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Efficient modelling of drillstring dynamics with spatially localised frictional contacts

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There are many examples of vibrating systems for which non-linearities are spatially localised and the majority of the structure can reasonably be approximated as linear. Such systems present a modelling opportunity: efficient linear methods can still be used to describe the majority of the structure so that the computational effort is focussed on the small regions of non-linearity.

The method described in this paper uses digital filters to describe the linear torsional and bending dynamics of oilwell drills. The drillstring interacts nonlinearly with the borehole wall at discrete locations (e.g. the drill bit and 'stabilisers' where the drillstring radius is larger). Digital filters are used to approximate the relevant impulse response matrix of the linear system, which are then coupled to the localised nonlinearities. Choosing a sampling period that is less than the group delay between 'nonlinear' degrees of freedom results in a decoupled set of equations that can be solved very efficiently.

Two case studies are presented: torsional vibration of a drillstring with a frictional contact at one end; and circular clearance nonlinearities with friction at discrete locations along the drillstring. The results are verified by comparison with an equivalent finite element model that is also reduced to nonlinear degrees of freedom and the two implementations are shown to be similarly efficient. The advantages of the digital filter approach are: it provides more physical insight into the observed behaviour; and the underlying linear description of the system could be derived from experimental measurement.

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