Effect of Topology Optimization Parameters on Additively Manufactured Space Frame Nodes

Luke Farrugia, Jeanette Muñoz Abela

University of Malta, Msida, Malta

Contact: luke.w.farrugia.15@um.edu.mt

Abstract

Topology optimization of a double layer grid space frame node was examined, considering load combinations and various optimization parameters including minimum member sizes and mass reduction constraints. Minimum member size constraints up to 15mm improved stiffness by creating slender secondary supports, enhancing the primary load path. Post-processing techniques involving smoothing and rationalization reduced maximum stresses by 47%. Compared to conventionally designed nodes, the optimized nodes showed remarkable structural performance, with stress levels reduced by up to 88%. Nodes that were optimized to the load combination performed significantly better than nodes optimized to single load cases. The study also explored physical prototyping feasibility.

Keywords: topology optimization; additive manufacturing; space frame; structural optimization; parametric design.

1 Introduction

The integration of additive manufacturing (AM) into the fields of architecture and structural engineering has the potential to create spatial structures that are no longer restricted by standardization. By coupling topology optimization (TO) with AM, structural engineers can design and fabricate bespoke nodes with optimized structural performance and reduced fabrication lead times.

To date, a number of continuing studies that designed and fabricated intricate geometries for structural nodes in bespoke space frames, gridshells [1,2] and tensegrity structures [3] are available. In the case of space frames, the structural performance of the topology optimized nodes was not compared to that of a node defined parametrically or conventionally. Furthermore, there is limited information on the performance of optimized joints against multiple load cases, where research to date focused on single load case topology optimization.

Consequently, this research paper considers optimizing space frame roof nodes to multiple load cases and compares the structural performance of the optimized nodes against a spectrum of load cases. Additionally, the effect of the various optimization parameters present in the Solid Isotropic Material with Penalization method (SIMP) was also investigated. The behaviour of a parametrically defined node using mesh subdivision was also assessed, where the results obtained using numerical analysis techniques were compared to the results of the topology optimized nodes as well as those designed conventionally. The suitability of AM in fabricating the optimized nodes was also assessed.

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