World Academy of Science, Engineering and Technology
International Journal of Aerospace and Mechanical Engineering
Vol:16, No:05, 2022

Influence of Intra-Yarn Permeability on Mesoscale Permeability of Plain Weave and 3D Fabrics

Authors : Debabrata Adhikari, Mikhail Matveev, Louise Brown, Andy Long, Jan Kočí

Abstract : A good understanding of mesoscale permeability of complex architectures in fibrous porous preforms is of particular interest in order to achieve efficient and cost-effective resin impregnation of liquid composite molding (LCM). Fabrics used in structural reinforcements are typically woven or stitched. However, 3D fabric reinforcement is of particular interest because of the versatility in the weaving pattern with the binder yarn and in-plain yarn arrangements to manufacture thick composite parts, overcome the limitation in delamination, improve toughness etc. To predict the permeability based on the available pore spaces between the inter yarn spaces, unit cell-based computational fluid dynamics models have been using the Stokes Darcy model. Typically, the preform consists of an arrangement of yarns with spacing in the order of mm, wherein each yarn consists of thousands of filaments with spacing in the order of μm. The fluid flow during infusion exchanges the mass between the intra and inter yarn channels, meaning there is no dead-end of flow between the mesopore in the inter yarn space and the micropore in the yarn. Several studies have employed the Brinkman equation to take into account the flow through dual-scale porosity reinforcement to estimate their permeability. Furthermore, to reduce the computational effort of dual scale flow, scale separation criteria based on the ratio between yarn permeability to the yarn spacing was also proposed to quantify the dual scale and negligible micro-scale flow regime for the prediction of mesoscale permeability. In the present work, the key parameter to identify the influence of intra yarn permeability on the mesoscale permeability has been investigated with the systematic study of weft and warp yarn spacing on the plane weave as well as the position of binder yarn and number of in-plane yarn layers on 3D weave fabric. The permeability tensor has been estimated using an OpenFOAM-based model for the various weave pattern with idealized geometry of yarn implemented using open-source software TexGen. Additionally, scale separation criterion has been established based on the various configuration of yarn permeability for the 3D fabric with both the isotropic and anisotropic yarn from Gebart's model. It was observed that the variation of mesoscale permeability Kxx within 30% when the isotropic porous yarn is considered for a 3D fabric with binder yarn. Furthermore, the permeability model developed in this study will be used for multi-objective optimizations of the preform mesoscale geometry in terms of yarn spacing, binder pattern, and a number of layers with an aim to obtain improved permeability and reduced void content during the LCM process.

Keywords : permeability, 3D fabric, dual-scale flow, liquid composite molding
Conference Title : ICFMCM 2022 : International Conference on Fluid Mechanics and Composite Materials
Conference Location : Paris, France
Conference Dates : May 16-17, 2022