# Accepted Manuscript


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PII: S0263-8223(17)31097-8
DOI: http://dx.doi.org/10.1016/j.compstruct.2017.07.016
Reference: COST 8671

To appear in: *Composite Structures*

Please cite this article as: Lieu, Q.X., Lee, J., Modeling and optimization of functionally graded plates under thermo-mechanical load using isogeometric analysis and adaptive hybrid evolutionary firefly algorithm, *Composite Structures* (2017), doi: http://dx.doi.org/10.1016/j.compstruct.2017.07.016

# Modeling and optimization of functionally graded plates under thermo-mechanical load using isogeometric analysis and adaptive hybrid evolutionary firefly algorithm

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**Abstract**

The paper presents an effective numerical approach for modeling and optimizing the ceramic volume fraction distribution of functionally graded (FG) plates in the thermo-mechanical environment. Ceramic volume fraction design variables at control points whose coordinates are located along the plate thickness by *Greville abscissae* are used to describe the material distribution using the B-spline basis functions. Continuously altering macroscopic material properties can therefore be easily captured by selecting a proper order of these B-spline functions without any extra terms. The temperature-dependent material properties are then evaluated by either the rule of mixture or the Mori-Tanaka scheme. A non-uniform rational B-splines (NURBS)-based isogeometric finite element model associated with the third-order shear deformation theory (TSDT) is utilized for the static analysis of the FG plates. A recently proposed adaptive hybrid evolutionary firefly algorithm (AHEFA) is employed to solve compliance minimization problems with volume constraints. This algorithm effectively enhances the trade-off between the global and local search abilities, the solution accuracy and the convergence speed are thus improved dramatically. Several numerical examples are examined to confirm the effectiveness and robustness of the present method.

*Keywords:* Optimization; Functionally graded plates; Thermo-mechanical load; Isogeometric analysis (IGA); B-splines/NURBS; adaptive hybrid evolutionary firefly algorithm (AHEFA).

## 1. Introduction

Functionally graded materials (FGMs) are one of the advanced materials in the family of engineering composites produced by at least two distinct constituents. One of the most commonly used FGMs that has attracted considerable attention of numerous researchers in the past decades is the ceramic-metal composite. The combination of these two constituents generates more preeminent mechanical features from the synergy for versatile adaptations in different severe working environments. In particular, the ceramic phase is superbly effective in withstanding high temperatures, while the metal is of superior fracture toughness. Its macroscopic material properties are often assumed to continuously and smoothly vary based on a certain predetermined mathematical function so that the discontinuities regarding strains and stresses are suppressed. Those usually cause crack and delamination phenomena, leading to unpredictable behavior, even undesired failures of the whole structure. Owing to the above prominent advantages, the ceramic-metal FGM has been very common and broadly applied to various engineering fields such as nuclear plants, high-speed vehicles, spacecrafts, etc.

Regarding this issue, a large number of works have been performed to study mechanical behavior of this material type, especially for plate structures under the thermo-mechanical load.

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