Thanasis D. Papathanasiou

Professor, Mechanical Engineering, U. of Thessaly, Greece

Science and Manufacturing of Polymers and Composites

EDUCATION

1990	PhD, Department of Chemical Engineering McGill University, Montreal, Canada *Field: Polymer Processing (Injection Molding)*
1987	MSc, Department of Chemical & Petroleum Engineering The University of Calgary, Calgary, Canada *Field: Biochemical Engineering (Reactor Design)*
1984	Chemical Engineering Diploma National Technical University of Athens, Athens, Greece.

POSITIONS

2016-	Professor of Mechanical Engineering
2008-2016	Associate Professor of Mechanical Engineering (tenured) University of Thessaly, Volos, Greece
1997-2008	Associate Professor of Chemical Engineering (tenured) University of South Carolina, Columbia, SC 29208, USA
2002-2004	Associate Director for Engineering South Carolina Center for Manufacturing & Technology (CMAT) University of South Carolina, Columbia, SC 29208
1993-1997	Unilever Lecturer in Process Engineering Department of Chemical Engineering & Chemical Technology Imperial College, London SW7 2BY, UK
1993-1997	Associated Academic Center for Composite Materials, Imperial College, London SW7
1991-1992	Director's Post-Doctoral Fellow Engineering Sciences & Applications Division (ESA/EPE) Los Alamos National Laboratory, Los Alamos, NM 87545, USA
1990	R&D Scientist, Aluminium Castings Division ALCAN International Ltd., Kingston R&D Center, Kingston, Canada

RESEARCH

My interests revolve around the investigation of processing-structure-property relationships in composite materials. Processes of interest involve flow into complex cavities or channels (injection molding, calendering) or through fibrous media of complex internal structure (liquid molding, pultrusion). Key to our approach is the use of computation to investigate the influence of microstructure on the details of the flow fields (processing-microstructure correlations) as well as on the details of concentration, thermal or stress fields (microstructure-property correlations). In addition we are interested in developing and testing realistic CAD models for composites manufacturing processes, with recent emphasis in die- and pin-assisted pultrusion. My work has been funded (over 2 mil. USD) by the EU, the US-NSF, US-DOD, US-ONR and US-DOE, as well as by local industry in the US and the UK.

SCHOLARSHIP

62 papers in refereed journals (ISI), over 60 conference proceedings, 1 edited book "Flow-Induced Alignment in Composite Materials", 4 book chapters. Over 550 citations. ISI h-score 17. Organizer, "Composites Symposium" 2014 and 2017 Polymer Processing Society Meetings. Reviewer, among others, Composites Part A, Physics of Fluids, Polymer Engineering & Science, Chemical Engineering Science, Composites Science & Technology, Polymer Composites.

TEACHING (Chemical and Mechanical Engineering Departments in the US, UK and Greece)

Fluid Mechanics, Thermodynamics, Heat Transfer, Advanced Fluid Mechanics, Polymer Processing, Introduction to Polymers, Polymer Rheology (post-graduate), Particle Technology, Composites Processing

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RESEARCH INTERESTS & ACTIVITIES

I am interested in the investigation of processing-structure-property relationships in composite materials, as a prerequisite to optimal process and product design. Processes of interest involve either flow into complex cavities or channels (injection molding, calendering) and through fibrous media of complex internal structure (liquid molding, pultrusion) or transport in filled systems. Key to our approach is the use of computation to investigate the influence of microstructure on the details of the flow fields (processing-microstructure correlations) as well as on the details of concentration, thermal or stress fields (microstructure-property correlations). In addition we are interested in developing and testing realistic CAD models for composites manufacturing processes, with recent emphasis in die- and pin-assisted pultrusion. My work has been funded by the EU as well as by the US-NSF, US-DOD, US-ONR and US-DOE. Specific projects:

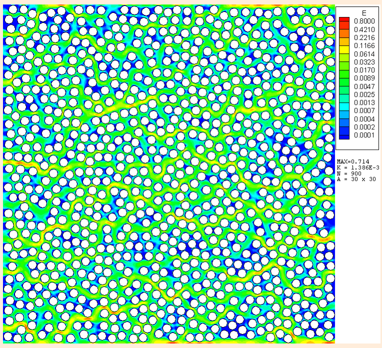


Figure 1: Velocity field for transverse flow across an array of ~1000 randomly placed fibers [2].

1 <u>Micro-Scale Flows in Fibrous Media [1-5]</u>: We are interested in the computational investigation of flow patterns (e.g Figure (1)) in fibrous media of complex internal structure, such as those encountered in liquid molding of high performance composites, and the determination of how such patterns are affected by the microstructural details of these media. Both Stokes' and finite Reynolds-number flows are considered. An immediate objective is the development of quantitative models for the effective permeability (K) of fibrous media as function of microstructural parameters. This involves differentiating between various hard-core arrays (currently lumped together under the heading "random") as well as identifying the point in microstructure evolution at which a fibrous medium's resistance to flow is significantly affected by clustering. A large part of this effort involves proposing and testing microstructural metrics that correlate with the observed trends in (K). Achievements include the development of predictive models which relate measures of microstructural randomness to the deviation of (K) from that of regular arrays.

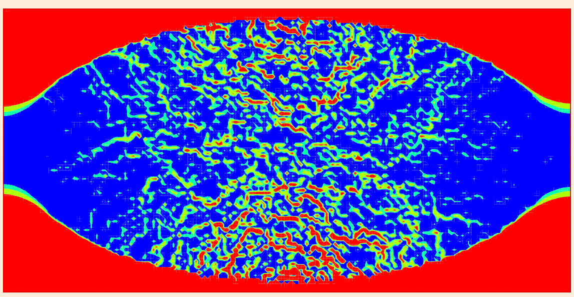
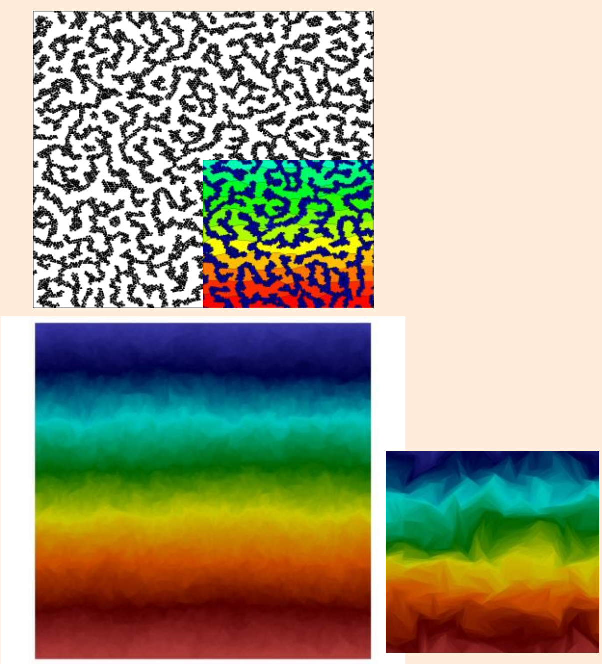


Figure 2: Distribution of interstitial fluid speed in a dual porosity fibrous material.

2 <u>Flow through Dual-Scale Porous Media [6-7]</u>: Such media are ubiquitous in the area of composites fabrication, where different types of reinforcement in different stages of orientation and aggregation are combined to produce preform architectures with optimal processability and products with optimal on-site performance. Our work here is aimed at elucidating the micro-scale flow patterns occuring in these materials and, specifically, the interplay between micro- and macro-scale flows. These flows are at the heart of the observed variation of permeability (K) and we are interested in developing/proposing and testing models for (K). Besides flows related to composite materials fabrication, dual-porosity fibrous systems are encountered in membrane separations and reactors as well as in biological systems, where they determine overall transport rates. Example flow in such dual-porosity medium consisting of a square array of fiber bundles, each containing 11000 individual filaments, is shown in Figure (2). Colors indicate dimensionless fluid speed levels - red for u>0.0.1, blue for u<0.025 and green for intermediate values.



3 <u>Transport across filled systems</u> [8-11]: We are using high performance computing (based on the BEM and the FVM) to investigate the manner in which the efficacy of filled systems is affected by their internal structure. Systems of interest include flake-filled membranes and particulate/fiber composites in which the dispersed phase shows various degrees of aggregation. An example of transport across a particulate containing 10,000 individual particles, the aggregation state of which is determined by the parameters of the NVT-MC algorithm used in its generation, is shown in Figure (3.a). Concentration contours for diffusion across a material filled with 50000 randomly placed and randomly oriented impermeable flakes at very high concentration ($\alpha\varphi$=10) are shown in Figure (3.b) and detail within a subsection containing 2000 flakes in (3.c). These illustrate the coupling between local inhomogeneity and macroscopic homogeneity and are the key in understanding the manner in which microstructure alters the effective properties of the composite.

Figure 3: Distribution of concentration in two random filled systems. Top (3.a). Bottom left (3.b) and right (3.c)

4 <u>Realictic Modeling of Polymer/Composites Manufacturing Operations [12-16]</u>: We are interested in developing and using realistic CAD models for polymer manufacturing processes (Figure (4)), especially processes which make use of flow and geometry to achieve the infiltration of a resin into a fibrous/porous scaffold. Our objective is to combine large numbers of CAD results in order to propose and test explicit process models relating material and process parameters to fabrication outcomes – in the case of pin-assisted pultrusion, such a model for the extent of resin infiltration was recently proposed in [15]. In addition, we are interested in coupling fluid mechanics and material deformability (flow/structure interactions) in pultrusion and liquid molding [16].

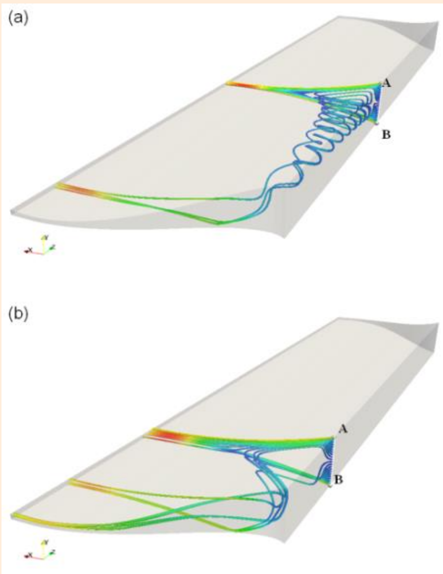


Figure 4: Predicted non-intuitive fluid trajectories (3D Calendering of a polymeric melt) showing that the sides of the calendered sheet originate in the interior of the fed material [14].

Selected Publications

1 T.D. Papathanasiou, "A Structure-Oriented Micromechanical Model for Slow Flow Through Square Arrays of Fiber Clusters", Composites Science & Technology, **56**(9), 1055-1069, (1996)

2 X. Chen and T.D. Papathanasiou, “The transverse permeability of disordered fiber arrays: A statistical correlation in terms of the mean interfiber spacing”, Transport in Porous Media, **71**(2), 233-251, 2007

3 X. Chen and T.D. Papathanasiou, “Micro-Scale Modelling of Axial Flow through Unidirectional Disordered Fiber Arrays”, Composites Science and Technology, **67**, 1286-1293,2007

4 X. Chen and T.D. Papathanasiou, “On the variability of the Kozeny constant for saturated flow across unidirectional, disordered, fiber arrays”, Composites Part A: Manufacturing and Applied Science, **37**(6), 836-846, 2006

5 T.D. Papathanasiou, B. Markicevic and E. Dendy, “A computational evaluation of the Ergun and Forchheimer equations for fibrous media”, Physics of Fluids, **13**(10), 2795-2804, 2001

6 B. Markicevic and T.D. Papathanasiou, “An Explicit Physics-Based Model for the Transverse Permeability of Multi-Material Dual Porosity Fibrous Media”, Transport in Porous Media, **53**(3), 265-280, 2003

7 B.Bijeljic, M.D.Mantle, A.J.Sederman, L.F.Gladden and T.D.Papathanasiou , "Slow flow across macroscopically semi-circular fibre lattices and a free flow region of variable width - visualisation by magnetic resonance imaging", Chemical Engineering Science, Vol.**59**(10) pp. 2089-2103, 2004

8 A. Tsiantis and T.D. Papathanasiou, “The Barrier Properties of Flake-Filled Composites with Precise Control of Flake Orientation”, Materials Sciences and Applications: Special Issue on Additive Manufacturing, to appear 3/2017

9 X. Chen and T.D. Papathanasiou, “Barrier properties of flake-filled membranes: Review and numerical evaluation”, Journal of Plastic Film and Sheeting, **23**(4), 319-346, 2007

10 T.D. Papathanasiou and A. Tsiantis, “Orientational Randomness and its Influence on the Barrier Properties of Flake-Filled Composite Films”, Journal of Plastic Film and Sheeting, in print, 2017 DOI: 10.1177/8756087916682793

11 M.S. Ingber and T.D. Papathanasiou, "A Parallel-Supercomputing Investigation of the Stiffness of Aligned, Short-Fiber-Reinforced Composites using the Boundary Element Method", International Journal for Numerical Methods in Engineering, **30**, 3477-3491, (1997)

12 N. Polychronopoulos and T.D. Papathanasiou, “A Study on The Effect of Drawing on Extrudate Swell in Film Casting”, J. of Applied Rheology, **25**(4), 31-37, 2015

13 N. Polychronopoulos and T.D. Papathanasiou, “Pin-Assisted Resin Infiltration of Porous Substrates”, Composites Part A – Applied Science and Manufacturing, **71**, 126-135, 2015

14 N. Polychronopoulos, I. Sarris and T.D. Papathanasiou, “3D Features in the Calendering of Thermoplastics: A Computational Investigation”, Polymer Engineering & Science, **54**,1712-1722, 2014

15 N. Polychronopoulos and T.D. Papathanasiou, “A Novel Model for Resin Infiltration in pin-assisted Pultrusion”, Polymer Composites, 2015 (DOI 10.1002/pc.23860)

16 N. Polychronopoulos and T.D. Papathanasiou, “Fluid Penetration in a Deformable Permeable Web moving past a Stationary Rigid Cylinder”, Transport in Porous Media, **116**:393-411, 2017