A genetic algorithm for configuration, shape, and sizing optimization of geometrically nonlinear dome structures

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Domes are structures largely used in exhibition pavilions, terminals, hangars, convention centers, gymnasiums, etc. A preliminary engineering analysis usually comprises a few conventional configurations, pre-defined by the architect, and the engineer only chooses the sizes of the bars to satisfy the applicable codes, considering economic aspects. In this paper a genetic algorithm is proposed to solve the weight minimization problem of domes composed of standard modules considering configuration, shape, and sizing design variables. Previous work done by the authors [1] did not consider the geometrically nonlinear behavior of the domes which is included in this paper, since it is an important aspect not to be neglected in this kind of structure. It is important to observe the differences between the optimized solutions obtained considering or not nonlinear analysis to be discussed in this paper. The set of design variables includes: (i) sizing design variables (cross-sectional areas of the bars); (ii) a shape design variable corresponding to the height of the dome, and (iii) shape design variables corresponding to the inner diameter of the dome at certain heights

The domes are assembled from standard modules composed by 10 members which are grouped into seven distinct profiles. In addition, cardinality constraints are introduced to define alternative member groupings [1], of the standard modules. It is then clear that such a grouping procedure affects the final results and that its effectiveness depends crucially on the designer's skill in allocating members/variables to a group. As a result, it would be advantageous to the designer to be able to: 1) limit the number of different design parameters (such as cross-sectional areas) in order to (a) achieve economies of bulk purchasing/fabrication, and (b) simplify construction, 2) leave to the optimizer algorithm the task of deciding how to group members and/or design variables, and 3) achieve the best possible solution within the available computational budget.

Objectives 1) and 2) can be achieved by introducing a cardinality constraint as shown in [1]. A cardinality constraint arises naturally when the designer, faced with the task of selecting from a large set of commercial profiles, wishes to employ a reduced number of distinct profiles. Objective number 3) can only be attained with a careful formulation of the optimization problem on the part of the designer.

This type of evolution of the whole structural configuration is an attractive feature because it allows the designer to automate the search for the global configuration of the dome finding the best number of standard modules simultaneously with the shape and sizing design variables for these modules. Several experiments are performed using a 120-bar dome as test-bed.

References

[1] A.C.C. Lemonge, H.J.C. Barbosa, L.G. Fonseca, A.L.G.A. Coutinho. A genetic algorithm for topology optimization of dome structures 2nd International Conference on Engineering Optimization September 6-9, 2010, Lisbon, Portugal.

[2] H.J. C. Barbosa, A.C.C. Lemonge, C.C.H. Borges. A genetic algorithm encoding for cardinality

constraints and automatic variable linking in structural optimization. Engineering Structures, 30 (2008), pp. 3708–3723.