## Application of a Newer Inter-Fiber-Failure Criteria on CFRPs in Aero Engine Development

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Abstract: Carbon-fiber-reinforced plastics (CFRP) are being used for highly loaded lightweight structural components for many years. Up to now mostly insufficient two-dimensional classical failure criterions, which are embedded into FE-software like Tsai-Wu, Hill, etc. have been used for the dimensioning of composites. To achieve better predictions of the three-dimensional complex composite failure behavior newer, so-called action-plane based failure criterions have been developed, e.g.: PUCK, JELTSCH-FRICKER or LaRC04. In addition to this, the complex step-by-step component failure process including post-failure load redistribution can be accurately simulated using a combination of these newer criterions with a convincing material degradation model. Within this work this new method was implemented into Abaqus to investigate the complex failure behavior of a CFRP flange connection of a Rolls-Royce aero engine. For instance, it is shown, that small radii next to the bolt-connection result in three-dimensional stress states that initialize delamination and gradual component stiffness reduction. The comparison of additional experimental and numerical data confirmed the implementation and prediction quality of new action-plane based failure criteria into Abaqus. Due to this the knowledge about the complex component behavior has been significantly extended, such that finally a cost-reducing design improvement was available.

Keywords: Aircraft, Composites, Crack Propagation, Delamination

## 1. Introduction

Aiming at more environmentally-friendly, more efficient and more powerful aero engines, lightweight structures will become more important in the future. Compared to conventional, isotropic materials, fiber-reinforced plastics leads to in reduced masses, higher stiffness-to-weight ratios and higher structural damping. Apart from these advantages a number of disadvantages occur. Some of them are for example a much lower maximum allowable operation temperature, the need for two-dimensional stress states and high requirements for load application areas.

From this, the knowledge about the complex failure behavior and the applicability of realistic failure criteria are the basis of an optimum design of multi-ply composites.

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