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METHODOLOGICAL ASPECTS OF REGULARIZATION FOR SHAPE OPTIMIZATION PROBLEMS

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ABSTRACT

Structural Optimization algorithms are tools for mechanically motivated design of structures. The mechanical properties are formulated via response functions like objectives and constraints. In contrast to other optimization strategies like topology optimization and sizing optimization, shape optimization algorithms utilize geometrical parameters as design variables. Most of the shape optimization approaches apply CAD elements like splines to define the geometry. This yields to the well known CAGD approaches which are commonly used in industry. Other approaches which define the nodal coordinates of the Finite Element nodes as design variables are called CAD free or mesh based optimization methods. For shell optimization algorithms, the design variables are separated according to their direction into in plane and out of plane design variables. Due to the absence of intermediate CAD geometries the modelling effort is decreased significantly in this method. Furthermore there exists a huge design space with a maximum flexibility for design improvements. However, the huge design space causes also some difficulties. Obviously the number of design variables is increased tremendously compared to CAGD methods which yields to more expensive optimization problems. Additionally, CAD free optimization methods require mesh regularization algorithms to ensure robust element aspect ratios. For 3-d shell problems these methods can be separated regarding to the design variables into inplane and out of plane regularization methods.

Filter methods are applied to regularize the sensitivity field which defines the design update in gradient based optimization strategies. Sensitivities itself are not as smooth as the basic system response, hence they must be regularized in general. Non smooth sensitivity fields also result from several other phenomena like the intersection of global vs. local improvements of the objective, non-robust element formulations, unstructured grids, among some others. There exist several types of algorithms to overcome the mentioned problems, e.g. the Laplace filter, the Traction Method and the so called Sigmund filter which originally was developed in the field of signal theory. The application of this filter method allows the definition of a filter radius which implicitly defines the maximum curvature of the optimized geometry. Additional parameters are the type of the filter functions and special boundary modifications. Whithin this contribution we apply the filter method to regularize the sensitivity field of minimal compliance shell problems. We introduce the theory, special improvements for shell optimization problems and numerical examples.

In-plane regularization is used to preserve robust element aspect ratios. It is motivated by the form finding of membrane structures. The basic idea is to solve a minimal surface problem with constraint equations in order to preserve improved geometry resulting from the optimization algorithm. An additional constraint considers the element shape control which is realized by pseudo anisotropic prestress. In this approach, element distortion is measured by the eigenvalues of the right Cauchy Green tensor. Control of maximum allowable distortion yields an update scheme for the prestress and, consequently, of the in plane mesh regularization. The authors will present basic theory and several illustrative examples which show the success of the proposed method.

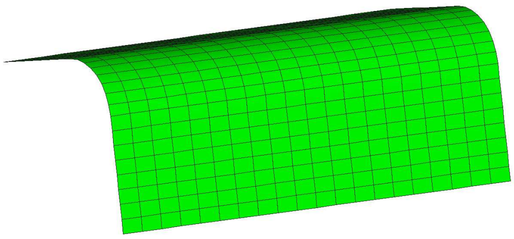

Figure 1: Initial geometry

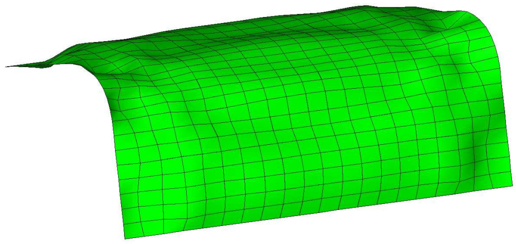

Figure 2: Not regularized optimum

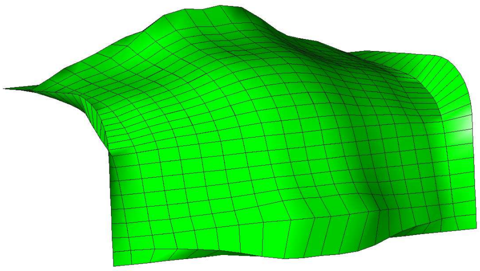

Figure 3: Optimum with filter

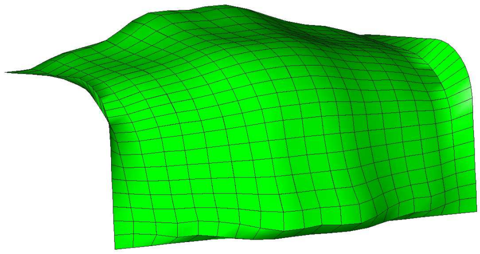

Figure 4: Full regularized optimum

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