Time and Cost Effective Handling for Building Up Carbon Fiber Tailored Blanks

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Abstract

Nowadays handling of dry carbon fiber material is mainly made manually. In aerospace as well as in the automotive industry these processes are made with handling toolings and lead by worker interaction with a low to medium accuracy. For a fully automatic handling and production processes there is the target to build-up tailored blanks made by carbon fiber patches within 90 seconds as they exist in production cycles for metallic parts, for example in the automotive industry. During development projects within technology development at Premium Aerotec GmbH (PAG) important steps for automated handling of dry carbon fiber patches have been developed (size up to 1m²). The new process is based on new handling components, which were developed together with the company J. Schmalz GmbH. As a result of these developments carbon fiber tailored blanks can be built up with more than 15 patches in less than 90 seconds at an accuracy of less than ±1 mm. This is a main step for efficient handling processes for manufacturing carbon fiber parts within RTM- and VAP-Processes.

1. Introduction

Parts made of fiber reinforced plastics (FRP) have become more and more common in light-weight driven products, especially in the aircraft or automotive industry. Compared to metallic parts, FRP have distinct advantages in aspects of weight, stiffness and strength. However, high material and production cost have prevented the usage of FRP in further areas or products.

One way to decrease material costs is to replace large areal layers of fabrics with specific local reinforcement strips or patches, thus decreasing total part weight and increasing material efficiency. However, the individual placement of local reinforcement layers increases production complexity: a wider range of fabric-geometry has to be handled and a higher positioning accuracy has to be ensured. This inevitably leads to higher production costs.

In order to decrease production costs and reach a more efficient production, automation is a valid option. Targets of FRP-automation is to decrease manual work, to increase accuracy, to cut production time, and to reach higher production rates.

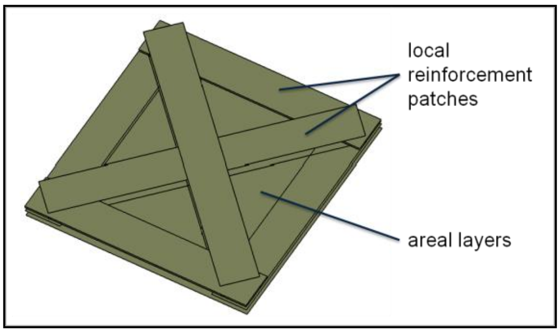

FIG. 1: Sample of a possible stack with local reinforcement patches.

This paper describes an alternative way to handle different geometries of dry carbon fabrics in a more efficient and accurate production process with a flexible endeffector. Aim of this process is to stack 15 different layers of carbon fabrics (a

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sample is illustrated in FIG. 1) within 90 seconds with an accuracy of ±1 mm.

2. Possible Handling Processes

There are generally three different types of processes to build the displayed stack (see FIG. 1). These processes differ in the number and length of movements (process time for movements), and the number of fabric layers picked and transported during these movements. Namely, these movements are:

- Single layer and patch handling
- Parallel transport of multiple layers and patches
- Handling of stacked layers and patches

2.1. Single Layer and Patch Handling

In a single layer handling process (see FIG. 2) every single layer has to be transferred individually from storage to its aim position in the stack. This means, there is a large number of individual movements. In addition, every movement tends to be lengthy (long distance transport movement) and the pick-and-place movement of the grippers has to be executed two times per layer or patch. The result is a long lead time, with a large part being occupied by a non-value adding process of transportation movement.

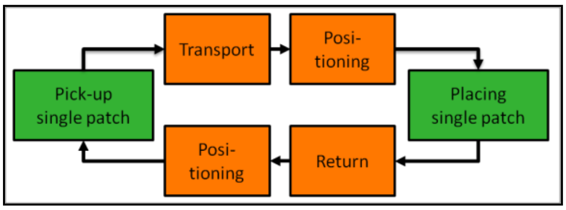

FIG. 2: Process of single layer and patch handling.

The advantage of a single layer and patch handling is the simplicity, size and flexibility of the handling device. Disadvantage is the large amount of time needed for all transportation processes.

2.2. Parallel Transport of Multiple Layers and Patches

The difference of a parallel transport process (see FIG. 3) to a single layer handling process is the number of layers and patches being transferred to the stack in one long distance movement. During pick-up, several patches (see FIG. 4) can be attached to the handling device (depending on the size of this device and the location of every single patch) in one single pick-up step, thus saving time for pick-up and transportation movement. At best only one long transport movement is necessary (if there is an device large enough to handle all layers and patches at once).

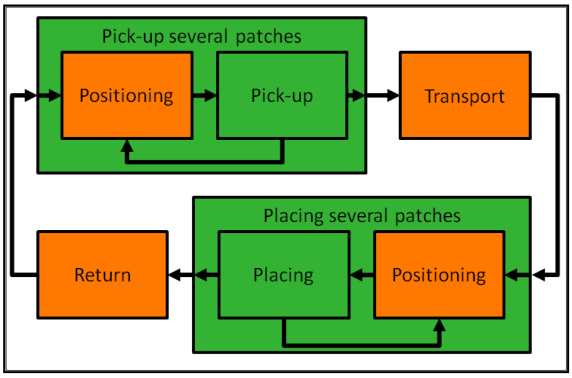

FIG. 3: Process of parallel handling of multiple layers and patches.

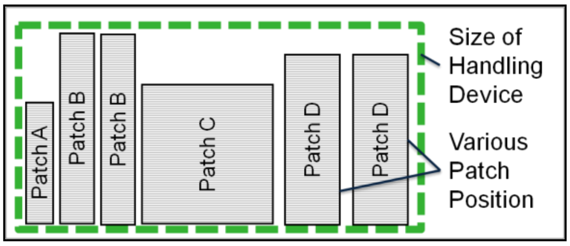

FIG. 4: Positioning of patches on the handling device during parallel handling.

Placing every single patch in its correct position, however, still takes up time. On the one hand, the position of every single patch has to be adjusted, on the other hand each patch placement needs a gripper device movement.

In sum, there is still a veritable amount of time saved by this process. The disadvantage is the complexity and the large size of the handling device. If the size and mass is too big, some time can

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be lost during all movement actions (compared to the single handling process).

2.3. Handling of Stacked Layers and Patches

During a stacked handling process [1], multiple patches are individually picked from the storage, directly stacked beneath the handling device, transported to the target position and placed there in one single step (see FIG. 5).

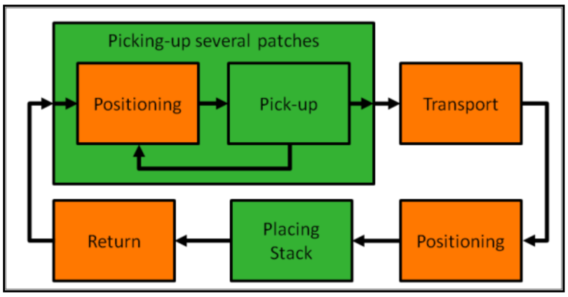

FIG. 5: Handling process of stacked layers and patches.

In comparison to the parallel transport process this process can save more time. Apart from the lighter design and more compact size of the handling device (see FIG. 6), which makes movements faster and positioning easier (also faster), the number of movements can also be slightly reduced.

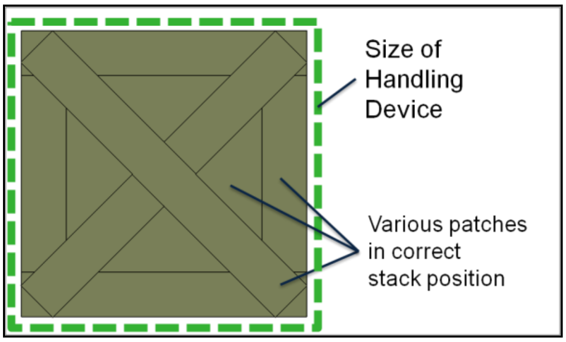

FIG. 6: Positioning of patches on the handling device during stacked handling.

Depending on the number of patches and layers, and their position in the stack, the complexity of the handling device increases, since every single patch needs to be attached to the endeffector in its correct position.

The greatest advantage of this process is the remarkable decrease in lead time. If the entire stack can be transported with the handling device, even space can be saved, since there is no need for an additional position to place the patches. Thus, even the handling process itself becomes a value-added process.

3. Gripping Elements for the Stacking Endeffector

A handling device (endeffector) has to be equipped with gripping elements, in order to pick and place objects. Different gripping elements have different areas of application [2], e.g. sutions cups are rather used for non-permeable elements, needle grippers can pick up multiple layers of fabrics and floating suction cups are able to de-stack a stack of fabrics (picking up only the top patch) (see FIG. 7). A new gripping system, which has been developed during this project with J. Schmalz is the combined needle and floating gripper, which consists of a floating suction cup and a needle gripper.

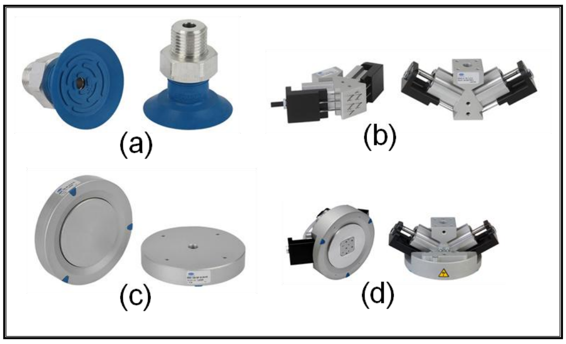

FIG. 7: Gripping elements [3]: (a) suction cups, (b) needle grippers, (c) floating suction cups (Bernoulli gripper), (d) combined needle and floating gripper.

While all gripping elements can be used for single or parallel handling, the stacking process requires a special gripper element to pick up multiple layers of fabrics. The best way to pick-up fabrics with conventional needle grippers is to place the needle orthogonal to the fibers. This makes the positioning of gripping elements difficult for complex geometries or thick stacks with numerous patches. Thus, a new type of the needle gripper has been introduced, which is not dependent on fiber direction.

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The result is an arrangement of gripping elements at the most critical positions of the stack, especially at crossing points of patches (see FIG. 8).

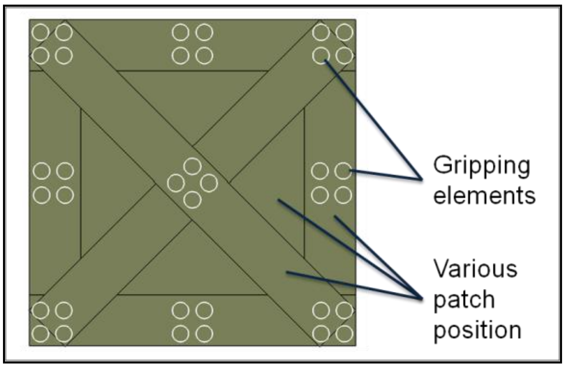

FIG. 8: Arrangement of gripping elements for the stacking endeffector.

The number of patches which can be handled by this kind of endeffector is limited by the needle length / penetration depth of the needle grippers. At best, a full stack can be built beneath the endeffector and reduce the lead time enormously.

4. Test Setup for the Stacking Process

The test setup has been installed at Premium Aerotec in Varel (Germany). It included two industrial robots (KUKA) with two endeffectors, a storage with stacks of patches, a measuring table with a camera for position detection and a target position for the stack built in this process (see FIG. 9).

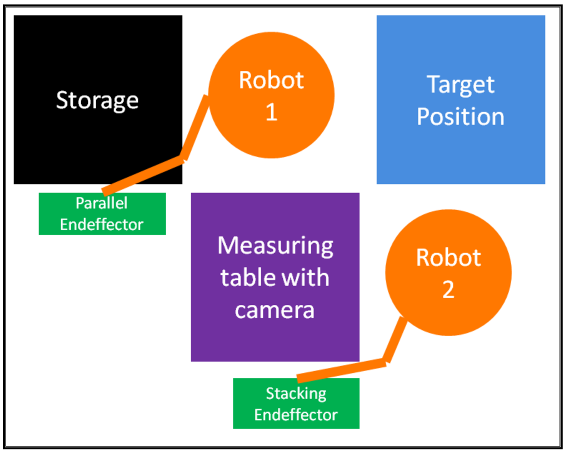

FIG. 9: Test arrangement for a stacking process.

One cyclic process runs as follows:
Robot 1 is equipped with a parallel handling endeffector, consisting of several combined needle and floating grippers. This endeffector (see FIG. 10) picks up several patches simultaneously from different stacks (maximum number of patches with this endeffector is 4), transports them to the measuring table and places them there at once. A positioning for defined pick-up (cf. stack-building endeffector) and placement on the measuring table is not necessary, thus making this process even faster as described in chapter 2.2.

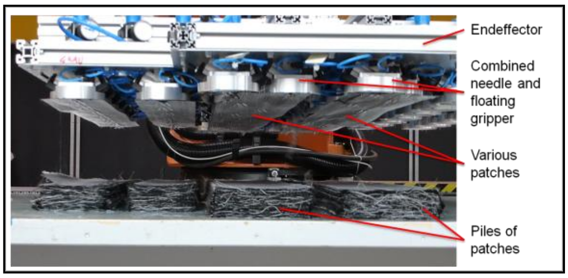

FIG. 10: De-stacking with Robot 1.

Since the patch position on the measuring table is not exactly known, a camera locates the exact position on the table and transfers the data to robot 2 for further handling.
Robot 2 is equipped with a stack-building endeffector. This endeffector picks up all patches from the measuring table individually while building a stack beneath the endeffector (see FIG. 11). When the measuring table is empty, robot 2 either waits in a waiting position for further patches or it places the yet incomplete stack onto the target position.

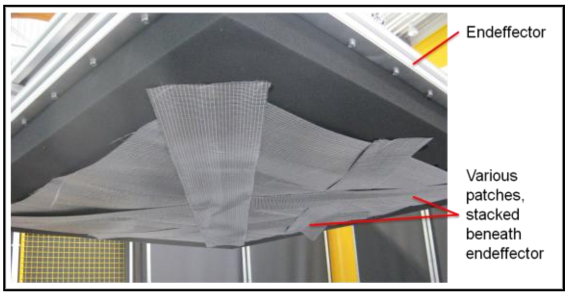

FIG. 11: Sample of a stack beneath stack-building endeffector.

Since the measuring table and the parallel handling endeffector are both limited in size, the number of patches stacked beneath the stack-building endeffector was limited to 4 during the final test run.

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Thus it was possible to reduce the maximum needle length and create further stability. The maximum number of patches handled with this endeffector is 10.

5. The Result

The result of the test runs is that a stack (see FIG. 12) with 15 patches has been built up within 90 seconds and an accuracy of ±1 mm has been reached.

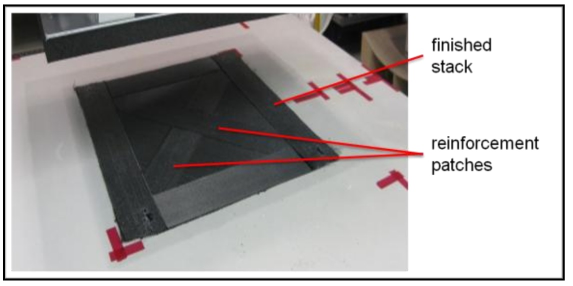

FIG. 12: Finished stack on target position.

The accuracy achieved can still be improved by a better camera system and positioning and tracking system.
Compared to a single layer handling process there is a reduction in lead time up to 60%, if a full stack is built even up to 75% is possible.
The time needed for this stack can also be further reduced with following steps:

- General robot movement optimization
- Reduction of waiting time for both robots (due to the limited size of the measuring table and the calculation speed of the camera)
- Enlarging the parallel handling endeffector to transport more patches at once
- Building-up the full stack on the stack-building endeffector

6. Summary and Prospects

This developed process uses a process of stack-building on the endeffector instead of building a stack on a target position. This enables a reduction in production time of up to 75% (compared to single layer handling). Apart from time saving, this process also saves space (no permanent available target position is needed and a smaller-sized endeffector compared to parallel handling).
Next possible steps are to build a gripper that is ready for serial production and test the process on a bigger scale. In addition, possible improvements, that are listed in Chapter 5, can be implemented to enhance productivity.

7. References

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