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A numerical approach to the design of gridshells for WAAM

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Among different Additive Manufacturing (AM) processes, Wire-and-Arc Additive Manufacturing (WAAM) results particularly suitable for applications in structural engineering. The WAAM process, which consists of off-the-shelf welding equipment mounted on top of a numerically controlled robotic arm, allows realizing large-scale structural elements up to few meters, with limited constraints in terms of forms and shapes. The WAAM technique employing "dot-by-dot" printed stainless steel rods is herein considered, see in particular investigations in [1].

Gridshells take their strength from their double curvature, being constructed from members that mainly undergo axial forces [2]. A numerical approach based on funicular analysis, see e.g. [3], is proposed to cope with the design of spatial truss networks fabricated by "dot-by-dot" WAAM. The equilibrium of funicular networks can be conveniently handled through the force density method, i.e. writing the problem in terms of the ratio of force to length in each branch of the network. As investigated in the literature for the case of vertical loads, independent sets of branches can be detected for networks with fixed plan geometry [4].

In this contribution, following [5], the minimization of the horizontal thrusts in networks with fixed plan geometry is stated both in terms of any independent subset of the force densities and in terms of the height of the restrained nodes. Local enforcements are formulated to prescribe lower and upper bounds for the vertical coordinates of the nodes, and to control the force densities in the branches. This allows also for a straightforward control of the length and maximum force magnitude in each branch. Constraints are such that sequential convex programming can be conveniently exploited to handle grids with general topology and boundary conditions.

Preliminary numerical simulations are shown concerning the optimal design of grid shells with minimum thrusts, under the combined effect of different sets of the above prescriptions. The ongoing research is mainly devoted towards endowing the design formulation with buckling constraints.

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