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Testing Flexible Couplings for Geothermal Wells

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Keywords

Flexible Couplings, Strain mitigation, Geothermal wells, Buckling, Collapse, Strain reduction, Production casing.

ABSTRACT

Flexible Couplings (FC) as a solution to mitigate thermal straining of casings in geothermal wells have been tested, where its function to allow intermittent displacement of the production casing during warm-up has been verified both for straight and deviated wellbore. During warm-up, free thermal expansion of the steel used for casing in geothermal wells is blocked in conventional design, resulting in high stresses that are often above the yield strength of the material. This stress can both damage the casing as it will release the stress by permanently deforming the casing plastically. The proposed solution allows the casing to expand into the FC that replace conventional connections, and by that ensure that the stress level will remain below the yield strength of the material. Chance of generating plastic strains will therefore be lowered reducing the risk of casing failures. Testing in two, third party, laboratories have been performed within the EU funded projects, GeoWell (www.geowell.eu) and DEEPEGS (www.deepegs.eu) and the plans are to make the first full scale testing in a high-temperature geothermal well in the end of 2019.

1. Introduction

The Flexible Coupling concept has been under development since 2015. The concept, to mitigate plastic strain in the production casing during warm up by allowing the casing to expand axially, has been tested and verified in two independent testing laboratories. The axial displacement, designed according to the difference between cementing temperature and operational conditions can be adjusted to operational temperatures up to 600°C. The design criteria for the FC is to fulfill all requirements for drilling, cementing and completion of the geothermal well, meaning that the anchor casing and drilling diameters are the same as with use of conventional connections. With the release of the axial stress in the production casing it is expected that the risk for buckling/collapse will be reduced significantly and plastic strains minimized. Therefore, the risk of tearing the casing out of couplings during cooling, e.g. for well workovers, should be lowered significantly.

The European Union-funded Horizon 2020 research and development program has funded two projects (www.geowell.eu, www.deepegs.eu) where the FC has been designed, tested and verified. The next step is final tests in laboratory followed by production of FCs for full length of the production casing. The plan is to have it ready for a high enthalpy well in Iceland by the end of the year 2019 – early 2020.

2. Failure modes and mitigation.

Thermal expansion of the constrained casing material is one of the major issues causing failures in high-temperature geothermal wells. While it is well documented and standardized how to tackle thermal expansion in surface installations, no solution has been available for casings in drilled wells both in oil and gas as well as in geothermal applications. The casings are made of steel of grades chosen according to standards API 5CT and ANSI/NACE MR0175/ISO 15156. Carbon steel commonly used for geothermal casings has a thermal expansion coefficient around 0.012 mm/m°C. The material strain often well above yield has been linked to statistical studies of well failures in an unpublished paper at ÍSOR (Iceland GeoSurvey) by Björn Sveinbjörnsson (Figure 1). Around 250 geothermal wells in Iceland were analysed, whereof 136 have been regarded as production wells, reveal that 75 wells or 55% have reported incidents. The number could be higher as not all the wells have been analysed or in some cases logged since production started.

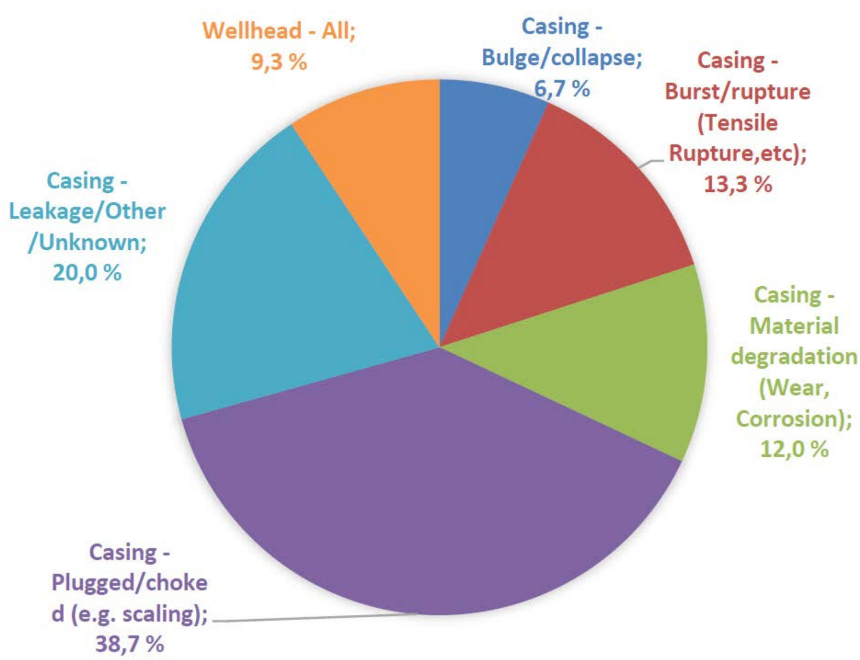

Figure 1: Reported failures in a series of 136 high temperature geothermal wells in Iceland. In total 75 wells, out of the 136, have reported failures (Lohne et al. 2017).

Mitigation of the axial load for the production casing with Flexible Coupling allow each casing segment to expand axially into the FC, thereby enabling design where the stress level of the casing material is controlled to be lower than the yield strength of the material. This allows for the first time, a well design following the same design criteria as used for surface installations, i.e. to be designed elastically. The allowed axial movement is according to expected temperature in the well and more specifically temperature difference between cementing temperature and operational temperature. Flexible Couplings are therefore designed in, but not limited to, several temperature intervals as shown in Table 1.

Table 1: Table showing proposed temperature intervals for the Flexible Couplings.

	Operational temperature: [°C]
Flexible Coupling 200	200-300
Flexible Coupling 300	250-350
Flexible Coupling 400	300-400

Design work and related parameters have been reported by Kaldal et al (2011), Kaldal and Thorbjornsson (2016) and Thorbjornsson et al (2017).

3. Testing and verification of Flexible Couplings.

Flexible Couplings were made as prototypes in two casing dimensions, 9⅝″ and 13⅜″. The prototypes were made of medium carbon steel type AISI 4140-4, commonly known in the geothermal industry as L80. Three of the 9⅝″ prototypes were tested at SINTEF (www.sintef.no) laboratories in Trondheim, Norway, and one 9⅝″ and one 13⅜″ prototype were tested at NORCE (www.norce.no) laboratories in Stavanger, Norway. Test setup in SINTEF and NORCE can be seen in Figure 2 and Figure 3, respectively. The test procedure was based on the ISO/PAS 12835:2013(E) testing standard for premium connections, but as the standard is intended for connections with no moving parts, modifications were made. Test loads for the 9⅝″ FC was 1000 and 2000 kN in compression, and 1000 kN in tension. In all load cases as well as unloaded, pressure tightness with water at ambient temperature was measured. Finally, the ultimate tensile load capacity was measured.

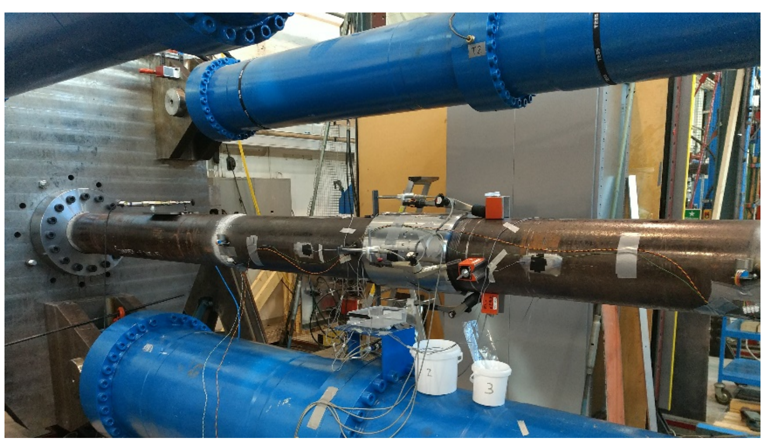

Figure 2: Test setup for testing 9⅝″ Flexible Coupling in SINTEF laboratories in Norway.

Test loads for the 13⅜″ FC were 1400 and 2800 kN in compression, as well as the ultimate tensile load. Sliding forces and start up force for sliding were measured in both straight and bended position. For the first three prototypes in 9⅝ a bending curvature of 2,5°and 5° pr. 30 m length was applied and sliding forces measured.

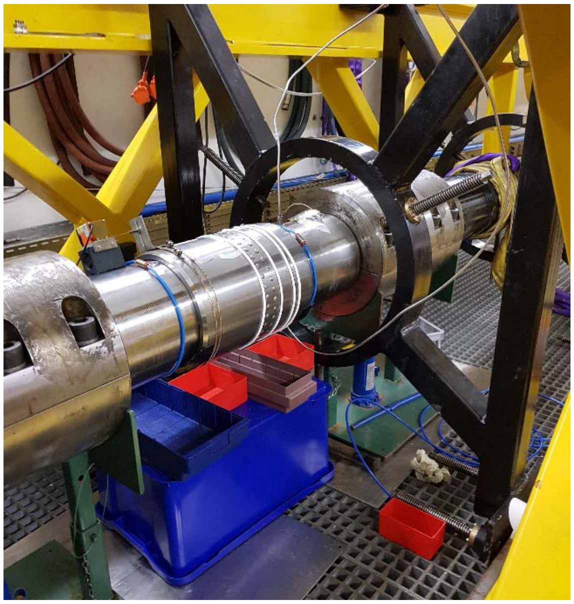

Figure 3. Test setup for testing 9⅝″ Flexible Coupling in NORCE laboratories in Norway.

Table 2 shows result from testing three 9⅝″ FC in SINTEF, one 9⅝″ and one 13⅜″ in NORCE.

Table 2: Test result of 5 FC prototypes at SINTEF (Prototype 1-3) and NORCE (Prototype 4 and 5). Sliding forces in bending only performed on prototype 1-3.

Prototype:	Start force [kN]	Sliding force [kN]	2,5° bending: Sliding force [kN]	5° bending: Sliding force [kN]	Ultimate tensile load [kN]
1 - 9⅝	200	200	200	200	1837
2 - 9⅝	300	300	300	300	1926
3 - 9⅝	320	320	320	320	3135
4 - 9⅝	247	176-219	-	-	3032
5 - 13⅜	267	189-229	-	-	3922

4. Conclusion

Testing of five prototypes of Flexible Couplings have been performed whereof four tests for 9⅝″ casing diameter and on for 13⅜″ casing diameter. Results show that the concept of the FC with sliding mechanism is working well, for straight as well as deviated test setup. Sliding forces have been recorded and are consistent during several runs of opening and closing the couplings.

Sliding forces have been slightly adjusted between prototypes as well as improvements to the ultimate tensile strength. Leakage has been recorded to be over given limits by the standard for premium connections. Part of the improvements between prototypes have been focusing on pressure tightness of the FC. Prototype 4 in 9⅝″ casing diameter showed pressure tight connection in all positions up to 110 bar water pressure at ambient temperature. Two international patent applications have been filed to the European and USA patent agency, both have now been accepted as Icelandic patents.

Schedule for the next steps in the verification process is to test 2-3 more prototypes of the 13⅜″ diameter and thereafter the plan is to make a full demonstration by producing up to 100 pcs of the 13⅜″ FC for production casing in a well to be drilled in Iceland late 2019 or early 2020.

Acknowledgement

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