

NONLINEAR STRUCTURAL RESPONSE OF GEOMETRICALLY
IMPERFECT SKEWED SANDWICH FGM PLATES WITH
MATERIAL UNCERTAINTIES

*Thesis submitted to the
Indian Institute of Technology, Mandi
for award of the degree*

of

Master of Science (by Research)

by

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Under the guidance of

Dr. Mohammad Talha



SCHOOL OF ENGINEERING
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July 2018

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Declaration by the Research Scholar

This is to certify that the thesis titled “**Nonlinear structural response of geometrically imperfect skewed sandwich FGM plates with material uncertainties**” submitted by me, to the Indian Institute of Technology Mandi for the award of the degree of **Master of Science (by Research)**, is a bonafide record of the research work carried out by me in the School of Engineering, Indian Institute of Technology Mandi, under the supervision of Dr. Mohammad Talha. The contents of this thesis, in full or in parts, have not been submitted to any other Institute or University for the award of any degree or diploma.

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Declaration by the Research Advisor

This is to certify that the thesis titled “**Nonlinear structural response of geometrically imperfect skewed sandwich FGM plates with material uncertainties**” submitted by **Sanjay Singh Tomar**, to the Indian Institute of Technology Mandi for the award of the degree of **Master of Science (by research)**, is a bonafide record of the research work done by him under our supervision in the School of Engineering, Indian Institute of Technology Mandi. The contents of this thesis, in full or in parts, have not been submitted to any other Institute or University for the award of any degree or diploma.

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Curriculum Vitae

Sanjay Singh Tomar received his Bachelor of Engineering degree in Mechanical Engineering from Rajiv Gandhi Proudyogiki Vishwavidyalaya, Bhopal, in the year 2014. He joined the master of science (by research) programme in the School of Engineering, Indian Institute of Technology, Mandi, in February, 2015. His research interest includes structural analysis, Finite element modeling, Composite structures, Uncertainty quantification and Imperfection sensitivity analysis.

His papers related to the present work are listed below.

1. **Sanjay Singh Tomar** and Mohammad Talha, “Thermo-mechanical Non-linear Vibration Response of Skew FGM Laminate”, *Mechanics of Advanced Materials and Structures*, 2017. DOI:10.1080/15376494.2017.1400619.
2. **Sanjay Singh Tomar** and Mohammad Talha, “Thermo-mechanical buckling analysis of functionally graded skew laminated plates with initial geometric imperfections”, *International journal of applied mechanics*, 10(2), 1850014, 2018. DOI:10.1142/S175882511850014X.
3. **Sanjay Singh Tomar** and Mohammad Talha, “On the flexural and vibration behavior of imperfection sensitive higher order skewed FGM sandwich plates in thermal environment”, *Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science*, 2018. DOI: 10.1177/0954406218766959.
4. **Sanjay Singh Tomar**, Sunny Zafar, Mohammad Talha, Wei Gao, David Hui, “State of the art of composite structures in non-deterministic framework: A review”. (Under revision, *Thin wall structures*)
5. **Sanjay Singh Tomar** and Mohammad Talha, “Influence of material uncertainties on vibration and bending behaviour of skewed sandwich FGM plates”. (Under review, *Composite Part-B*)

6. **Sanjay Singh Tomar** and Mohammad Talha, “Buckling Analysis of Finite Element Modeled FGM Laminate in Thermal Environment”, *XIX National Seminar on aerospace Structures (NASAS-2017)*, VIT Vellore, Feb 23-25, 2017.
7. **Sanjay Singh Tomar** and Mohammad Talha, “Stochastic Vibration Analysis of Skew Functionally Graded Plates Using Higher Order Shear Deformation Theory”, *IEEE International Conference on Advances in Mechanical, Industrial, Automation and Management Systems(AMIAMS-2017)*, MNNIT Allahabad India, Feb. 3-5, 2017. DOI:10.1109/AMIAMS.2017.8069201
8. **Sanjay Singh Tomar** and Mohammad Talha, “Vibration Response of Finite Element Modeled FGM Plates in Thermal Environment”, *Proceedings of International Conference on Recent Advances in Mechanical Engineering(RAME)*, DTU India, pp. 185-192, Oct. 14-15, 2016.
9. **Sanjay Singh Tomar** and Mohammad Talha, “Thermo- mechanical bending analysis of skew FGM laminated plates”, *International Conference on Theoretical, Applied, Computational and Experimental Mechanics (ICTACEM 2017)*, IIT Kharagpur.

Acknowledgment

It is an honour for me to thank all the people who have made this thesis possible and has led me where I am now.

First and foremost I offer my sincere gratitude to my thesis supervisor **Dr. Mohammad Talha**. In every sense, this work would not have been possible without his constant encouragement, valuable guidance, support and patience during the course of this research.

I would like to thank **Dr. Rajeev Kumar**, Chairperson, school of Engineering and my Maters Scrutiny Committee members viz., **Dr. Rajesh Ghosh, Dr. Arpan Gupta, and Dr. C. S. Yadav** for their encouragement and critical assessment at various stages of the study. I am very much thankful and greatly recognise the financial support provided by **M.H.R.D., Govt. of India**, New Delhi, to carryout this research.

I would also like to thank and recognise the efforts of my friends and fellow research scholars who contributed invaluable suggestions and making the stay more enjoyable.

My deepest gratitude goes to my parents for their unparallel contribution and blessings, and also to my brother and sister for all their love and care.

This thesis is only a beginning of my journey.

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Abstract

Functionally graded material (FGM) has been recognized as a potential candidate to be used in the high temperature applications such in aero craft, space shuttle industries. FGM is microscopically inhomogeneous materials having the graded variation of material properties in the preferred direction in term of the volume fractions of constituent materials. These materials are usually made of ceramics and metals. Metal provides the strength to the structure, whereas ceramic helps to withstand the high thermal gradient. In the presence of high temperature gradient, the ceramic metal interface leads to some distortion. Such conditions can be observed in a nuclear power plant having continuous fission reactions. To withstand such type of high thermal gradient during service life the ceramic and metallic sheets have been integrated to the graded superstructures. This construction is known as the functionally graded sandwich structure with FGM core and homogeneous face sheets. The complex processing of the functionally graded materials leads to the inclusion of the uncertainties and geometric imperfection in the structures. In order to obtain the accurate and realistic response of the structures these parameters needs to be incorporated in the analysis.

The present study investigates the nonlinear deterministic and stochastic response of the functionally graded skew sandwich plates with initial geometric imperfections. Reddy's higher shear deformation order theory (HSDT) has been employed in the study. Von-Karman strain assumptions have been used to model the non-linearity in the system. Variational principle has been used to derive the governing differential equations. Direct iterative method with finite element methodology have been used to solve nonlinear system of equations. The convergence and comparison studies have been performed to show the effectiveness and reliability of the present formulation. A large number of examples have been solved to assess the effect of various design parameter on structural response of skew sandwich FGM plates.

Keywords: Functionally graded sandwich structures, Large amplitude free vibration, Post buckling, Nonlinear bending, skew plates, Imperfection sensitivity, Perturbation technique, finite element analysis, C^0 continuity.