PRODUCTION METHOD EVALUATION FOR LARGE CYLIDRICAL COMPOSITE PARTS UNDER A COST PERSPECTIVE

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Abstract
A major challenge in composite design and manufacturing is accurate cost estimation. It can be demonstrated, that not only the raw material costs are the main cost driver, butsecondary processes as machining, assembly and the according subcomponents are also cost drivers to be challenged.

1. Introduction

1.1 Market description

Composite parts have been widely used in the civil aircraft industry, especially on the latest development programs. Historically, the main selling proposition for composites has almost always been the weight benefit, often aligned with added assets such as acoustic performance, electrical shielding or thermal insulation. Additional costs were often accepted due to expected performance increase (e.g. higher payload) or lower fuel consumption. Cost-to-weight-ratios (CTW-ratios) were applied to parts, often favorable judging lightweight designs, as the expected gain over during average service time was considered to be more beneficial.

As of today, the market paradigm for weight saving over cost saving seems to be shifting. CTW-ratios are significantly reduced, and the target costs applied to developments are less forgiving. Therefore, the aim must be to estimate production costs from the very beginning of the development phase, in order to adapt the design to the most economic manufacturing route [1]. This can either be achieved by a dedicated cost analysis engineers as part of development teams, or with the use of software-based cost analysis tools. Whilst commercially available software fulfills its task on past-production cost analysis, pre –design cost estimation is not yet demonstrated sufficiently [2].

1.2 Part description

In order to validate several cost reduction hypotheses, the ideal part candidate needs to be
- established in serial production for several years, avoiding ramp up phase influence
- manufactured for several customers to have different assessment values

- in comparable, yet not identical designs
- examined well enough to provide reliable cost data

All criteria were matched by the outer bypass duct, a cylindrical structure vital for the performance of modern bypass jet engines. It is a structural part defining the gas path for the cold airstream and transfers loads from the front flange to the rear flange, with main load cases being bending and tension along the engine axis as well as inner pressure.

Figure 1. Example of an outer bypass duct, assembled

This part is produced in different diameters, various configurations (e.g. integral or differential, sandwich or monolithic, with or without acoustic treatment), for different jet categories ranging from small business jet engines to large scale passenger aircraft engines and for several customers. It has been in production for over a decade, with reliable cost data available.

2. Cost analysis and breakdown

In order to identify the cost drivers and validate their contribution to the total manufacturing costs, in-depth analysis of the existing cost data was performed. A breakdown of costs was performed over almost fifteen different existing configurations to determine a significant causality for expected cost drivers, independent of manufacturing route, design or customer.
The data has then been normalized in percentages of the actual production costs, as the absolute numbers would be substantially different, depending on part size.

As a starting point, manufacturing costs can be described along

$$\sum PC = \sum MC + \sum LC + (\sum AC) \tag{1}$$

PC= production costs; MC= material costs; LC= labour costs; AC= additional costs (e.g. transport, administration, R&D)

In this study, additional costs summarizing all non-directly production related costs were neglected.

2.1 Material costs

The raw material costs of FRP parts often considered being the dominant cost driver, as, in comparison to metals, the raw material prices scale by a factor 10 and more [3]. The first idea therefore was to create a breakdown of the total material costs into the major cost groups:

- CFRP raw material costs
- Honeycomb costs
- Purchased metallic parts (incl. inserts and rivets)
- Other parts

The material cost distribution is very even among the test sample, with a deviation of maximum 3 percent. This was rather unexpected, as the part sizes vary significantly (diameters from 0,7 to 3,6m; length from 1,1 to over 3m).

Unsurprisingly for an almost pure CFRP part, the CFRP parts accumulate over 50% of the total material costs. It is still interesting to see, that the purchased parts (standard parts such as titanium fasteners and rivets) accumulate to the second most expensive material costs, way ahead other materials, which sum up bonding and sealing materials.
Whilst some bypass ducts are monolithic structures and therefore do not have spendings for honeycomb, the large (and expensive) structures make heavy use of both Nomex® and aluminum based honeycombs. It is therefore very important to see that honeycomb material costs are not very important as cost drivers. A graphical overview of the material cost distribution can be seen in figure 2.

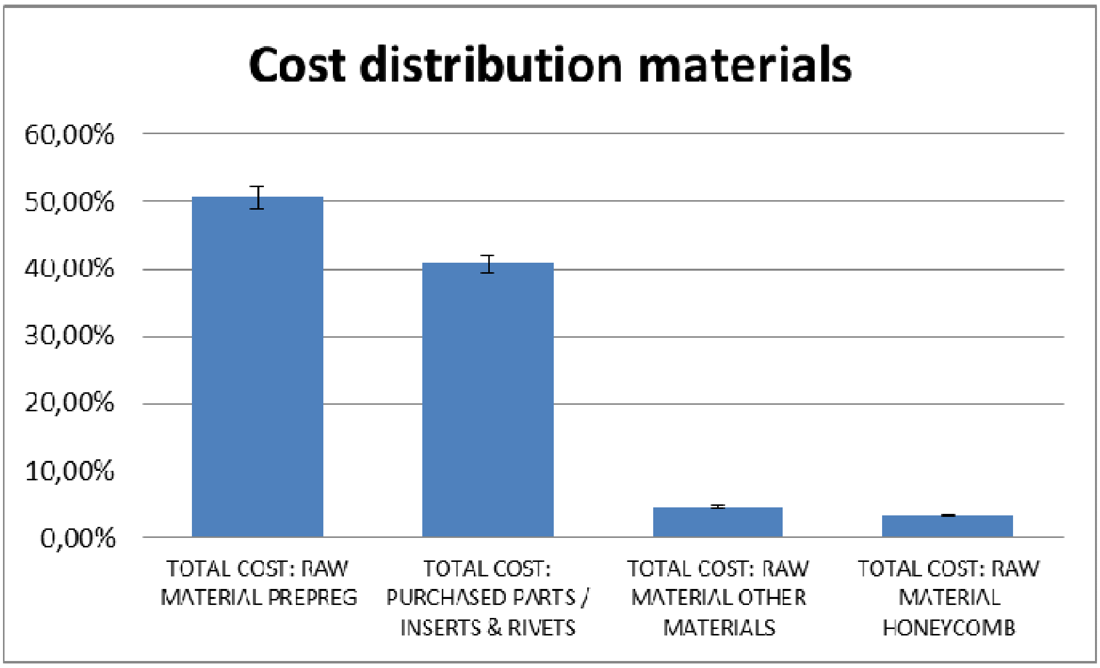

Figure 2. Material cost distribution, normalized

2.1 Labour costs

After the materials costs have been classified, the labour costs are analyzed. The classification of times has been set along the quality inspection gates within the manufacturing process, as those inspection steps are identical among the sample. The main cost driver, which is the manual layup of the parts, contributes about 35% of the total labour costs. The two other major cost contributors, insert installation and deburring & countersinking, can both be related to the installation of fasteners and inserts. Another important cost driver is the quality inspection (Non-destructive testing and dimensional inspection), mainly due to expensive equipment. All other matters of expense are below 5 percent of the total costing (see fig. 3).

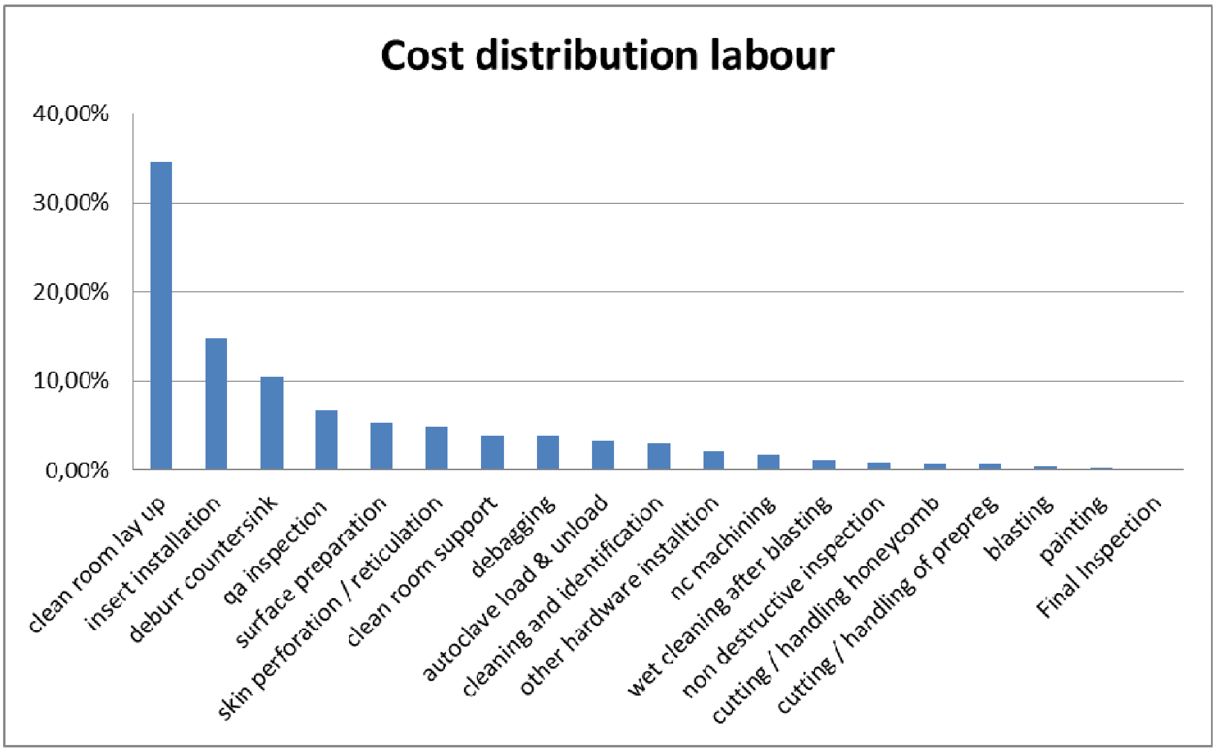

Figure 3. Labour cost distribution, normalized

2.3 Total cost analysis

Whilst the separation of material and labour costs allows a better overview of process capabilities and material cost effectiveness, the absolute interest lies in the cost distribution of the total part.

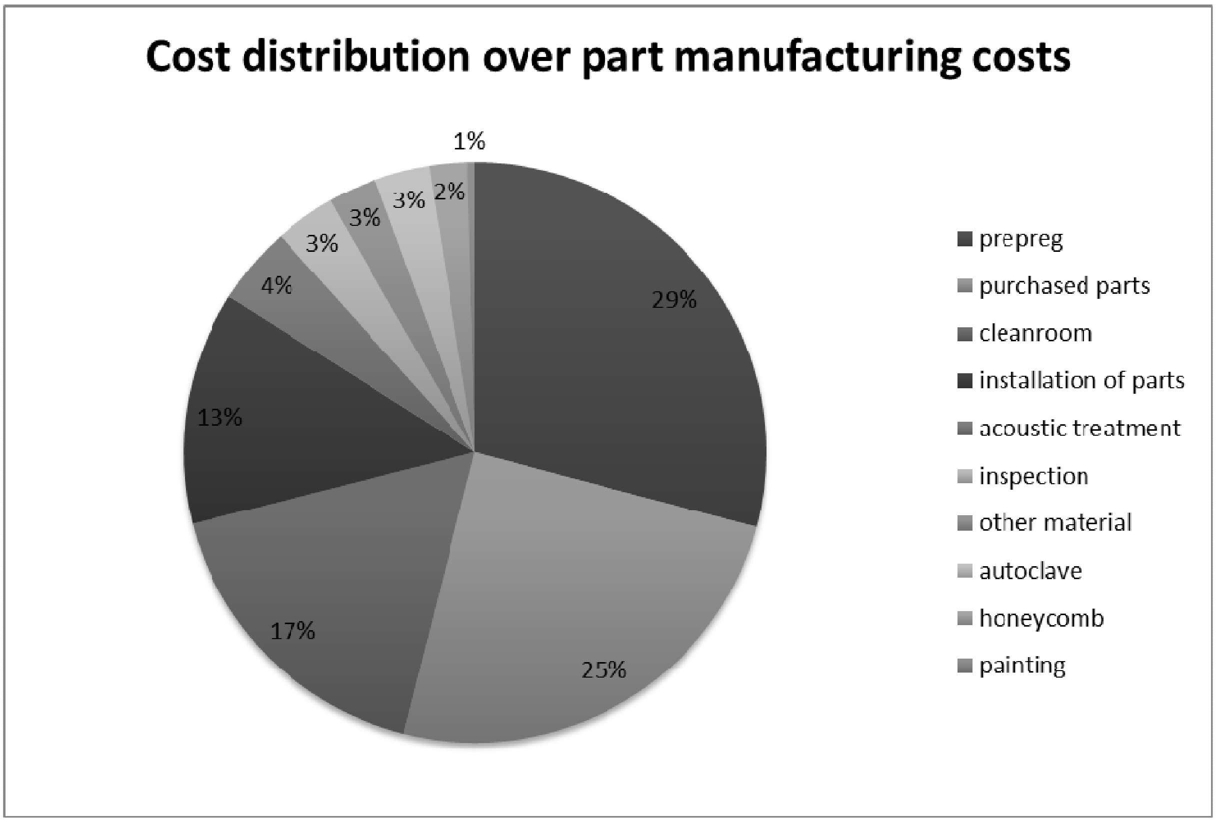

Figure 4. Total cost distribution, normalized

The most interesting fact which can be derived from fig.3 is, that the sum of prepreg and layup costs [~46%] is expectedly high for a CFRP part, but the sum of purchased parts and installation of them is not far behind [~38%].All post-curing machining and installation including the acoustic performance enhancement sums up to 42%!
The major cost reduction options are therefore to

- Reduce the prepreg purchase costs significantly
- Automize the manual layup and post cure machining
- Reduce the amount of purchased hardware

3. Cost estimations

A market research for low cost CFRP prepregs conducted by FACC AG showed a cost potential for a maximum purchase price reduction of 15 percent, resulting in a total part price reduction of approximately 2 percent, not considering the lower processability of certain low-cost prepregs. Major reason for that is the aerospace qualification requirement, which limits potential suppliers to known manufacturers.

Automation is a key technology for the production of CFRP part. If it is possible to reduce the layup time by 50 percent (a rather pessimistic value for automation, see fig 5.), the total part costs can be reduced by almost 6 percent already. Combined with the automation of assembly, another 8 percent reduction rate is possible.

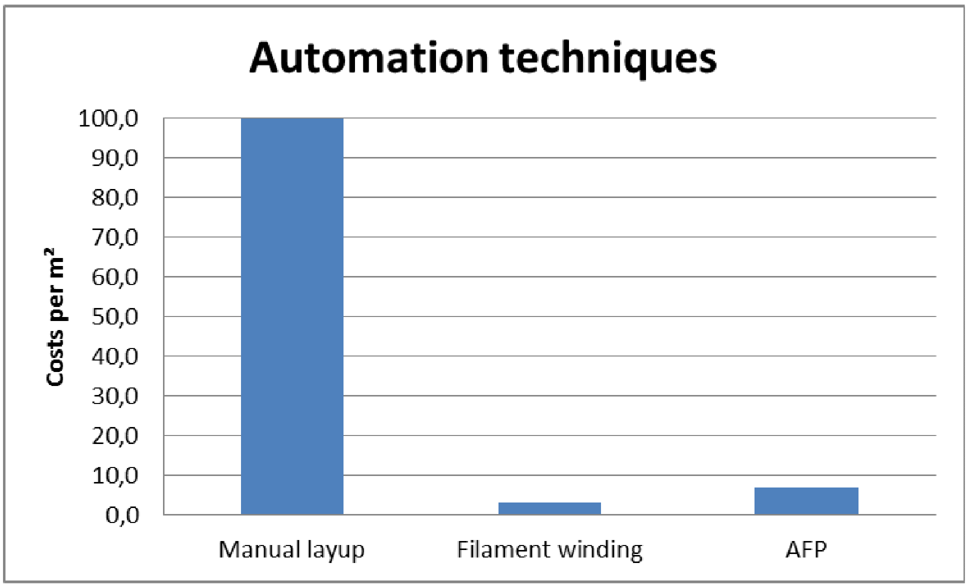

Figure 5. Potentials for several automation techniques, normalized

The easiest cost reduction can be achieved by addressing the additional parts. On current designs, all fastener combinations are made of titanium and were never changed due to potential weight issues and low expectations in the benefits. With the given cost data, an analysis replacing the costs of the titanium inserts with stainless steel showed a remarkable cost reduction over 9% with a weight gain of less than a kilogram.

4. Conclusion & acknowledgement

With the database now created, the cost estimations can be performed at very early design stages. Whilst additional work needs to be done, especially on the manufacturing time assumption, the current results are promising. The separation of costs into very detailed production steps and the grouping into categories afterwards demonstrates vital information for cost competitiveness.

The ongoing work will adapt the gathered information to other cylindrical-shaped parts and compare it against existing cost data.

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