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Floating frame of reference based flexible bodies and high-speed maneuvers

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ABSTRACT

Flexible body modeling is one of the well-developed and mature field in multibody system dynamics (MSD) [1]. When small deformation assumption is sufficient, so-called floating frame of reference formulation (FFRF) is commonly used. FFRF coupled with order reduction method results in effective and efficient method. However, due to complex kinematics, writing and handling equations of motion is challenging [1]. Wallrapp [2] proposes a standardized definition of FFRF bodies using so called standard input data (SID). It results in elegant, preprocessed, and efficient description. Part of efficiency gains are due to neglecting of higher-order inertia terms (details are presented in Table 1 of [2]).

This paper analyses application of the FFRF to so-called speedup maneuver, where free-clamped beam is attached to a rotating base. Wind turbine blades are good example of such system. Due to geometric stiffening effect, the solution easily became unstable when linear elasticity is employed. One relatively easy solution to this issue is a substructuring technique, where body is divided into multiple shorter flexible bodies connected with fixed joints.

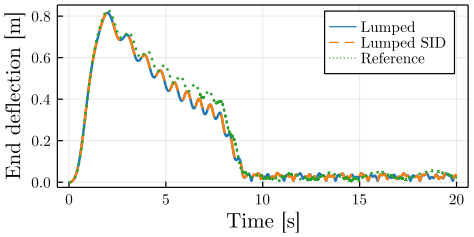

Figure 1: Results for 4 substructures

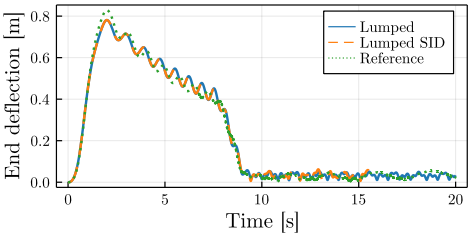

Figure 2: Results for 2 substructures

Figures 1 and 2 show end deflection of a simple rotating beam. Reference solution is computed using nonlinear finite element method. FFRF bodies are modeled with Craig-Bampton method and employs simply supported reference conditions. Plots present solution only for lumped mass approximation. Equations of motion are solved using Baumgarte stabilization method and implicit BDF differential equations solver. Flexible bodies are modeled using full inertia representation and with simplification proposed for SID description. As it can be observed in plots, all results are in good agreement. Moreover, results for FFRF bodies are almost indistinguishable. However, as can be seen in Figure 2, SID solution is incomplete, as it became unstable at certain point. For consistent mass formulation such instability manifests far earlier – at around 3.9 s. While SID representation of flexible bodies is convenient and effective for typical analysis scenarios, it should be applied with care when FFRF is pushed to its applicability boundaries.

Keywords: flexible multibody systems, floating frame of reference, speedup maneuver, standard input file, mass integrals representation.

REFERENCES

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