Variable communication steps and stiffness computation in co-simulation of large MBD and FEA systems.

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Abstract

While co-simulation algorithms for small and medium systems (e.g. 1D systems) offer a gamut of options to better control the numerical accuracy and stability of the solution, most of the existing co-simulation algorithms for large multi-body systems (MBS) interacting with large finite elements models (FEM) are limited to the exchange of small sets of data, namely force and displacement values at the points where the MBS and FEM models interact.

This paper presents an enhanced algorithm by which, in addition to the exchange of force and displacement data at each interaction point, the tangent stiffness matrix of the finite element model is computed and sent to the controlling glue code (master code) and shared with the multi-body model. The tangent stiffness matrix is obtained by a condensation of the global stiffness matrix (involving all displacements) into a stiffness matrix involving only the displacements at the interaction points. Both forces and the tangent stiffness matrix are used by the multi-body system to better predict the overall motion of the coupled systems.

The proposed algorithm belongs to the family of co-simulation algorithms that enforce the MBS model to step first (using force and stiffness of the FEM models) and later impose the computed displacements onto the FEM models. However, there is no fixed communication interval. Each code (MBS and FEM) are free to take a simulation steps that fits well the current status of the numerical solution; the communication with the glue code is constant.

The presented algorithm succeeds in allowing the co-simulating models to take considerably larger simulation steps with the additional benefit of providing stable solutions and better accuracy. The algorithm is comparable to recent Jacobian-based co-simulation algorithms. Although the stiffness matrix does not account for an exact Jacobian of the FEM models, it provides an exact Jacobian for the case of static analysis and an approximate Jacobian for the case of dynamic analysis.

A discussion of the overall theoretical implementation is presented along with a list of main features, limitations and proposed enhancements. Finally, industrial examples (manufacturing, vehicle dynamics) are presented with comparisons with other numerical solutions.

References

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