CHEMICAL ENGINEERING

Fater S.p.A. - Development of CFD models for the simulation of fluid flow and transport in absorbent hygiene products

Funded By	FATER S.P.A. [P.iva/CF:01282360682]

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Context of the research activity	The research (in collaboration with FATER) aims to develop computational models for absorbent hygiene products (AHP), focusing on fluid absorption in porous media made of SAP and fluff. Building on previous validated models, this work introduces two innovations: separate analysis of layers (outer fabrics vs. absorbent core) and a multiscale approach combining macroscale (porous medium) and pore-scale (voids between SAP and fluff) modeling to predict absorption, distribution, and rewet behavior.

	The three-year research project will use computational fluid dynamics (CFD) and machine learning (ML) tools, structured as follows: Year 1 The first year will focus on literature review, training of newly hired staff, and alignment with Fater's internal expertise. Various software tools (COMSOL, OpenFOAM, Blender, Yade, PoreSpy, Keras, TensorFlow, PyTorch) will be tested to define an effective, manageable, and maintainable workflow in collaboration with Fater. Special attention will be paid to which tools Fater can internalize, assessing pros and cons of commercial vs. open-source software. Experimental validation activities will also be defined, using literature data or experiments carried out at Fater. Material characterization needs will be discussed to identify potential new experimental capabilities. Expected outcomes by Year 1 end: trained personnel, tested and functional workflow, experimental campaign planned, and selection of target materials, including property ranges to explore different behavior regimes. Year 2 This year will focus on selecting materials and performing pore-scale simulations using small representative elementary volumes (REVs), following previously developed methodologies. Unlike past models based on Lagrangian particle tracking, the new simulations will adopt methods like volume-of-fluid or immersed boundary/level-set, better suited to describing two-phase water-air flow in absorbent materials. The goal is to quantify

Objectives	hydraulic resistance and fluid spreading, and to develop realistic constitutive equations. ML tools will also be used to build surrogate models replacing these equations. Modeling will run in parallel with experimental validation. A scientific article will be written and submitted as a requirement for the PhD. Expected outcomes by Year 2 end: improved understanding of fluid transport, spreading, absorption, and rewetting in AHPs; improved constitutive equations; ML-based surrogate models. These will enable: Avoiding assumptions on key material properties; 50% reduction in lab testing currently used for material and product characterization. As a further goal, at least two innovative materials will be proposed for future Fater products. These may be existing or reverse-engineered. Year 3 This year will complete Year 2 activities and integrate analyses across materials and scales. Macroscale simulations (at full AHP scale) will be performed using the previously developed constitutive equations. A macroscale model based on ML surrogate models will be validated, aiming for higher accuracy and efficiency compared to lab-only testing. This model will be 2D or 3D, realistically representing the worn product without constitutive equations, using behavior “actively learned” from pore-scale simulations via ML. The PhD thesis will be written and submitted this year, along with a second scientific article, if possible. Expected outcomes by Year 3 end: submitted thesis, validated constitutive equations tested in macroscale models, and a working prototype of a surrogate-based simulator. All data and codes will be archived using FAIR principles (Findability, Accessibility, Interoperability, Reusability). The simulator will be tested by predicting the performance of a new product for a consumer test.

Skills and competencies for the development of the activity	The ideal candidate should have a solid background in CFD, transport phenomena, and porous media. Experience with COMSOL and OpenFOAM is particularly valued. Prior knowledge of fluid flow and transport in porous media is highly appreciated. Familiarity with machine learning—especially neural networks—is considered a plus, though not a mandatory requirement.