Design of new membrane housings for a Portable Artificial Kidney

Chemical Engineering

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Introduction

Patients with end stage renal disease (ESRD) are progressively increasing [1]. The most used therapy is hemodialysis (HD) [2]. Studies show that higher frequency HD not only increases the quality of life of ESRD patients but also lowers morbidity and mortality rates [3].

Novel microdevices designed to perform continuously will result in a smoother correction of uremic abnormalities and offer greater mobility for ESRD patients. Early development of a portable artificial kidney (PAK) for the treatment of ESRD is envisioned based on a novel blood purification device that integrates membrane technology in a microfluidic system – the microfluidic membrane device (MFMD).

Materials and methods

Software: Onshape®
Printer: Ultimaker®
Material: Acrylonitrile butadiene styrene (ABS)

The device was connected to an in-house built experimental system that simulates the extracorporeal blood circulation circuit found in HD machines and is capable of measuring very low pressure variations (< 1 mmHg) under dynamic conditions (Figure 1).

To characterize the membrane housing, experiments were performed by placing a non-permeable polyester transparency film in the place to be occupied by the HD membranes in the future (Figure 2 and 3).

Figure 1 – Schematic representation of the experimental setup used to characterize the MFMD: Blood reservoir: ; Roller pump: ; Pulsation damper: ; Pressure sensor: ; Three-way valve: ; MFMD:

Theory

The half-height of the microchannel (B) is obtained by an equation analogous to the Hagen-Poiseuille law that describes the laminar flow of a Newtonian fluid in a narrow slit [4]:

\[ B = \frac{3 \mu Q}{2 W 

\Delta P} \]  

The shear stress (\( \tau \)) exerted to the walls of a microchannel is defined by the shear force generated by the fluid flow on the surfaces [4]:

\[ \tau = 3 \mu \frac{Q}{B^2 W} \]  

Where \( \mu \) is the viscosity of the fluid, \( L \) is the length of the microchannel, \( Q \) is the feed flow rate, \( W \) is the width of the microchannel and \( \Delta P \) is the pressure drop across the microchannel.

Results

Both channels were approximately 100 \( \mu \)m in height and that flow rates between 14 and 60 mL/min impose shear stresses between 6.3 and 27.8 Pa.

![Figure 2 – Illustration of the separate pieces of the MFMD, top view.](image)

![Figure 3 – (A) Illustration of the semi-assembled MFMD; (B) Illustration of assembled MDFD and the representation of the fluid pathway. (C) Prototype of MFMD.](image)

References