Proceedings of the 4th International Conference on Fluid Flow and Thermal Science (ICFFTS'23)
Lisbon, Portugal- December 07 - 09, 2023
Paper No. 120
DOI: 10.11159/icffts23.120

Asymptotic Modeling of Microstructured Optical Fibres Drawing Process

Giovanni Luzi[1], Bernhard Gatternig[2], Antonio Delgado [1]
[1]LSTME Busan,
1276 Jisa-Dong, Gangseo-Gu, Busan, Republic of Korea
giovanni.luzi@lstme.org; antonio.delgado@lstme.org
[2]Hochschule Weihenstephan-Triesdorf,
Markgrafenstraße 12, Weidenbach, Germany
bernhard.gatternig@lstme.org

Extended Abstract

Microstructured Optical Fibres (MOFs) or "holey" fibres are a new type of optical fibres that has revolutionized the field of fibre optics. They are employed in a wide range of applications including telecommunication, sensing, and biophotonics. This new type of optical fibres has a microstructure typically consisting of air holes arranged in a periodic lattice patterned into the core of the fibre. The unique properties of MOFs originate from the fact that light is confined both by total internal reflection at the core/cladding interface and by the photonic bandgap created by the periodic lattice of air holes. This allows for control of the dispersion, nonlinearity, and confinement of light within the fibre [1]. These fibres are manufactured in special high-tech furnaces by feeding a preform with appropriate geometry into a heated region and by pulling it some distance downstream after the neck-down region. The resulting fibres usually have a diameter of some hundredths micrometres and the internal air holes typically have diameters in the micro-or nanoscale range. During the drawing process, both the cross-sectional shape and scale of the preform are altered due to thermo-fluid mechanical effects, and the final fibre may not possess the shape required to guide the light in the desired way. Therefore, precise control of the drawing process is highly desirable to manufacture fibres with the requested optical properties. Unfortunately, achieving a desired fibre design is not a trivial task, since only a few parameters can be adjusted in the drawing process. Mathematical models that describe the drawing process of MOFs are highly desired since they can predict both the changes in the fibre structure during the drawing process and the final fibre shape and size. Therefore, they can assist and potentially improve the MOFs technology. In the present contribution, we derive a new asymptotic energy equation for modeling the drawing of MOFs of any shape, by extending the previous work of Luzi *et al.* [2] and combining it with the contributions of Taroni *et al.* [3] and Stokes *et al.* [4]. We integrate the novel asymptotic energy equation into the asymptotic model of Chen et al. [5] for the case of an axis-symmetric capillary and into the Generalized Elliptical Pore Model (GEPM) of Buchak *et al.* [6] for the case of a MOF that contains many holes. We find very good agreement between experimental results and those of the whole asymptotic models both for the unpressurized case and when internal pressurization is applied.

Ackowledgements

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korean government (MSIT) (No. 2021R1F1A1050103)

References

[1] P. S. J. Russell, "Photonic-Crystal Fibers," *J. Lightwave Technol.*, vol. 24, no. 12, pp. 4729–4749, 2006.
[2] G. Luzi, S. Lee, B. Gatternig, and A. Delgado, "An Asymptotic Energy Equation for Modelling Thermo Fluid Dynamics in the Optical Fibre Drawing Process," *Energies*, vol. 15, no. 21, p. 7922, 2022.
[3] M. Taroni, C. J. W. Breward, L. J. Cummings, and I. M. Griffiths, "Asymptotic solutions of glass temperature profiles during steady optical fibre drawing," *J. Eng Math.*, vol. 80, no. 1, pp. 1–20, 2013.
[4] Y. M. Stokes, J. J. Wylie, and M. J. Chen, "Coupled fluid and energy flow in fabrication of microstructured optical fibres," *J. Fluid Mech.*, vol. 874, pp. 548–572, 2019.

[5] M. J. Chen, Y. M. Stokes, P. Buchak, D. G. Crowdy, and H. Ebendorff-Heidepriem, “Microstructured optical fibre drawing with active channel pressurisation,” *J. Fluid Mech.*, vol. 783, pp. 137–165, 2015.

[6] P. Buchak, D. G. Crowdy, Y. M. Stokes, and H. Ebendorff-Heidepriem, “Elliptical pore regularisation of the inverse problem for microstructured optical fibre fabrication,” *J. Fluid Mech.*, vol. 778, pp. 5–38, 2015.