# A simplified approach to the topology optimization of structures in case of unilateral material/supports

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**Abstract**

Most of the available formulations for topology optimization are conceived to cope with linear elastic structures exhibiting the same behavior in tension and compression for both material and ground constraints.

Alternative formulations have been proposed in the recent literature to cope with tension-only or compression-only materials resorting to non-linear modeling, see e.g. [1], or to approaches mainly based on remodeling theories or material-replacement strategy that distribute the unilateral material depending on the stress flows directions in the design domain, see e.g. [2]. The assumption of unilateral behavior applies to boundary constraints in case of non-bilateral supports that provide a compressive reaction while being inactive in tension. A few methods have been proposed in the literature of structural optimization to address this particular class of problems and most of them resort to nonlinear equations from contact mechanics, see e.g. [3,4].

This contribution investigates the use of a simplified stress-based approach that is especially conceived to the optimal design of truss-like elastic structures in case of unilateral behavior of material or supports. The well-known volume-constrained minimization of compliance is endowed with a set of stress constraints that can efficiently control, all over the domain or along prescribed boundaries, the arising of bars with tension–only (or compression-only) strength. A smooth approximation of the no-tension (or no-compression) conditions governing the stress field is provided through the formulation of a suitable version of the Drucker-Prager strength criterion. An ad hoc strategy is implemented to robustly handle the arising multi-constrained formulation that is solved through mathematical programming. The adopted numerical framework combines the selection approach investigated in [5], along with the use of aggregation techniques, see e.g. [6].

The presented numerical investigations point out that a limited set of constraints is needed in the first iterations of the optimization to steer the solution of the energy-driven optimization towards designs that account for the prescribed assumption of unilateral strength of material of supports. It is also shown that, removing the volume constraint, the proposed formulation may be also adopted as a simplified but efficient tool for the preliminary analysis of structures that are made of no-tension (or no-compression) material.

The assumption of unilateral behavior of material/supports remarkably affects the achieved optimal design along with its structural performances. Non-trivial layouts can be achieved, depending on the design constraints.

Key words: topology optimization, stress constraints, unilateral materials, unilateral supports, Drucker-Prager strength criterion.

**References**

[1] Chang CJ, Zheng B, Gea HC (2007) Topology optimization for tension/ compression only design. Proc. of the 7th WCSMO,COEX Seoul, Korea, 2488–2495

[2] Cai K (2011) A simple approach to find optimal topology of a continuum with tension–only or compression–only material. Struct Multidiscip Optim 43:827-835

[3] Fancello EA (2006) Topology optimization of minimum mass design considering local failure constraints and contact boundary conditions. Struct Multidiscip Optim 32:229-240

[4] Strömberg N, Klarbring A (2010) Topology optimization of structures in unilateral contact. Struct Multidisc Optim 41:57-64

[5] Bruggi M, Dusyinx P (2012) Topology optimization for minimum weight with compliance and stress constraints. Struct Multidiscip Optim 46:369-384

[6] Le C, Norato J, Bruns TE, Ha C and Tortorelli DA (2010) Stress-based Topology Optimization for Continua. Struct Multidiscip Optim 41:605-620

[7] Luo Y, Wang MY, Kang Z, An enhanced aggregation method for topology optimization with local stress constraints (2013) Comp Meth Appl Mech Eng 254:31-41