On The Permeability Simulation of Multifilament Woven Fabrics

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Because of their strength, flexibility, and high permeability, multi-filament woven materials are used in various applications in our daily life. Traditional studies dedicated to permeability of multifilament fabrics are mainly experimental and many of them are designed for specific applications. Most of the previous simulations of multifilament fabrics are based on monofilament geometries made of porous materials. In such studies, the flow field is divided into two zones of intra-yarn and inter-yarn and solved separately. The intra-yarn zone is obtained via 2-D simulations whereas the inter-yarn zone is often calculated in 3-D space. Assuming the intra-yarn zone to be a porous filament greatly reduces the computational requirements, but instead, requires accurate information regarding the yarn's permeability. In 1922 B. R. Gebart (***Journal of Composite Materials*** 26 (8), 1100-1133) conducted 2-D simulations for the flow of Newtonian fluid perpendicular to and parallel with the hexagonally packed unidirectional filaments in a yarn.

The Gebart's expressions have been widely used in the literature and have given reasonable predictions of the experimental data. Gebart's expressions, however, have never been accurately validated by experiment. This is simply because these expressions are derived for an idealized arrangement of the filaments in the yarns which is impossible to duplicate in an experiment.

The study reported here, is aimed at solving the flow field inside the multifilament fabrics in one step using a continuous flow field, i.e., without breaking the simulation domain into inter-yarn and intra-yarn zones. Such calculations result in an accurate flow field prediction. Figure 1 shows the unit cell of a monofilament woven fabric followed by a similar cell made of idealized multifilament yarns.

The dimensionless permeability, $\boldsymbol{K}/\boldsymbol{r_y}^2$, of the multifilament fabrics with $\boldsymbol{L_y}$= 0.4 mm and $\boldsymbol{d_y} = 2\boldsymbol{r_y}$ = 0.2 mm are computed and presented in Figure 2. The intra-yarn SVF, a_y, is changed from 33% to 67.6%, for yarns having filament diameters ranging from $\boldsymbol{d_f}$ = 9.75 to 13.95 micrometer. Similar simulations are performed for fabrics made of monofilament porous yarn with the same $\boldsymbol{d_y}$ and $\boldsymbol{L_y}$, and $K_{\parallel}$ and $K_{\perp}$ are taken from Gebart's equations for yarns in right or parallel directions of flow.

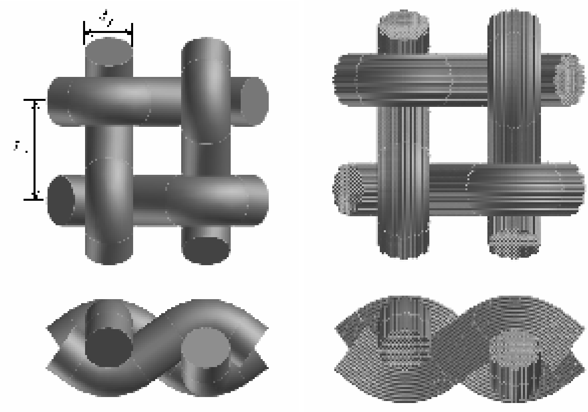

Figure 1: Unit cell of a monofilament and multifilament woven fabrics from top and side views. The multifilament woven fabric is made of 139 filaments packed in a hexagonal arrangement within the yarns having the same diameter as the monofilament fabric.

It can be seen that there is a good agreement between the predictions of Gebart's expression and our simulations. Gebart's expression however, seem to underestimate the fabrics' permeability by 10% to 15% even at high SVFs (SVF>0.6) where it was claimed to be accurate.

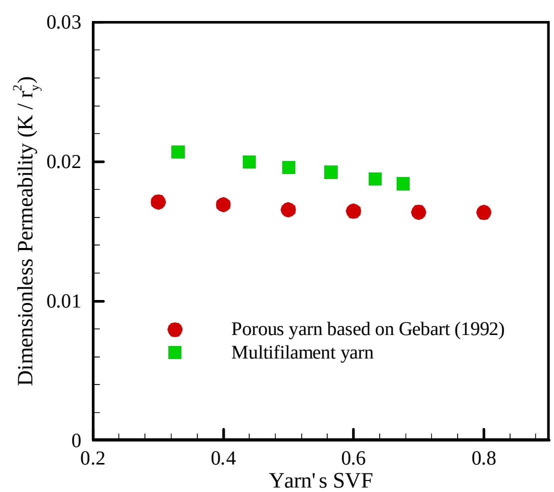

Figure 2: Comparison between the fabric's permeability obtained via the Gebart's expressions for the permeability of yarns and our full 3-D simulations.

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