Chair of Carbon Composites
Department of Mechanical Engineering
Technical University of Munich

Bachelor's Thesis, Term Project, Master's Thesis

Numerical Investigation on the Influence of Alternative Needle Geometries during Insertion into Carbon-Fiber Preforms for Advanced Rocket Nozzle Manufacturing

The performance of cryogenic liquid rocket engines can be significantly improved through the use of nozzle extensions that increase exhaust gas velocity and overall propulsion efficiency. Among the most promising advancements in this field are composite nozzle extensions (CNE) that offer a drastic reduction in engine mass, which is a critical factor in aerospace engineering (Valentine, P. G. & Gradl, P. R., 2019) (Fig. 1, right). CNEs are built based on a two-dimensional textile structure, strategically reinforced in the third dimension through advanced carbon fiber (CF) stitching. Cutting-edge textile manufacturing techniques, such as tufting, enable the cost-effective production of high-performance complex geometries within the aerospace field (Fig. 2).

Needle and thread breakage limit the reliability of the tufting process in space applications. The aim of this work is to extend an existing numerical model to predict the penetration forces of various needle geometries piercing through layers of CF preform. Some model parameters need to be determined through standard experiments. The scope of this work can be adjusted according to the type of the thesis.

Figure 1: The launch of Delta IV Heavy (left), CNE of the Delta IV upper stage (right) [Wikipedia].

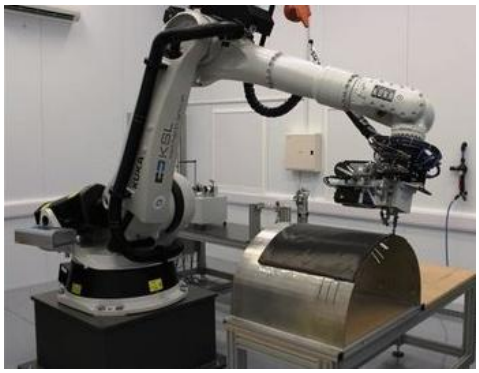

Figure 2**:** Tufting of CF components with complex geometries for aerospace applications [Dell'Anno et al. 2015].

Research focus of the thesis

- Literature research and familiarization with the existing numerical model of the tufting process
- Integration of various needle geometries into the existing Abaqus model
- Conduction of standard experiments for model parameter determination
- Extension of the model with the experimentally determined parameters
- Discussion, comparison and documentation of the results

Requirements

- Structured and thorough work attitude
- Interest and knowledge about carbon-fiber reinforced plastics
- Experience with FEA software (Abaqus) is beneficial
- Experience with the programming language Python is beneficial
- Experience with CAD software such as Autodesk Inventor
- Excellent knowledge of German or English language

Starting date: Now

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