Title: Modelling gaps and overlaps for assessing the structural response of AFP composite structures by means of numerical simulation

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Within current composite part development and manufacturing processes a disproportional high effort is implied in order to find optimal process parameters and to meet required qualities and tolerances of high performance light weight structures. The ECOMISE project aims to enable next generation of thermoset composite manufacturing and post-processing. Within this project high precision process techniques for advanced dry fibre placement (AFP), infusion/ injection (RTI/ RTM) and curing will be developed in order to maximize process efficiency at reduced costs and production time due to less material consumption, higher reproducibility, less energy, less waste and less rework.

For the presented work the focus lies on the AFP composite manufacturing process where common manufacturing defects are investigated for their influence on the mechanical performance. These effects are caused by machine deviations, material variation and laminate designs that require ply angle transitions and consequently cutting of tows. The gap defect and the overlap defect are investigated using numerical approaches which are compared to experimental coupon test results.

A multi-scale approach is exploited, which is dedicated to assess the difference in mechanical performance of “as-designed” and “as-built” structures. This method is based on numerical simulations in order to predict the ‘as-built’ material properties of the composite laminate strength. Figure 1 shows the overall workflow in which the multi-scale analysis is embedded. By means of the multi-scale analysis local ply discontinuities can be considered and a suitable macroscopic resolution of composite ply deviations like gaps and overlaps can be provided. The effective stiffness and strength on the macro level is calculated by numerical analysis on the local level in conjunction with a homogenization. This way the macro level structural response can be calculated computationally efficient.

The results give evidence that the manufacturing defects investigated have a significant effect on the stiffness and in particular the strength. The focus of the research has been initially on tension loading. A decrease in strength for the gap defect has been observed from the finite element analyses using progressive damage methods. For the overlap cases also a strength decrease has been observed which might be related to the introduced fibre misalignment. These results are also compared with experimental test results to validate the presented approaches.

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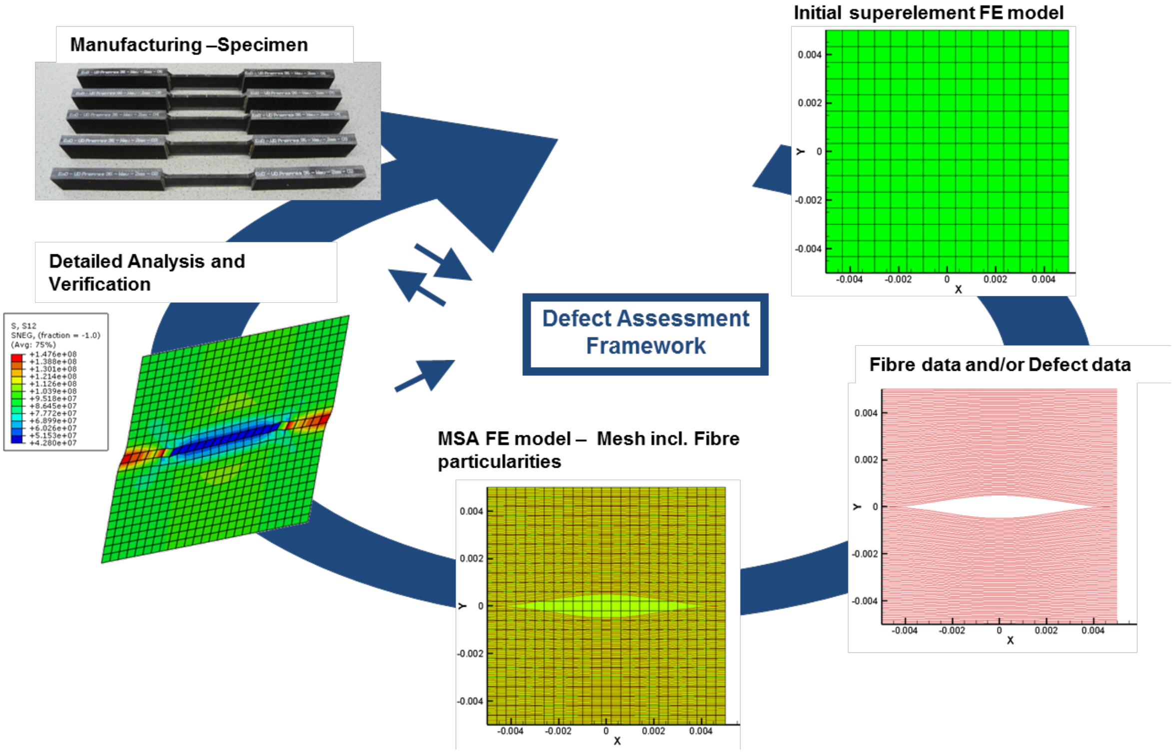

Figure 1: Schematic of multi-scale approach to capture manufacturing defects