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NON-LINEAR FINITE ELEMENT MODEL FOR CASING CENTRALIZATION

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ABSTRACT

This work is part of a larger project intending to combine fluid and solid simulations of primary cementing processes to help in design decisions in the primary cementing industry. In the construction of oil and gas wells, a steel casing is placed in the center of the borehole and cement is pumped into the annular gap between the casing and the borehole in a process called primary cementing. Displacing the drilling mud in the annular gap and replacing it with the cement is crucial for the well to be properly sealed and to achieve zonal isolation. A key parameter identified to affect the fluid flow and stress development in the cement sheath during this process, and thus the overall effectivity of the cement job, is the eccentricity of the casing within the well. Accurately calculating casing location and eccentricity are crucial for simulating the cementing process and optimizing design decisions to prevent gas migration and well integrity failures.

Casing eccentricity arises from multiple interacting factors, including borehole tortuosity, casing flexibility, buoyancy effects from wellbore fluids, and the influence of centralizers. Centralizers are mechanical components intended to reduce casing eccentricity by providing a rigid standoff between the casing and borehole wall or by applying a restoring force against an eccentric casing position. Earlier centralization calculations use analytical models to estimate eccentricity for discrete sections of casing but lack the ability to fully position the casing within the 3D borehole. Although proprietary finite element software exists for this purpose, it cannot be easily modified to incorporate more complex physics or geometry, such as non-linear centralizer forces or elliptical wellbore cross-sections.

To address these limitations, we are developing a non-linear finite beam element formulation and implementing it in Python to compute casing centralization with enhanced flexibility. The element formulation is validated with benchmarks from literature. Using a non-linear formulation, we can see any effects of non-linearities in the beam bending as well as being well positioned to include non-linear centralizer restoring forces. This software is being designed to accommodate detailed well survey and caliper data to allow for elliptical wellbore cross-sections.