Optimising the Manufacture in Composites Materials of a Box Shaped Geometry through Ergonomics and Human Factor Assessments

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1. Introduction

Contact moulding, (or open moulding) is a low cost manufacturing process using composite materials, utilised to make the widest variety of composite products. It generally includes brushing a gelcoat into a mould followed by the application of a reinforcement (typically fiberglass), then 2 part pre-mixed resin, over the surface. The resin is rolled into the reinforcement with some degree of force to remove entrapped air and to thoroughly wet-out and consolidate it. Product quality is dependent on operator skill, materials when prepared and applied, mould size and surface preparation.

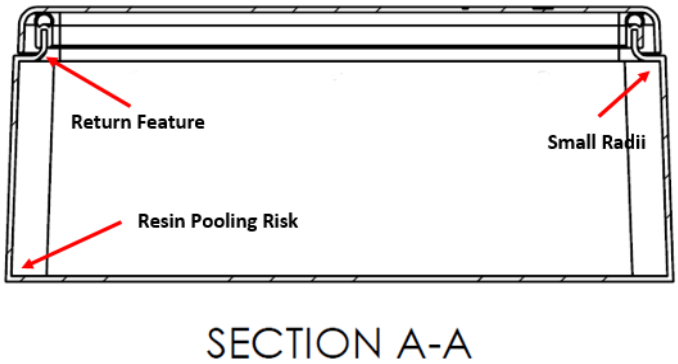

Figure 1. Composite box geometry.

This paper reports on research into improvement and defect risk minimisation in manufacture of the box-shaped geometry in Figure 1. As a geometry, it is deceptively simple. It requires the use of experienced operators by being labour intensive, owing to its small volume with sharp corners, and the return features make forming the reinforcement into shape particularly hard. This potentially makes the product-to-product result rather variable and unoptimised, owing to a lack of instruction in manufacture and different operators apply their own learnt processes and experiences.

2. Methods

Three staff members of varying experience levels were observed making the candidate structure using their own procedures. Manufacturing the box geometry was recorded by the use of video and semi-structured questioning of the processes employed per staff member. The expectation was to assess activities and variations according to product manufacture. Observations centered on tool use, task sequence, and materials consumption/application. The methodology then explored materials in use, with aims of reducing manufacturing burden and improving process control.

Finally, manufacturing management tools were employed to assess the process (cause and effect diagrams, process flows, takt time, and Pugh matrix to identify the suitable tools for the product).

3. Results

Table 1 summarises normalised results from observing and recording laminators manufacturing the box-shaped geometry. Whilst takt time was reasonably consistent, significant variation in manufacture occurs, mostly evident through waste generation. This potentially progressed into part quality as the Volatile Organic Compounds (VOC's) can be a measure for the extent of resin use and cure quality, as well as impacting the working environment. Significant variation in general process of manufacture was not observed between experienced staff, however when examining the video for specific activities, the task sequence and method of applying materials (quantity, preform shape etc.) suggested major variation. This was further corroborated by analysis of the tools in use, which showed no consistency for type, application, nor quality impacts.

Table 1. Observation results from manufacture of the box-shaped geometry, normalised to Laminator 2.

Laminators	Takt time	Material Wastage	Cost	VOC (max.)
1 (Experienced)	1.14	1.63	1.12	High
2 (Experienced)	1	1	1	Medium
3 (Beginner)	N/A	1.88	1.19	High
New Method	0.56	0.25	0.69	Low

From this initial review, a trial and error process of method improvements for ergonomic and human factor (HF) processing was undertaken. This included:

- Using a Pugh matrix to identify the right tools for each step in the manufacturing process, using conditions of comfort, quality, and geometry matching - leading to a drastic reduction in the number and variation used.
- Identifying the critical path for manufacture, to form reliable instruction sets - leading to a halving of the number of previous operations used.
- Exploring improvements in materials (quality, quantity) - leading to the introduction of methods to control materials application, preparation, variation, and waste.

When fully implemented as a combination, the impact of this is clear (Table 1 'New Method'). It suggests capture and exploitation of operator knowledge in diverse areas such as materials, manufacturing management, ergonomics, and HF studies can be combined to better inform process control in the manufacture of a component with high variability in task sequence and operation.

4. Conclusions and Further Work

This work has shown how ergonomics and HF studies can be employed in manufacture of a simple composite component, produced exclusively with human operators. The activity showed that takt time improvement ~ 50%, and waste reduction of ~25% are possible, simply by observing laminators activities and employing best practice. By minimising the materials in use, significant improvements in the environmental working conditions were also possible. There are research limitations in the work

(sample size means it should be considered a pilot study). Future work will require a continuation of data collection to further validate these initial results; and exploring the design of the geometry, to further improve ergonomic factors.

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