Design optimization of multi-point constraints in structural analysis

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Abstract

Multi-point constraints (MPCs) have been used in the analysis of structures since the early 1970's. However, limited research regarding the sensitivity analysis and design optimization of MPCs has been done. We recently showed [1] that when solving non-linear MPCs using Newton's method, the exact consistent tangent contribution requires the second derivative of the MPC relations. However, this second derivative contribution is usually omitted when conducting the primary analysis, resulting in an inexact consistent tangent. Since the consistent tangent is used to compute the design sensitivities during the sensitivity analysis, using the inexact consistent tangent results in inexact gradients.

In this study, we investigate whether the exact consistent tangent is essential when designing MPCs for structural applications. The design problem is to design a frictionless roller guide for a center loaded simply supported beam. The unconstrained design problem aims to find the geometry of a frictionless roller guide such that the centroid of the beam follows a prescribed load path. This frictionless roller guide is modeled using MPCs. We compute the exact analytical gradients of the objective function using the the exact consistent tangent contribution of the system. This includes a contribution from the MPCs, in particular the second derivative contribution that is usually omitted. In addition, we also compute the approximate gradients of the objective function, where the only approximation in the sensitivity analysis is the inexact consistent tangent contribution of the system.

We then investigate the ability of conventional gradient based algorithms to solve this multi-point constraint design problem when supplying the exact and inexact gradients of the obejctive function. The algorithms we consider are steepest descent and the well-known BFGS Quasi-Newton algorithms. We demonstrate that it is essential to use the exact consistent tangent when computing reliable design sensitivities.

References

[1] Kok, S and Wilke, D.N. Understanding linear and non-linear multi-point constraints in finite element analysis, 9th South African Conference on Computational and Applied Mechanics, Somerset West, 14 - 16 January 2014.