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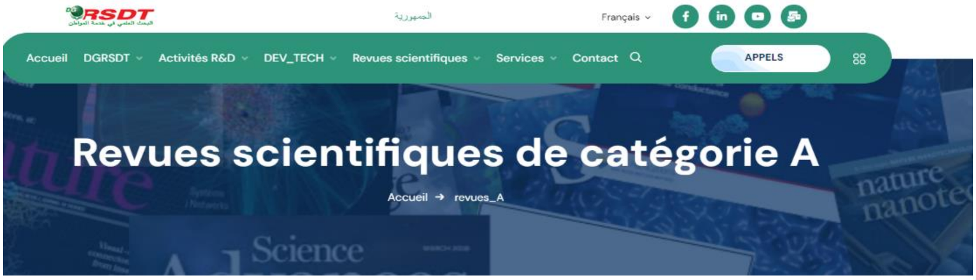

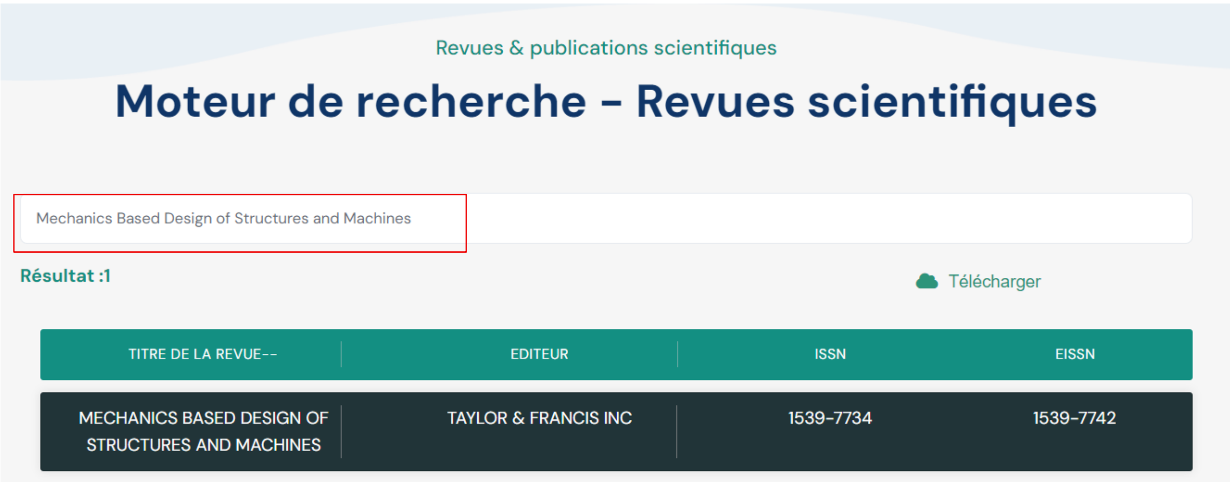

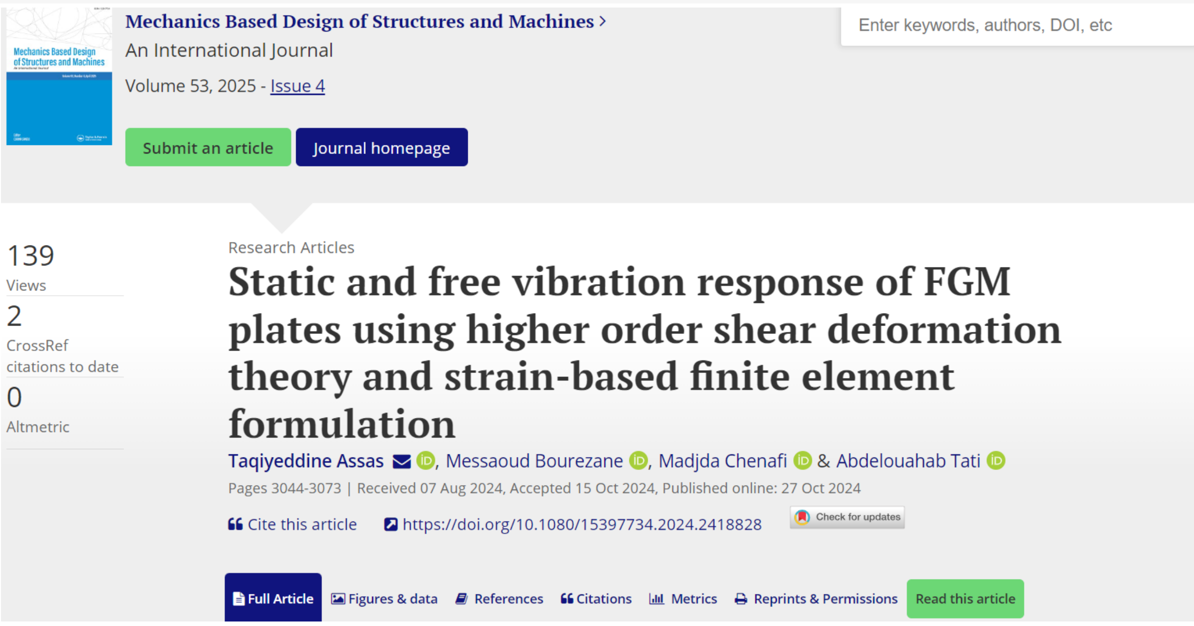

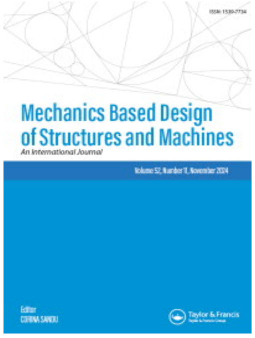

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Static and free vibration response of FGM plates using higher order shear deformation theory and strain-based finite element formulation

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ABSTRACT

The primary objective and novelty of this work lie in the development of a new four-node quadrilateral finite element based on strain-based high-order shear deformation theory (HSDT). This is the first study to apply this innovative approach to analyze both the static and free vibration behaviors of functionally graded (FG) plates. Another key novelty is the reduction in the number of unknowns to five, unlike other high-order shear deformation theories that employ a larger number of unknowns. This reduction is achieved by applying the condition of zero transverse shear stress at the top and bottom free surfaces of the FG plate and by assuming that the transverse shear strains are sinusoidally distributed through the thickness. The material properties of FG plates are modeled to vary according to a simple power law based on the volume fractions of their constituents. The developed finite element possesses five degrees of freedom (DOFs) per node, resulting from the combination of two strain-based elements: the first is a membrane with two DOFs, and the second is a bending plate with three DOFs. The displacement fields of the proposed element are expressed using high-order terms based on the strain approach, which satisfy compatibility equations and rigid body modes. Furthermore, the concept of the neutral surface is introduced to eliminate membrane-bending coupling. The elementary stiffness and mass matrices are derived using both the total potential energy principle and Hamilton's principle. The performance and convergence of the proposed element are validated through examples from the literature.

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KEYWORDS
Static; free vibration; high-order shear deformation; functionally graded; strain-based

1. Introduction

Functionally graded materials (FGMs) are a type of heterogeneous composite material comprising a blend of isotropic substances, typically ceramics and metals, which were first introduced by a team of Japanese scientists in 1984 (Fukui 1991). The mechanical characteristics of FGMs transition continuously and seamlessly between the surfaces, effectively avoiding the stress concentrations at the interfaces observed in laminated composites (Akavci and Tanrikulu 2015). Since their inception, FGMs have found widespread applications beyond their original use as thermal barriers in aerospace structures and are now extensively used in various structural applications. Owing to the remarkable properties of FGMs, many studies have been conducted on the static, dynamic, and buckling responses of FGM beams, plates, and shells using several numerical and analytical

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