Effect of variability of mechanical parameters on the deformation behaviour and failure of fibre reinforced plastic materials

László Kovács[1,2]

[1] eCon Engineering Ltd, Budapest, Hungary

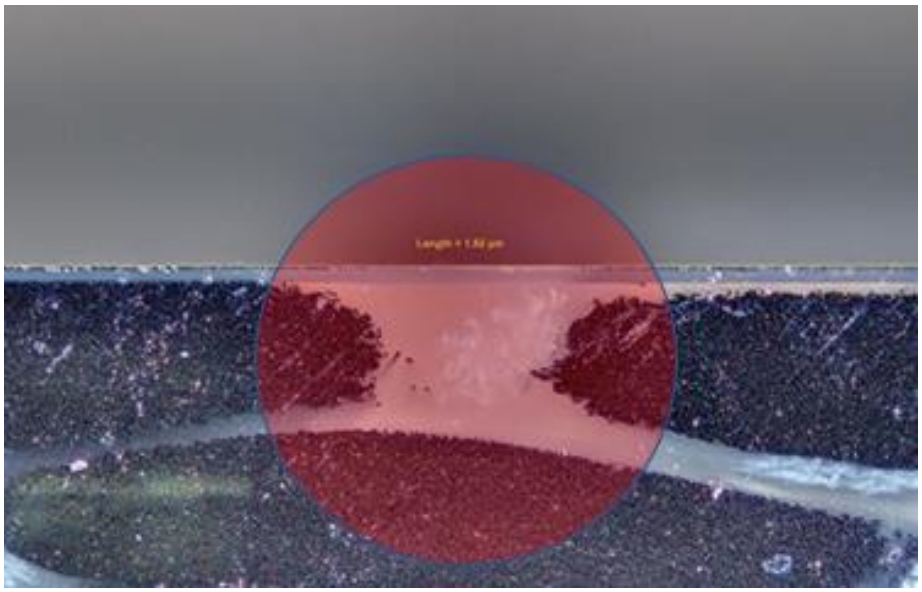
[2] Budapest University of Technology and Economics, Dept. of Polymer Engineering

Email: laszlo.kovacs@econengineering.com

Phone: +36302937135

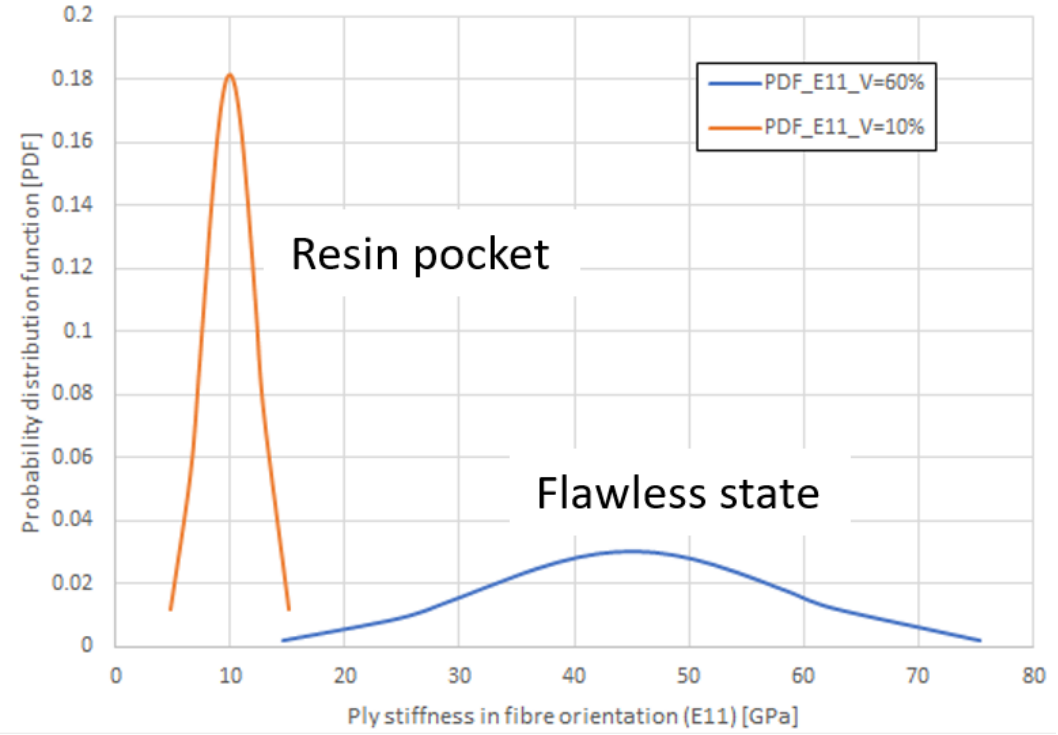
Composite parts are light, stiff and can be very durable due to the possibility to design the ply structure so that it fits for purpose. However, such high performance composite components can only be safely used in exclusive applications and narrow industry segments. Partly the reason for this is the relatively high uncertainty levels including the underlying material models (deformation as well as static failure and fatigue) and the implications of manufacturing process and defects on the mechanical performance.

This work shows how the uncertainty in stiffness and material strength data affects the properties of a selected composite part via treating the material constants (stiffness and static strength) as probabilistic variables. These ply specific material constants were inferred from Cumulative Distribution Functions (CDF) assumed for the constituents of a ply (fibre and resin). In addition, the influence of local manufacturing defects (such as resin pocket shown in 1. Figure) were quantified by assuming lower fibre volume contents in the affected zones.



1. Figure – Typical example of a resin pocket generated by a non-ideal pressing process of a composite laminate [1]

Based on the results, the fibre content determines the CDFs of the material parameters representing the lamina level as showed in 2. Figure and thus, the behaviour of the whole laminate.



2. Figure – Derived distribution of E_{11} ply stiffness with and without manufacturing defect (resin pocket)

As part of this study an extensive Monte-Carlo approach and Finite Element model based analysis was performed on a selected composite part assuming varying stiffness and strength of the base ply material with and without the presence of a resin pocket in the critical area. The Monte-Carlo assessment for mechanical parameters was fed by the individual CDFs of fibre and resin at given fibre volume content level and each individual set of material parameters was transferred to a separate FE analysis of the part for subsequent deformation and strength assessment.

As an outcome it was clearly proven that the scatter in material data can significantly (and in some cases adversely) affect the deformation behaviour and strength of a highly loaded slender composite structure. The existance of a resin rich area in a utilised zone can magnify this sensitivity, thus, ignoring the scatter in material data and manufacturing imperfections can lead to unsafe part designs.

References:

[1] M. LeGault, „Carbon fiber auto body panels: Class A paint?," 10 January 2015. [Online]. Available: https://www.compositesworld.com/articles/carbon-fiber-auto-body-panels-class-a-paint.