Abstract ICMAC 2018

Authors: Dominik Delisle, Markus Schreiber, Christian Krombholz, Jan Stüve

German Aerospace Center
Institute of Composite Structures and Adaptive Systems
Ottenbecker Damm 12
21684 Stade
Germany

Topic: High rate deposition and rapid processing technologies

Efficient Wing Cover Manufacturing by Means of Cooperating Robots

To increase the competitiveness and efficiency of next generation aircraft, the production costs and the time of production of large structures made out of carbon fibre reinforced plastics (CFRP) need to be reduced. Among other things, this can be achieved with highly industrialized layup technologies as well as improved layup strategies. At present the technologies of automated tape laying (ATL) and automated fibre placement (AFP) are predominantly used for the automated manufacturing of fibre reinforced structures. A closer look at current fibre placement process, however, shows that the proportion of fibre deposition over the entire production time is usually in the order of 13 to 40%. This is due to visual inspections and reworks, planned and unplanned maintenance as well as material loading processes of the placement units [6, 9]. With the research platform GroFi®, the german aerospace center (DLR) in Stade has therefore developed a new manufacturing approach through which the manufacturing time can be significantly reduced. By the use of several cost-effective robot units which operate autonomously and automatically on a rail system, a parallelization of manufacturing and maintenance work, as well as the use of cooperating units working simultaneously at the same part is achieved. The suitability of the GroFi® concept could be demonstrated for the first time in the middle of 2017 by manufacturing a wing cover using two AFP layup units (see Figure 1). In addition the improvement in efficiency of a fiber placement process using multiple industrial robots was investigated.

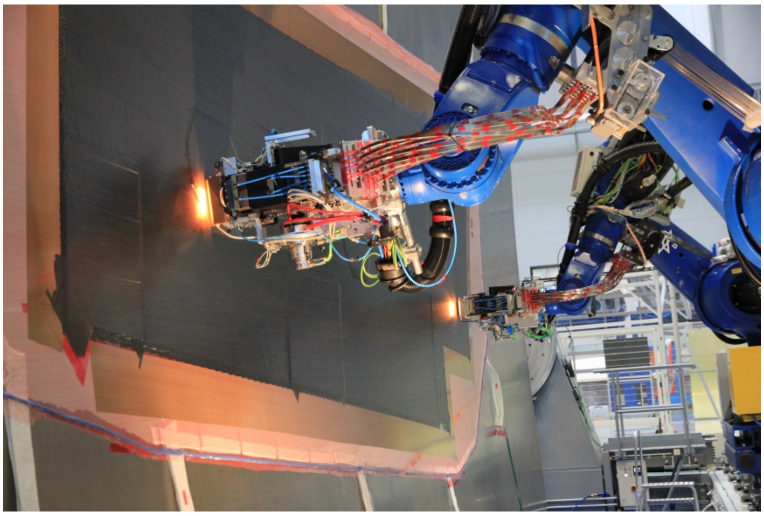

Figure 1 Automated wing cover manufacturing using two AFP units (© DLR)

Within the scope of the GroFi® concept the production process should be simultaneously executed by several layup units moving on the same rail, using dynamic and overlapping work spaces. To enable this multihead approach, DLR developed a task scheduling tool, which provides work packages to available robot units with respect to productivity and collision avoidance by using specialized mathematical models and algorithms.

For the modelling of the layup process the Quay Crane Scheduling Problem (QCSP), an intensively researched problem with some similar constraints, gets modified. The QCSP considers scheduling the process of loading and unloading ships on sea port container terminals using several quay cranes. The aim usually is generating time efficient schedules. A detailed description of the problem can be found in [7], and surveys of scientific papers in [3] and [4].

This problem was selected because of an analogy in its machine movement. In both, the QCSP and the process described above, the machines are mobile on a shared linear track and cannot pass by each other. Bierwirth and Meisel presented an MIP formulation for the QCSP which respects crane movement and interference in [2]. The quay cranes in the model of [2] do not move on the track while loading containers in a bay. The layup units on GroFi® can move on the rail while applying prepreg on a tool. This difference causes the need to modify the model. The details of the modifications go beyond the scope of this paper.

The aim for the first solver for this problem is to find good schedules that are not influenced by an intuitive strategy. The solver should be able to find schedules for problems of realistic size. In [5] Chung and Choy developed a genetic algorithm for the QCSP which performs well for Kim and Park's benchmark instances in [8]. It was modified by the Precedence Preservative Crossover, a crossover operator, which was introduced in [1] to reduce computational effort that is caused by the big number of precedence, constrains in the problem. The DLR solver was implemented in MATLAB and tested on several wing components.

The GroFi® multihead-approach was demonstrated for the first time by realizing a real manufacturing process using two coordinated layup units working simultaneously (see Figure 1). Therefor a generic wing cover with a span of 8 m was manufactured. The complexity of the demonstrator design, thereby, presents all challenges of a real wing, made out of CFRP.

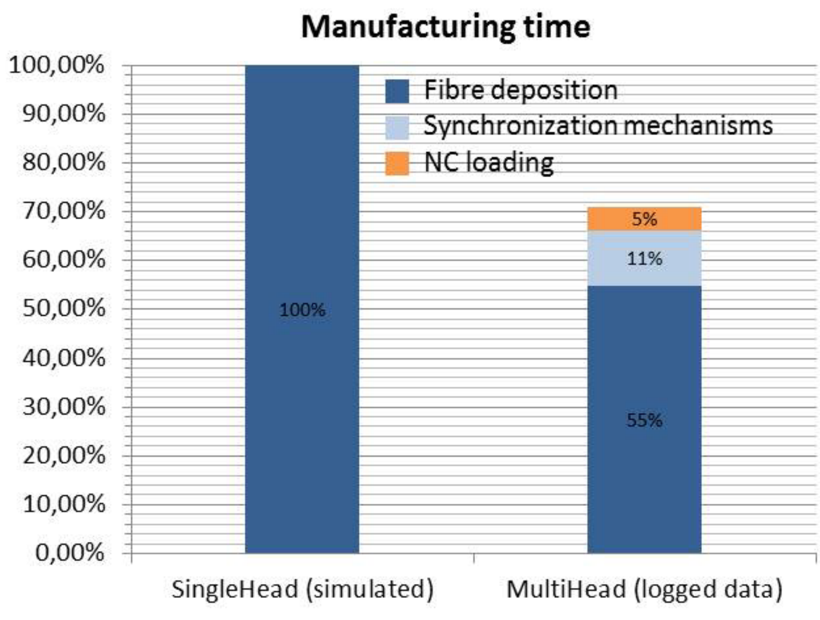

Figure 2 Evaluation of the manufacturing time of the EWiMa demonstrator (© DLR)

The improvement in efficiency of the multihead approach, compared to a single unit manufacturing process, was validated by using process data which was recorded during the production process by a manufacturing execution system (MES). Since the wing demonstrator was merely manufactured once, using two layup units, the manufacturing time for a single unit process was simulated. For that reason a validation of the simulation environment of the GroFi research platform was performed in advance. It could be shown that the deviation between simulated and recorded production times is less than 2%. On this basis the validation of the improvement in efficiency of the multihead approach was performed. The results are shown in Figure 2. It can be seen that in the present case a time saving of approximately 30% can be expected through the simultaneous use of two coordinated layup units. The time needed for loading NC-programs results from the current data and communication structure of the GroFi® research platform. This is designed for research operations and can be optimized for industrial use.

The results shown in Figure 2 only represent the current status of the DLR scheduling tool and the MES of the GroFi® research platform. Further development of both systems holds additional potential in terms of time saving. As an example synchronization mechanisms are used to ensure a higher level of safety with regard to collision control. By further development of the online collision monitoring of the MES, these mechanisms can be adapted and thus a greater improvement in time saving can be expected. In addition, currently, the scheduling of the manufacturing process considering multiple layup units takes place offline. In the future, further developments will allow an online re-scheduling, which will make it possible to respond to unplanned maintenance or errors and thus increase the flexibility and efficiency of the manufacturing process.

References

[1] Christian Bierwirth, Dirk C Mattfeld, and Herbert Kopfer. On permutation representations for scheduling problems. In Parallel Problem Solving from Nature-PPSN IV, pages 310–318. Springer, 1996.

[2] Christian Bierwirth and Frank Meisel. A fast heuristic for quay crane scheduling with interference constraints. Journal of Scheduling, 12(4):345–360, 2009.

[3] Christian Bierwirth and Frank Meisel. A survey of berth allocation and quay crane scheduling problems in container terminals. European Journal of Operational Research, 202(3):615–627, 2010.

[4] Christian Bierwirth and Frank Meisel. A follow-up survey of berth allocation and quay crane scheduling problems in container terminals. European Journal of Operational Research, 244(3):675–689, 2015.

[5] Sai Ho Chung and K. L. Choy. A modified genetic algorithm for quay crane scheduling operations. Expert Systems with Applications, 39(4):4213–4221, 2012.

[6] Allen Halbritter and Robert Harper. Big Parts Demand Big Changes to the Fiber Placement Status Quo. In *SME Composites Manufacturing*, 2012.

[7] Kap Hwan Kim and Young-Man Park. A crane scheduling method for port container terminals. European Journal of operational research, 156(3):752–768, 2004.

[8] Frank Meisel. Seaside operations planning in container terminals. Springer, 2009.

[9] Todd Rudberg, Justin Nielson, Mike Henscheid, and Joshua Cemenska. Improving AFP Cell Performance. *SAE International Journal of Aerospace*, 7(2), 2014.