Investigation of Design Features on the Performance of 3D-Printed Dry Powder Inhalers. Part 2: Swirl Pipe Design

Yuqing Ye[1,2,3], Ziyi Fan[1], Ying Ma[1,3], Jesse Zhu[1]

[1]Department of Biomedical Engineering, Western University, 1151 Richmond Street, London, N6A 3K7, Canada
[2]China Beacons of Excellence Research and Innovation Institute, University of Ningbo Nottingham, China
[3]Suzhou Inhal Pharma Co., Ltd., 108 Yuxi Road, Suzhou, 215125, China

Introduction

- Turbulence introduced by swirl pipe designs in dry powder inhalers is believed to promote detachment and dispersion[1,2], consequently improving delivered fractions of fine drug particles .
- The feasibility and performance of the swirl pipe design in a capsule-based inhaler have not been investigated yet.

Objective

In this study, the spiral pipe design with different configurations is introduced into a capsule-based inhaler to study its influence on the drug-carrier separation and overall aerosolization performance.

Methods

- Design: The swirl pipe (SW) design was incorporated into the Breezhaler®, and changes were made to the inner diameter, thus generating three spiral channels with an inner diameter of 3 mm, 6 mm, and 9 mm, as can be seen in Figure 1.
- Aerodynamic analysis by a Next-Generation Impactor (NGI)
- Computational analysis by ANSYS Fluent

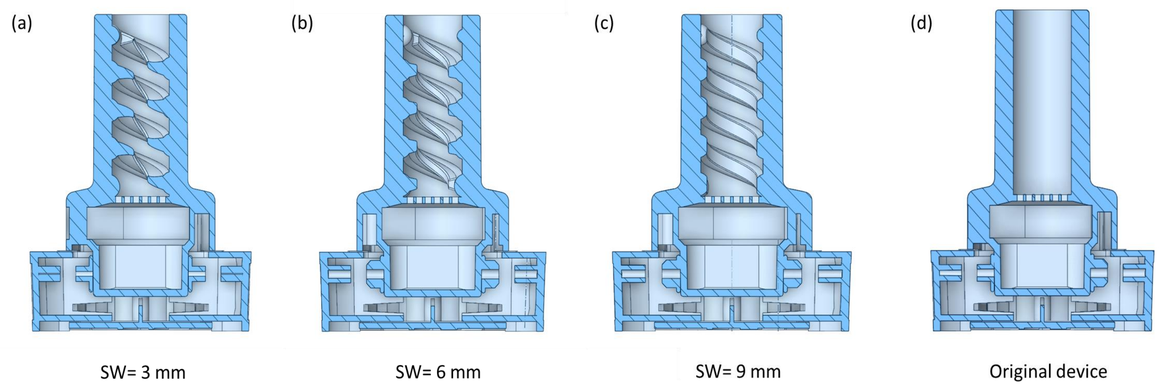

Figure 1 Illustration of 3D models of the inhalers with different swirl pipe designs

Results and Discussion

Aerodynamic results

- Mass retention of the API is remarkably high for the narrow spiral channel
- Narrower swirl pipe shows better API-carrier separation but lower aerosolization performance in terms of FPF and emitted dose

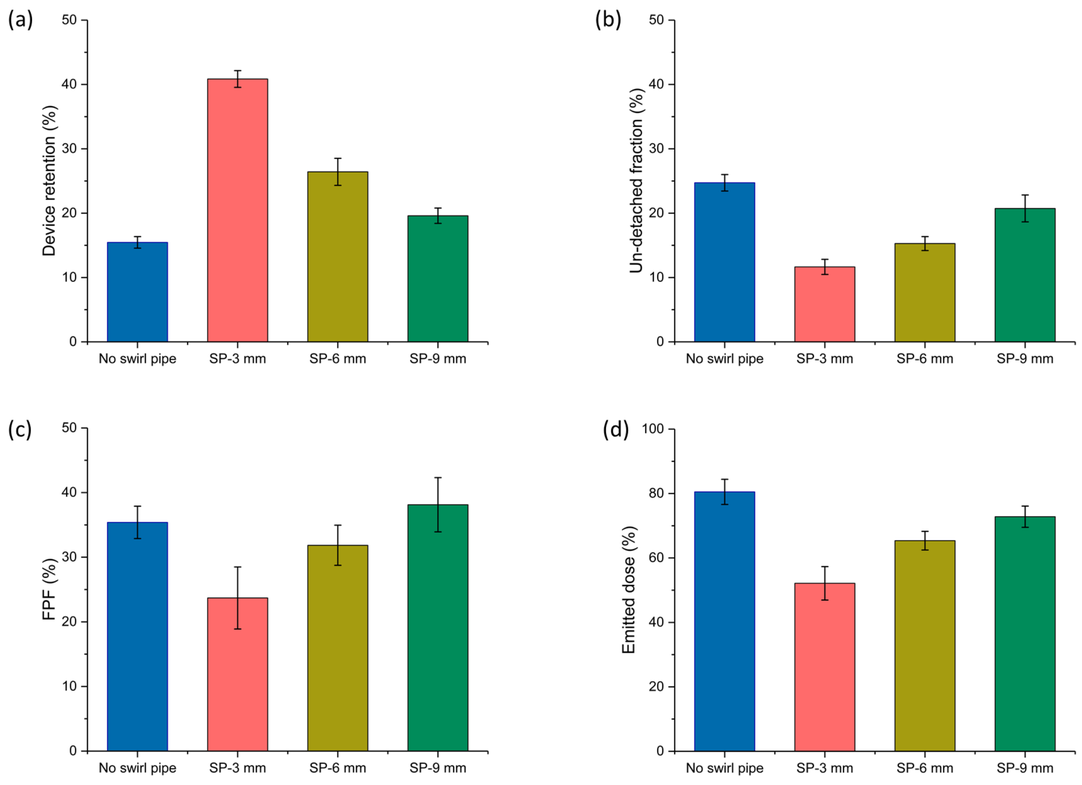

Figure 2 The aerosolization performance including (a) drug retention in the device, (b) un-detached drug fraction in pre-separator, (c) fine particle fraction, and (d) emitted dose

Computational results

- The narrower spiral pipe produced more swirled flow with higher velocity, intensive turbulent value, and wall shear in the mouthpiece when compared with straight air trajectories with relatively small velocity in the original inhaler.

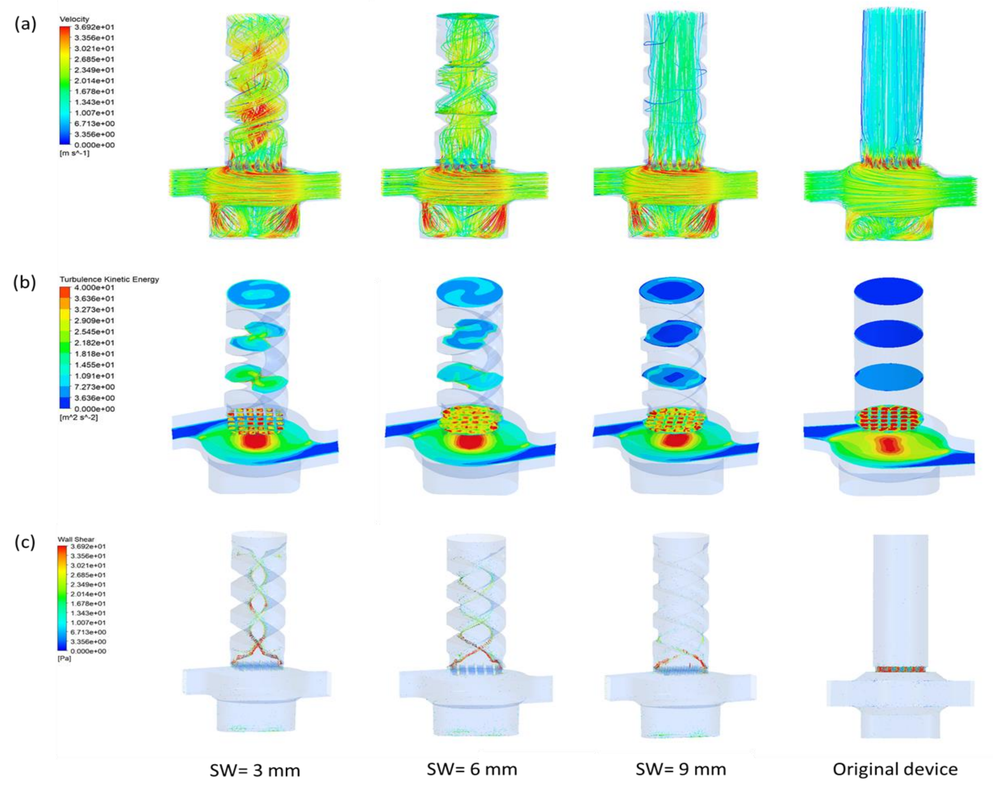

Figure 3 Contour maps of (a) airflow trajectories, (b) turbulent kinetic energy, and (c) wall shear in the inhalers with different swirl pipe designs

Discussion

- The increased turbulence and velocity in the swirl pipe promote API-lactose detachment.
- Possible reasons for the inconsistency between aerodynamic and computational results include: (1) sudden geometric transition for the flow from a large circular cross-session to a constricted spiral channel; (2) strong particle-wall collision introduced by the tangential velocity; (3) the complex interaction among the API and carrier particles.

Conclusion and Future Work

- Overall, the swirl pipe design could promote de-attachment of the API from the carrier.
- Narrow swirl pipe shows better separation but lower aerosolization performance in terms of FPF and emitted dose.
- Future work will be placed on the modifications of the swirl pipe design to further improve its dispersion and aerosolization.

Acknowledgement

This work was partially funded by Natural Sciences and Engineering Research Council of Canada (NSERC). The first authors (Yuqing and Ziyi) also acknowledge the financial support from the China Scholarship Council (CSC).

References

[1] T. Suwandecha, W. Wongpoowarak, K. Maliwan, and T. Srichana, “Effect of turbulent kinetic energy on dry powder inhaler performance,” *Powder Technology*, vol. 267, pp. 381–391, 2014.

[2] K. Elserfy, A. Kourmatzis, H.-K. Chan, R. Walenga, and S. Cheng, “Effect of an upstream grid on the fluidization of pharmaceutical carrier powders,” *International Journal of Pharmaceutics*, vol. 578, p. 119079, Mar. 2020.