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Thermal Stress Analysis of Casing in Cyclic Steam Injected Well

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Abstract – *In extraction of viscous oils high pressure high temperature steam is injected, it is done to reduce the viscosity of the oil. In steam injection wells the casing failure rates are high. It is because of the high thermal stresses and the internal pressure. Casing can fail by buckling, collapse, Internal diameter restriction and parting-off. The injected fluid cause fracturing of the formations and this induces local compression and tensile stresses in the various casing strings landed and cemented in the well*

This work involves study of grades of casing to analyse its performance in the given steam injection conditions. The grades selected were the commonly used grades (J55 & P110) with least strength and highest strength, this is done to make sure that the entire range of API grades of casing is capable of withstanding the stresses generated. An analytical study is carried out using the Lames theory assuming the casing to be a thick cylinder. In the injection cycle of a steam injected well, the casing can be assumed to perform like a pressure vessel. Analytical study for the calculation of temperature between the surface of casing and cement is also found using Fourier's' Law in cylindrical coordinates. An fem model is made in ANSYS 16 using the casing geometry and the material properties. The model was subjected to steam at 450 deg. C and a pressure of 1125psi. Models were created for both P 110 and J55.

The result show that P110 grade performed better than J55, even though both the grades are safe for the working conditions the stress in P110 were much lower than the stress in J55, this gives a significant safety margin in case of using P110 in case of any abnormal pressure raise.

Key Words: **Thermal stress, Casing, Steam Injected Well, ANSYS, Radial stress**

1. INTRODUCTION

Oil well Casing in steam injection wells that are used in heavy and viscous crude oil extraction are usually exposed to high temperature steam and pressure fluctuation which results in failure of cement and the casing which is held by the cement. The stresses that are generated are local compression and tensile stresses that can cause yielding in conventional API casing strings cemented in the well. The thermal stresses and thermal strains that are generated in the casing, cement holding the casing and the formation are the major reason for the well failure. Hence it is required to check the integrity and ability to withstand the given steam injection condition of the oil well casing to make sure necessary structural integrity of the casing and cement over the entire service life of the well is obtained. Casing design for a steam injection wells is a significant challenge, the reason being no casing is designed to be subjected to extreme temperature fluctuation without passing the yield strength of the material. Hence, for a secure and environmentally safe crude oil production well, steam injection wells casing design can be done in advance finite element analysis to analyses the effect of temperature and stress on casing material properties.

This paper presents thermal stress analysis and consideration using finite element software ANSYS 16 to analyses the well design by subjecting the casing and cement to the high pressure and high temperature conditions and study the responses for various load conditions for different casing grades to check for the casing integrity in injection wells.

2. BACKGROUND

Crude oil wells consist of set of concentric casing strings along with cement to secure it in place to provide required structural integrity along the entire service life of the crude oil well. In the current scenario where steam injection EOR is practiced the casing failure is becoming increasingly significant in injection (high temperature, high pressure) wells, which adversely affect the performance of such reservoirs. Investigation indicates that a significant amount of these casing string failures can be associated to the severe thermal loading conditions of the various casing, such as those for the production of viscous oil reservoir. A common feature of steam injection wells is the cyclic thermal loading with maximum temperature that causes in high thermal stresses, which typically crosses the elastic limit of the material and might result in the casing to be deformed plastically). Appropriate casing design, material selection has a significant role in the long term structural and hydraulic integrity and reducing the risk of casing failure in steam injection. Hence, selecting proper casing material properties for use in steam injection wells becomes a challenge.

The casing design starts with properties of the surface and bottom hole well parameters and the dimensions and variables of the surface casing and production casing that will be used when crude oil are found in economic quantities. The number and dimension of casing strings determine the minimum ID of the production casing and the surface casing. Generally casing loading conditions do not consider axial stress resulted by difference in temperature after the casing is cemented and fixed in the well. To calculate the cost-effective design, casing strings often consist of number of parts of various steel grade, wall thickness, and coupling types. As a common practice, each casing string is designed to withstand the most adverse loading conditions estimated during casing placement and the service period of the well. Special conditions will also include the well environment (e.g., high temperature zones) and the well application (e.g., steam injection wells).

Significant casing deformations causes the failure of injection wells due to the difference in temperature. A large number of these failures occur at the interface between the injected fluid and the casing wall. Conventional methods for casing design employs the design concept which depends on stress data which the casing stress to the elastic state are dependent. But, in design cases for steam injected well casings, the magnitude of casing strains resulting from thermal loading due to steam crosses the elastic strain limit, making the stress-based design method inappropriate for these steam injection applications

The present well design techniques show that limited plastic strain is allowable for casings given that the driving forces are usually controlled by displacement. The thermal strain and formation stresses are calculated and restricted by the magnitude of the well temperature and operating conditions in the specific application.

2. ANALYTICAL STUDY OF THE TEMPRATURE

The well under consideration is analyzed in the steady state one dimensional heat conduction condition. The heat transfer is assumed to be only in the radial direction. The well under consideration is assumed to be in steady state which indicates that there is no abrupt change in heat transfer. It also assumed that there is no heat generation within the well due to the injection of steam. The properties of the casing material and the cement material is isometric in nature, this implies that there is no change in properties of materials along any direction. When the steam is injected into the well the heat from the steam passes through the well. The heat energy of the steam injected is found out. Assuming steady state 1-dimensional heat transfer the thermal resistance of each layer of casing and cement is found out. This study involves analysis of two grades of casings in a given casing program, To reduce the complexity of the modelling both the models will be analyzed in two parts of 30ft each. The pressure analysis of the casing is carried out considering the casing as a cylinder and applying Lames' theorem. The stress generated in the casing are found to be lower than the yield strength of the materials.

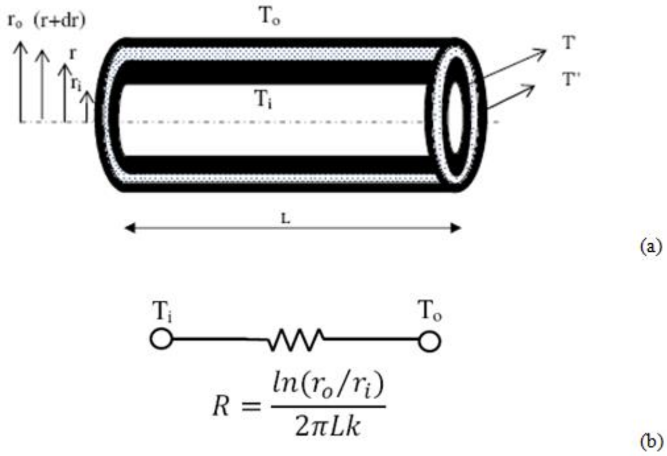

Figure 1:Thermal resistance of a Cylinder

Table 1: Interface temperature of the casing, cement and formation

	Casing 7" (K)	Cement 7" (K)	Casing 9 5/8" (K)	Cement 9 5/8" (K)	Formation (K)
J55 UPPER	654.3	448.6	466.6	415.6	300.3
J55 LOWER	692.7	498	472	425.6	300.3
P110 UPPER	654.3	448.6	-	-	408.6
P110 LOWER	692.7	448.6	-	-	408.6

3. FINITE ELEMENT ANALYSIS

3.1 MODEL OF THE WELL

The casings are modelled in design modeller module of ANSYS 16 according to the dimensions obtained fron the drilling data book. Modelling was done for a length of 30 ft since it is axisymmetric in nature. The fig. 2 shows the model of the upper section of the J55 casing grade well. For the analysis of both the grades of the casing the well is modelled in two parts of each grade, a total of four models are analysed.

3.2 MESHING

Meshing is the process of producing a unit entity of polygonal or polyhedral mesh that approximates a geometric domain. In this analysis, the mesh type used is tetrahedral because of its accuracy in static structural analysis. The mesh size is controlled and it is set as fine mesh.

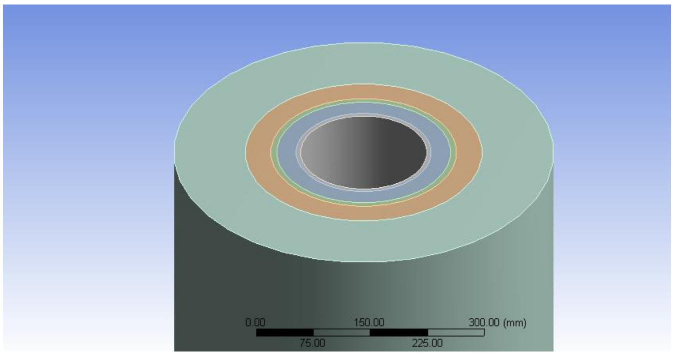

Figure 2:Model of J55 casing of upper section of well

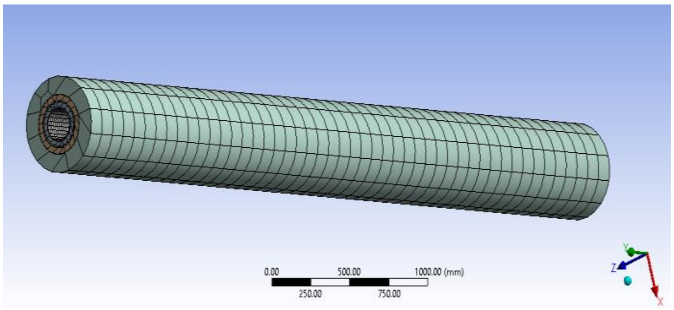

Figure 3: J55 model showing mesh

3.3 Input parameters

For the analysis the steam injection temperature is taken as the temperature of inner walls of the 7" casing, The injection pressure exerts a pressure of 1125 psi on the inner walls of the well. The injection temperature of the steam is 450 Deg. C.

4. Results from ANSYS 16

The models created were analysed in ANSYS 16 , the stress and equivalent strain plot in all four models are obtained. From the analysis it can be seen that the stress magnitude increases across the radius within a casing, cement or formation. The strain magnitude in the cement and formation were found to be higher because of lesser yield strength.

4.1 Equivalent Stress

The equivalent stress in the upper section of the J55 casing grade showed that the maximum amount of stress was found to be 134.91 N/mm^2, The yield strength of J55 is 275.3N/mm^2 hence it is safe, the maximum stress is found at the inner surface of the 7" casing, This is because the hoop stress acting on the casing will be highest at the least radius part which is the inner radius. Figure 4 shows the equivalent stress plot. The minimum stress induced is 0.375 N/mm^2.

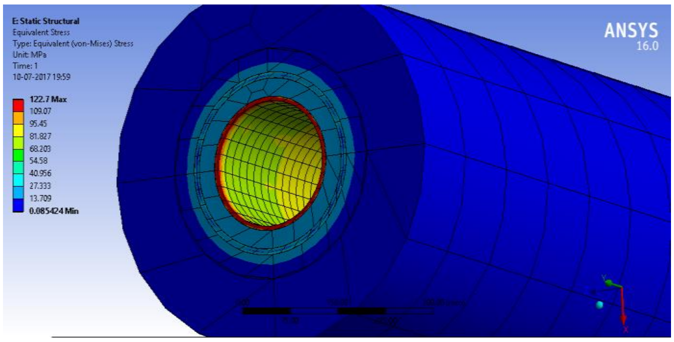

Figure 4:Equivalent stress in J55 upper section

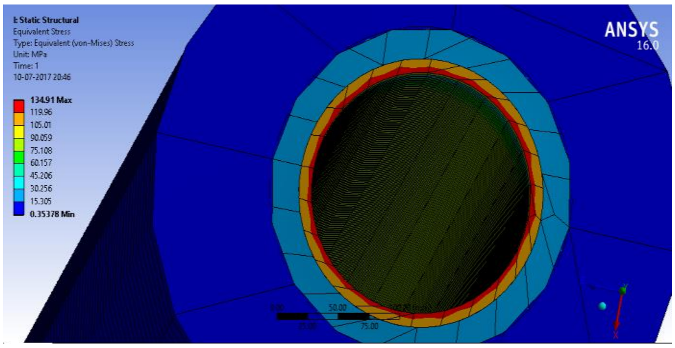

Figure 5:Stress in J55 lower section

4.2 Equivalent strain

The equivalent strain in the lower section of the J55 casing grade showed that the maximum amount of strain was found to be 0.01, this is found at the cement of the 7" casing and cement of 9 5/8" casing. It is because the yield strength of cement is lower compared to casing. Figure shows the normal strain. The minimum strain is -0.01.

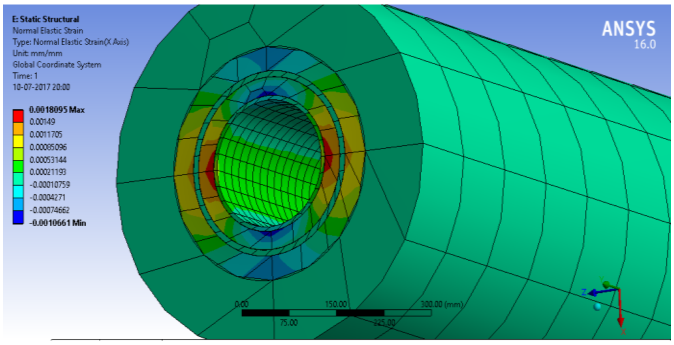

Figure 6:Normal elastic strain in the J55 grade

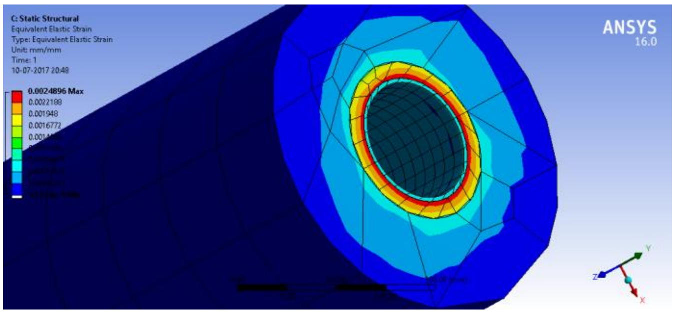

Figure 7:Strain in P110 lower section

5. Conclusion

It can be concluded that the P110 and J55 both are safe to operate in the give steam injection condition, because the stresses generated in both the grades are within their respective yield strengths. But higher grades like P 110 are more preferable because the difference in the stress generated and the yield strength is more than lower grades like J55, This gives us a safety margin in case of any abnormal pressure difference

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