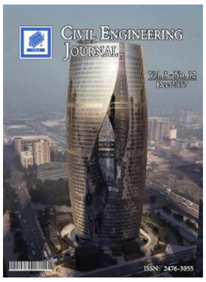
Available online at www.CivileJournal.org

Civil Engineering Journal

Vol. 3, No. 12, December, 2017



Size and Shape Optimization of Space Trusses Considering Geometrical Imperfection-Sensitivity in Buckling Constraints

Fardad Haghpanah [a*], Hamid Foroughi [a]

[a] *Department of Civil Engineering, Johns Hopkins University, Maryland, United State.*

Received 07 November 2017; Accepted 27 December 2017

Abstract

Optimal design considering buckling of compressive members is an important subject in structural engineering. The strength of compressive members can be compensated by initial geometrical imperfection due to the manufacturing process; therefore, geometrical imperfection can affect the optimal design of structures. In this study, the metaheuristic teaching-learning-based-optimization (TLBO) algorithm is applied to study the geometrical imperfection-sensitivity of members' buckling in the optimal design of space trusses. Three benchmark trusses and a real-life bridge with continuous and discrete design variables are considered, and the results of optimization are compared for different degrees of imperfection, namely 0.001, 0.002, and 0.003. The design variables are the cross-sectional areas, and the objective is to minimize the total weight of the structures under the following constraints: tensile and compressive yielding stress, Euler buckling stress considering imperfection, nodal displacement, and available cross-sectional areas. The results reveal that higher geometrical imperfection degrees significantly change the critical buckling load of compressive members, and consequently, increase the weight of the optimal design. This increase varies from 0.4 to 119% for different degrees of imperfection in the studied trusses.

Keywords: Optimization; Space Trusses; Teaching-Learning-Based-Optimization; Imperfection; Buckling; Metaheuristics.

1. Introduction

Stability of thin-walled members, such as composite plates, shells, and steel cross-sections, is a major concern in the design of lightweight structures [1-4]. For many years, optimal design considering buckling of members under compression was an interesting subject in structural engineering. In 1995, Cheng [5] carried out an optimal solution for truss members with local buckling constrains using the ε-relaxed approach. Guo et al. [6] applied a new approach for truss topology optimization with stress and local buckling constrains. Many researchers have proposed different methods to handle the truss optimization problems with buckling constrains [7-10]. New applications of truss elements in robotics to achieve the optimum stiffness-to-weight ratios have brought a new perspective into buckling failure of truss structures. It is well-recognized that the strength of compressive members, specifically thin-walled members such as shells and pipes, is generally influenced by their initial imperfection due to the manufacturing process [11,12]. Initial steps to solve truss optimization problems with local buckling constraints considering sensitivity to geometrical imperfection was carried out by Pedersen and Nielson [13], based on the Danish Standards DS409 using Sequential Linear Programming. In the recent years, different methods have been proposed to study the effects of geometrical imperfection in optimal solution of truss structures. Jalalpour et al. [14] proposed a topology optimization method for the design of trusses with random imperfection using a gradient-based optimizer. Madah and Amir [15] studied local and global buckling of trusses with geometrical imperfection based on geometrically nonlinear beam modeling using the gradient-based Method of

* Corresponding author: fhaghpa1@jhu.edu

http://dx.doi.org/10.28991/cej-030960