Intelligent Machining Cell for CFRP Mast: Case study, Roadmap & Initial proof of concept

Degree programme : Master of Science in Engineering
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This thesis explores integrating an automated machining cell at Hall Spars to address workforce challenges and cost reduction goals. It identifies other automatable operations, evaluates scanning methods to improve the digital twin, and assesses marking solutions to reduce human error. A prototype software also demonstrates the feasibility of this project.

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Context

Hall Spars is a well-established Dutch designer and producer of sailboat carbon fibre-reinforced plastic (CFRP) mast and rigging. Working in the high-end market, it operates in a high-mix low-volume model. Therefore, Hall's manufacturing process is exclusively manual and faces challenges in finding the workforce. Hall aims to solve these challenges through automation.

The manufacturing process starts by having the mast laminated and cured, then moves to the pre-assembly, where all the various openings and part fitting are manually made. Then, the mast goes through a sanding and painting stage before having all the rigging and electronics installed and checked. The pre-assembly stage is the most critical and time-consuming stage of the manufacturing process, requiring experienced and skilled workers.

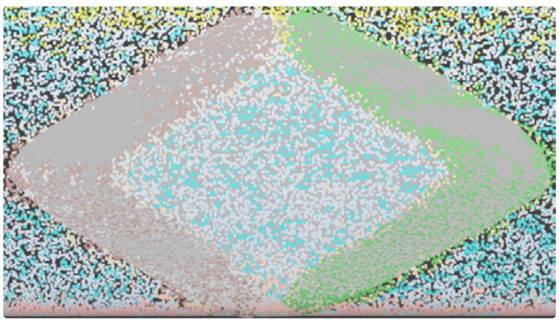
Goal & Approach

This master's thesis investigates how an automated intelligent machining cell can be implemented as a first step in that direction. The project is divided into four sections.
First, it provides a comprehensive list of manufacturing steps suitable for automation. It profiles each project by grading their complexity, ROI and added value. Secondly, it evaluates various scanning methods to acquire a valid digital twin, ensuring accurate CAD data to assist the machining process. This step is seen as a crucial part as it can offset the variability of the manufacturing process and is the foundation of an "intelligent" system. Thirdly, this thesis compares and grades different marking solutions to establish references on the mast. The goal is to reduce human error and use the new marking method as a stopgap solution before introducing a machining centre to the manufacturing process. Lastly, a prototype software processes the scanned data to extract the critical features necessary for the machining process. This is the first step to creating "intelligent" software that adjusts the machining operation according to the actual part.

All of the parts are made of carbon fibre-reinforced plastic, and the manufacturing process is manual.

Results

My work highlights the benefits of a scanning solution using a laser tracker and a structured light scanner. It also suggests a two-stage deployment, starting only with the laser tracker, offering more time to gain experience with the new tool. My analysis also elaborates on the probable unnecessary aspects of the marking meant as a stopgap. Lastly, the trial data processing software I developed convincingly recognises the critical features for machining.
In conclusion, my work outlines an overarching roadmap with four distinct steps to introduce a state-of-the-art machining solution. The first two steps will have the most significant impact, reducing costs and bringing new capabilities to the company. The last two steps are more optimising and minimising the manhours through some automated processes.



Outline of a reinforcing patch given by the prototype software.