International Journal of Engineering, Mathematical and Physical Sciences
ISSN: 2517-9934
Vol:6, No:8, 2012

Numerical Analysis and Experimental Validation of Detector Pressure Housing Subject to HPHT

Hafeez Syed, Harit Naik

***Abstract*—**Reservoirs with high pressures and temperatures (HPHT) that were considered to be atypical in the past are now frequent targets for exploration. For downhole oilfield drilling tools and components, the temperature and pressure affect the mechanical strength. To address this issue, a finite element analysis (FEA) for 206.84 MPa (30 ksi) pressure and 165°C has been performed on the pressure housing of the measurement-while-drilling/logging-while-drilling (MWD/LWD) density tool.

The density tool is a MWD/LWD sensor that measures the density of the formation. One of the components of the density tool is the pressure housing that is positioned in the tool. The FEA results are compared with the experimental test performed on the pressure housing of the density tool. Past results show a close match between the numerical results and the experimental test. This FEA model can be used for extreme HPHT and ultra HPHT analyses, and/or optimal design changes.

***Keywords*—**FEA, HPHT, M/LWD, Oil & Gas

I. Introduction

As conventional sources of oil and gas decline, operators are increasingly turning their attention to unexplored areas. Reservoirs with high pressures and temperatures (HPHT) that were considered to be atypical in the past are now frequent targets for exploration. HPHT (Fig. 1) environments pose major hazards to people, property, and the environment. For downhole oilfield drilling tools and components, the temperature and pressure affect the mechanical strength. In high pressure situations, the greater the pressure, the more stored energy is available. Should there be an uncontrolled release, it could cause serious injury to people and damage to property. To further complicate matters, most companies are hesitant to invest in HPHT technology because the market size for HPHT wells is still small relative to conventional wells. Consequently, the successful and cost effective exploration of HPHT reservoirs remains a challenge [1]. In addition to complex wells, the tool strings become correspondingly more sophisticated. To ensure the tool (or) equipment safety, a high hydrostatic proof test pressure is used. As a result, equipment designed is usually heavy, robust, and expensive [2].

Hafeez Syed is with Halliburton Technology centre, Pune, India (Phone: 91-20-40158000, fax: 91-20-40158199, email: Hafeez.syed@halliburton.com)
Harit Naik is with Halliburton Technology centre, Pune, India (Phone: 91-20-40158000, fax: 91-20-40158199, email: Harit.Naik@halliburton.com)

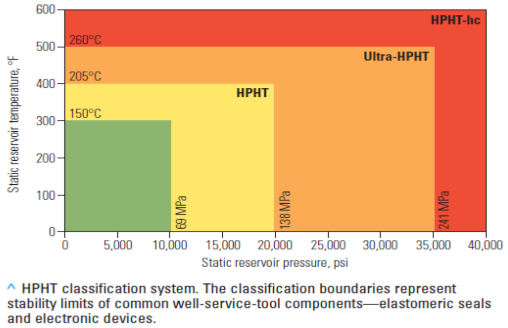

Fig. 1 HPHT classification

The typical numerical FEA programs that are currently available to the industry are run on personal computers, in which models are easy to develop and use. Multiple analyses can be run to refine and improve new conceptual designs. The application of FEA has changed the design processes in other industries; the benefits could be brought to drillstring design and innovation. FE modeling and solutions for the complete drillstring, however, are exceptionally time consuming and complex; consequently, it is limited to drillstring components [3] [4]. The objective of this study is to test the current pressure housing assembly of a 0.17145 m (6.75 in.) density tool to determine whether or not it will withstand 206.84 MPa (30 ksi) service pressure at 165ºC. The density tool is a MWD/LWD sensor (Fig. 2) that measures the density of the formation. The tool also measures the photoelectric index, which is used to identify rock type. Formation porosity is computed from the density of the formation and rock type. It is one of the most advanced downhole sensors in the MWD/LWD industry. One of the components of the density tool is the pressure housing that is positioned in the tool stabilizer. This pressure housing contains a measurement sensor, the detection package, which senses the radioactive rays that have travelled through the formation. The pressure housing is made from a titanium alloy with a minimum yield strength of 1172.11 MPa (170 ksi). The housing is rated to 172.37 MPa (25 ksi) maximum operating pressure at 165ºC.

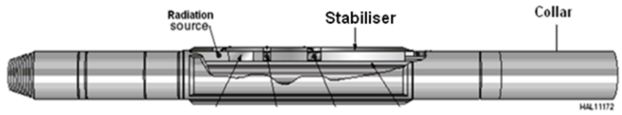

Fig. 2 Basic density tool layout [5]

II. FEA Modeling

The 3D non-linear finite element analysis of the pressure housing subjected to 206.84 MPa (30 ksi) bore pressure is performed using FEA numerical software.

In this analysis, a physical model of the housing is built using computer-aided modeling software.

Next, FEA numerical software is used to assess the structural non-linearity of the model. In this FEA, the parts of the pressure housing assembly are treated as separate components, with the appropriate contacts on their interfaces, and the investigations are based on the stress distribution and deformation pattern.

After making the geometric model, the high temperature derated mechanical properties are defined. The next step is to mesh the model, in which the solid model is divided into nodes and elements. For this problem, a solid element with a higher order 3D, 10-node element is used.

With solid modeling, the geometric shape of the model is described, and then instructions are given to the FEA numerical software to mesh the geometry with nodes and elements. Fig. 3a and 3b show a typical finite element mesh of components. The number of nodes and elements in the part model analyzed are approximately 3,908,928 and 2,703,935 respectively. A mesh independent/sensitivity test is performed (Fig. 4) to ensure that the results are not mesh dependent.

The boundary conditions and loadings used in the analysis are the pressure and external constraints with appropriate contacts on their interfaces.

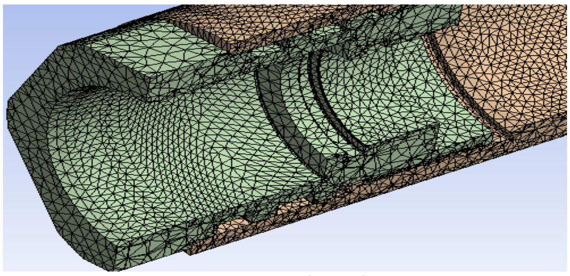

Fig. 3 (a) Mesh at the interface of adjoining parts

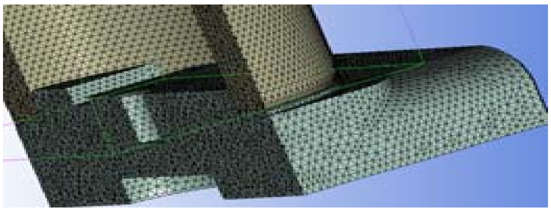

Fig. 3 (b) Mesh at the interface of adjoining parts

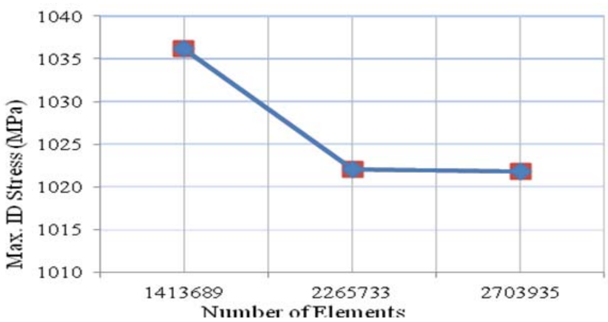

Fig. 4 Mesh sensitivity/independent check

III. Results And Discussion

The density tool pressure housing was tested at the Halliburton testing laboratory with a defined time interval and defined pressure intervals of up to 241.32 MPa (35 ksi) rating at 165ºC. After the completion of each pressure test cycle, the testing fixture assembly was disassembled and internal parts removed; the internal diameter of the housing was examined for deformation by comparing the after-test measurements to the pre-test measurements. Based on the evaluated test results of the pressure testing, it was concluded that the pressure housing assembly can be safely operated at 206.84 MPa (30 ksi) and 165°C [6].

The 3D FE analysis helps us to visualize that the stress distribution is not uniform throughout the thickness. The variables that affect the behavior of pressure housing are the externally applied pressures on the surfaces. The maximum value of von Mises stress occurs on the surface of the insert at the fixed sharp edge corner. Because it is not located in the body, however, it is not discussed here. The FEA results are compared with the experimental test performed on the pressure housing of the density tool. Past results show a close match between the numerical results and the experimental test.

Fig. 5 shows the comparison between experimental and FEA results at 206.84 MPa (30 ksi) over the length of the pressure housing. Fig. 6 shows the comparison between experimental and FEA results at the mid centre of the pressure housing for pressure ratings from 206.84 to 241.32 MPa (30 to 35 ksi). In both figures, the difference in values between the experimental and FEA results are attributable to different elastic modulus values. The supplied material from the vendor usually has approximately 10% greater strength, but the specified minimum strength values are used in the FEA.

The current API design verification methods are based on linear-elastic stress analysis with the maximum allowable stresses limited to 83 to 90% of material minimum yield strength [2]. Modeling showed that the greatest stress on the housing is 1020.42 MPa (148 ksi) (Fig. 6), which provides a comfortable operating margin; the material has a specified stress limit of 1172.11 MPa (170 ksi). The stresses were found to be within the permissible range. The FEA model developed for numerical analysis substantiates and validates the experimental work performed. This FEA model can be used for extreme HPHT and ultra HPHT analyses, and/or optimal design changes.

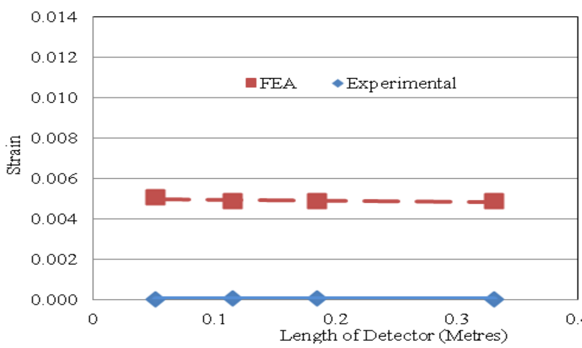

Fig. 5 Comparison between experimental and FEA results at 206.84 MPa (30 ksi) pressure

International Journal of Engineering, Mathematical and Physical Sciences
ISSN: 2517-9934
Vol:6, No:8, 2012

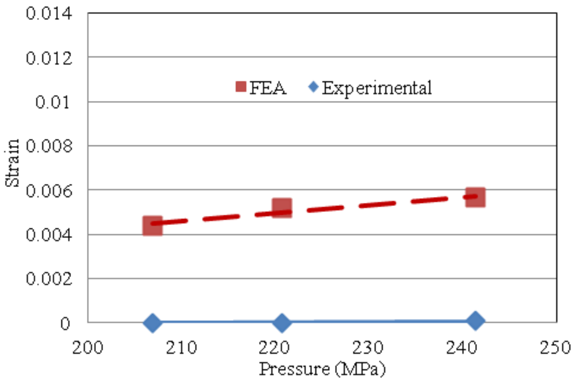

Fig. 6 Comparison between experimental and FEA results with varying pressure

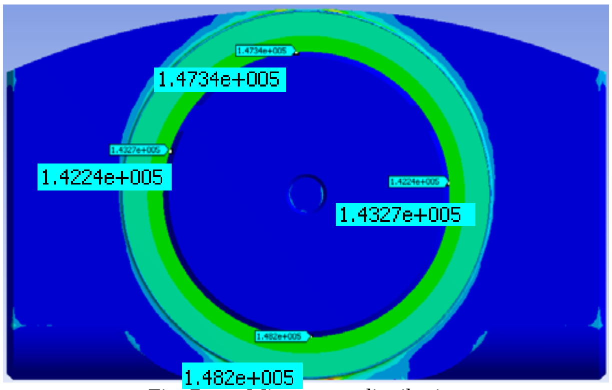

Fig. 7 von-Mises stress distribution

IV. CONCLUSIONS

The FEA results are compared with the experimental results show a close match between the numerical results and the experimental test.

The FEA model developed for numerical analysis substantiates and validates the experimental work performed. This FEA model can be used for extreme HPHT and ultra HPHT analyses, and/or optimal design changes.

REFERENCES

[1] Halliburton, “Delivering success in HPHT reservoirs through experience, innovation and reliable technologies.” http://www.halliburton.com/public/solutions/contents/HPHT/related_docs/HPHT_Global_Client_Brochure.pdf, 2011.
[2] K. Young, C. Alexander, R. Biel, and E. Shanks, “Updated design methods for HPHT equipment,” Paper SPE 97595 presented at the Applied Technology Workshop on High Pressure /High Temperature Sour Well Design held in The Woodlands, TX, USA, 17-19 May 2005.
[3] H. Aslaksen, M. Annad, R. Duncan, A. Fjaere, L. Paez, and U. Tran, “Integrated FEA modeling offers system approach to drilling optimization,” Paper IADC/SPE 99018 presented at the IADC/SPE Drilling Conference, Miami, Florida, USA, 21-23 Feb 2006.
[4] D.C-K Chen and M. Wu, “Maximizing drilling performance with state-of-the-art BHA program,” Paper SPE/IADC 104502 presented at the SPE/IADC Drilling Conference held in Amsterdam, The Netherlands, 20-22 Feb 2007.
[5] K.H. Kok, H. Hughes-Jones, E. Chavez, K. Azmee, A. Aziz, K. Yusof, and M. Lambert, “Case history: A robust point-the-bit rotary steerable system with at-bit imaging and 3D geosteering service integral to optimal wellbore placement in a complex thin sand reservoir,” Paper SPE 121186 presented at the 2009 SPE EUROPEC/EAGE Annual Conference and Exhibition; Amsterdam, The Netherlands, 8-11 June 2009.
[6] D. Whishunt and B. Navarrete, “25ksi 6.75 Detector Housing Pressure test to 30 ksi at 165°C”, Halliburton.