Robust Design Optimization of gridshells using the Force Density Method

M. Bruggi[1,*], B. Tóth[2] and J. Lógó[3]

[1]Department of Civil and Environmental Engineering, Politecnico di Milano
Piazza Leonardo da Vinci 32, 20133 Milano, Italy
e-mail: matteo.bruggi@polimi.it

[2]Department of Structural Mechanics, Budapest University of Technology and Economics
Department of Civil and Environmental Engineering, Politecnico di Milano
e-mails: toth.balint@emk.bme.hu, balint.toth@polimi.it

[3]Department of Structural Mechanics, Budapest University of Technology and Economics
Műegyetem rakpart 3, 1111 Budapest, Hungary
e-mail: logo.janos@emk.bme.hu

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The Force Density Method (FDM) [1] provides a framework for generating the shape of reticulated shells by formulating the equilibrium of forces in terms of force-to-length ratios. Building on this principle, the present work proposes a Robust Design Optimization strategy [2] specifically developed for elastic gridshells. Assuming that fabrication-induced imperfections and fluctuations are sufficiently small compared to the overall dimensions of the truss, the form-finding task is reformulated as an enhanced deterministic problem derived through perturbation techniques, following the approach outlined in [3]. This reformulation circumvents the significant computational burden of probabilistic analyses and Monte-Carlo-based optimization, which typically require repeated assembly and inversion of the global stiffness matrix. To mitigate the impact of stochastic variations, the method identifies the force densities that generate an optimal spatial configuration minimizing a weighted combination of mean compliance and its standard deviation. This optimization is carried out using sequential convex programming. The dependence of both the geometry and the global stiffness matrix on the design variables is efficiently managed by leveraging the formal structure of the FDM, as demonstrated for similar applications in [4]. This representation is particularly advantageous for addressing the elastic equilibrium and for computing the associated sensitivities with respect to the design unknowns. The proposed formulation is assessed through numerical studies involving gridshells subjected to vertical loading and a slender column-like structure representative of components manufactured through metal additive processes. These examples illustrate how optimal configurations respond to uncertainties in material properties. Further extensions to accommodate additional forms of uncertainty are anticipated.

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