Term Project, Master's Thesis

Investigation of Needle Indentation in 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 lightweight, high-performance components with complex geometries within the aerospace field (Fig. 2).

Needle and thread breakage due to the use of thick stacks of material and a CF sewing thread limit the reliability of the tufting process in space applications. The aim of this work is to extend an existing numerical model to simulate the needle piercing through layers of CF preform. The model should predict the penetration forces of the needle during the tufting process for various parameters.

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
- Extension of the existing model
- Discussion 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 but not necessary
- Experience with the programming language Python is beneficial but not necessary
- Excellent knowledge of German or English language

Starting date: Now

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