

## IDENTIFICATION OF EFFECTIVE HEALING LOCATIONS FOR RECOVERING COMPRESSIVE STRENGTH

C. Knipprath, G.P. McCombe, I.P. Bond and R.S. Trask

University of Bristol, Advanced Composites Centre for Innovation and Science, Department of  
Aerospace Engineering, Queen's Building, University Walk, Bristol. BS8 1TR. UK.  
Email: [c.knipprath@bristol.ac.uk](mailto:c.knipprath@bristol.ac.uk)

**Keywords:** Self-healing, Compression testing, Genetic algorithm, Bi-objective optimisation

### ABSTRACT

This paper investigates the effective distribution of self-healing resin within a delamination area in a fibre reinforced composite material. The study aims to deliver information on the healing resin volume required for achieving mechanical performance recovery across a delamination plane. Targeted healing agent infusion of critical delaminations within the entire damaged volume is critical to minimise localised stress concentrations within the delamination plane during polymerisation, especially when optimised for healing under operational loading. A genetic algorithm (GA) [1] has been applied to perform a bi-objective optimisation [2,3] with respect to (a) maximum compressive strength recovery and (b) minimal infused healing resin volume.

In order to evaluate the first objective of maximal compressive strength, a finite element model is repetitively solved using LS-DYNA [4] incorporating the methodology illustrated in figure 1. Here a layer of cohesive elements is located in the mid-plane between two sub-laminates. The GA individually controls the state of each cohesive element within the zone of potential delaminations, located in the middle section of the specimen (see figure 1b). Through the implementation of a user defined cohesive elements [5], a deactivated element, representing a delamination, numerically functions as a contact definition. Hence, the status of an element (active cohesive formulation or delamination) can be used to generate the genetic representation of the solution domain. The state of all elements within the region of potential delaminations is encoded as a chromosome (bit string containing 1 and 0's). To ensure an acceptable run-time of the finite element model with respect to the optimisation process, a slice model with a single element thickness is used.

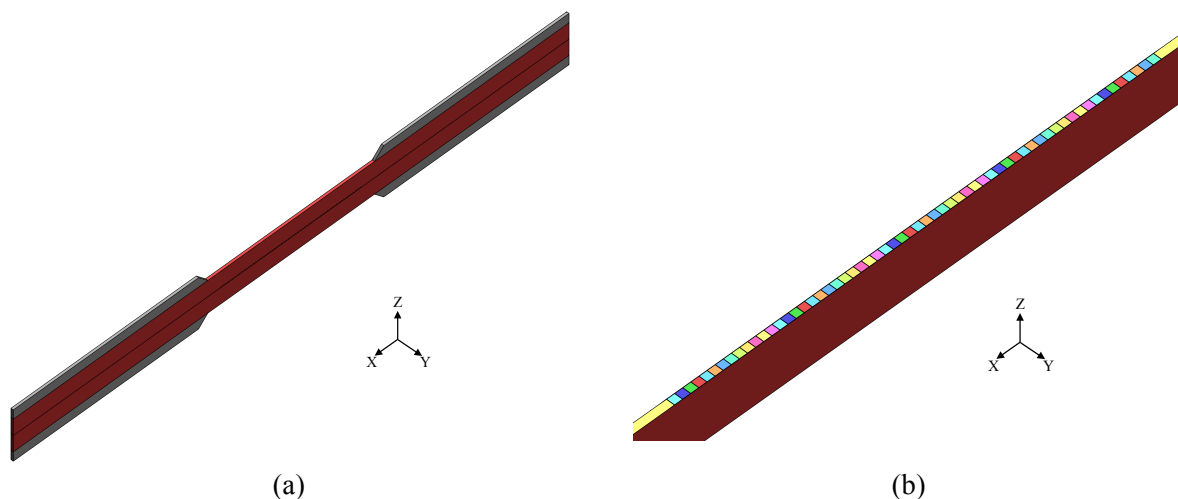


Figure 1: Finite element model for compressive strength assessment, (a) entire model and (b) cohesive element layer with emphasised healing zone.

The second objective function for the optimisation applies directly to the chromosomes of a population. The GA assesses the individual fitness of a chromosome with respect to maximal

occurrence of delaminations, i.e. the chromosome within a population that contains more 0 ‘bits’ is considered a better or ‘fitter’ solution.

Consequently, the overall fitness of a chromosome is given by the combined individual fitness values provided by both objectives. A ‘fitter’ chromosome is more likely to be accepted for reproduction. By doing so the GA converges towards a local Pareto optimal point. For such a point in the objective space, no improvement with respect to all objectives can be achieved by moving to an adjacent feasible point. Therefore, a Pareto front, schematically illustrated in figure 2, is an important tool to visualise the results of a multi-objective optimisation [6]. Here  $f_1$  represents the fitness of objective 1, namely maximal compressive strength, and  $f_2$  plots the fitness of objective 2, minimum healing resin volume. The points in figure 2 belonging to the red line represent a set of non-dominated solutions while the solutions found in the blue line, i.e. obtained from an initial guess population, are dominated by one of the objectives.

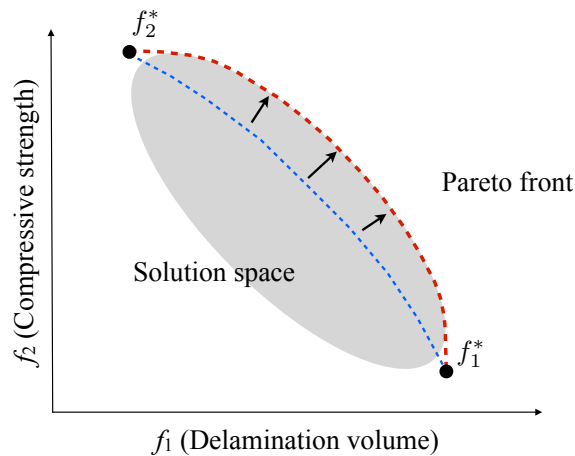


Figure 2: Schematic Pareto front for a bi-objective optimisation.

In addition to the computational efforts, experimental results are obtained for a representative subset of delamination patterns and the identified optimal solution. The results from the experimental test series are used for model validation.

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