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## Modeling and applications of FGMs in aerospace structures

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Functionally Graded Materials (FGM) are the new generation of advanced composites that has gained interest in several engineering applications such as, spacecraft heat shields, high-performance structural elements and critical engine components. They are formed of two or more constituent phases with a continuously variable composition producing properties that change spatially within a structure. FGM possess a number of advantages that make them attractive in improving structural performance, such as higher natural frequencies of composite beams and plates and broader stability boundaries of aircraft wings. This paper presents practical realistic models for improving performance and operational efficiency of some types of composite aero-structural elements. The concept of material grading has been successfully applied by incorporating the distribution of the volume fractions of the composite material constituents in the mathematical model formulation. Various scenarios in modeling the spatial variation of the material properties of functionally graded structures are addressed. Case studies include optimization of thin-walled composite box sections, spinning beams against torsional buckling and whirling and aeroelastic optimization of trapezoidal wings against divergence. Design variables encompass the distribution of volume fraction, ply angle and wall thickness as well. Several design charts that are useful for direct determination of the optimal design variables are given. It is shown that by using material and thickness grading simultaneously, the aeroelastic stability boundary can be broadened by more than 50% above that of a known baseline design having the same total structural mass. The wing panel length is proved to be the most significant design variable in the whole optimization process. The attained optimal solutions using continuous grading depend entirely upon the prescribed power-law expression which represents an additional constraint on the optimization problem. Results show that material grading in the spanwise direction is much better than grading through the wall thickness of the cross section.

### Biography

Karam Y Maalawi born in Cairo, Egypt on January 12, 1952. He was educated at the Faculty of Engineering, Aerospace Engineering Department, Cairo University. He is now Professor Emeritus of Aeronautics and Mechanics at the Department of Mechanical Engineering, National Research Centre in Cairo, Egypt. He has been active in research in structural and solid mechanics and has involved in numerous research projects related to wind energy applications. His primary research interest is in computer based analysis and design of metal and composite structures. He has been recognized for his contributions in training programs conducted by the National Research Centre in the fields of composite materials, optimum design and wind energy technology development. He has published extensively in the field of structural optimization and wind turbine design and performance. In 2006, he was a visitor at the Department of Engineering Science and Mechanics, Virginia Tech, doing research work in the field of aeroelastic optimization of aircraft wings. His current research is concerned with the optimal design of functionally graded material beams, aircraft wings and wind turbine blades. At present, he is involved in research projects related to Renewable Energy Industrialization for Egypt's Sustainable Development.

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