Commentary
Volume 12:4, 2022

Journal of Textile Science & Engineering

ISSN: 2165-8064

Open Access

A Porous Capillary Tube Approach for Textile Saturation

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Description

Capillarity plays a crucial role in many natural and engineered systems, ranging from nutrient delivery in plants to functional textiles for wear comfort or thermal heat pipes for heat dissipation. Unlike nano- or microfluidic systems with well-defined pore network geometries and well-understood capillary flow, fiber textiles or preforms used in composite structures exhibit highly anisotropic pore networks that span from micron scale pores between fibers to millimeter scale pores between fiber yarns that are woven or stitched into a textile preform. Owing to the nature of the composite manufacturing processes, capillary action taking place in the complex network is usually coupled with hydrodynamics as well as the (chemo) rheology of the polymer matrices; these phenomena are known to play a crucial role in producing high quality composites. Despite its importance, the role of capillary effects in composite processing largely remained overlooked [1].

Their magnitude is indeed rather low as compared to hydrodynamic effects, and it is difficult to characterize them due to a lack of adequate monitoring techniques to capture the time and spatial scale on which the capillary effects take place. There is a renewed interest in this topic, due to a combination of increasing demand for high performance composites and recent advances in experimental techniques as well as numerical modeling methods. The present review covers the developments in the identification, measurement and exploitation of capillary effects in composite manufacturing. A special focus is placed on Liquid Composite Molding processes, where a dry stack is impregnated with a low viscosity thermoset resin mainly via in-plane flow, thus exacerbating the capillary effects within the anisotropic pore network of the reinforcements. Experimental techniques to investigate the capillary effects and their evolution from post-mortem analyses to in-situ/rapid techniques compatible with both translucent and non-translucent reinforcements are reviewed. Approaches to control and enhance the capillary effects for improving composite quality are then introduced. This is complemented by a survey of numerical techniques to incorporate capillary effects in process simulation, material characterization and by the remaining challenges in the study of capillary effects in composite manufacturing [2,3].

Capillary action is defined as the process whereby a fluid flows on a surface, thus displacing air or another immiscible phase present on this solid surface, under no external forces, simply due to the presence of intermolecular forces between the liquid and the solid surface. These forces arise from the presence of the liquid/air surface tension and the interfacial tension between the solid and the liquid phase. A pressure difference is thus created between the pressure in the air and that in the fluid phase, driving fluid flow at the interface between solid, liquid and generally air.Owing to the nature of the composite manufacturing processes, capillary action is usually coupled with hydrodynamics, since flow is driven by externally applied pressure, as well as with the (chemo)rheology of the polymer matrices; in addition, the matrix material in liquid form is generally much more viscous than water, up to several orders of magnitude, leading to a strong dependence of the mechanisms to the interface velocity. Despite their importance, capillary effects largely remained overlooked in composite processing research. Their magnitude is rather low as compared to hydrodynamic effects, which dominate the flow kinetics [4,5].

Conflict of interest

None.

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How to cite this article: Worku, Amare. “A Porous Capillary Tube Approach for Textile Saturation.” J Textile Sci Eng 12 (2022): 477

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Received: 02 April 2022, Manuscript No jtese-22-64536; **Editor assigned:** 04 April, 2022, PreQC No. P-64536; **Reviewed:** 16 April 2022, QC No. Q-64536; **Revised:** 21 April 2022, Manuscript No. R-64536; **Published:** 28 April, 2022, DOI: 10.37421/2165-8064.2022.12.477