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A HOLISTIC APPROACH TO QUALITY MANAGEMENT FOR COMPOSITE FORMING PROCESSES - PROCESS ASSESSMENT, SIMULATIVE MODELS, PROCESS DEVELOPMENT

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Abstract

The reduction of production costs and the realization of lightweight targets for composite forming parts can only be successfully achieved by thinking and planning quality aspects in an integral way. Using the example of automated preforming, the article introduces a holistic development approach, which covers process selection and process design as well as error detection and mechanical analysis of manufacturing effects on the part performance.

1. Quality issues as reasons for increasing cost and weight

For series production of composite parts, some of the most important challenges are quality, reproducibility and reliability. Fabric forming technologies show a high potential for automation and are suitable for medium to high volume production when they are combined with LCM processes.

For overall quality issues, the process step “preforming” plays an important role. Defects that occur in this stage can lead to rejection of whole preforms, influence following process steps or result in damage of tools due to folds and wrinkles. Beyond that, geometries not suitable for composite forming can cause time-consuming modification loops of the manufacturing tools.

Furthermore, the fiber angles and other quality aspects that dominate the final mechanical properties are revealed only after forming on the geometry. Since the actual preform quality and their structural impact are typically unknown, composite parts tend to be overdimensioned to compensate uncertainties related to the part quality. Fiber sliding, fiber waviness or the loss of structural integrity of the fabrics have direct influence on the part performance, but are rarely taken into account in the initial component dimensioning [1].

Therefore, a holistic quality approach contributes not only to the reduction of production costs, but can also improve the lightweight potential and structural performance if already embedded in an early stage of part and process design.

2. Optimizing and ensuring quality by holistic approaches

High performance composite parts show a strong interaction between the manufacturing process and the lightweight design objectives. The sooner these dependencies are considered in the overall development process, the faster the development cycles for new parts and products can get.

The presented approach for holistic quality optimization of composite forming structures is based on the four pillars process planning, manufacturing, defect analysis and structural analysis, where all domains require an exchange of information with each other (Figure 1). In this context, local quality criteria for preform production result from numerical analysis since global limiting samples do not meet the complex stress behavior in composite materials.

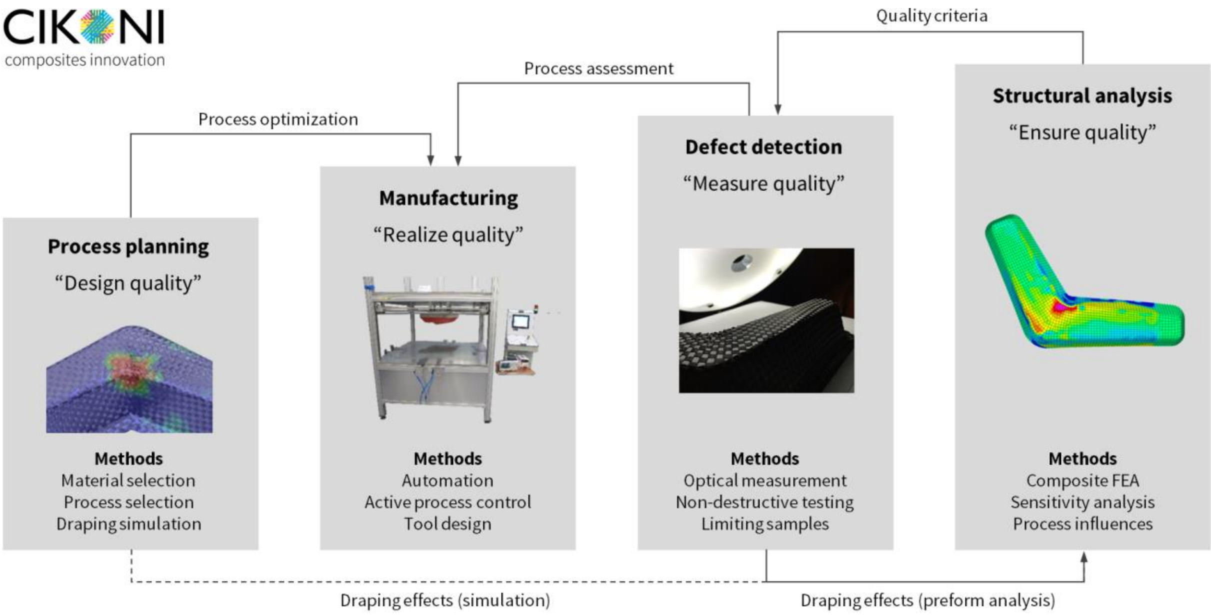

Figure 1. The four pillars of quality improvement using the example of automated preforming applied at Cikoni

For CFRP forming processes, the achievable quality depends on the system of geometry, fabric and process and is strongly coupled to the resulting mechanical material properties. These complex interactions have to be taken into account during the planning stage to assure optimum solutions.

Database tools can provide the required process knowledge for a bottom-up process selection but cannot replace detailed studies with coupled process and part simulation, which is done for preforming processes by using draping simulation [2]. Beyond the knowledge about possible optimization strategies within the process, this requires also meaningful material characterization on the fabric level. Figure 2 shows examples for shear, binder and interaction characterization. Based on experimental measurement of the fabric integrity and the assessment of formability, the draping characteristics of different fabrics can be determined and the producibility of a part can be studied using simulative methods [3].

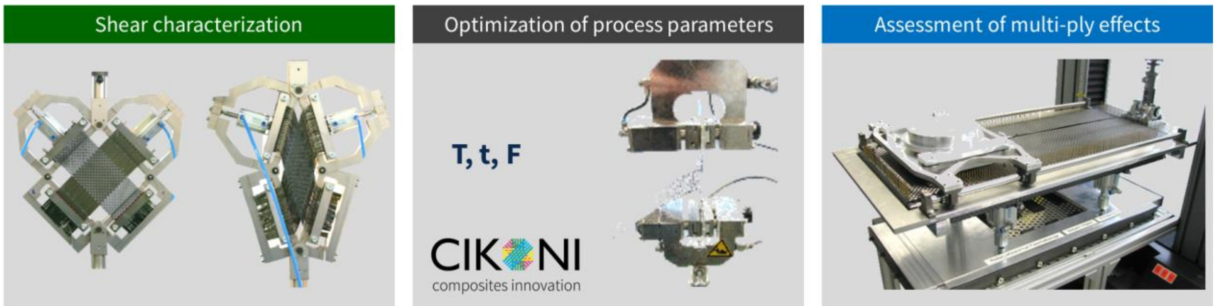

Figure 2. Material and process characterization of fabrics

3. Quality realization by part specific process development

In order to guarantee fast process development, module based morphological methods are used. This leads to high transparency and cost control for the costumer and helps to build up a systematic development already in the planning phase. For example, the degree of automation and the quality demand can be adapted to the customer and part requirements.

Numerous possibilities to improve the part quality (e.g. by active material manipulation systems and tool design [4]) can be integrated. Benefits are particularly evident for components which previously have been manufactured using a cost-intensive prepreg process. Those components can now be produced efficiently for a lot size range up to 10.000 pieces per year with simple automation solutions by using high quality preforming of textiles and subsequent liquid resin infiltration.

Especially process design and layer sequence show a huge influence on the achievable preform quality. Using the example of multilayer draping of fabric semi-finished parts on an L-shaped geometry, Figure 3 shows two preform results without (A) and with active material guiding system "Tailored Drape" (B) [5]. The area of heavy fiber waviness [6] in the central part of preform A can be reduced significantly by adapting active process control and by changing the component design. Particularly for complex shaped geometries, highly stressed components or visible surfaces, the use of ply specific material manipulation systems and active friction reduction for multi-layer forming has been proved effective [4].

Figure 3: Preform variations using the example of an L-shape and preforming device with single-layer material guidance for small volume production

Figure 4 illustrates the technical solution to the "TailoredDrape" approach. The active control and tensioning of the plies is archieved by active interlayers, which can be removed after the preforming step. Additionally, piezo ceramics are utilized to introduce high frequency oscillations to the layers during forming.

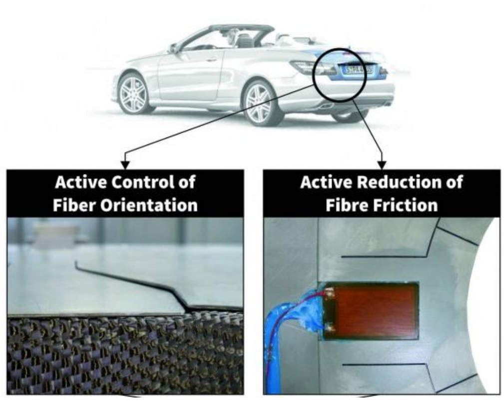

Figure 4: Process induced methods of quality improvement for composite forming: Active forming control and active reduction of fibre friction

Summary and outlook

In order to establish CFRP as a lightweight material with high quality standards which is suitable for series production, holistic approaches for part and process development are required. This was demonstrated here by using the example of automated preforming. A close coupling of part development, composite manufacturing, failure detection and structural analysis [7,8] provides a basis for high quality, reliability and optimum use of the lightweight potential. At the same time, this enables the reduction of production costs. Based on the present knowledge for process development, low-cost automation solutions can be provided even for small and medium volume production. For automated preforming it can be concluded that the right combination of *ply-specific tensioning* and *reduction of friction between the plies* will lead to an strong increase of quality.

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