

Optimization of a DPI Inhaler: A Computational Approach

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Dry Powder Inhalers, DPIs, have been used commercially since 1971 and are continuously being improved and updated with new models. The main function of a DPI device is the dispersion of powder into particles which effectively transfer and deliver a drug to the respiratory system. The optimal function of a DPI requires a sufficiently large emitted dose and fine particle fraction, FPF, in the outflow. The outflow characteristics (i.e., the velocity flow field and the spatial distribution of outflowing particles) determine particle losses due to deposition in the oral cavity and thus influence the delivered dose. The emitted dose depends on the efficiency of powder dispersion and the internal losses due to deposition.

Several computational studies have been reported including computational fluid dynamics, CFD, and the discrete element method in order to describe DPI devices. Recently, (Milenkovic et al., 2014) a detailed CFD based computational model was employed to describe the particle motion and deposition in the Turbuhaler DPI under both steady state and dynamic flow conditions. The computational results were in agreement to available experimental data for total deposition as well as the FPF. This computational model is employed to evaluate the operation of two alternate geometries of the Turbuhaler DPI in terms of outflow characteristics, FPF, and total deposition. The original DPI Turbuhaler device geometry, G-A, consists of: two powder cylinders, an inhalation channel, a circulation chamber and a helical region of the mouthpiece. In this work two additional geometries (G-B and G-C) of the Turbuhaler DPI are proposed and constructed consisting of a larger circulation chamber with a spherical ceiling (G-B) or a different helical region geometry (G-C).

Steady flow CFD simulations were performed for $Q = 30-70$ L/min. Numerical convergence was achieved when all residuals (continuity, momentum, turbulence) were under 10^{-5} . A total of 40,000 particles were injected at $t=0s$. The particles followed a size distribution equal to that of the free flowing budesonide powder (e.g., ranging from 0.5-20 μ m). Particles deposited on the DPI walls only under specific conditions determined by an adhesion/collision model.

Both G-B and G-C DPIs displayed slightly less flow resistance than the G-A DPI mostly at low flow rates. For example, the flow rate in G-C at $\Delta P=8800$ Pa was increased by 8.3%. Significant, flow pattern differences are observed in the circulation chamber of G-B and in the helical region of G-C. Both G-B and G-C DPIs displayed decreased total deposition and increased FPF and G-B provided the largest improvements. Finally, the outflow pattern from the G-C DPI was found to be more uniform.

Milenkovic, J., Alexopoulos, A.H. and Kiparissides, C. *“Dynamic Flow and Particle Deposition in the Turbuhaler DPI. A CFD Simulation”*, International Journal of Pharmaceutics, 2014;461, 129-136

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