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Recent developments in optimization of flexible components of multi-body systems

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Recently mechanical engineering has extended from a component to a system oriented approach. The structural analysis of components is now completed by the whole mechanical system simulation using multibody system analysis. This evolution aims at capturing better the real loading conditions accounting for the component interaction and couplings in the system. Structural optimization is continuing along the same tracks. Recent works in structural optimization have tried to optimize components with respect to loadings conditions defined through dynamic loading coming from multibody system dynamic analysis [1, 2, 3]

Generally, optimization techniques consider that the structural component is isolated from the rest of the mechanism and use simplified quasi-static load cases to mimic the complex loadings in service. In contrast, we have shown in previous works devoted to topology optimization [3] that an optimization directly based on the dynamic response of the flexible multibody system leads to a more integrated approach.

In order to overcome the limitations of some previous approaches [1, 2], a more integrated optimization technique is proposed here, based on the nonlinear finite element approach for flexible multibody systems described in [4]. The non linear finite element formalism accounts for both large rigid-body motions and elastic deflection of the structural components. In Ref.[3] the optimal design of components was realized as an optimal truss / beam layout. The present communication investigates the optimal design of components considered as a continuum medium. We study first sizing optimal design of structural components and we later extend the method to optimal material distribution approach as described in [5] to address their lay out optimization. The continuum domain is discretized into finite elements. For sizing optimization, the design variables are wall-thickness and lumped element variables. For topology optimization the design variables are classically density-like parameters associated to a power law interpolation of effective material properties for intermediate densities, also known as Simply Isotropic Material with Penalization (SIMP).

This study assesses the feasibility of this approach, which extends optimization techniques to continuum flexible bodies included in MBS. The numerical implementation is conducted in SAMCEF MECANO for the flexible MBS analysis and BOSS Quattro for the optimization shell. The nonlinear equations of motion are solved using a generalized-α time integration scheme while the sensitivity analysis of mechanical responses is based on a direct differentiation method as described in [7] or finite differences.

For sizing and parametric optimization the paper investigates and compares several optimization approaches methods such as classical gradient-based methods (SQP, Augmented lagrangian), sequential convex programming methods (CONLIN, MMA), but also surrogate-based optimization method (with

Neural Networks) combined with genetic algorithms. The formulation of the problem is also discussed, and its influence on the convergence history is illustrated. Optimal sizing, shape and topology optimization of a simple model of a robot are addressed.

The optimization approach is illustrated on numerical applications of sizing optimization of robot arms [6] during trajectory tracking and lightweight layout optimal design of automotive components [1].

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