Deep Learning-Based Surrogate Model for Predicting Air Permeability of Technical Textiles

Eleonora Bianca[a], Ghasem Beiginalou[a], Gianluca Boccardo[a] & Ada Ferri[a]

[a] Politecnico di Torino, Torino, Italy

E-mail: eleonora.bianca@polito.it

The permeability of technical textiles is of crucial importance for industrial applications. It plays a key role in the development of high-performance fabrics as well as in the production of composite materials. In this context, porosity and structural properties have a much stronger influence on permeability than fibre composition, so the geometric design of the fabric is a more decisive factor than the choice of material. Air permeability is critical to fabric comfort, drying efficiency and production processes (such as drying itself), where the structure of the fabric can significantly affect performance. Direct measurement, however, is slow—particularly for tightly woven reinforcements—so a predictive tool available early in design would streamline development and reduce experimental cost.

The aim of this project is to develop a surrogate model for permeability prediction based on deep learning techniques: in particular Fully Connected Neural Networks (FCNNs) and Convolutional Neural Networks (CNNs). These models are selected based on the desired output dimensionality: integral values or full-field spatial data. The model aims to predict the permeability from structural input parameters such as the weave type (plain weave, basket weave, filled rib and twill), cover factor (the ratio of the area covered by the fabric to the open area) and the aspect ratio (the shape ratio of the space between the yarns).

To achieve this goal, a training dataset was generated from CFD simulations performed for different geometries (weave pattern and yarn density) and were generated using custom Python code implemented in the TexGen software API. Permeability was calculated using Darcy's law under laminar flow conditions. This approach made it possible to evaluate the permeability through the air velocity flowing through the fabric.

Finally, the CFD models were refined and validated against experimental results from the existing literature. By combining CFD simulations with deep learning techniques, this study provides a powerful set of tools for the prediction of air permeability that facilitates the design and optimisation of technical textiles in various industrial applications.

Keywords: *CFD, Neural networks, porous media, technical textile*

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