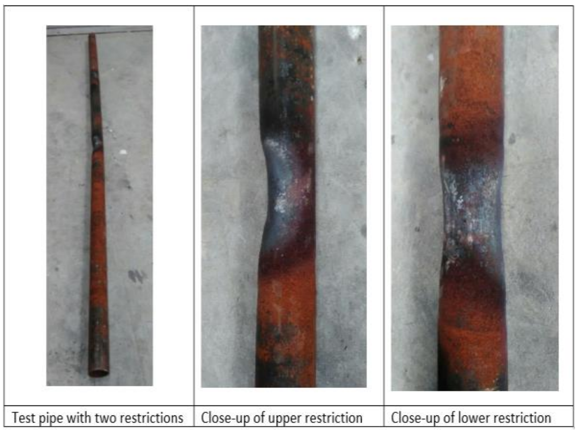

Figure 3: Test Pipe Images

The outcome of the test is shown in Figure 4.

Figure 4: Casing restriction and swage before and after the run

The tubular got re-shaped by incrementing the swage size after multiple passes, as shown in Figure 5.

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Figure 5: Re-shaped Tubular

Overall, the trial should be considered a success. The swages were able to open the two tubing restrictions to 2.8in ID. Table 1 gives the results obtained from this trial.

Table 1: Swagging trial results

Swage OD (in)	Upper Restriction		Lower Restriction	
	Start OD (in)	Final OD (in)	Start OD (in)	Final OD (in)
2.4	2.8	2.9	2.8	2.9
2.6	2.9	3.0	2.9	3.0
2.8	3.0	3.2	3.0	3.2

3. IMPLEMENTATION

This section outlines the process of performing swaging in geothermal wells in New Zealand. The method explained here has been generalised for simplicity. The following are some scenarios where Western Energy has performed swaging for different purposes.

The 1st case, a monitoring geothermal well in New Zealand, was planned for abandonment. Casing deformation was expected to prevent the successful placement of gravel and cement., so the wellbore ID needed to be widened. Figure 6 shows a casing failure/break at 52 m.

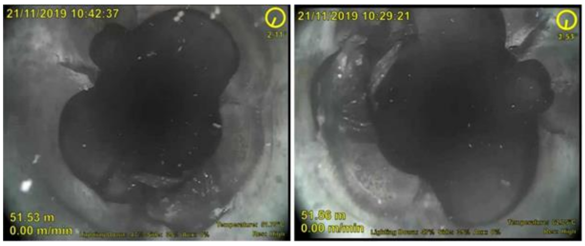

Figure 6: Geothermal well with casing restriction @52m

Swaging was determined to be the best candidate to re-shape the deformed section of the well. A 4" production liner was opened from 2.4" to 3.25" using 0.2" increment swage sizes, allowing the successful abandonment of the well. The job required a significant amount of jarring before getting clear.

One of the most significant risks of performing swagging operations is that the swage becomes stuck either at or below the restriction. Tool string selection was considered the best risk mitigation method, as well as specific operations parameters when jarring on the restriction.

Jarring is vital when referring to swaging procedures. Jarring is a technique that delivers an impact force over an area. This is achieved by accelerating a jar up and down, causing a stroke (Slk Connect, 2020)

BHA selection needed to also consider the effects of stress on the slickline itself due to the impact force generated during swagging; this risk is particularly acute in shallow well operations. A swaging tool string does not differ much from a standard slickline-service tool string; it has an addition of a swage at the end of it and extra jars as required.

The 2nd scenario includes swaging casing damage at 755 m to enable anti-scalant tubing to be installed to the desired depth. Due to the casing damage, the tubing had not been able to be run to the depth where it would be most effective for preventing the build-up of scale and therefore, the scale had built up in the production liner.

The job consisted first of pulling the anti-scalant tubing out the well, then broaching the scaled section up to the known casing damage. Swaging was then carried out to widen the damaged 6 5/8" liner from approx. 4.5" to 5.6" to allow for an X-Y caliper survey. Further broaching, and finally, anti-scalant tubing installation below the re-shaped restriction was carried out, leading to an increase of production and anti-scalant being able to be injected to the desired depth to prevent further build-up of scale.

Swagging resulted to be a very efficient and practical technique, especially for those wells which have a small footprint would prove difficult to have a coil tubing spread on-site to carry out abandonments.

5. CONCLUSIONS

Western Energy designed swages and developed a method for testing and refining swaging methods at our facility in Taupo. Following successful testing, we deployed this technique in a range of wells to increase well ID as an enabler of further operations. Firstly, shallow deformation in a monitoring well was successfully swaged from 2.4" to 3.25" diameter to enable sufficient access for abandonment. For the second case, larger swages were made (see Figure 7), and deformation in 6-5/8" liner in production well was successfully opened from 4.5" to 5.6" to permit broaching of the scale below the obstruction and installation of antiscalant tubing to the required depth. Additional operations have further developed and improved the method.

Figure 7: Multiple OD swages

Swaging has been demonstrated as a successful and cost-effective practical solution to address casing deformation in both pre abandonment and production optimisation work as part of a standard wireline/slickline operation, avoiding the need for more complex repair operations.

Critical to the success of swaging operations are:

- Wellbore data (e.g. calliper data, camera survey images, drift survey results, LIB's, casing/liner specs) must be reviewed and a detailed technical program developed;
- Detailed design of the tool string, including determining the use of power jars and/or accelerators and their setup
- Design and use of swages, swage size increment selection selection
- Wireline procedures for swaging, including jarring
- Selection and preparation of well diagnostic tools to determine well conditions to inspect casing as swaging operations progress

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