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Conclusions and Suggestions for Future Work

This research presents a study of non-uniform loading induced by salt creep upon poorly-cemented casings, and was motivated by Petrobras' research and development center CENPES. The aim was to establish stress controls for cement failure, the locations where the maximum stresses occur, the percent reduction of parameters E, v and c triggering plastic strain, the effect that casing ovalization and eccentricity has on the cement defect and also how the casing is affected.

The results summarized in the following tables indicate that ovalization and eccentricity play an important role for poor cement jobs in salt drilling. The performed analyses lead to the conclusion that ovalization can have a weighty effect on the defected cement region. However, this depends upon the defect's size, geometry and eccentricity. The maximum compressive stress reduces in Geometry No. 1 and No. 2, while the opposite effect is seen for Geometry No. 3.

Eccentricity greatly diminishes the influence of casing ovality, and can in fact worsen the cement's intactness. Moreover, ovalization puts highly eccentric casings at risk of poor cementing by leaving less spacing in the annulus.

Compressive stress controls plastic straining in the cement for nearly all scenarios. Plastic straining appears in all three geometries and areas when the elastic and strength parameters *E*, *v* and *c* are reduced by 15 percent; a 75 percent reduction in the parameters causes the entire defected area to become plastic. Tensile stress controls plastic straining in scenarios having large areas of defected cement being no less than 20 percent of the annulus. This is observed, however, when the elastic and strength parameters are reduced to 75 percent. In all of the simulations, maximum stresses are always located along the upper and lower boundaries of the defected cement.

Analyses Results (Stage 2)			
	Geometry No. 1	**Geometry No. 2**	**Geometry No. 3**
Ovalization (compared to circular casings)	Significantly reduces maximum compressive stress; tensile stress vanishes.	Marginally reduces maximum compressive stress; tensile stress vanishes.	Increases maximum compressive stress; tensile stress remains unaffected.
Compressive stress	Intermediate values.	Lowest values.	Greatest values.
Tensile stress	Intermediate values.	Insignificant values.	Greatest values.
Evaluation	Favorable with ovalization.	Most favorable[2].	Unfavorable.

Analyses Results With Eccentricity (Stage 3)			
	Geometry No. 1	**Geometry No. 2**	**Geometry No. 3**
Ovalization (compared to circular casings)	Marginally reduces maximum compressive stress; tensile stress vanishes.	Marginally reduces maximum compressive stress; tensile stress vanishes.	Increases maximum compressive stress; tensile stress remains unaffected (estimated).
Compressive stress	Intermediate values	Intermediate values	Greatest (estimated) values.
Tensile stress	Insignificant values.	Insignificant values.	Greatest (estimated) values.
Evaluation	Favorable with ovalization.	Most favorable.	Unfavorable (estimated).

Table 7-1: Summary of results with and without eccentricity.

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[2] *Favorable* and *unfavorable* refer to scenarios that present relatively less dangerous and more dangerous cement conditions, respectively.

7.1 Suggestions for Future Work

For future work related to this research, it is suggested that models be used with the Mohr-Coulomb failure criterion that account for cement crushing, namely the cap plasticity model. Other failure criteria that account for the intermediate stress σ_2 could lead to more accurate results. Another recommendation is to consider simulating cement stress development upon setting while accounting for its thermal properties. Cracking may also be considered in cement modeling. The wellbore could also be simulated as non-circular. Performing a 3D analysis would also be ideal; incorporating different salt layers such as halite, carnallite, tachyhydrite and sylvanite. Finally, collecting salt samples from pre-salt basins in Brazil would assist in achieving more accurate mechanical properties for the salt a consequently, more accurate results.