



Axial Interaction Between Structural Casings and Soil Under Cyclic Thermal Loads

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Presenting: Hongjie Zhou (Perth)

Outline

- Background knowledge
 - 1) Multi-string well configuration
 - 2) Loading conditions: static + cyclic
 - 3) Soil t-z response to static and cyclic movements
- Modelling approach
 - o Modified RATZ t-z spring
 - o Summary
- Example case
 - 1) Well model
 - 2) Soil inputs
 - 3) Example results
- Concluding remarks

1) Multi-string Well Configuration

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Interaction between internal casings & tubing and grouted conductor & surface casing is important.



Static distributed loads (e.g. self-weights of conductor, surface casing and grout)



Simplified Subsea Well Model

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- Static axial loads at well head (e.g. weights of top structures and internal casings)



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- Cyclic axial thermal loads due to:
 - expansion and contraction of internal casings and tubing (pulling conductor + surface casing upward)



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 - expansion and contraction of conductor and surface casing themselves
- Torque (e.g. induced by snag loads)



3) Soil Response to Static and Cyclic Loads

Cyclic Constant Normal Stiffness (CNS) direct shear test and grouted section test (GST) are typically used for characterising the interaction between well/pile and surrounding soil:



Test results reported in Randolph et al., (1996)

Measured response from a CNS test (Erbrich et al., 2010)

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Modified RATZ (Randolph, 2003) t-z curve: monotonic



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Modified RATZ t-z curve: cyclic



(a) Scenario 1: without 'cyclic residual shaft friction'

(b) Scenario 2: with 'cyclic residual shaft friction'

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Modelling of soil cyclic t-z behaviour

Predicted t-z response by NGI cyclic t-z spring vs. test results



Summary: Modelling approach

- <u>Beam-column approach modelling the</u>
 structural casings
- <u>Enhanced t-z spring models</u> (similar modifications have also been made by Erbrich et al. (2010) and Bailie (2013))
- If necessary, <u>s-z spring</u> models the grout in the annulus (i.e. interaction between the grouted casings)
- <u>Cycle-by-cycle</u> analysis models complicated loading conditions: Cyclic forces and strains (+ Torque)



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Simplified Well Model

- Conductor and surface casing are modelled explicitly;
- Static vertical loads before operation (6000kN);
- Cyclic thermal forces from internal casings and tubing.
- In-operation: -7500 kN 0 (upward)
 - Shut-in: 500 kN 0 (downward)
- Cyclic thermal strain applied to the conductor and surface casing, $\varepsilon = \alpha \Delta T$;

Source: ProjectConnect, 2017

2018

Soil Strength Profiles (typical low estimate profile offshore WA)





file Design line of residual strength profile OTC-28932-MS - Recent Advances in Well Modelling - NGI

Results: Load/displacement Response



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Results: Internal axial force and Mobilised shear stress



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Results: Local t-z Behaviour



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Concluding Remarks

- Well-soil interaction can be very complicated, particularly in offshore Australia dominated by the brittle carbonate sediment.
- Thermal cycling can have significant effect on well performance in degradable soil.
- This modelling approach is equally applicable to conventional piles and energy piles.
- Working together of different disciplines may provide opportunity of significant optimisation. For example:

Potential optimisation: behaviour of steel-grout interface







Acknowledgements / Thank You / Questions

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