Zero defect manufacturing in the aerospace industry

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Some questions for you

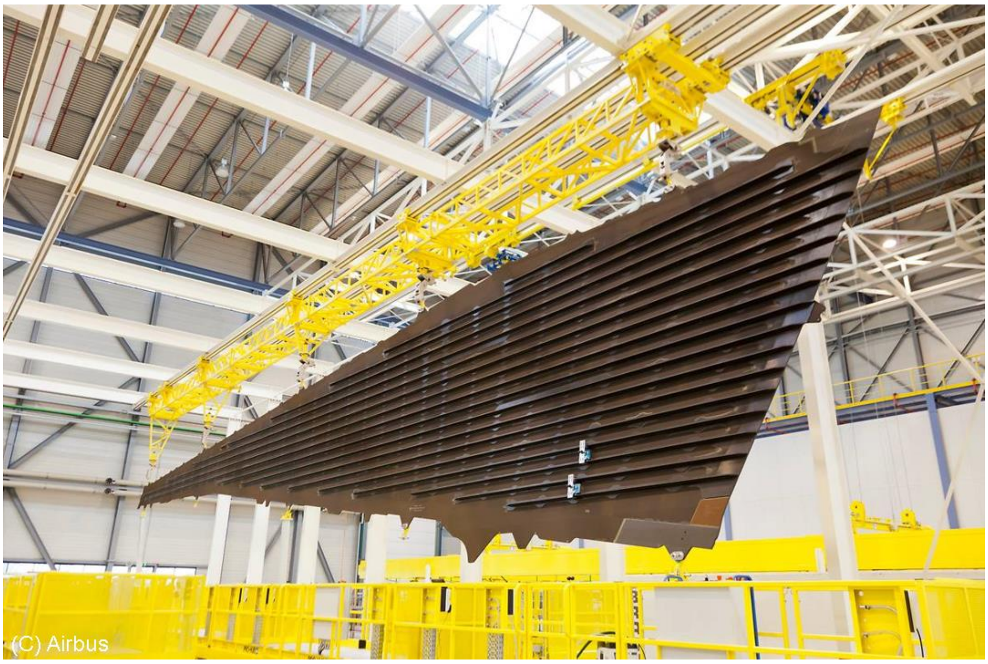
- Why does the aerospace industry need a zero-defect approach, given that they already have very tight quality control?
- Have you ever thought about what is needed so that we all can fly safely?
- What does it take to manufacture a large structural aerospace component and make sure it "flies"?
- What could be the future of quality control in this domain?

Quality control in the aerospace industry

For good reasons the aerospace industry has adopted very tight quality control regulations and requirements regarding documentation. A plane that carries more than 300 passengers simply needs to be safe and any kind of failure may have catastrophic consequences. The current approach to quality control for structural parts is to perform extended end-of-line testing, typically including ultrasonic testing, followed by X-Ray inspection for those parts that have showed deviations from specification. The manufacturing of a large carbon fibre structural component, eg a wing cover, costs several 100.000€ and if defects show up during the end-of-line tests, parts are not scrapped but re-worked. Such re-work is time-consuming and occasionally finite element calculations are repeated including the re-worked elements to make sure that the part is still specification compliant. These calculations assess the mechanical strength of the part and ensure that there is still sufficient margin of safety left, even after the re-work. Obviously all of this goes with a significant amount of documentation. About 30% of the manufacturing costs of structural components relate to quality control.

Zero defect manufacturing enables the early defects detection through inline monitoring and direct process feedback. Process deviations that are detected early can often be re-worked in a much simpler way [1]. Using again the example of a carbon fibre part, a defect, eg a foreign object caught on a layer of carbon fibre, can be easily removed while the lay-up process is still ongoing. But once the part is cured and finished, all the carbon fibre layers need to be ground down to the depth of the defect, followed by a local re-building of the layered carbon fibre structure. Based on defect statistics it is estimated that about 50% of the defects could be corrected earlier in the process, which would greatly reduce the number of defects that show up during the end-of-line testing.

However, zero defect manufacturing has more to offer than just a reduction of rejected / non-compliant parts. Through inline monitoring systems detailed information about the manufacturing process is acquired at the level of single part. It is thus possible to collect all these data in a digital twin of the part. This will result in a model of the part 'as manufactured' and enable, eg to perform quick finite lement calculations [2] that determines the mechanical properties of this specific part. Such information can be used already during the production to assess whether the re-work is required. This is a



substantial change from quality control based on fixed tolerance limits. Fixed limits need to include very high safety margins, as they cannot consider all possible combinations of deviations and always need to be based on a worst-case assumption.

What will ZDMP achieve?

ZDMP aims at the development of several components that will be helpful for the aerospace industry. Most notably, there are inline inspection systems that can be integrated directly into the manufacturing process. This will substantially improve the efficiency of quality control. Data analysis methods based on recent machine learning techniques, such as convolutional neural networks, will help with the classification of process deviation and provide feedback to the quality expert. Decision support tools will display information, such as the impact that a certain deviation might have on the performance safety margin of the particular part. This will allow a much more targeted decision as compared to generically applied (worst case) tolerance limits.

Considering the need for documentation in the aerospace industry, also the digital twin technologies developed in ZDMP will be helpful. Through these technologies all the data can be collected in a structured way and create a full representation of the part 'as manufactured'. A digital twin, however, will go beyond of a process of collecting data. For structural parts, finite element calculations can be done, using models of possible deviations and predicting the knock-down factors under the specific load case scenario for this part.

The goal of all these methods is to make sure that all critical deviations are corrected as early as possible. One might claim that zero defect manufacturing and ZDMP have reached their long-term vision, when end-of-line quality control is no longer needed – even in the aerospace industry.

ZDMP Links

• **Architecture Component(s)**	Prediction and optimisation run-time
• **Work Package**	WP7 – Process Quality
• **Tasks**	T7.2 – Equipment performance optimisation

References

[1] Christian Eitzinger, Sebastian Zambal, Inline Inspection Technologies for Processing of Dry Fibre Materials, Conference of the Society for the Advancement of Material and Process Engineering (SAMPE), Southampton, 11th-13th September 2018

[2] Sebastian Zambal, Christian Eitzinger, Michael Clarke, John Klintworth, Pierre-Yves Mechin, A digital twin for composite parts manufacturing, Conference on Industrial Informatics, Porto, 18th - 20th of July