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Abstract

Static in-line gas mixer for physiological capnogram simulation

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In order to physically simulate the physiological CO_2 content over time (a so-called capnogram) in the exhaled air using a lung simulator, it is important to ensure adequate homogenization of the injected CO_2 within the airflow.

A static in-line mixing element is used for this purpose, which is required to fulfil various requirements at the same time: sufficient homogenization at different flow rates, small volume and low pressure drop [1]. After a literature review on the most common static in-line mixers and their respective application-specific advantages and disadvantages [2], we focused on two designs. We design and test different mixers based on a helical blade design (Kenics) and a crossbar design (SMX) for optimized homogenization of CO_2 in air. The focus of this study was the investigation of different Kenics mixer designs. Therefore, 13 Kenics mixers with different combinations of element length and number of elements are investigated for mixing performance and pressure loss using SolidWorks Flow Simulation (Dassault Systèmes, Vélizy-Villacoublay, France). In addition to these Kenics designs, an SMX mixer with three parallel crossbars and six crossbars across the diameter is designed as proposed in Singh et al. [3].

As the requirement for a small volume determined the mixer designs, this requirement is met in all designs. For very low flow rates sufficient homogenization is not achieved with any mixer, but for most at higher flow rates. The homogenization is increased by reducing the size of the mixing elements and increasing the number of mixing elements in the mixer. Based on the results of the flow simulation of all 14 mixer designs, three mixers are selected that provide the best compromise between mixing performance and pressure drop. These three mixers are then additively manufactured from polyamide using selective laser sintering, as this process leaves little to no support structures inside.

To experimentally investigate of the mixing performance, capnograms are simulated without any mixer at all and with each of the three printed mixers attached to the lung simulator. The selected mixers are the Kenics mixer with the smallest element length and four elements, the Kenics mixer with the second smallest element length and five elements and the SMX mixer. Analysis of the capnograms shows that homogenization without a mixer is inadequate, while each of the three mixers induces adequate homogenization. With the current CO_2-sensor (Infinity Mcable-Mainstream CO_2 by Dräger), there was no significant qualitative difference measurable in the mixing quality between the three selected mixers in the experimental test. In the future it is therefore necessary to reevaluate the numerical simulation of the gas mixing process using an advanced flow simulation tool, as well as conduct comparable experiments for simulation verification.

Author's statement

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