FLUID STRUCTURE INTERACTIONS RESEARCH GROUP

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Reliability Based Life-time Prediction and Assessment of Composite Sandwich Structures

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Background

- Composite sandwich structures consisting of fibre-reinforced composite skins and foam cores are widely used in aerospace and marine applications due to their high flexural strength-to-weight and stiffness-to-weight ratios.
- The complex damage states in composites are closely related to anisotropy and include various mechanisms such as interfacial debonding, matrix cracking, ply cracking, fibre breakage, and so on.
- In many circumstances, due to time and resource constrains, it is infeasible to conduct extensive experimental investigations.

Aims

- To develop non-linear numerical methods for the prediction of the elastic property of composite sandwich structures.
- To address the paucity of data in assessing the structural probability of fatigue and facture performance.

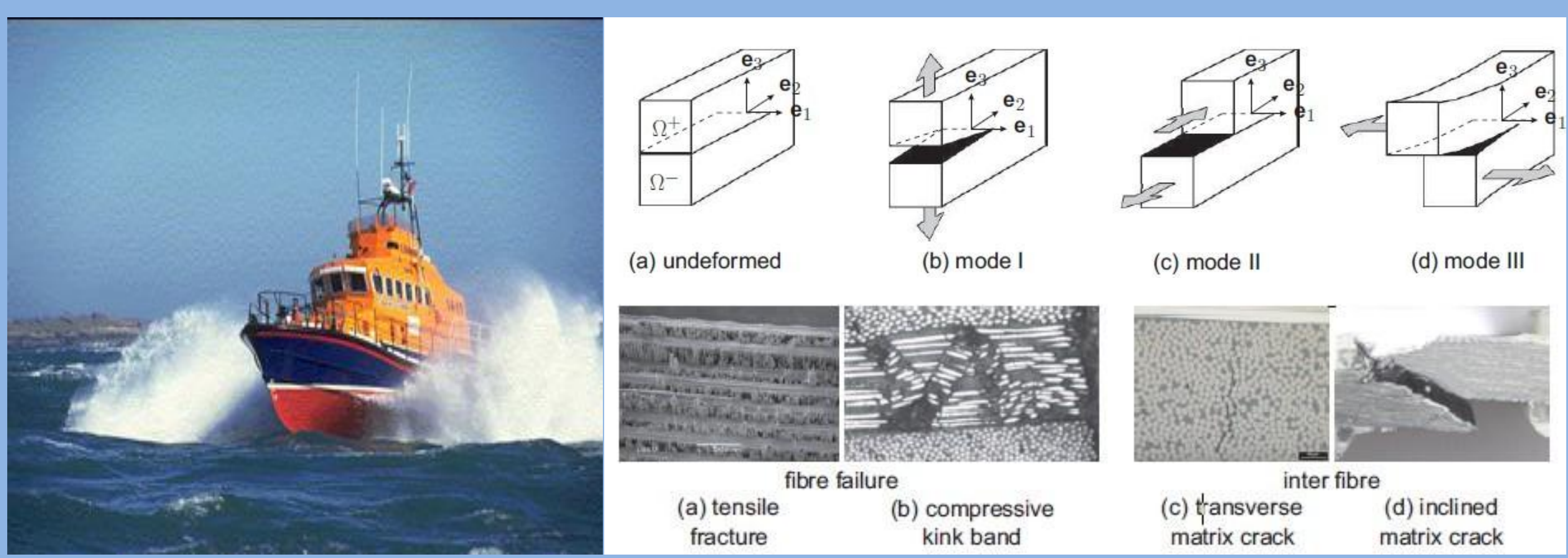

Figure 1: Loading modes; no crack tip opening and a general elastic deformation of buck material is possible, mode 1 (opening mode), mode 2 (in-plane sliding mode), mode 3 (tearing mode) with crack tip coordinate system.

Mechanics

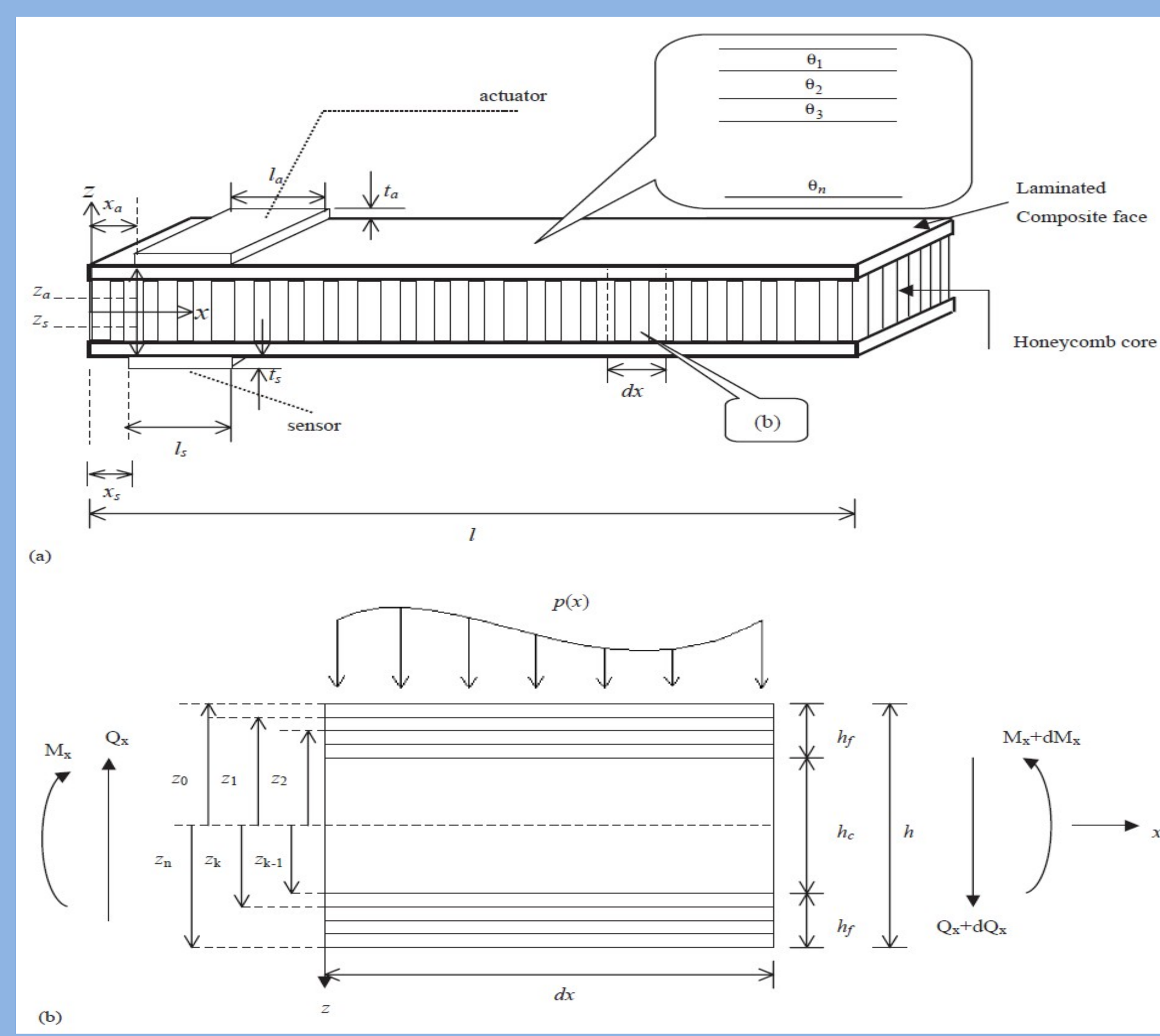

Figure 2: A composite sandwich beam with piezoelectric sensors and actuators.

$$\frac{\partial Q_x}{\partial x} + p = \rho h \frac{\partial^2 w}{\partial t^2}, \frac{\partial M_x}{\partial x} = Q_x + I \frac{\partial^2 \beta_x}{\partial t^2},$$

$$Q_x = S\gamma_{xy}, M_x = D\frac{\partial \beta_x}{\partial x}, \beta_x = \gamma_{xz} - \frac{\partial w}{\partial x}$$

$$S\left(\frac{\partial \beta_x}{\partial x} + \frac{\partial^2 w}{\partial x^2}\right) + p = \rho h \frac{\partial^2 w}{\partial t^2}, D\frac{\partial^2 \beta_x}{\partial x^2} = S\left(\beta_x + \frac{\partial w}{\partial x}\right) + I\frac{\partial^2 \beta_x}{\partial t^2}$$

$$D\frac{\partial^4 w}{\partial x^4} - \left(I + \frac{\rho h D}{S}\right)\frac{\partial^4 w}{\partial x^2 \partial t^2} + \frac{\rho h D}{S}\frac{\partial^4 w}{\partial t^2} + \rho h \frac{\partial^2 w}{\partial t^2} = p + \frac{I}{S}\frac{\partial^2 p}{\partial t^2} - \frac{D}{S}\frac{\partial^2 p}{\partial x^2}$$

Proposed Methods

- **Analytical Method:**

$$P_f = 1 - Exp\left[-\left(\frac{\sigma_1}{\beta_X}\right)^{\alpha_X} - \left(\frac{\sigma_2}{\beta_Y}\right)^{\alpha_Y} - \left(\frac{\tau_{12}}{\beta_S}\right)^{\alpha_S}\right]$$ **(maximum stress failure criterion)**

$$P_f = 1 - Exp\left[-\left(\frac{\sigma_1 \nu_{12} \sigma_2}{\beta_X}\right)^{\alpha_X} - \left(\frac{\sigma_2 \nu_{21} \sigma_1}{\beta_Y}\right)^{\alpha_Y} - \left(\frac{\tau_{12}}{\beta_S}\right)^{\alpha_S}\right]$$ **(maximum strain failure criterion)**

$$P_f = P\left[\sqrt{\left(\frac{\sigma_1}{X}\right)^2 - \left(\frac{\sigma_1 \sigma_2}{X^2}\right) + \left(\frac{\sigma_2}{Y}\right)^2 + \left(\frac{\tau_{12}}{S}\right)^2} \geq 1\right]$$ **(Tsai-Hill's failure criterion)**

- **FEA Method:**

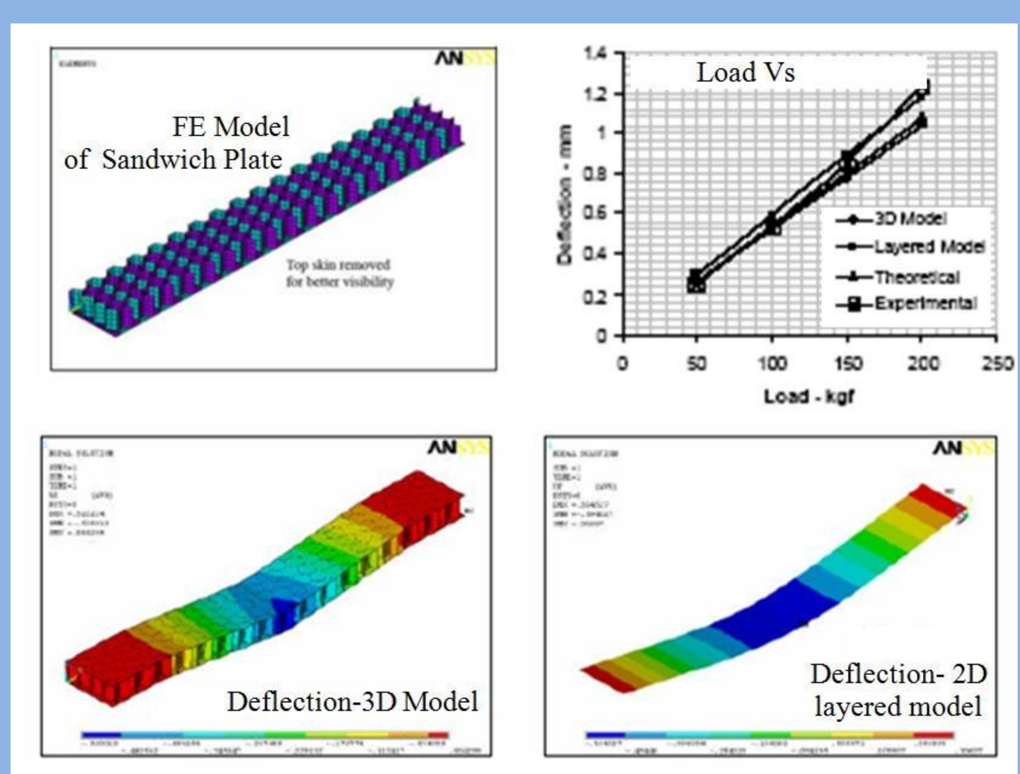

Figure 3: FEA based modelling and properties prediction

Conclusions

- It is critical to model the damage evolution accurately for reliability life prediction.
- The focus of this research will develop a new and practical model incorporating safe life methodology and damage tolerance approach to assess structural first inspection and maintenance period.
- Extending the stochastic methodology for composite sandwich structures will provide more insight into the benefits of adopting this approach for more complex and realistic composite structures.

•References

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FSI Away Day 2011