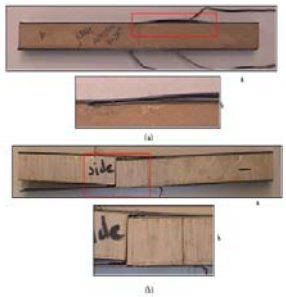
Elastic flexural behaviour of functionally graded composite structures

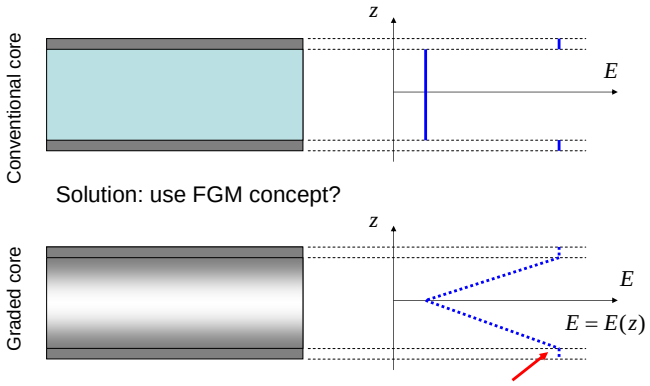
Introduction

Sandwich structures are used in many engineering applications where strong, stiff, light-weight structures are required, e.g. in ship hulls, aircraft structures, high-speed trains, building materials, cargo transport



Face sheet/core debonding due to high interfacial stresses is a major problem.

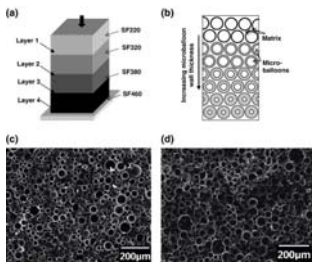
Cause: mismatch in stiffness properties at the interface.



Mismatch in properties eliminated

FGM concept

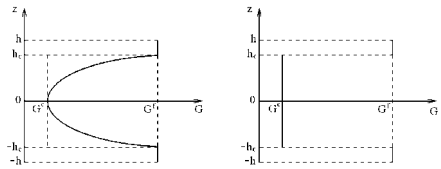
Functionally graded material (FGM) refers to the new class of advanced composite materials with gradient compositional variation of the constituents from one surface of the material to the other.



Advanced processing methods are being developed to introduce compositional gradients into various material systems, including core materials, e.g. syntactic foams.

Modelling

$$G^{(k)}(z) = g^{(k)} \exp\left[\gamma^{(k)}\left(\frac{z}{h} - 1\right)\right],$$



3-D displacement field

$$u_x^{(k)} = -\frac{1}{2G^{(k)}}\left(\nu^{(k)}\Delta - \frac{\partial^2}{\partial z^2}\right)\frac{\partial L^{(k)}}{\partial x} + \frac{\partial N^{(k)}}{\partial y}$$

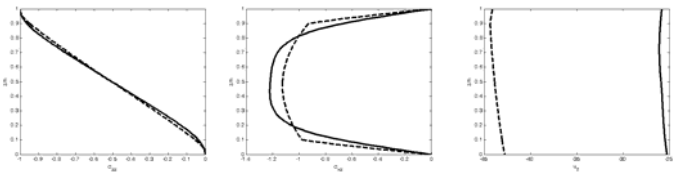
$$u_y^{(k)} = -\frac{1}{2G^{(k)}}\left(\nu^{(k)}\Delta - \frac{\partial^2}{\partial z^2}\right)\frac{\partial L^{(k)}}{\partial y} - \frac{\partial N^{(k)}}{\partial x}$$

$$u_z^{(k)} = -\frac{1}{G^{(k)}}\left(\Delta - \frac{\partial^2}{\partial z^2}\right)\frac{\partial L^{(k)}}{\partial z} + \frac{\partial}{\partial z}\left[\frac{1}{2G^{(k)}}\left(\nu^{(k)}\Delta - \frac{\partial^2}{\partial z^2}\right)L^{(k)}\right]$$

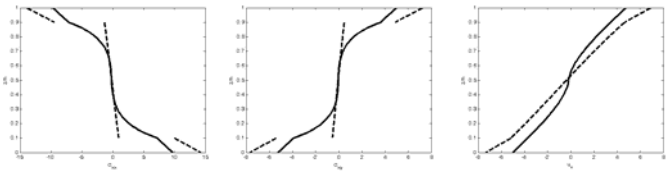
For 3-D stress field use constitutive equations

Results

Out-of-plane stresses and displacements

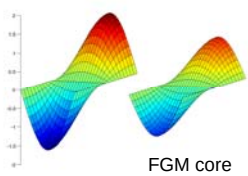


In-plane stresses and displacements



Interfacial stresses (top interface)

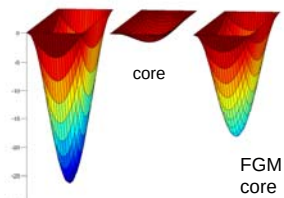
Transverse shear stress



FGM core

Homogeneous core

In-plane normal stress



Homogeneous core

Benefits of using FGM core :

- eliminates discontinuity of in-plane stresses across the face sheet/core interface
- reduces stress levels in the face sheets
- reduces deflection of the panel

REFERENCES

Kashtalyan M, Menshykova M. Three-dimensional elasticity solution for sandwich panels with a functionally graded core. Composite Structures (in press)

Kashtalyan M, Menshykova M. Three-dimensional elastic deformation of a functionally graded coating/substrate system. International Journal of Solids and Structures 2007; 44: 5272-5288

Kashtalyan M. Three-dimensional elasticity solution for bending of functionally graded rectangular plates. European Journal of Mechanics A/Solids 2004; 23: 833-854