PROCESS CHAIN DEVELOPMENT FOR 3D NET SHAPE WOVEN FABRICS

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ABSTRACT

A central challenge of the Anthropozoic era is the intelligent and efficient use of available material and energy resources. This leads to a steadily growing demand for lightweight solutions based on innovative materials with a broad spectrum of properties and sustainable production technologies. Textile-based structures in general and 3D woven structures in particular offer outstanding possibilities for the realization of fiber-reinforced lightweight structures. In addition, 3D woven structures have an enormous potential for complex medical devices individually adapted to patients. A current challenge, however, is the great effort involved in transferring 3D CAD models into the final 3D component. In order to avoid complex manual process steps, the efficient implementation of a flexible digital process chain is necessary. The aim of the presented work is the development of a continuous process chain for the fully automated production of new complex 3D woven fabric preforms, where the control files for the weaving machine are derived directly from the CAD model via defined intermediate steps.

Key Words: 3D net shape, woven fabrics, process chain

1. INTRODUCTION

Within the past decade, the use of technical textiles for lightweight engineering applications in the fields of automotive, machine engineering and textiles for medical applications has become increasingly profitable [1]. To increase the benefits of lightweight engineering and the economic efficiency of involved manufacturing processes, current researches focus on the development of cost-efficient and automated textile manufacturing procedures for complex 3D preforms in reproducible quality [2]. Whereas a variety of efficient technologies, such as tape laying, already exist for the production of planar and slightly curved shell elements and profiles, tremendous efforts are still required for the development of complex shaped components. Efforts are mainly involved in the preforming process including steps such as cutting, stacking, forming, condensing, and preconsolidation (they account for approx. 50 % of total component costs). Because the unavoidable use of several partial cuts impedes an ideal, material-adapted design. The path of load-bearing reinforcing yarns is interrupted at the cutting edges. Thus, overlapping areas need to be realized to ensure load transmission, which results in additional material costs and increased component weight. Therefore, textile technologies are being developed that enable the material-adapted manufacturing of 3D preforms with complex geometries. The braiding of complex 3D structure typically requires component-specific lost or segmented cores that limit the variety of feasible geometries and imply additional efforts. Therefore, braiding is characterized by high component costs due to considerable setup times and low productivity.

Weaving offers an enormous potential for the implementation of preforms with complex geometries in an industrial environment. Jacquard weaving provides beneficial technological conditions for a large variety of simple or complex weave patterns. Hence, it is highly suitable for the development of complex, load-adapted 3D geometries made of high-performance yarns with locally adjustable properties. A continuous process chain is necessary in order to enable the efficient production of various 3D woven structures. This work results in a continuous process chain that represents all requirements from the loads to material selection, textile technology implementation and machine control.

2. METHODS

In order to develop a continuous process chain that enables the efficient manufacturing of complex woven 3D preforms, the necessary process steps had to be derived and generalized. This includes the following steps: starting point is the CAD model of the component in SolidWorks. The model is optimized with the LS-DYNA software in order to optimally adapt the occurring forces and the yarn arrangements to each other. This optimized model is then flattened into a 2D image. This is necessary because the weft insertion always takes place in one plane due to the restriction of the conventional weaving process (one weft insertion level). Since this is to be done without distortion, the parts are virtually separately defined joints. Thereafter, the converting into one weave plane is possible. The software EAT DesignScope is used to develop the fabric pattern for the individual areas and to combine them with the unwinding process. This data is converted into a code that can be processed by machines. The woven product is fianlly manufactured on conventional weaving machines and then transferred from a 2D to a 3D structure.

3. APPLICATION EXAMPLE OF THE PROCESS CHAIN

The application of the process chain is demonstrated using the following example of a pressure actuated cellular structure (PACS). The functionality of the PACS results from the targeted combination of rigid areas (cell sides) with flexible areas (compliant sections). The cellular structures are subjected to an internal pressure (pneumatic), which causes the PACS to deform.

The spatial arrangement of the fabric layers must be transferred to the plane for the weaving implementation of the PACS and the necessary creation of a complete weave pattern. Due to the necessity of crossing the fabric layers and the different fabric layer lengths, floating areas are to be provided for PACS from several fabric layers, which must be withdrawn during the weaving process to form the structure. Solutions for the determination of the required draw-off length for homogeneous structures with constant wall thickness are known [3]. A CAE-supported process chain for simple homogeneous structures with constant fabric thickness was systematically investigated, whereby the complete weave pattern as well as the required machine control are configured based on the geometry to be achieved (cf. Fig. 1).

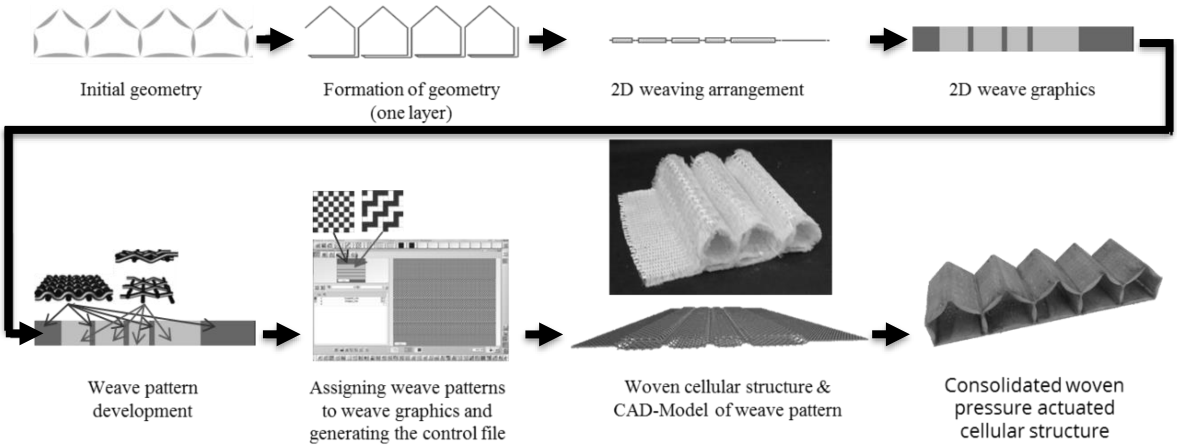

Fig. 1: Process chain for the woven cellular structures

The 2D weave graphic displays the individual subareas as colored areas. According to the previous development in pattern technology for the sub-areas of compliant sections and cell side, the weave patterns for the sub-areas of weaving were arranged. The total weave pattern of the PACS was created by assigning the individual patterns to the color areas of the 2D weave graphic. The structure was woven and transferred from the flat 2D surface to the final 3D preform. In the last process step the 3D preform was infused with resin by an RTM process. After the infiltration process the 3D preform was processed to the 3D composite part.

4. SUMMARY AND OUTLOOK

The use of textiles in automotive, mechanical and medical engineering sectors is steadily increasing. This is accompanied by an increasing demand for load-adapted, highly flexible and variable structures. Weaving technology offers outstanding approaches to the implementation of complex 3D geometries. However, there is a lack of methods for the formation of complex 3D geometries and for the technical implementation in the weaving processes. The extensive research in the development of various fiber-based structures was used to develop applicable tool sets for the field of geometry formation for the specific arrangement and connection of fabric layers. It has a generally valid character and can be applied to other 3D geometries. The modular process chain developed for weaving implementation, i. e. the transfer of layer arrangement into a 2D weaving arrangement and the creation of weave patterns by assigning individual patterns to a 2D weave graphic, can also be used for the realization of complex 3D structures in a weaving process. The results obtained serve as a basis for the development of a technology concept and are used as a technology platform for the development of novel complex 3D multi layered structures.

5. ACKNOWLEDGEMENT

The IGF research projects 18805 BR, 18930 BR 18774 BR, 19805 BR, 19922 BR, 20152 BR, 20245 BR of the Forschungsvereinigung Forschungskuratorium Textil e. V. are funded through the AiF within the program for supporting the „Industriellen Gemeinschaftsforschung (IGF)“ from funds of the Federal Ministry for Economic Affairs and Energy (BMWi) by a resolution of the German Bundestag.

Supported by:

Federal Ministry for Economic Affairs and Energy

on the basis of a decision by the German Bundestag

The authors would like to thank the German Research Foundation (DFG) for the financial support of the project DFG CH 174-42-1.

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