FULL SCALE OXYGENATOR GAS TRANSFER MODELING: PARAMETERS FOR A REDUCED ORDER MODEL APPROACH

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Introduction

Oxygenators, so-called artificial lungs, support patients with severe lung diseases by leading blood through bundles of thousands of fiber membranes. Hemocompatibility is a major challenge, mainly associated with the large surface area and priming volume [1]. New and more efficient oxygenator designs are required to tackle those challenges. Computational models that allow an a priori estimation of gas transfer are a key step to facilitate the rapid development and testing of new device concepts. Particularly the interaction between local flows conditions, fiber arrangement and gas transfer needs to be considered on a macroscopic device scale. Such models do not exist yet. The aim of this study was to extend a reduced order model [2] to incorporate the effect of different fiber arrangements. Therefore, gas transfer rates of isolated arrangements were correlated with flow conditions and local gas concentration differences. This correlation was applied to a porous medium domain of an experimental oxygenator [3].

Methods

We have used a recently developed and validated 3D computational fluid dynamics model of microscopic gas transfer and blood flow around various hollow fiber arrangement (Figure 1). Then, these microscopic simulations of different fiber arrangements and different blood gas concentrations were used to obtain gas transfer rates.

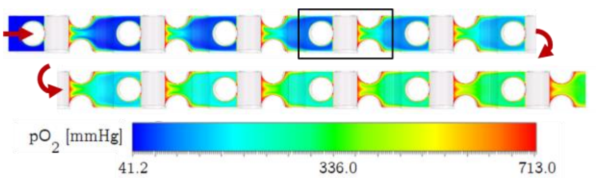

Figure 1: Microscale gas transfer simulation of a cross stacked fiber arrangement. Averaged gas transfer rates were determined for multiple sections (black frame) along the flow path.

These were translated into dimensionless Sherwood numbers (Sh) and correlated to dimensionless flow conditions (Reynolds number, Re and Schmidt number Sc) and a newly introduced dimensionless concentration difference (θ), using a polynomial curve fitting approach. This mass transfer correlation was implemented into a porous medium model and tested on the RatOx oxygenator [3].

Results

The polynomial function shows very high oxygen transfer for high velocities and high differences in partial pressure (Figure 2). For very high flow rates and for low partial pressure differences oxygen transfer is low. The correlation was implemented into the CFD model.

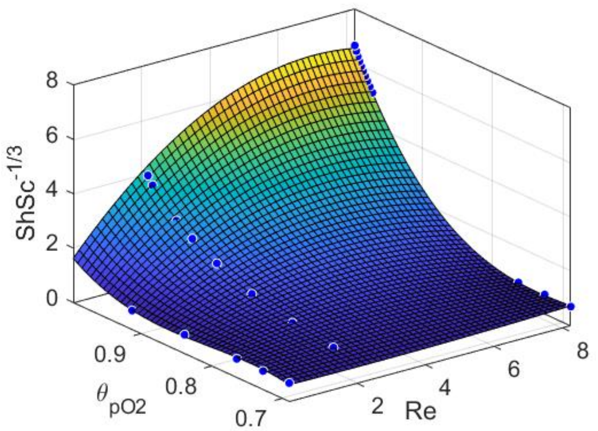

Figure 2: Polynomial mass transfer correlation for the fiber arrangement found in the RatOx oxygenator.

Discussion

Our newly introduced dimensionless concentration difference allowed us to better capture the intricate interplay between geometry, flow physics and gas transfer. The derived dimensionless relationship allows an easy implementation into widely used porous medium models and drastically accelerate development times of novel hollow fiber oxygenators.

References

1. Nguyen Thi et al, Acta Mater, 152:19-46, 2022.
2. Zhang et al, J Membr Sci, 288:268-279, 2007.
3. Strudthoff et al, Micromachines, 14(4):800, 2023.

Acknowledgements

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