Université de Technologie de Compiègne

PhD Grants from the China Scholarship Council: PhD proposal for 2022

Thesis title: Mass transfer from core-shell cylinders subjected to flow

Keywords: Transport phenomena, computational fluid dynamics, lattice Boltzmann method, artificial lung, heat sink exchanger

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Summary: The project aims to study systematically mass transfer from initially loaded cylinders covered with a semi-permeable shell and subjected to flow. Two-dimensional computer simulations based on two-component lattice Boltzmann method will be used to compute the flow around the cylinders and the mass transport of a released solute. Mass transfer efficiency will be characterized with the Sherwood number (the dimensionless transfer coefficient) as a function of different parameters, such as the shell permeability and the cylinders spatial arrangement. An in-house fully parallelized code developed with Fortran 2000 will be used together with the emerging techniques of machine learning to screen a wide range of control parameters. Access to modern advanced workstations and supercomputer platforms such as PILCAM2 of the UTC will be granted.

Planning of the PhD project:

1. First year: Extension of recent studies [1,2] to a large range of the blockage degree (ratio of the cylinder diameter to the width of the channel) to investigate numerically the effect of the confinement, which will be compared to the theory of Khan et al [3], while considering both cases: constant and varying boundary conditions at the surface of the cylinder,
2. Second year: Study the efficiency of mass transfer from a stationary array of core-shell cylinders, with the aim to complement the list of existing correlations in literature of heat efficiency in heat sink exchangers, while considering cylinders with semi-permeable shells (that adds an interfacial resistance). The model and the knowledge of this part of the project will be applied to model oxygen exchange in an array of cylinders for future design of artificial lungs,
3. Third year: Development of a numerical method to study mass transfer efficiency from a single core-shell cylinder, whose shell undergoes either growth or shrinkage (accumulation of an undesired matter or shell degradation due to aging), while coupling the lattice Boltzmann method (used for the transport phenomena) and the phase field model (used for the cylinder shape evolution).

International collaborations with:
CNR (Italy), Helmholtz Institute Erlangen-Nürnberg for Renewable Energy (Germany), Massachusetts General Hospital (USA), University of South Africa (South Africa)

References:

[1] C. Bielinski , N. Le, and B. Kaoui, Unsteady mass transfer from a core-shell cylinder in crossflow, Physical Review Fluids 6, 023501 (2021)
[2] B. Kaoui, Flow and mass transfer around a core-shell reservoir, Physical Review E 95, 063310 (2017).
[3] W. A. Khan, J. R. Culham, and M. M. Yovanovich, Fluid flow and heat transfer from a cylinder between parallel planes, J. Thermophys. Heat Transfer 18, 395 (2004).

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论文题目：核-壳结构圆柱在流场中的溶质质量转移研究

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该课题旨在系统性地研究具有初始溶质装载的圆柱在流场中的溶质质量转移，其中圆柱的壁面被假定为一个具有半渗透性的薄壳。二维的基于双组分的Lattice Boltzmann法求解圆柱周围的流场和其内部所释放溶质的质量输运。传质效率由Sherwood数（无量纲化的传递系数）来表征，并且其受不同参数的影响，例如壳的渗透性以及圆柱的空间排置。由Fortran 2000开发的内部完全并行化的代码将与新兴的机器学习技术一起对各种控制参数展开大规模计算机模拟。该工作将被授权使用学校的现代高级工作站和超级计算机平台，例如PILCAM2。

研修计划：

1. 第一年：扩展近来的研究 [1,2]，通过引入阻塞度（圆柱体直径和管道直径的比值）来探究管道的限制作用。该数值结果将和Khan等人的理论进行对比 [3]，并同时考虑下列两种情形：固定的和可变的圆柱壁面的边界条件。
2. 第二年：研究包含核-壳结构圆柱的固定阵列的传质效率，其目的是在现有研究中补充当考虑具有半透壳圆柱的散热交换器的质/热效率的相关性列表。该模型和该课题的部分成果将被用于模拟一组圆柱阵列中的氧气交换，并指导未来人工肺的设计。
3. 第三年：开发一种数值方法来研究单个核-壳圆柱的传质效率，其中壳考虑由于物质积累或壳降解所造成的增长或收缩。该模型耦合Lattice Boltzmann法（用于输运现象）和相场模型（用于圆柱外形演变)。

国际合作：
CNR (Italy), Helmholtz Institute Erlangen-Nürnberg for Renewable Energy (Germany), Massachusetts General Hospital (USA), University of South Africa (South Africa)

参考文献：

[1] C. Bielinski , N. Le, and B. Kaoui, Unsteady mass transfer from a core-shell cylinder in crossflow, Physical Review Fluids 6, 023501 (2021)
[2] B. Kaoui, Flow and mass transfer around a core-shell reservoir, Physical Review E 95, 063310 (2017).
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