effective means of identifying (near-)optimal truss layouts, these can be overly complex in form and hence unsuitable for practical use. Although to address this a range of practical considerations can potentially be incorporated in layout optimization formulations directly (e.g. via inclusion of nonlinear constraints and/or nonsmooth variables), this will normally greatly increase computational cost. Also, some practically important constraints are difficult to specify mathematically (e.g. aesthetic considerations). Furthermore, rather than being presented with a single "optimal" design, designers often seek flexible tools that allow them to interactively modify a design for a variety of reasons.

The present work addresses these issues by using a so-called "human-in-the-loop" optimization framework, in which a designer can step into the design loop to make modifications as required. Initially a standard layout optimization is undertaken, followed by refinement via a geometry optimization step. "Human-in-the-loop" refinement is then undertaken by the designer, who can manually modify the structural layout and/or apply additional design constraints. The modified design can then be checked and, if necessary, optimized further, utilizing geometry optimization. Several practical design problems are presented to demonstrate the efficacy of the interactive design tool developed, ranging from large-scale trusses, for use in building structures, to small-scale small mechanical components, designed to be fabricated via additive manufacturing (3D printing) techniques.

509 Level set topology optimization for design-dependent pressure load problems

Hélio Emmendoerfer Junior, Eduardo Alberto Fancello, Emílio Carlos Nelli Silva

This work presents a level set framework to solve the compliance topology optimization problem considering design-dependent pressure loads. One of the major technical difficulties related to this problem is the adequate association between the moving boundary and the pressure acting on it. This difficulty is easily overcome by the level set method that allows for a clear tracking of the boundary along the optimization process. In the present approach, a reaction-diffusion equation substitutes the classical Hamilton-Jacobi equation to control the level set evolution. This choice has the advantage of allowing the nucleation of holes inside the domain and the elimination of the undesirable level set reinitializations. In addition, the optimization algorithm allows the rupture of loading boundaries, that is, the crossing of the pressured (wet) boundary with the traction free boundary are not avoided. This gives more freedom to the algorithm for topological changes. In order to validate the proposed scheme, several numerical examples are presented.

510 Stress-constrained level set topology optimization for design-dependent pressure load problems

Hélio Emmendoerfer Junior, Emílio Carlos Nelli Silva, Eduardo Alberto Fancello

This work presents a level set framework to solve the topology optimization problem for mass minimization subject to local stress constraints considering design-dependent pressure loads. Two technical difficulties are related to this problem. The first one is the local nature of stresses. To deal with this issue, stress constraints are included to the problem by means of an augmented Lagrangian scheme. The second is the adequate association between the moving boundary and the pressure acting on it. This difficulty is easily overcome by the level set method that allows for a clear tracking of the boundary along the optimization process. In the present approach, a reaction-diffusion equation substitutes the classical Hamilton-Jacobi equation to control the level set evolution. This choice has the advantage of allowing the nucleation of holes inside the domain and the elimination of the undesirable level set reinitializations. In addition, the optimization algorithm allows the rupture of loading boundaries, that is, the crossing of the pressured (wet) boundary with the traction free boundary are not avoided. This gives more freedom to the algorithm for topological changes. In order to validate the proposed scheme, several numerical examples are presented.

511 Topology optimization of mechanical components fabricated by additive manufacturing for a Shell Eco Marathon vehicle

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Since 2004, a team of students and researchers of University of Liege takes part to the Shell Eco Marathon race with a lightweight electric vehicle. The goal of this pedagogical project is to design, fabricate and operate a vehicle exhibiting the least energy consumption. A key factor to reduce the energy consumption is to minimize the vehicle mass. Besides the body structure made of CRFP, engineers have also to focus on the weight reduction of any mechanical parts of the powertrain, transmission and of rolling gear.

The combination of topology optimization with additive manufacturing techniques allows to propose innovative designs exhibiting a high performance to weight ratio. Topology optimized designs are often characterized by a high geometrical complexity that is not possible to manufacture without 3D printing.

This work presents the CAE design methodology that was developed to combine topology and shape optimization with 3d printing manufacturing. Novel developments both in shape and topology optimization have also been realized for the specific character of these components.

The design methodology is illustrated with several applications of components of our new Eco Marathon prototype. They include a support for electric traction motors and different torque arms of the steering mechanism to be implemented in the new 2017 vehicle.

The presentation is going to show the different design steps from the specifications and the formulation of the design problem to the 3D-printing of the parts: the topology optimization, interpretation and CAD reconstruction, shape optimization and detailed finite element verification of the solution. The optimization is performed thanks to the commercial software NX-TOPOL and the final CAD design is reconstructed in the CATIA environment software after a smoothing procedure in the NX-CAD environment. We show that the final design can be 3D-printed and a comparison with a design produced using traditional design approach is provided.