

Combined influence of variable distribution models and boundary conditions on the thermodynamic behavior of FG sandwich plates lying on various elastic foundations

Djamel Eddine Lafi¹, Abdelhakim Bouhadra^{1,2a}, Belgacem Mamen^{1,2a}, Abderahmane Menasria^{1,2a}, Mohamed Bourada^{1b}, Abdelmoumen Anis Bousahla^{*1,3}, Fouad Bourada^{1,4a}, Abdelouahed Tounsi^{1,5,6,7b}, Abdeldjebbar Tounsi^{1a} and Murat Yaylaci^{8b}

¹Material and Hydrology Laboratory, Faculty of Technology, Civil Engineering Department, University of Sidi Bel Abbes, Algeria

²Department of Civil Engineering, Faculty of Science and Technology, Abbès Laghrour University of Khenchela, Algeria

³Laboratoire de Modélisation et Simulation Multi-échelle, Université de Sidi Bel Abbès, Algeria

⁴Science and Technology Department, Faculty of Science and Technology, Tissemsilt University, Algeria

⁵YFL (Yonsei Frontier Lab.), Yonsei University, Seoul, Korea

⁶Department of Civil and Environmental Engineering, King Fahd University of Petroleum & Minerals, 31261 Dhahran, Eastern Province, Saudi Arabia

⁷Department of Civil and Environmental Engineering, Lebanese American University, 309 Bassil Building, Byblos, Lebanon

⁸Department of Civil Engineering, Recep Tayyip Erdogan University, 53100, Rize, Turkey

(Received March 20, 2023, Revised September 14, 2023, Accepted December 4, 2023)

Abstract. The present research investigates the thermodynamically bending behavior of FG sandwich plates, laying on the Winkler/Pasternak/Kerr foundation with various boundary conditions, subjected to harmonic thermal load varying through thickness. The supposed FG sandwich plate has three layers with a ceramic core. The constituents' volume fractions of the lower and upper faces vary gradually in the direction of the FG sandwich plate thickness. This variation is performed according to various models: a Power law, Trigonometric, Viola-Tornabene, and the Exponential model, while the core is constantly homogeneous. The displacement field considered in the current work contains integral terms and fewer unknowns than other theories in the literature. The corresponding equations of motion are derived based on Hamilton's principle. The impact of the distribution model, scheme, aspect ratio, side-to-thickness ratio, boundary conditions, and elastic foundations on thermodynamic bending are examined in this study. The deflections obtained for the sandwich plate without elastic foundations have the lowest values for all boundary conditions. In addition, the minimum deflection values are obtained for the exponential volume fraction law model. The sandwich plate's non-dimensional deflection increases as the aspect ratio increases for all distribution models.

Keywords: boundary conditions; distribution models; FG sandwich plates; harmonic thermal load; thermodynamic bending; Winkler/Pasternak/Kerr foundation

1. Introduction

Recently, functionally graded materials (FGMs) are advanced composite materials composed of at least two different materials, such as metal and ceramic. The material properties of FGMs vary continuously from one side to the other, which prevents stress concentration and allows them to withstand high-temperature environments. The ceramic constituents of FGMs have low thermal conductivity, which makes them well-suited for high-temperature applications. Sandwich structures have high structural effectiveness through their exceptional properties: lower density, sound absorption capability, higher stiffness, higher strength, good energy, and often low production cost compared to aluminum or steel. These features have led sandwich plates

to find wide applications in mechanical, civil constructions, and many other engineering fields (Li *et al.* 2008, Brischetto 2009, Wang and Shen 2011, Alipour and Shariyat 2014, Katariya *et al.* 2018, Bharath *et al.* 2020, Sobhy and Alakel Abazid 2022, Mula *et al.* 2022, Polat and Kaya 2022, Man 2022, Fan *et al.* 2022, Zhu *et al.* 2022, Bochkareva and Lekomtsev 2022).

Over the past several decades, these structures have experienced significant difficulties with durability due to the stress concentration at the face sheet-core interfaces (Funari *et al.* 2018, Burlayenko and Sadowski 2020, Van Vinh 2021, Swaminathan *et al.* 2022). Consequently, a local separation through delamination often occurs between the core and face sheets. Additionally, sandwich materials do not provide high operating temperatures. These disadvantages are resolved using functionally graded materials (FGMs) of two or more phases with different material properties varying smoothly and continuously in one or more directions (Akbaş 2015, Attia 2017, Avcar 2019, Vinyas 2020, Selmi 2020, Akbaş 2022, Liu *et al.* 2022, Chinnapandi *et al.* 2022, Rezaiee-Pajand *et al.* 2022,

*Corresponding author, Professor
E-mail: bousahla.anis@gmail.com

^aPh.D.

^bProfessor