Systematic development of technical textiles

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Abstract. Technical textiles are used in various fields of applications, ranging from small scale (e.g. medical applications) to large scale products (e.g. aerospace applications). The development of new products is often complex and time consuming, due to multiple interacting parameters. These interacting parameters are production process related and also a result of the textile structure and used material. A huge number of iteration steps are necessary to adjust the process parameter to finalize the new fabric structure. A design method is developed to support the systematic development of technical textiles and to reduce iteration steps. The design method is subdivided into six steps, starting from the identification of the requirements. The fabric characteristics vary depending on the field of application. If possible, benchmarks are tested. A suitable fabric production technology needs to be selected. The aim of the method is to support a development team within the technology selection without restricting the textile developer. After a suitable technology is selected, the transformation and correlation between input and output parameters follows. This generates the information for the production of the structure. Afterwards, the first prototype can be produced and tested. The resulting characteristics are compared with the initial product requirements.

1. Introduction

Textiles can be used in various fields of applications, e.g. the automotive sector, sports industries medicine and apparel. The implementation of new textile product ideas is hindered due to the variety of usable machinery and process parameters. A suitable design method for the development and production of new technical fabrics can be used as a guideline for the systematic realisation of these ideas. The method helps to link different views; know-how of technicians, customer wishes and machine possibilities are all take into consideration to avoid misunderstandings or limitations. A new, successful development can only be achieved in close collaboration between these different disciplines (Figure 1.) [1]

General design methods for the systematic development and production of new products already exist [2, 3, 4, 5]. These existing methods are laid out for product development without link to a specific technology field which makes the transfer into the textile industry difficult. Therefore, a new approach is presented that includes the different textile fabric technologies.
2. Methods of product development

A new approach is presented within this paper for the systematic development of technical textiles. Following, an overview of different, currently existing methodologies and tools for the product development in different industries and development steps are described. These methodologies contain methods to support the development process, methods for the general proceeding during the product development and construction methodologies. The deficit of these methodologies for the development of textile structures is shown.

2.1 Classification of current methods

Supporting methods for the product development are used in various steps during the development process. The following overview shows exemplarily methods for different application areas. A possible classification of supporting methods is given. Often, these supporting methods can be applied for multiple product development steps.

Figure 1. Linking of different perspectives with the help of a development method for technical textiles.
2.2 General product development methods

The steps during the development process of new products are similar independent on the market and field of application. The main part of each development process is the planning of the product, the product conception and the product design (Figure 2.).

During the product planning the requirements are defined. Customer requirements and competitor products are systematically analyzed and an economic analysis is made. The requirements should be quantized and generally 10 – 20 requirements are sufficient to fulfill all requirements. The product conception contains the search for possible solutions for the new product. With the help of assessment criteria the most suitable solutions are chosen. Within this product development phase the suitable technology for the production needs to be identified. The final phase, the product design, contains the actual construction of the product. During all these steps of the product development process, the supporting methods of Table 1 are used.

2.3 Deficit of current methods

Several product development methods already exist (Figure 3). Some of these methods can be universally used. These methods can be transferred to all kinds of product development processes (e.g. Quality Function Deployment (QFD), VDI Guideline 2221). Other methods have been especially deve...
A universally usable methodology for the development of technical textiles does not exist. The textile methodologies all focus on specific product categories or technologies. To ease the development of new textile products and to accelerate the market entry for companies in a new sector a universally usable textile methodology is needed. This methodology focuses especially on textiles. A main part of the method is the identification of a suitable production technology.

3. TED Method – Universal Textile product development method
The developed and proposed TED Method (TExtile Development Method) is subdivided into six steps (Figure 4). Following, these six steps from requirement definition to the validation of the new product are described. The steps are described without link to a specific textile product and its requirements to show the general proceeding within the method.

Figure 3. Portfolio illustration of different product development methods.

| Type of Product | Methods for Product Development |
|-----------------|---------------------------------|
| general         | QFD                             |
| medium          | VDI 2221                        |
| Textile         | Ramakers                        |
| Textile Supporting | TPD                      |
| general         | Jungbecker                      |
| Textile         | Arshi                           |
3.1 Step 1 - Requirement Definition
The identification of the requirements of a new textile product is essential for the development thereof. The fabric characteristics vary depending on the field of application. Therefore, the first step is the identification of the desired requirements. The definition of requirements is further subdivided into the following steps:
- collection of all requirements / benchmark test
- ranking of requirements
- transfer into measurable fabric parameters
- value allocation – defined, prioritized requirements list

Overall requirements are collected within a workshop (brainstorming, clustering and ranking) with experts of the development team. Terms for the overall requirements are e.g. soft, strong and good climate comfort. These general requirements are often non-measurable properties. Therefore, if a benchmark or similar product exists, this product is tested to identify measurable properties. The collected requirements are ranked to identify the most important characteristics. Some properties can be contradictory like air permeable and water-repellent. After the ranking or the requirements, they are transferred into measurable fabric characteristics. Non-measurable characteristics can be correlated to multiple measurable characteristics and test standards (e.g. fabric breathability = air permeability, fabric density). For the validation after production, target values of the characteristics are needed.

3.2 Step 2 - Technology Selection
A suitable technology needs to be selected depending on the requirements of the desired product in development. Fabric production technologies vary from weaving, weft and warp knitting, braiding and non-woven production to multi non-crimp fabrics. All these technologies can be further sub divided dependent on resulting dimensions (2D, 3D), structure (velvet, tubular, etc.), configuration (weft insertion technology, weft and warp yarns, plush, etc.). Moreover, the productivity and economic efficiency are taken into consideration for the technology decision. [10, 11]

Aim of this method step is to outline all possible production technologies applicable for the desired product. This allows broadening the scope within the development process. Finally, the best fitting technology solution for the application will be selected, to follow within the next method steps. To build a robust technology selection tool the method of a construction catalogue [12] is used. This construction catalogue is a data collection of all market available fabric production technology solutions.
3.3 Step 3 - Parameter Correlation

The requirements, gathered in method step 1, define textile characteristics of the final fabric. These characteristics are the targeted output parameters of the production process. Up to this point, the input parameters of the production process are not known. The input parameters (such as material, yarn tension, machine velocity and pattern) are the determining factors for the output characteristics. Input and output parameters need to be correlated based on a Design of Experiment (DoE) study to choose the appropriate input (material, machine setting, pattern) for the requested output (fabric requirements). This correlation of parameters is carried out in method step 3. Figure 5 shows the necessary transfer link from product requirements into machine input parameters.

First, the production technology specific process input parameters are identified. Depending on the selected technology, different process parameters can be changed. All input parameters can be divided into three groups: material, structure/pattern, machine setting.

A correlation matrix is needed to correlate the input and output parameters. The correlation effects have to be determined within pre-trials. One example is a knitted product where the air permeability is required to be as high as possible (Table 2). The given correlation matrix shows, that a low machine gauge is suitable to archive this fabric characteristic. Moreover, the number of used yarns per system should be as low as possible as well as the yarn tension. The sinking of the loops influences the stitch size of the mesh. The stitch size should be high, to produce fabrics with an open structure. The correlation effects are moreover shown in corresponding diagrams.

| Fabric property | Input parameter - Machine setting |
|-----------------|----------------------------------|
|                 | Machine gauge ↑ | No. of feed yarns per needle ↑ | Yarn tension ↑ | Sinking (stitch size) ↑ |
| Air permeability| ↓ | ↓ | ↓ | ↑ |

3.4 Step 4 - Process parameter transformation

The defined parameters need to be transferred into machine data. The production parameters that influence the resulting fabric properties have been identified within method step 3. Within method step 4, the relevant parameters are transferred into measurable values with the help of the tendencies from Table 2. Input parameters such as material, structure/pattern and machine setting are dependent on the used textile production machinery.
Value ranges for all parameters are given by the technology specific limits. For example for the production of highly breathable knitted fabrics, the yarn tension is varied. Exemplary for a selected machine, the tension can be adjusted from 1 cN to 20 cN. The tendencies from the correlation matrix are multiplied by the influencing amount (air breathability is influenced by multiple parameters (e.g. machine gauge, no. of yarns, stitch size). The resulting value is calculated (Figure 6).

3.5 Step 5 - Production & Testing
Production as well as testing is carried out in method step 5. The machine needs to be setup for the production of the new product. The setup is carried out according to the defined process parameters from method step 4. After the set-up phase, the machine needs to produce as much material as necessary for the laboratory tests. For standard fabric tests (stress/strain, air permeability, thickness and mass per unit area) about three square meters of fabric are necessary.

The produced material samples are tested in a laboratory regarding their mechanical properties. The testing standards have already been defined in method step 1 and are linked to each characteristic in the requirement document. The results of this sub-step are numerical fabric characteristics, such as air permeability and mesh density.

3.6 Step 6 - Validation
The final step within the design method is the validation. The produced material needs to be evaluated regarding the fulfillment of the requirements from the specification sheet. The first step is the review of the material sample results. The tested fabric properties (laboratory) are compared to the defined requirements (requirements list, Figure 7). If necessary, an adjustment loop is carried out with adapted process parameters based on the correlation tendencies. For this, the design method is used once more, starting from method step 4.

![Figure 6](image6.png)

**Figure 6.** Transfer from correlation tendencies into values.

![Figure 7](image7.png)

**Figure 7.** Comparison: target and achieved value.
4. Summary
To perform a systematic development of new products, several general method approaches are available on the market. Before though, there was no specific method for the development of technical textiles. To simplify the approach of developing new textile products a new method was developed and presented – The TED Method (TExtile Development Method). The TED Method was validated at the Institut für Textiltechnik (ITA) der RWTH Aachen University, Aachen, Germany for two different knitted products from different application categories, a functional apparel component and a technical automotive textile. It was shown that for both applications, the development iteration steps using the design method could be reduced drastically to a maximum of two overall iterations per product. The core element of the design method to reduce the number of needed iterations is the parameter correlation, based on detailed material trials. The next step at ITA to further develop the method will be to establish parameter correlations for each common fabric production technology.

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