Artificial Lift R&D Council

Modeling Side Loads in 4-D

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2023 International Sucker Rod Pumping Workshop
Aug 28-31, 2023. Midland TX

Historical Modeling for Vertical Wells

$$\frac{\delta^2 u(x,t)}{\delta t^2} = a^2 \frac{\delta^2 u(x,t)}{\delta x^2} - \frac{\pi a \nu}{2L} \frac{\delta u(x,t)}{\delta t}$$

- Gibbs

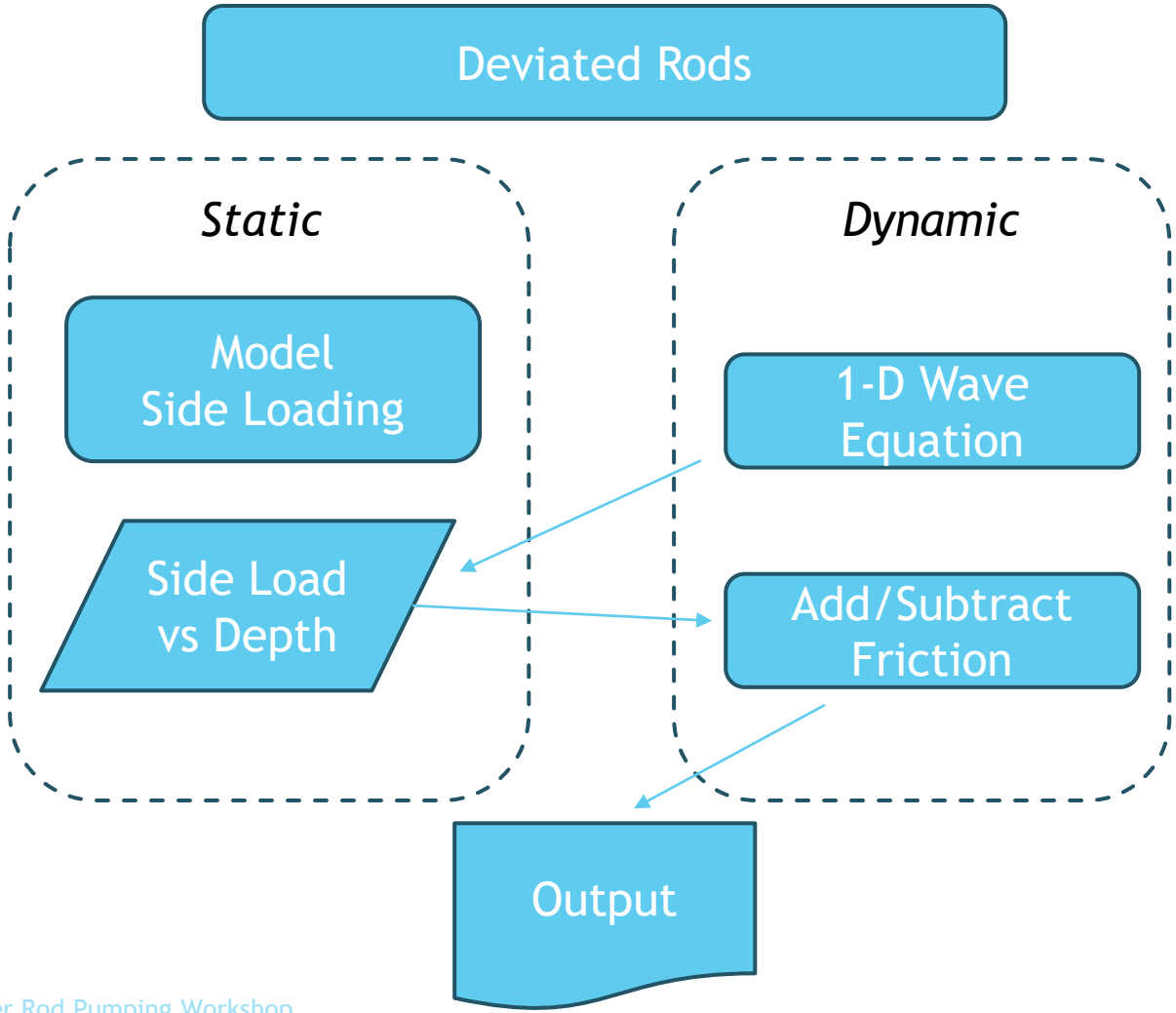
- Considered:
  - Elasticity of the Rods
  - Viscous Damping
- Simplified:
  - Gravitational forces
  - Buoyant forces
- Ignored:
  - Coulomb friction

Non-vertical Wells

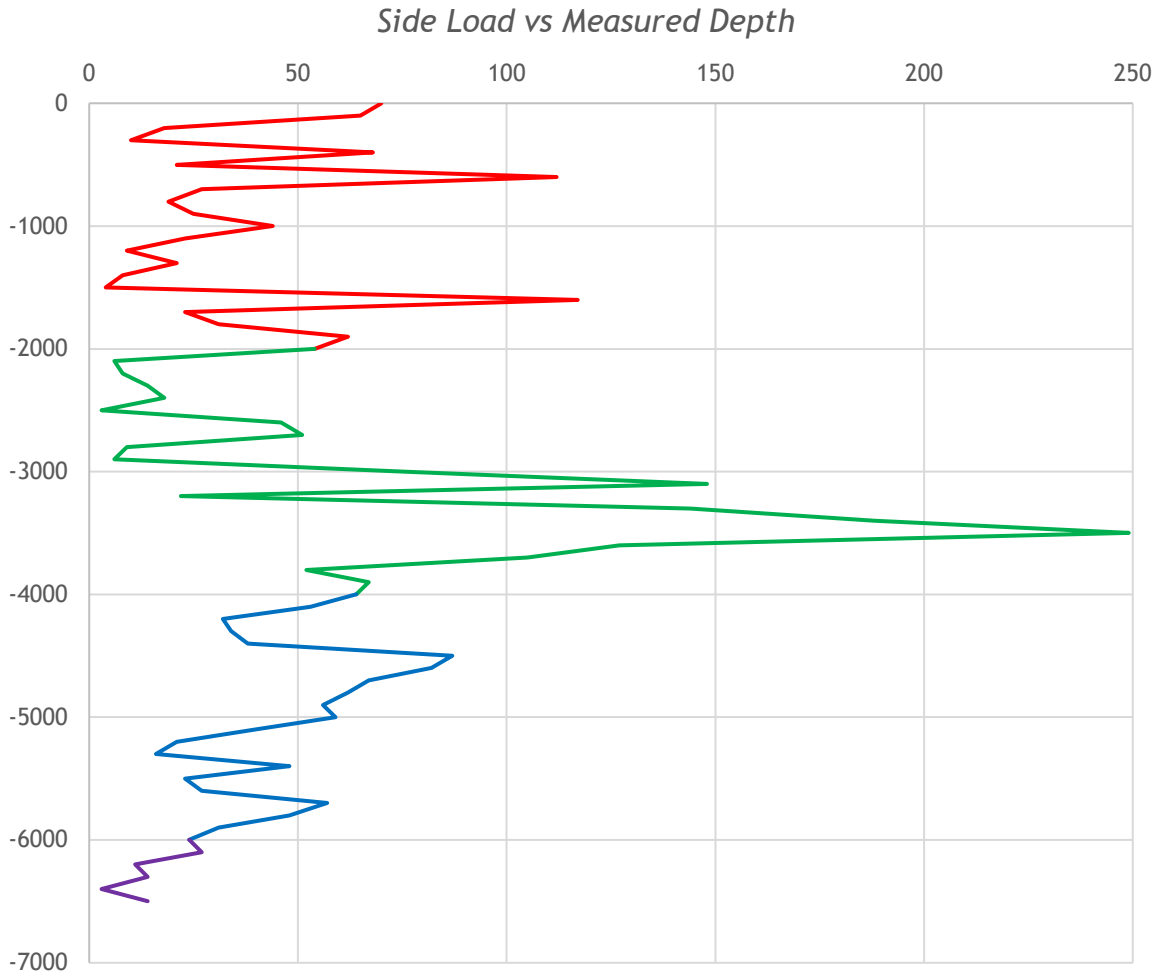
- Gravitational Forces:
  - Gravity/Weight pressing rod string against tubing wall
- Buoyant Forces:
  - Unbalanced forces caused by hydrostatic fluid pressure
  - Induce additional rod/tubing interaction

"Side Loading"/Reaction Forces

Traditional Approach



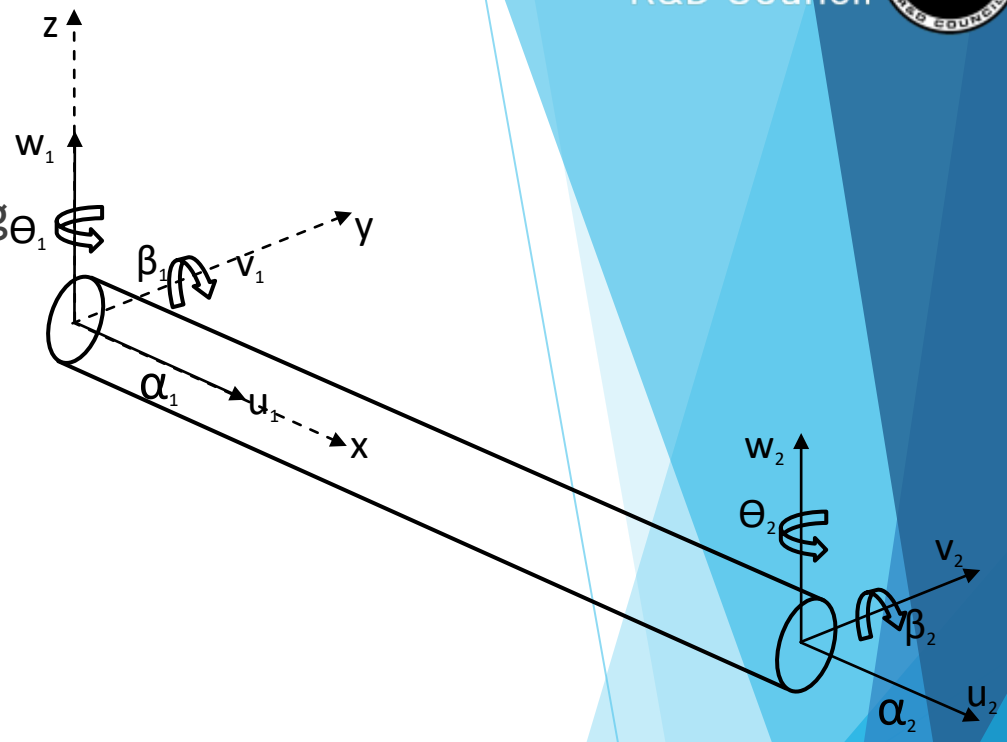
Customary Side Load Presentation



- 2 spatial dimensions
- Static (no time dimension)

More Modern Approach

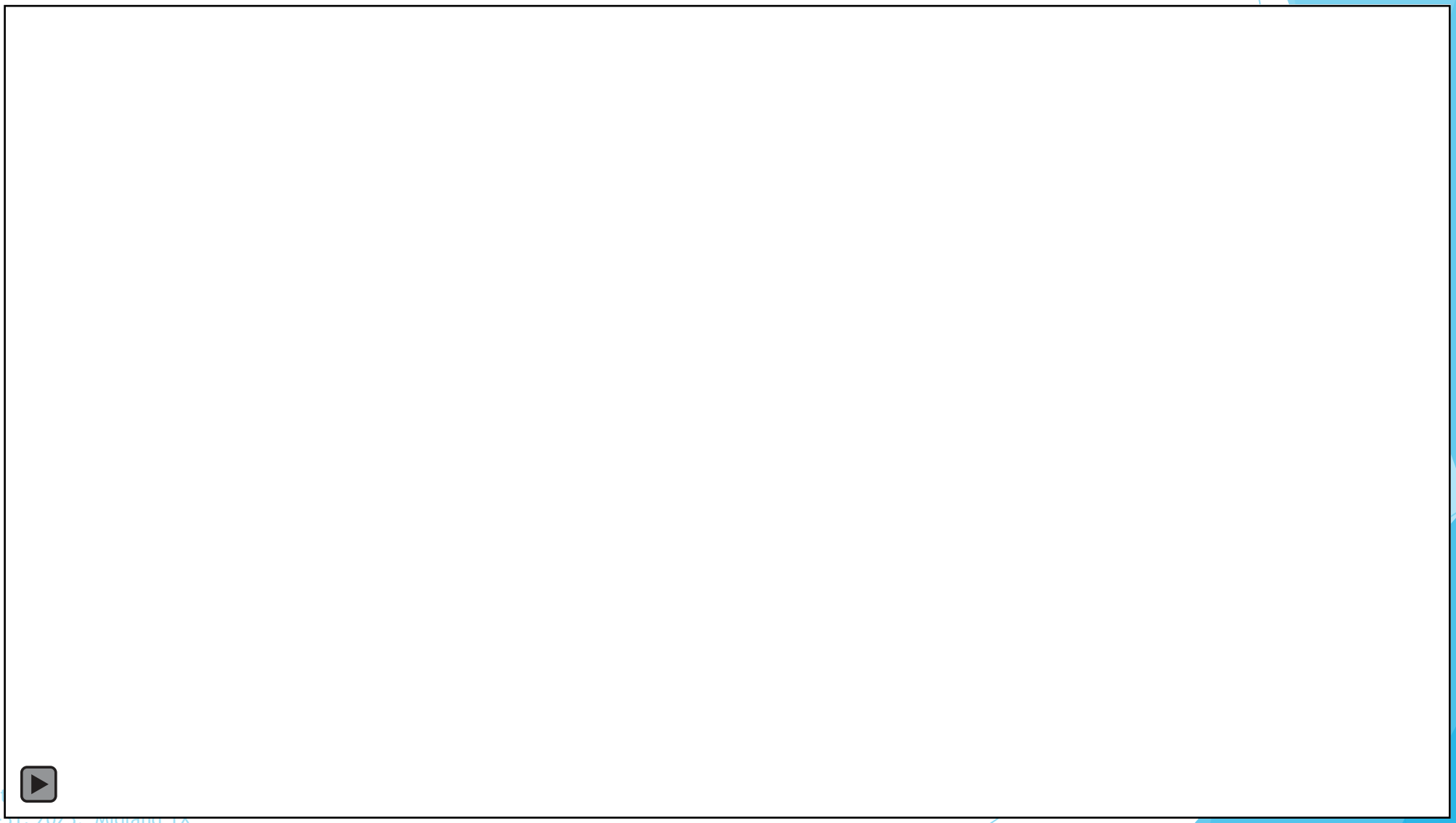
- 3-D Finite element modeling (FEM) of the sucker rod string
  - Treat each rod as a cylindrical “bar element” with 6 degrees of freedom at each end
- Consider Gravitational Forces in 3-D
- Consider Buoyancy as an unbalanced force acting in 3-D
- Parameters are calculated at each time step (4-D)



ROD3D

- 3-D, dynamic FEM specifically formulated to address deviated sucker rods
- Full consideration for the specific “problem”
- Easy to configure
- Fast run times

ROD3D – Reaction Forces in 3D + Time



Does it make a difference?

Conclusions

- The dynamic nature of the rod string forces at various depths and times throughout the stroke induce dynamic side loading
- These changes are significant both for the magnitude and range of the PR loads, but also for the stroke length
- Therefore, sucker rod modeling software must consider dynamic – rather than static – side loading
- Finite element modeling can account for this *4-D side loading*
- Special FEM formulations – like ROD3D – deliver improved understanding of sucker rod systems

Thank You

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Questions?

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