Journal of Non-Crystalline Solids 481 (2018) 412–423

Contents lists available at ScienceDirect

Journal of Non-Crystalline Solids

journal homepage: www.elsevier.com/locate/jnoncrysol

Hole distortion and drift in extruded microstructured optical fiber glass preforms: Part II – Optimization

Mohamed Trabelsi[1], Paul F. Joseph*

Department of Mechanical Engineering, Clemson University, Clemson, SC 29634-0921, USA

ARTICLE INFO

Keywords:
Glass preform
Extrusion
Microstructured optical fiber
Photonic crystal fiber
Computational
Optimization

ABSTRACT

In Part I of this computational study, scalar variables were introduced to quantify the quality of the cross-sectional geometry of a glass preform used to draw Microstructured Optical Fibers (MOF). These non-dimensional variables measure the processing induced distortions that occur during extrusion of the preform. That study investigated flow through two die designs, and showed that the distortions, which can limit the use of this technology, are a strong function of friction that accompanies interface slip. Furthermore, it was observed that a short welding chamber length, while producing a complex flow, might allow for an optimization of the die to produce a desired final geometry. An extensive sensitivity analysis set the stage for the current optimization study, which includes two approaches. First, the radii of the circular feed holes in the two die designs were altered. Within the computational domain, there are 17 and 13 feed holes in the two designs. Second, the five circular pins that create the holes in the preform were modified in both shape and position. Results show that the DAP parameter, which quantifies the degree of circularity of the holes, can be used to guide optimization of the feed hole size and pin shape to drastically reduce hole distortion. Furthermore, for the examples considered, the drift of the holes from their desired positions was simultaneously improved.

1. Introduction

Microstructured optical fibers (MOFs) constitute a promising research field in the development of future optic fibers. This class of fiber relies on precise cross sectional, geometric features to operate effectively [1–3]. Preform extrusion [4,5] is one of several methods (stacking [6,7], drilling [8–10], casting [11,12]) used to manufacture MOF preforms. This computer controlled process is generally praised for its high levels of surface quality, reproducibility, and geometric versatility [4], [13–23].

Unfortunately, the extrusion process lacks control over the final shape of the preform [4] due to mechanisms such as die swell, which can cause severe distortions in the cross-section. These distortions may require repeated trials and adjustments to the die in order to obtain the desired preform geometry [20,24,25]. The focus of the current two-part study is that computational mechanics can be used to determine what adjustments should be made to the die geometry. As 3D printed dies have been recently used in MOF extrusion [26], the die designer now has the ability to create a precise and complex geometric pattern. Therefore, computational simulation can now be fully utilized to determine the required pattern in order to achieve a targeted preform shape.

In Part I of this two-part study [27], an extensive sensitivity analysis was conducted. The study involved two different die designs using four different measures of distortion, which addressed the following: 1) die swell, 2) hole shape, 3) hole deformation and 4) periodicity and geometric integrity. The interpretation of the results required a normalization of these variables, since shape rather than the size of the preform is important. The presence of several mechanisms that led to deformation was apparent. A sensitivity analysis was also performed on the circularity of the holes using a single variable for each hole. Quality variables of this type, such as the DAP parameter [27], were introduced to guide an optimization of the die insert geometry, and to control the deformation of the holes. The goal of this study is to improve the final outcome of the extrusion by modifying the feed holes and pin shapes to minimize the DAP parameter.

In Part I of the study two different die geometries were introduced and the computational procedure was reviewed. The current study makes use of these geometries and applies the same computational approach. Refer to Part I [27] for this material, as it will not be

* Corresponding author.
E-mail address: jpaul@clemson.edu (P.F. Joseph).
[1] Currently: Applied Mechanics and Systems Research Laboratory, Tunisia Polytechnic School, University of Carthage, B.P. 743, La Marsa 2078, Tunisia, and Department of Mechanical Engineering, Tunis Higher National Engineering School, University of Tunis, Tunis 1008, Tunisia.

https://doi.org/10.1016/j.jnoncrysol.2017.11.021
Received 9 July 2017; Received in revised form 9 November 2017; Accepted 10 November 2017
Available online 17 November 2017

repeated.

In this manuscript, preliminary results are presented that show the extreme distortions that occur with the original die designs, which motivates the optimization study. The results that follow are separated into three studies: 1) sensitivity analysis of feed hole adjustments for Design A, 2) manual optimization of Design B, and finally 3) a refined optimization of the Design B result using the compensation approach [28].

1.1. Feed holes size effect and possible adjustments

In this optimization study for the final cross sectional geometry of the preform, the DAP parameter introduced in Part I [27] was used to quantify the quality of the outcome. Both Designs A and B, which were defined in Figs. 1 and 2 of Part I [27] were used in the current study. These figures show dimensions and the numbering scheme, used for the feed holes and the pins that create the holes in the preforms. The starting point in the current study is the preform shapes that result from these original two die designs. These preform shapes are presented in Figs. 1 and 2 for Designs A and B, respectively. In these figures the initial pin arrangement (lightly colored lines) and final hole pattern in the preform (darker lines) are shown, along with the numbering scheme for the five pins. The objective is to modify the feed holes to have the final hole pattern match the pin arrangement of the original design. In presenting these results, the preform size has been scaled to the size of the die. This normalization is justified since only the shape of the preform is important, not the size.

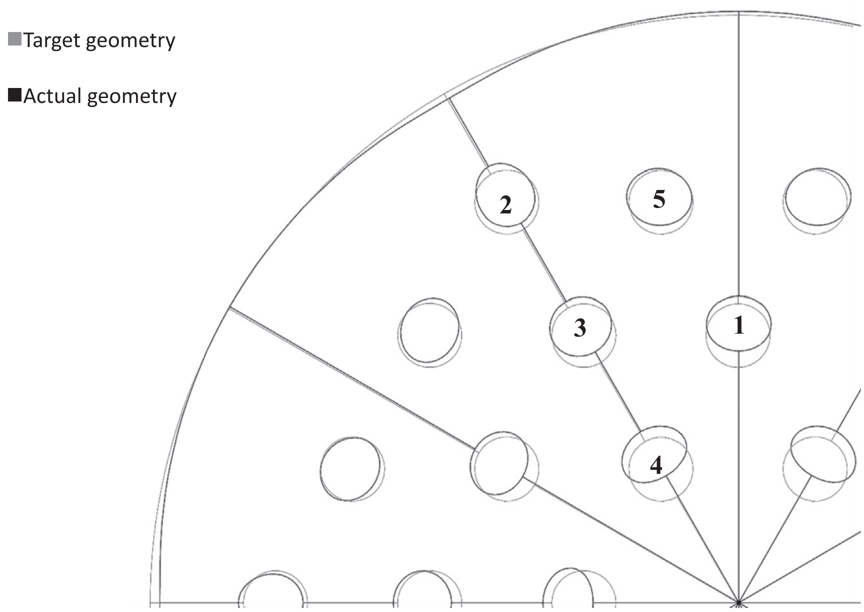

Fig. 1. Hole distortion and drift for the unmodified Design A die using a normalized friction coefficient of 4.

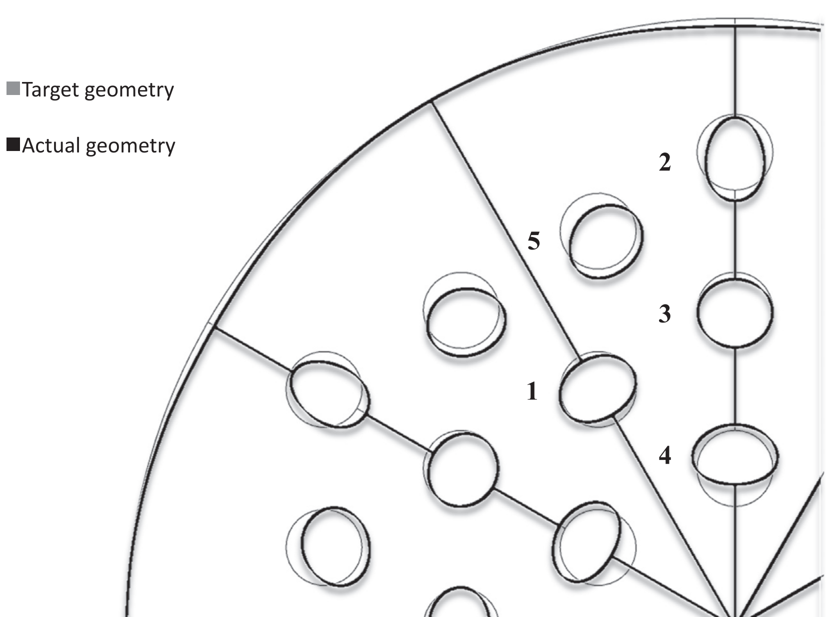

Fig. 2. Same as Fig. 1 for the original Design B die.