Non-Destructive Testing Applied to Rig Inspection (A Case Study of Menengai Geothermal Project)

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Keywords
Non-destructive testing, Menengai Geothermal Project, rig inspection, magnetic particle inspection, visual inspection, electromagnetic inspection and drill string

ABSTRACT
This paper describes the various Non-destructive-testing (NDT) techniques that have been applied and used in ensuring the integrity of geothermal drilling components at the Menengai Geothermal Project in Kenya.

NDT is an analysis technique that finds wide application in the Oil, Gas and Geothermal Industry to determine the state or function of equipment without requiring invasive approaches such as disassembly or failure testing. It mainly involves the statutory testing of the lifting equipment, derrick, the drill string and associated components.

Other applications include maintenance/repair aid testing of miscellaneous equipment and quality and safety assurance testing of new equipment parts and fabrications.

Aspects concerning the inception of the inspection service at Menengai, the techniques/methods and equipment applied, the business significance of the project and areas of improvement are discussed and analyzed in this paper.

1.0 Introduction
In the year 2009, the government of Kenya created the Geothermal Development Company to fast track the development of geothermal resources in the country. The company was given the mandate to drill up to 1400 steam wells to provide steam for the generation of 5000MW of geothermal power by the year 2030.

For this reason, the company has so far acquired through purchase 4 (2000Hp) drilling rigs complete with all the accessories, drill string tubular, cementing equipment, air drilling package, fishing tools, directional drilling and lifting equipment to support its drilling operations.

Best Industry practice according to International standards i.e. API, DSI and statutory regulations require that drilling rigs and their components be subjected to inspection and monitoring of their components to ensure their integrity of service, safety of working personnel and reliability of information.

2.0 Logistics and Operations
Non-destructive Testing (NDT) in GDC commenced in 2012 following the need to investigate the integrity of equipment and assets and to monitor and improve the reliability of these equipment, tools and processes after being in use for approximately two years.

The need to fast track the procurement of the inspection services was also necessitated by the rising cases of washouts and failure of drill string components and resulting costs and extensive down time from tripping and fishing, or even loss of entire wells.

The inspection service entailed Magnetic particle/Visual/Dimensional inspection on BHA Tools such as; Drill Collar, Stabilizers, Heavy weight drill pipes, Kelly, Roller Reamers, Fishing Tools, Pup Joints, Various crossover subs, Penetrant Testing on Non-magnetic drill collars, Electromagnetic inspection on Drill Pipes, API Drifting/VTI for Casings/ Tubing and Visual/ MPI on Lifting equipment.

In addition, straightening of bent pipes, re-facing and hard banding of tool joints was part of the inspection services.

The tender was awarded to a local inspecting company, Quality Inspectors Limited, who followed guidelines provided by; API (API RP 7G-2: Recommended practice for Drill Stem Design and Operating Limits) and TH Hill (DS-1 Fourth Edition: Drill Stem Inspection Standards). The inspectors also mobilized the services of an OCTG inspections supervisor as team leader to ensure the quality of inspection and to implement the effectiveness of international practice.

3.0 Methods/Techniques and Equipment Employed
The following is a summary of the NDT methods, equipment and required standards, which were applied.
a) Visual Inspection
This is a Trained Naked-eye examination that was used to detect mechanical damages like gross fatigue cracks, dents, corrosion, seal damages, hard facing, bevel damages, box swell, tong space and thread damage on the components. Pipe outside diameters were also inspected using an OD gauge.
However visual evaluation does not detect discontinuities. Therefore inspections were not limited to visual examination.

b) Magnetic Particle Testing (MPI)
MPI is consisted of the wet continuous magnetic particle inspection and the dry continuous magnetic particle inspection.
The wet fluorescent MPI method was applied to the BHA, HWDP tool joints & drill pipe tool joints. It was used to detect transverse surface flaws in the tool-joints.
The Dry Magnetic Particle Inspection involves the examination of the external surface of drill pipe and HWDP upsets and slip areas.
The pipes are magnetized with a DC magnetizing coil with longitudinal magnetization for detection of transverse cracks.

c) Penetrant Testing
This is a very sensitive nondestructive testing method that was used to detect very small surface discontinuities that could not be inspected with MPI.

d) Ultrasonic Testing (UT)
This method was used mainly to check the wall thickness of the tubular.

e) Electromagnetic Inspection (EMI)
This method was used to locate three dimensional flaws. It was used to evaluate the full length of drill pipes tubes for locating internal and external pitting, cuts, gouges, localized wall loss and fatigue cracks.

There was an inspection protocol covering the delivery of components and access to the rig and color coding of accepted and (Picture 1. Showing an inspector conducting Magnetic Particle Inspection on a drill pipe).

(Table 1. Different methods of NDT as applied to various equipment and the tools used).

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Methods</th>
<th>Defects</th>
<th>Tools</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drill pipe tube bodies (API RP 7G)</td>
<td>Electromagnetic Inspection</td>
<td>Fatigue cracks, corrosion pits, mechanical damage</td>
<td>EMI kit, Black light, 220V, 100W. Inspection mirror, Blanket, Spray can, lead gauge, profile gauge, vernier caliper, OD &amp; ID caliper, steel rule, tally meter, depth gauge.</td>
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<tr>
<td></td>
<td>Ultrasonic wall thickness measurement</td>
<td>Wall reduction</td>
<td></td>
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<td></td>
<td>OD (outside diameter) gauging</td>
<td>OD wear, crushing, necking, swell</td>
<td></td>
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<tr>
<td></td>
<td>Visual inspection</td>
<td>Mechanical damage</td>
<td></td>
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<tr>
<td></td>
<td>Dry magnetic particle inspection (MPI) of end areas</td>
<td>Fatigue cracks in end areas</td>
<td></td>
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<tr>
<td></td>
<td>Electronic end area inspection</td>
<td>Fatigue cracks, corrosion pits, mechanical damage in end areas</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Optical inspection of internal upsets</td>
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<tr>
<td>Drill pipe tool-joints</td>
<td>Visual</td>
<td>Mechanical damage, weight/ grade identification. (including thread damages)</td>
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<tr>
<td></td>
<td>Dimensional</td>
<td>Mechanical damage, wear</td>
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<tr>
<td></td>
<td>Wet magnetic particle inspection / liquid suspension inspection</td>
<td>Fatigue cracks.</td>
<td></td>
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<tr>
<td>Rotary shouldered connections on drill collars and BHA components (DCs, stabilizers, reamers and subs etc.)</td>
<td>Visual</td>
<td>Mechanical damage</td>
<td>Black light, 220V, 100W. Inspection mirror, Blanket, Spray can, lead gauge, profile gauge, vernier caliper, OD &amp; ID caliper, steel rule, tally meter, depth gauge.</td>
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<tr>
<td></td>
<td>Dimensional</td>
<td>Mechanical damage, wear, inadequate BSR.</td>
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<tr>
<td></td>
<td>Wet magnetic particle inspection (MPI)</td>
<td>Fatigue cracks in threads.</td>
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<tr>
<td></td>
<td>Ultrasonic inspection</td>
<td>Fatigue cracks in threads</td>
<td></td>
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<tr>
<td>Tool bodies</td>
<td>OD (outside diameter) gauging over the full length</td>
<td>OD wear, crushing, necking, swell</td>
<td></td>
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<tr>
<td></td>
<td>Wet magnetic particle inspection (MPI)</td>
<td>Fatigue cracks.</td>
<td></td>
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<tr>
<td>Handling Equipment (Slips, tongs, elevators, Kelly drive bushings, rotary table bushings etc.) (API RP 7G)</td>
<td>Magnetic particle inspection of stressed areas</td>
<td></td>
<td>AC yoke, Inspection mirror, penetrant, OD &amp; ID caliper, Steel rule, Tally meter, depth gauge.</td>
</tr>
<tr>
<td>Lifting equipment; (slings, chains, Air receivers, cranes, forklifts, air winch lifting tackles.(API RP 7G)</td>
<td>Visual</td>
<td>Mechanical damage</td>
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<td></td>
<td>MPI of stressed areas</td>
<td>Fatigue cracks</td>
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rejected items. Every inspected item was given its own inspection report countersigned by both parties. (Client and contractor)

Where necessary a technical opinion was given covering integrity of the item, test method and frequency of testing to enhance components reliability.

4.0 Significance/Benefits Arising From Adopting NDT

NDT was applied by GDC typically for the following reasons:

• Cost reduction
  This includes costs incurred in purchase of replacement tools and spares, fishing, labor and other logistical costs that results from equipment failure. Preventive maintenance costs a lot less than equipment failures.

• Improve equipment reliability and maximize productivity
  Through reduced down times and increased performance expectancy of tools.

• Accident prevention
  Ensuring that employees and assets remain safe. Slings and other lifting tackles are inspected to ensure no failure occurs during operation that could cause accidents.

• Improve company’s competitive levels in the industry
  Quality assurance in all operations, conservation of capital as well as being at par with the company’s overall time based targets. (i.e. 5000Mwe by 2030)

A typical time analysis for a well drilled at Menengai shows that, approximately 40% of total time is taken during wait on repairs, sticking and fishing operations.

During fishing operations, for instance, a lot of effort is applied in attempts to free the string which most times, result to over pulls, tensional and bending stresses, increasing the need for periodic drill string inspection.

**Time Analysis for Different Activities During a Drilling Operation**

<table>
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<th>Time Analysis for Different Activities During a Drilling Operation</th>
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<tbody>
<tr>
<td>Time</td>
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<tr>
<td>------</td>
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<tr>
<td>Hours</td>
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<tr>
<td>Days</td>
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<td>%</td>
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Being a pilot inspection project, there were a lot of challenges faced in the execution of the project namely;

• The contract was limited to the quantities submitted for inspection by the drilling operations department. A permanently based inspection system could address all inspection needs where quantities to be inspected are not limited.

• No site space was allocated for the exercise. This was difficult since the inspectors were forced to use the drilling site and sometimes even operating from the catwalks. (As shown in picture 2 below). A specific site should be set aside for the inspection exercise, and not the storage yard or the rig sites.

• The inspection program was adversely interrupted by weather (during heavy rains).

• There were considerable delays in the project resulting from the unavailability of handling equipment e.g. fork lifts and their operators.

• Complex reporting structures that involved both the client and the service provider resulting in slow critical decision making.

• Lack of consistency in the inspection service. The time lapse between the first and the second inspection service contract was overly extended, hence, some concerns/ problems that could have been avoided occurred.
5.0 Areas of Improvement

Following the inception of the inspection service by a third party company to GDC, the project does not seem to have benefited from additional investments, leading to stagnation in equipment capitalization and human resource training and development. NDT at present fully depends on expatriate and third party labor, this is proving to cost just as much as the failure costs we are trying to evade, since the company does not have trained and certified personnel and equipment to facilitate this need.

Considering data collected from a sample of GDC’s completed wells at Menengai, the average drilling day rate is approximated at USD. 30,000 and an average of 20 days are lost as down time due to drill string and BHA failure. Thus the approximate cost for the down times is;

\[ 30,000 \times 20 = 600,000 \text{ USD (for every well)} \]

Therefore, if a proper inspection system is implemented, the above cost plus varying fishing costs would be substantially reduced.

GDC should also implement a highly effective tubular management system to increase efficiency and performance of drilling operations. A tubular management system, with a full inspection yard and machining shop, will streamline the coordination between drilling operations and the inspection service, and improve the quality level and reliability of components. The conventional method of bundling tubular as currently followed by GDC, results in excessive damage and subsequent costs. Use of a cradle system in packaging, storage, transportation and handling of tubular will ensure minimal damage and increased safety.

6.0 Conclusion

Non-destructive testing (NDT) inception was a timely and critical step taken by GDC towards improved operation standards and increased level of competitiveness in the geothermal industry as a whole.

This was a major driving force for the company towards achieving its milestone goals of producing 5000Mwe worth of steam by the year 2030 as mandated by the government of Kenya.

The company has a lot to achieve and will take even more bold steps to ensure that the inspection service delivery is improved and use the outcomes as key performance indicators to outline and measure its progress towards achieving strategic goals.

An effective NDT culture will, consequently lead to the improvement of other key operations for the company. A separate inspection yard along with a proper tubular management system in place will provide the best improvement by operating as an independent system. Safety standards would also improve as an outcome of the NDT inspection service.

7.0 References

GDC well completion reports