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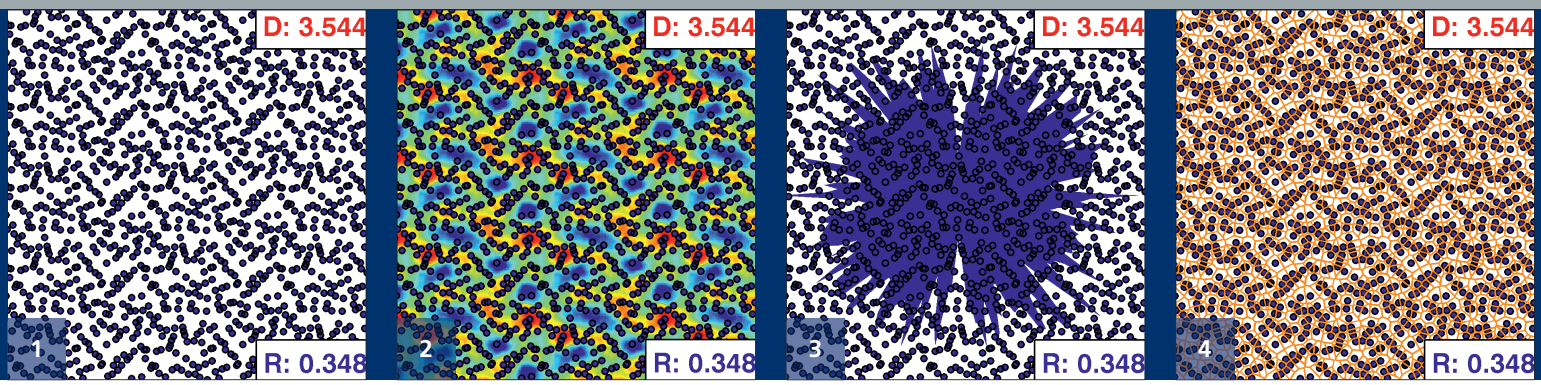

1 *Needle punch pattern*

2 *Density distribution of a needle punched non-woven*

3 *Directional distribution of a needle punched non-woven*

4 *Voronoi criterion*

DESIGN OF NEEDLE BOARDS: SIMULATION AND OPTIMIZATION OF PENETRATION PATTERNS

Needle punching is a well-established method to bond nonwovens mechanically. The needle punching process is based on the needles penetrating into the material with barbs perpendicular to the nonwoven surface. In the process, a part of the fibers in the nonwoven material is reoriented to the direction of the needle punch so that an interlocking of the fibers occurs. The qualities of the nonwoven are heavily dependent on the plant layout and the process parameters: number of needles per linear metre, stroke frequency or feed per stroke, belt speed and working width.

An important production characteristic is the penetration density, which is defined as the number of punches per area of the felt. Homogeneous penetration densities are desirable, because they determine the strength and strain characteristics of the nonwoven. By contrast, stripes or patterns on the material surface should be avoided.

In close collaboration with Oerlikon Neumag Austria, the Fraunhofer ITWM has developed a software tool to simulate the needle punch pattern and to optimize the positions of the needles in the board according to specified process settings.

Simulation of Needle Punch Patterns

The simulation of the needle punch pattern in the nonwoven can be easily described. The coordinates of every needle in the needle board are known in the machine and cross machine direction. Without draft they are transferred directly to the punches in the nonwoven fabric. Hereby, the feed per stroke in the machine direction is multiplied by the sum of the corresponding number of strokes. Since the material shrinks from the needle punching and is also warped in the machine direction as a result of the transport by rolls, the Fraunhofer ITWM has en-

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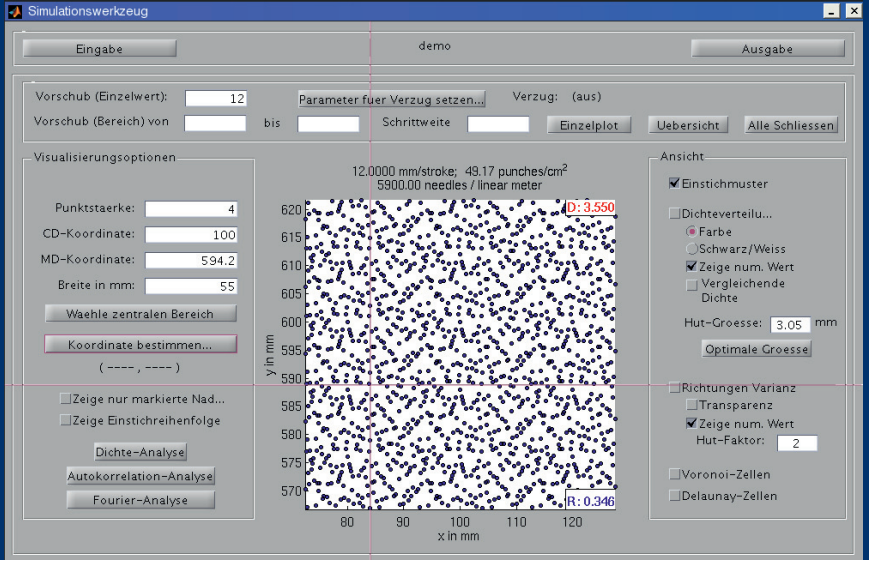

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hanced this simple description through the inclusion of a draft model for the realistic simulation of the needle pattern and has implemented it in a software tool. A comparison of the needle punch patterns in the nonwoven simulated with draft to the punched nonwoven fabrics of Oerlikon Neumag Austria showed a very high level of congruence.

Evaluation of Needle Punch Patterns

On the basis of the innovative enhancement of the simulation of needle punch patterns with a realistic draft model, needle boards can be evaluated and compared for different process conditions, particularly for various working points of the feed per stroke. The Fraunhofer ITWM has developed multiple evaluation criteria for this purpose, which reproduce the perceptions of the human eye and thereby reproduce the subjective evaluation of the needle pattern in quantifiable sizes. Of particular importance is the criterion density distribution, which determines the homogeneity of the needle punching, and the evaluation criterion of the directional distribution, which serves for the analysis of stripes in the punch pattern. These two methods form the basis for the automated optimization of existing needle patterns and for the automatic construction of new needle boards with customer-specific requirements. Additional methods for the evaluation of the needle punch patterns originate from statistics and Fourier analysis.

Optimization of Needle Boards

The earlier procedure for the construction of needle boards consists of the manual positioning of needles on the board. In the process, the experience of the design engineer plays an important role in the development of the needle arrangement. With the simulation of needle punch patterns and the implementation of evaluation criteria, the manual construction of needle patterns can be supported to a considerable extent. The evaluation methods provide the design engineer with information about the zones in the nonwoven fabric exhibiting inconsistent penetration densities or markings. In addition, the simulation tool provides the possibility of identifying any such needles which cause these problems through an inverse search. In doing so, the design engineer is supported in the decision as to which needles require repositioning on the needle board in order to attain a better punch pattern. Naturally, this concept can be generalized and expanded in order to design a needle board under full automation. In the process, needles are successively placed on the board in adherence to the construction conditions, such as the hole diameter or web thickness. In doing so, each new needle is added in such a way that the produced nonwoven fabric has optimal characteristics. The quality of a needle position is always determined by the evaluation criteria mentioned above.

This approach provides us with the opportunity not only to evaluate one simulated needle punch pattern but also several needle punch patterns with varying process parameters (e. g. for various feeds per stroke or drafts). Combining these measures of quality offers the advantage of constructing needle boards that produce a good needle punch pattern for multiple working points.

Looking to the Future

The successful development of simulation-based evaluation criteria for needle punching as a basis for automated needle board construction as well as their implementation as software with an operator-friendly user interface now enables Oerlikon Neumag Austria to develop needle patterns with customer-specific process parameters and with improved nonwoven characteristics in shorter times than in the past.

1 *Screenshot of the simulation software for needling processes*