Simulating Composites Manufacturing Processes

Michael R. Wisnom, Stephen R. Hallett

Bristol Composites Institute, University Walk, Bristol BS8 1TR, UK.

M.Wisnom@bristol.ac.uk

Abstract

Finite element structural analysis of composites is relatively mature and widely used in industry. Simulations are able to represent overall structural behaviour well, and high-fidelity models can capture detailed failure mechanisms. Simulation of manufacturing processes is much less mature and has not yet been taken up as widely by industry, but substantial advances have been made in recent years. This paper presents state of the art simulations and shows that they are able to represent important processes in composites manufacturing, offering great potential to reduce costly and time-consuming physical trials and demonstrators.

Defects which occur during composites' manufacturing can have a profound effect on mechanical performance, and so have to be taken account of in design. Process simulation can be applied to many different aspects of composites manufacturing, with scope to reduce defects by better understanding the behaviour, leading to more manufacturable parts. There are still challenges due to the complexity and inherent variability, together with the significant computational requirements for carrying out large scale simulations. However, current tools can already be used to troubleshoot problematic cases,

and the continuing improvements in computer hardware and growing capabilities of artificial intelligence mean simulation is likely to become more and more important in the future.

This paper presents examples of successful simulations of prepreg and textile manufacturing processes. Through-thickness consolidation can lead to variability and defects such as wrinkles. The process has been effectively simulated in lab coupons [1-3] and scaled up to more realistic parts [4]. Simulation of Automated Fibre Placement (AFP) has also demonstrated the ability to predict and reduce wrinkles [5-7].

Residual stresses and distortion during cure can be modelled [8,9] and the workflows automated to make application to components easier [10]. Manufacturing simulations can be linked to structural analysis to improve strength predictions by accounting for the differences between as-manufactured and as-designed parts [11]. These approaches can be applied at the structural scale to reduce the size of the pyramid of testing required for certification [12].

The as-manufactured yarn geometry is important in analysis of 3D textile parts, and simulations can capture the deformations during consolidation, leading to better predictions of stiffness and strength [13-16]. Forming simulations can also be used to reduce defects such as wrinkles [17-20]. Simulations of resin infusion processes can reduce the risk of problems such as race-tracking or dry spots and help in tooling design [21-24].

A range of examples of state-of-the-art composites manufacturing simulation techniques are presented, addressing some of the many challenges and proposing solutions which can be used to help produce better parts.

Keywords: Manufacturing, Simulation, Defects

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