Structural Topology Optimization of Multibody Systems

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Abstract

Flexible multibody dynamics (FMD) has found many applications in control, analysis and design of mechanical systems. FMD together with the theory of structural optimization can be used for designing multibody systems (MBS) with bodies which are lighter, but stronger. Topology optimization of static structures with constant loads is an active research topic in structural mechanics. However, the extension to the dynamic case is less investigated as one has to face serious numerical difficulties. One way of extending static structural topology optimization to topology optimization of dynamic flexible multibody system with large rotational and transitional motion is investigated in this paper. The optimization is performed simultaneously on all flexible bodies. The simulation part of optimization is based on an FEM approach together with modal reduction, [2]. The resulting nonlinear differential-algebraic systems are solved with the error controlled integrator IDA (Sundials) wrapped into Python environment by Assimulo [7]. A modified formulation of solid isometric material with penalization (SIMP) method [1] is suggested to avoid numerical instabilities and convergence failures of the optimizer.

One of the strategies for structural optimization of bodies under dynamic and transient loads is the equivalent static loads method (ESLM) [3, 5]. ESLM is mostly developed for size and shape optimization. Using this method for topology optimization causes instability and failure of the optimization algorithm. In [5] this problem is attenuated by removing some of the elements and updating the gird data in every optimization process. This approach has to restrict the design area and later revival of removed elements cannot be treated. Moreover, the element removal needs post processing of the data which is not unique for different problems. In addition constraints and the objective function cannot be defined based on the overall system response [6].

We present here an alternative approach treating topology optimization of all flexible bodies simultaneously while they are operating in an MBS based on the system overall response considering all transient reaction and inertia forces. In this paper this approach is called Topology Optimization of a Multibody System (TOMBS). In [4] a related approach is used with two different regimes of stiffness penalization. The switching criteria between two regimes might differ between problems, so that this formulation is not always applicable. Standard SIMP method in structural topology optimization suggest stiffness penalization. To overcome the problem of instabilities and mesh distortion in the dynamic case we consider here additionally element or lumped mass penalization.

The suggested method in dynamic topology optimization is demonstrated by two simple two-dimensional MBS, Fig. 1. The objective function history and a comparison between the maximal deformation of an optimized topology and the non-optimized one are shwon in Fig. 2.

The approach is applicable for designing vehicle components, high-speed robotic manipulators, airplanes and space structures.

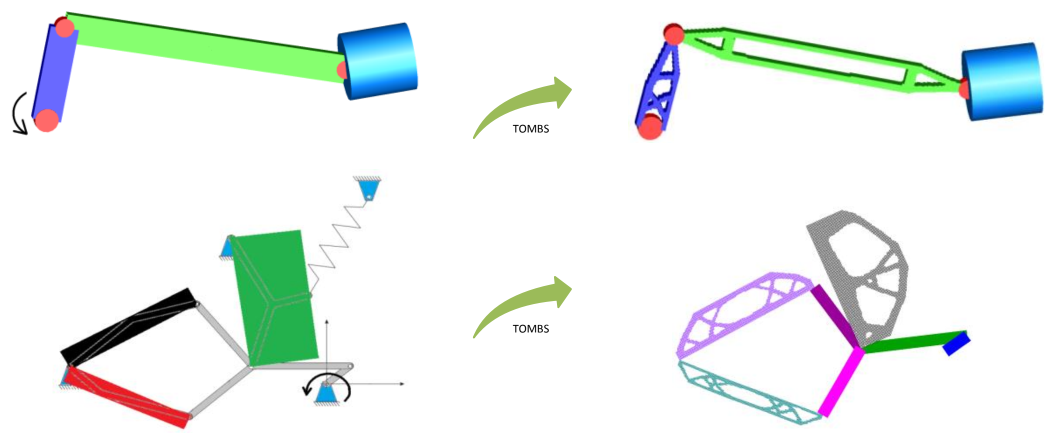

Figure 1: TOMBS performed on a slider crank system, two flexible bodies (top); TOMBS on a seven body MBS, three flexible bodies (bottom).

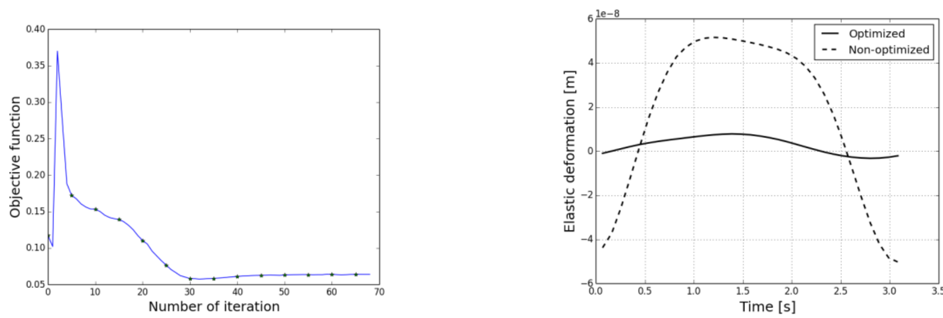

Figure 2: Objective function history with SIMP and element masses penalization (middle); elastic deformation of the lower center of the connecting rod for two different designs, non-optimized and optimized (right).

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