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Material uniformity assessment technique for the nonwovens and automotive industries

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A novel real time evaluation of the uniformity of high-loft nonwovens using patented in-line measurement technology is introduced. Autins Group, a specialist in thermal and acoustic materials for the automotive industry, utilizes data acquired by a patented Hammer-IMS industrial basis-weight scanner and a modified uniformity index algorithm, originally developed for full-area camera images, to provide a standardized approach for assessing nonwovens uniformity. The use of this technique was tested at Autins facilities in Tamworth/UK which is currently the only nonwovens supplier in the automotive industry to implement it and offer such a high level of quality control. The importance of nonwovens uniformity in automotive applications, the manufacturing challenges, and the potential for standardization in the industry is shown.

The automotive industry is a well-regulated domain and demands high-quality and consistency from the materials for its various applications, with a particular focus on improving acoustic and thermal performance. Nonwovens are commonly used in automotive components for thermal and NVH (Noise, Vibration, and Harshness) purposes and are supplied by various tiers of manufacturers. The nonwovens manufacturing process varies depending on the specific application and the type of fibers employed. In the automotive sector, staple fiber dry-laid needle punched or thermo-bonded nonwovens as well as continuous filament spunbond or meltblown nonwovens are widely used.

The success of nonwovens in providing acoustic and thermal insulation hinges on their exceptionally high porosity, with some high-loft materials achieving porosities exceeding 99%. In these materials, where 99% of the volume is air, only 1% is occupied by the fibrous matter. Therefore, it is crucial to ensure an even distribution. The insulation properties of such materials are highly sensitive to any irregularities or clustering in fiber distribution. Since achieving perfect uniformity in nonwovens is inherently challenging due to the random distribution of fibers, a method for quantifying material uniformity is essential for organizations in the industry's supply chain to enable the design, specification, selection, and communication of this property effectively. Currently the most used parameter to describe nonwovens uniformity is the average areal density, typically measured in g/m².

Whilst meltblown, spunbond, carded, or hybrid materials are preferred choices for automotive trim, thermal and NVH applications, they often face challenges in achieving a high level of uniformity, particularly when using dated equipment, high-diameter fibers, or low material grammages. Although techniques like MicroPunch by Dilo and ProDyn by Andritz have been developed to improve uniformity in carded nonwovens, there is currently no industrywide recognized standard for expressing the uniformity of nonwovens after production, leaving automotive supply chain organizations without clear quantitative methods for specifying material uniformity requirements.

Here, a solution is presented that combines mathematical methods with technology to measure and profile areal density, as provided by the Hammer-IMS scanner, offering potential for standardizing nonwovens uniformity assessments in the automotive industry.

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Production setting

Autins employs a patented production technology[1] for manufacturing the high-performance NVH material known under their trademark Neptune. This material offers very good acoustic and thermal insulation at a significantly lower weight compared to similar materials in the automotive market. Hammer-IMS has installed an industrial scanner in-line with the Neptune production line. This scanner utilizes a time-of-flight principle[2] based on high-frequency microwave signals, a technique branded as Hammer-IMS' (M-Rays), to measure the basis-weight distribution of the lofty polyester-polypropylene (PET/PP) nonwovens. Unlike non-sustainable technologies like X-Rays or beta-radiation, this scanner offers a more eco-friendly approach.

↓ FIG. 1A

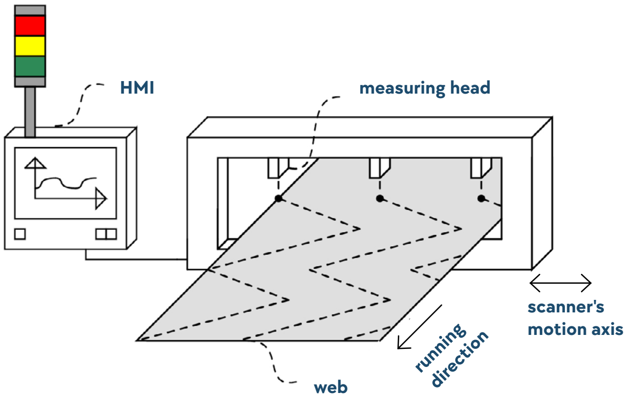
Standalone Hammer-IMS scanner

↓ FIG. 1B

Location of the scanner after inline installation on the Neptune production line at Autins' Solar Nonwovens plant in Tamworth. The scanner is positioned in the production line after the slitting stage and before the winding unit.

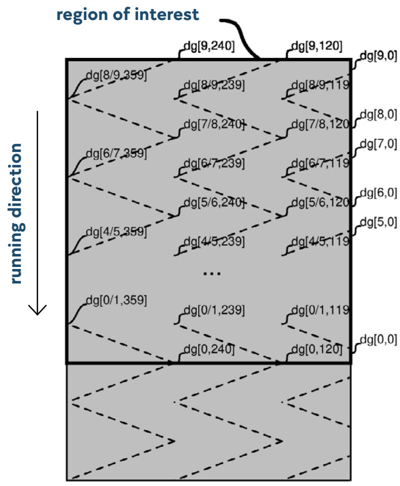
↓ FIG. 2A

Concept drawing of the measuring principle. The 3 available M-Ray heads create 3 so-called zig-zag-traces on the material. For the area lying along these traces, basis-weights are measured. Depending on the relative speed of the material vs. the scanner's scanning speed, the zig-zag coverage approaches a 100% surface coverage.



↘ FIG. 2B

Representation of the matrix to which the uniformity index algorithm is applied.



Another key advantage of using this scanning system is the continuous measurement taken not only in machine direction, but also in cross direction. This is thanks to the traversing movement of the Marveloc-Curtain frame which carries the measuring sensors (Fig. 1).

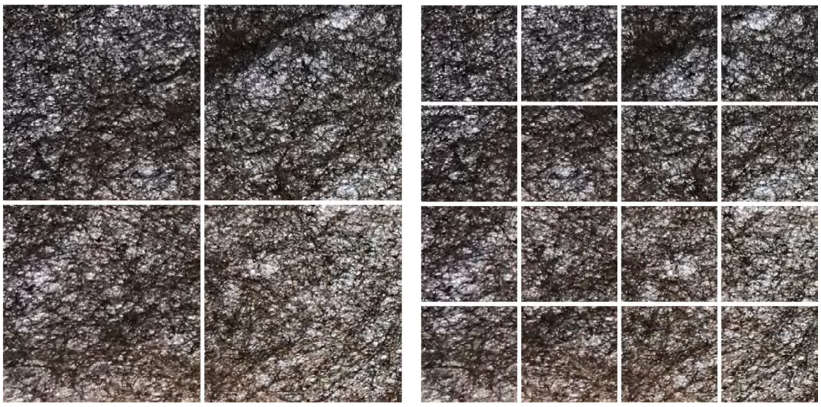
The scanner consists of 3 M-Ray measuring heads that generate traces of measurement data, combining them to provide full-width basis-weight measurements in g/m² (Fig. 2). The scanner's resolution in the cross-machine direction is 2 mm, and it operates using its control software, Connectivity 3.0, built on a C++ runtime environment.

Uniformity index

Autins saw the opportunity to arrange the scanner values in cartesian coordinates to form an image-like map of material density. This allows the implementation of statistical image analysis methods such as the quadrant method using the uniformity index algorithm. The quadrant method was originally used in image processing and inspired by ecological studies. The algorithm, as originally presented by Amirnasr[3] for camera images, is based on the quadrant method assesses the variance between quadrants within an image and how it changes as the number of quadrants increases. Images with a high level of color clustering result in increased variance with more quadrants, yielding a lower uniformity index. Conversely, images with a more homogeneous color distribution exhibit a lower increase in variance with additional quadrants, resulting in a higher uniformity index. For example, Fig. 3 shows a grayscale image of nonwovens taken at Autins laboratory.

FIG. 3

Dividing the image into quadrants is key in the algorithm.



On the left-hand side, the image is divided into 4 quadrants, whereas on the right-hand side, the same image is divided into 16 quadrants. The variance between quadrants in the image on the left-hand side is lower than that of the right-hand side. This is due to the uneven, or clustered, distribution of fibers. The higher the number of quadrants, the higher the variance. The change in variance represents the material uniformity. A perfectly uniform image exhibits no change in quadrant variance, yielding a uniformity index of 1 (or 100%).

Hammer-IMS was able to integrate the algorithm with its control software Connectivity 3.0 which assumes an OpenCV grayscale 'Mat'-object as the data source.

The algorithm was adopted, but the histogram flattening was left out to condition the input basis-weight data. Histogram flattening can occur in many ways, and its effect on the remainder of the algorithm is sometimes hard to predict, so we decided to remove this from the algorithm. This means that the statistics are not being altered in the same way as in the original uniformity index algorithm. Instead, a single scale-factor K=200 was applied to the index-of-dispersion $I=K*VAR(X)/E(X)$. This value has the effect of making the uniformity index more sensitive to the typical variations in the considered nonwovens production process for the case when histogram flattening is not present. The result was a real-time map of material's local density distribution and consequently, processed into a live assessment of the uniformity during the production process of the Neptune material.

The algorithm has been made open-source in both MATLAB compatible code and C++ compatible code on a repository[6] to encourage its standardization and contributions from other researchers to be made. In the in-line application, the algorithm is used with a sliding-window dataset generated by the scanner, which captures data while scanning back and forth to create a matrix that represents material density map.

This sliding-window dataset is generated by scan-data obtained by the Hammer-IMS scanner while it is scanning back and forth, generating one additional line of data in the source matrix 'dg' for the algorithm. Each row of the source matrix 'dg' contains full-width scan data, equidistantly resampled in a 5 mm cross-direction resolution. The typical width of 1,800 mm which Autins uses corresponds to 360 values across the material width. The dataset dg only keeps data from the most-recent 10 scans. Any older scan data is being removed from the dataset but saved onto the Autins cloud for future analysis. The size of the dg matrix is therefore 360 x 10 as shown in Fig. 2B. Since both the product and the scanner are physically moving, each line in the matrix does not correspond to a single position in the running-direction of the material. Furthermore, the 3 zig-zag traces provide spare data since it has been generated by three discrete M-Ray heads. This non-orthogonality and sparsity of the dataset

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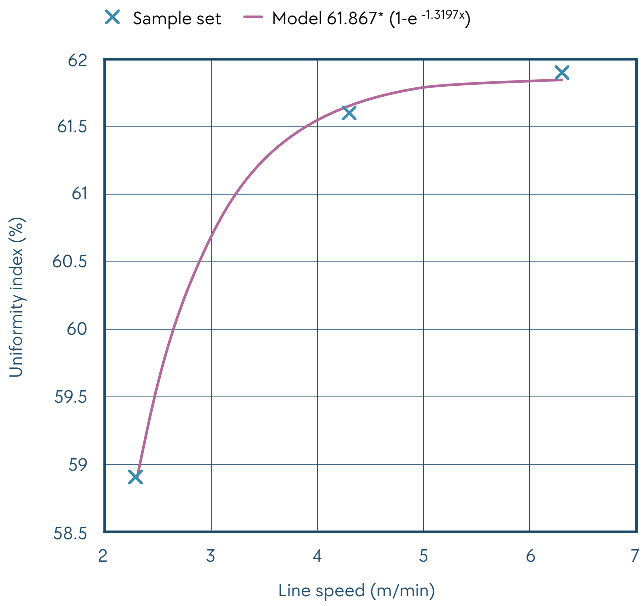
FIG. 4

Uniformity Index modelled against the production line speed



Calendar

2023	Trade Fairs and Conferences
December	
13-14	AATCC Webinar on Haptics & Textiles, Virtual → www.aatcc.org/aatcc-events/haptics/

2024	
January	
9-12	heimtextil 2024, Place: Frankfurt/Germany → www.heimtextil.de
11-14	Domotex 2022, Place: Hanover/Germany → www.domotex.de
20-22	Innatex 2024, Place: Hofheim-Wallau/Germany → www.innatex.de
23-25	Munich Fabric Start, Place: Munich/Germany → www.munichfabricstart.com
24-25	16. Bautextilien-Symposium, Place: Chemnitz/Germany →www.stfi.de/veranstaltungen/symposium-bautex
24-25	MENA Nonwovens Event 2024, Place: Dubei/UAE → https://edana.idloom.events/mena-nonwovens
31	Forum Funktionalisierung, Place: Hohenstein/Germany → www.afbw.eu/aktuelles/veranstaltungen/details/forum-funktionalisierung-2024/
February	
5-7	Texworld Evolution, Place: Paris/France → www.texworld-paris.fr
7	10th Congress Composite Simulation, Place: Augsburg/Germany → www.afbw.eu/aktuelles/veranstaltungen/details/10-fach-kongress-composite-simulation-2024/
19-23	R+T 2024, Place: Stuttgart/Germany → www.rt-expo.com
22-24	20th International Istanbul Yarn Fair, Place: Istanbul/Turkey → https://iplikfuari.com/en/?_ga=2.89351704.260516422.1693916143-1850808752.1693916143
March	
5-7	JEC World 2024, Place: Paris/France → www.jeccomposites.com
6-8	Composites 2024 International Conference, Place: Sevilla/Spain → www.setcor.org/conferences/composites-2024
6-8	Intertextile Shanghai Home Textiles, Place: Shanghai/China → www.intertextilehome.com
13-14	Cellulose Fibres Conference, Place: Cologne/Germany → www.cellulose-fibres.eu
18-22	International Week of Narrow and Smart Textiles, Place: Dresden/Germany → www.tu-dresden.de/mw/itm/narrow-2024
20	DITF-Innovationstag, Place: Denkendorf/Germany → www.ditf.de/innovationstag
20-21	Performance Days, Place: Munich/Germany → www.performancedays.com
April	
23-26	Techtextil 2024, Place: Frankfurt/Germany → www.techtextil.com
23-26	Texprocess 2024, Place: Frankfurt/Germany → www.texprocess.com

varies based on the production line speed and is in the current state-of-the-work not compensated for. Evaluation of the technique in the next section discusses this approximation.

Evaluation of the technique

The technique was evaluated by testing its results of scanning the same sample material at different line speeds (2.3, 4.3, 6.3 m/min) to assess the effect of dataset sparsity on the uniformity index. The results show that variations in line speed impact the uniformity index by no more than 5%. The correlation between line speed and the uniformity index was modelled using an exponential model (Fig. 4). As future work, the inclusion of a process-specific empirical model to mitigate this dependence is proposed. The sparsity of the dataset, due to the scanner's discrete M-Ray heads and non-orthogonal data, can be a challenge, particularly for faster production lines.

Conclusion and future work

A novel application of a uniformity-index calculation was introduced to assess nonwovens uniformity in an in-line production setting. The influence of the relative speeds of the production line and the basis weight scanner on the accuracy of the uniformity index was discussed. Future work aims to develop a model to compensate for variations in the uniformity index caused by changing line speeds. Further research and experimentation would help to understand the effects of dataset sparsity on the algorithm's application.

Ultimately, this work seeks to address the absence of standards for assessing nonwovens uniformity in the nonwovens and automotive markets with this proposed solution and contributes open-source code to encourage collaborative standardizations efforts.

Neptune, MicroPunch, ProDyn = trademarks

References
1. Lee, H.J. et al: European patent "Waved meltblown fiber web and preparation method therefor", Patent No: EP2918718B1
2. Deferm, N.; Redant, T.; Dehaene, W.; Reynaert, P.: Patent family "Sensor for non-destructive characterization of objects", Patent No.: WO2016198690A1
3. Amirnasr, E.; Shim, E.; Yeom, B.Y.l.; Pourdeyhimi, B., Basis weight uniformity analysis in nonwovens, The Nonwovens Institute, North Carolina State University, Raleigh, NC/USA. Published online: September 5, 2013
4. MicroPunch, demonstrated at ITMA 2023, Milan/Italy, June 2023, www.nonwovens-industry.com/contents/view_breaking-news/2023-06-23/dilo-details-success-at-itma/
5. www.andritz.com/products-en/group/nonwoven-textile/needlepunch/excelle-range/prodyn-forming-needlepunch-nonwoven-and-textile
6. https://bitbucket.org/hammerims/uniformity_index