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A RBDO APPROACH FOR THE RELIABILITY ASSESSMENT OF COMPOSITE STRUCTURES

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**ABSTRACT**

The introduction of reliability assessment methods in safety analysis of composite structures increased the complexity and the efficiency of failure evaluation proposed methodologies. Here an approach based on surrogate modelling of first ply failure (FPF) to obtain the reliability of the whole composite structure is proposed and analysed for reliability-based design (RBDO). This approach overcomes the expensive costs associated with exhaustive local reliability evaluation. The identification of different failure modes and its importance in reliability analysis are outlined and discussed.

***Keywords:*** composite structures, surrogate modelling, reliability, multiple failures, RBDO.

**INTRODUCTION**

Composite plates and shells structures develop interactions in the physical response between ply, laminate and structure levels inducing failure events at different scales and competing failure paths. As a result of the associated analysis and design complexity the structural response becomes highly unpredictable since uncertainties in geometry, loading, or material properties can completely change the failure path. Composite structures introduce many failure modes and exhibit failure responses across various length scales (Boyer et al., 1997; Carbillet et al., 2009; Conceição António and Hoffbauer, 2009). In the presented paper approximate representations of failure events were introduced aiming to obtain an improvement of the efficiency in reliability analysis. The errors introduced by some approximations used in structural reliability calculations of composites are studied.

## RESULTS AND CONCLUSIONS

Defining the *Tsai number,* , as a strength/stress ratio (Tsai 1987), it can be used together the interactive quadratic failure criterion of Tsai-Wu at the *k-th* point of the structure, where the stress vector is evaluated, by solving equation

 (1)

where  are the components of the stress vector, and  and  are the strength parameters associated with unidirectional reinforced laminate. The most real scenario for the reliability assessment is to consider a reliability index  for each  in Equation (1) as follows,

 (2)

Thus the system reliability index of the composite structure is defined as

 (3)

It is troublesome to evaluate the reliability index associated with each *k-th* limit state function in an explicit way for complex structures and then to calculate the reliability of the structural system, . So, the influence of multiple failures  on the surrogate model in Equation (3) must be analysed on reliability assessment. The study is driven for the maximum load capability of the composite structure for a target reliability index, .The optimal maximum load  for  is obtained over the ply angle design variable, *a,* as follows,



subject to  and  (4)

where **** is the random variable vector. To solve the RBDO inverse problem in Equation (4), an optimisation algorithm is implemented and applied to a clamped cylindrical shell laminated structure. The composite system E-glass/epoxy (Scotchply 1002, GFRP) (Tsai 1987) is used in the presented analysis. The balanced angle-ply laminates with five layers and the stacking sequence  are considered.



Fig. 1 - Influence of load on reliability index for multiple failures, ply angle, a=70º (GFRP)

The influence of multiple failure modes in reliability assessment of composite structures is studied within the context of RBDO. The validity of the approximation used to define the structural reliability is discussed comparing with the critical . Although the most critical Tsai number is associated to critical reliability index, Figure 1 shows that the ranking in terms of Tsai number is not the same when made in terms of reliability index values.

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