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Numerical Analysis of Early Casing Collapse in Deviated Wells

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Abstract

Collapse of casings during production has been reported on many occasions in different fields. Regardless of the root for the failure of the casings, this is due to stresses applied to the casing exceeding its ultimate strength. Failure of the casing similar to any pipe could be due to compressional, tensional, and burst or collapse forces due to various loads being applied to the casing string. Although several analytical models have been developed based on elastic or plastic approaches to estimate the ultimate strength of casing, it has been shown that these methods underestimate the casing strength. Casings' mechanical and geometrical parameters, effective in-situ stresses, temperature, formation properties and other intervening are simultaneously required for a complete design of casing. To simulate the failure of casing in the presence of various forces, numerical modeling is a robust approach that can be employed. In this study, finite element simulation was used through the use of ABAQUS software to model the failure of casings in one of the wells located in the southern part of Iran. The results revealed that increasing the diameter to thickness (D/t) ratio decreases the ultimate strength of casing, leading to unexpected failure in the wells under consideration. It was also shown that eccentricity drastically reduces the strength of casing. Since the numerical results of current study were in an acceptable agreement with experimental studies, numerical simulation method proposed here can be used to predict the casing collapse.

Casing is a set of several steel pipes joined together and used to protect the wellbore after it is drilled. The casing is subjected to various loads in short term during drilling and long terms during production. Buckling due to axial load and burst and collapse as a result of high internal and external pressures, respectively, are examples of excessive loads and subsequent casing failure mechanisms. Casing damage is perhaps one of the most frequently reported failures in oil and gas drilled wells. This may happen during reservoir depletion due to excessive load caused by buckling or change in temperature gradient. Casing failures induced by formation compaction have also been observed in various reservoirs located at the North Sea, the US Gulf of Mexico, California, South America and Asia. These examples demonstrate that casing must be designed appropriately in order to resist excessive external forces during its intended life. A casing with lower diameter to thickness ratio (D/t) and higher material strength will be more resistance to applied forces. However, optimum sizes should be chosen for economical purposes. To determine the proper casing specifications the worst loading condition that the casing may experience during its life should be identified. During installation, casing experiences a combination of pressure, bending and axial loads, but when it reaches to its predetermined location it would be under external pressure only. Practically, the hydrostatic pressure applied to the outside surface of casing inside the annulus space during drilling phase before cementing is perhaps the most important load to be considered for the design of casings. Practical methods initially used for prediction of casing collapse were principally based on the empirical solutions. These equations have been developed to establish a linear or nonlinear relationship between collapse pressure and important parameters causing a casing to collapse. From the reported literature the ratio of outside diameter to wall thickness (D/t), initial ovality and eccentricity are the most important geometrical parameters of the casing to be considered for design purposes.

The important mechanical properties include the Young's modulus, Poisson's ratio and the yield strength of casing. Residual stress and applied axial stress are also needed to be considered. However, it is important to realize that casing collapse occurs under plastic regime, as a result of which yield stress based on Von-Mises failure criterion has been embedded into the empirical equations. Further investigations have suggested that considering the yield stress through the Von-Mises criterion underestimates the collapse strength. Therefore, several equations were proposed later to predict the collapse of casing including both elastic and plastic behavior of the pipe. The casing in that study was assumed to have an elastic–plastic behavior and showed to be accurate when it was used for collapse prediction of metal pipes. The analytical equations proposed for estimation of collapse strength are limited to the assumptions used in their development and are reliable for specific type of materials. Numerical simulations may be used alternatively for such analysis. In this study, an elastic-plastic FEM model was used to analysis the collapse strength of casing in one well located in South part of Iran.