Co-simulation in mechanical systems with nonlinear components

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Abstract. Co-simulation is used to enable global simulation of a coupled system via composition of simulators. Within this work, a co-simulation approach is developed and presented for mechanical systems with nonlinear components. Specifically, dynamics of a model two-degree-of-freedom oscillator, including Duffing type nonlinearities, is investigated first. The method of multiple time scales is applied and a set of averaged equations is derived for cases of primary external resonance, whose solution is then used as a reference solution. The main focus is placed on mechanical subsystems. However, the new method is developed so that it has general validity and can be applied to coupling arbitrary solvers.

Introduction

Co-simulation or solver coupling has already been applied extensively to various engineering fields [1, 2]. The basic idea is founded on a decomposition of the global model into two or more submodels. The different subsystems are connected by coupling variables, which are exchanged only at the macro-time (or communication) points. Between these points, the subsystems are integrated independently, using their own solver. Generally, the subsystems can be coupled by physical force/torque laws (applied forces/torques) or by algebraic constraint equations (reaction forces/torques) [3]. In the present work, the system shown in Fig. 1 is employed as a model. Also, solver coupling by applied forces/torques is considered only.

Two well-known co-simulation approaches are used. More specifically, a parallel and a sequential scheme is applied, known as Jacobi and Gauss-Seidel scheme, respectively. Furthermore, co-simulation approaches can be subdivided into explicit, implicit and semi-implicit methods. Finally, concerning the decomposition of the overall system into subsystems, three different possibilities can be distinguished. Namely, force/force, force/displacement and displacement/displacement decomposition.

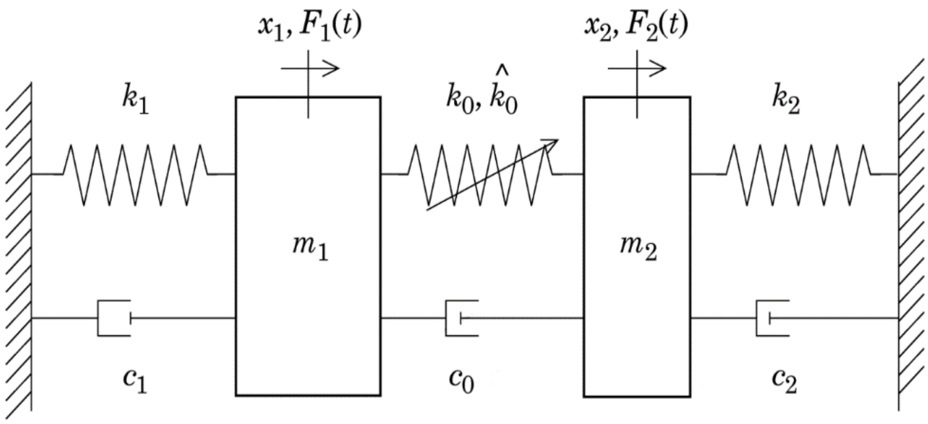

Figure 1: A mechanical model of the dynamical system examined.

Results and discussion

In this work, the example mechanical system shown in Fig. 1 is examined [4, 5]. Specifically, the dynamic behavior of a two-degree-of-freedom oscillator involving restoring force characteristics modeled by linear and cubic displacement terms is investigated. In the case examined, the external forcing possesses a component with frequency close to one of the natural frequencies of the linearized model. A detailed analysis of the convergence, the numerical error and the stability behavior is carried out in order to examine the different properties of the various well-known co-simulation schemes from the literature, applied to a (weakly) non-linear system. Despite the fact that the model examined has a simple structure and is purely mechanical, these techniques used can also be extended and applied to arbitrary multibody or structural dynamics systems.

References

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