Sivanathan, L., Ward, C., & Koutsomitopoulou, A. (2016). Optimising the Manufacture in Composites Materials of a Box Shaped Geometry through Ergonomics and Human Factor Assessments. Paper presented at Ergonomics and Human Factors 2016, 19-21 April 2016, Staverton Park, Daventry, Northamptonshire, United Kingdom.

Peer reviewed version

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

Laxman SIVANATHAN[1], Carwyn WARD[1], Anastasia KOUTSOMITOPOULOU[1], and Guy ATKINS[2]

1. *ACCIS, University of Bristol, Queens Building, Bristol, BS8 1TR, UK*

2. *Jo Bird & Co Ltd, Factory Lane, Bason Bridge, HighBridge, TA9 4RN, UK*

Keywords. Contact moulding, manufacture, ergonomics, human factors

1. Introduction

Contact moulding, also known as open moulding, is a low cost manufacturing process using composite materials; and is utilised to make the widest variety of composite products in various sizes and shapes. It generally includes brushing a gelcoat into a mould (for high quality surface finishes) followed by the application of a reinforcement (typically fiberglass), and then a 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 the skill of the operator, the materials when prepared and applied, the mould size, and the mould surface preparation.

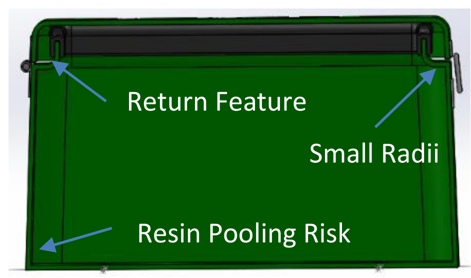

Figure 1. Composite box geometry.

The aim of this paper is to report on research into the improvement & defect risk minimi-sation in the manufacture of the box-shaped geometry in Figure 1. As a geometry it is deceptively simple. It requires the use of rather experienced operators by being labour intensive, owing to its small volume with sharp corners, and the return features especially 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 its manufacture and that different operators apply their own learnt processes and experiences.

2. Methods

First, three staff members of varying experience levels were observed making the candidate structure using their own procedures. Manufacturing of the box geometry was recorded, uninterrupted, by the use of video and semi-structured questioning of the processes employed per staff member. The expectation was to be able to assess activities and variations according to product manufacture. Observations centered on tool use, task sequence, and also materials consumption/application. Once complete, the methodology then moved onto exploring the materials in use, with aims of reducing the manufacturing burden and improving process control (to reduce costs). Finally manufacturing management tools were employed to assess the process. These were cause & effect diagrams, process flows (value added and non-value added activities), takt time, and the Pugh matrix to identify the suitable tools for the product.

3. Results

Table 1 summarises normalised results from observing and recording the laminators manufacturing the box-shaped geometry. It suggests that 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 on the working environment. Significant variation in the general process of manufacture was not observed between the experienced staff, however when examining the video for their specific activities then the task sequence and method of applying materials (quantity, preform shape, order etc) suggested major variation. This was further corroborated by the analysis of the tools in use, which showed no consistency for type, application, or quality impacts.

Table 1. Observation results from the 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 processing was undertaken. Relating to earlier observations, 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, for quality and 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 how capture and exploitation of operator knowledge in diverse areas such as materials, manufacturing management, ergonomics, and human factor studies can be combined to better inform for process control in the manufacture of a component with high variability in task sequence and operation. Further, measurable product quality and working environment improved through this work.

4. Conclusions and Further Work

This work has shown how ergonomics and human factor studies can be employed in the manufacture of a deceptively simple composite component, produced exclusively with human operators. The activity showed that tact time improvement in the range of 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, mainly in that the 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; as well as exploring the design of the geometry, to further improve on ergonomic factors.

5. Acknowledgements

This work was supported by the Engineering and Physical Sciences Research Council through the Centre for Doctoral Training in Composites Manufacture (Grant: EP/L015102/1). The authors also gratefully acknowledge the collaborations of the laminating staff at Jo Bird & Co Ltd in this research activity.