Simulation of Temperature Profile of Soot Preform during Sintering Process

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Abstract— Sintering process in optical fiber manufacturing technology densifies the soot preform to glass preform which is used for drawing optical fiber. The analysis of temperature profile of the soot preform during sintering has been studied using Computational Fluid Dynamics (CFD) simulation software. The temperature profile inside the soot preform is discussed by changing the preform diameter during sintering process.

1. INTRODUCTION

Sintering is an important process to convert soot preform to glass preform by densification phenomena. There are many literature papers available to discuss on theoretical calculation during sintering process. Mathematical modeling is developed to quantify the heat conduction and helium gas diffusion inside the soot preform during sintering process [1]. The sintering rate of a soot body has been calculated using Frenkel approach [2]. The effect of temperature on fluorine dopant concentration profile is studied inside porous silica performs during sintering [3]. It has been understood from the literature survey that the temperature profile plays an important role in sintering process.

The quality of densification depends on the temperature profile of the preform which is controlled by furnace temperature and gas flow rate. The article presents a Computational Fluid Dynamics (CFD) calculation to find out the temperature of soot preform during sintering process. In this study, the temperature inside the soot preform has been discussed with varying the preform diameter following to a validation study.

2. THEORETICAL CALCULATION

ANSYS FLUENT [4] software is used to find out the temperature profile inside the soot preform by solving a set of the governing equations, which is a finite volume method (FVM) based CFD code. As part of the CFD calculation, the 3D geometry of the sintering apparatus is drawn including the soot preform as per Figure 1. The preform diameter in Figure 1(b) is 4 times more than that of Figure 1(a) keeping all others dimensions remaining unchanged. Another 3D geometry of sintering apparatus is constructed similar to Figure 1 without the soot preform for the validation study. A good quality mesh is generated in 3D geometry and the governing equations of mass conservation, Navier-Stokes, turbulence and species transport, energy conservation and radiation are solved.

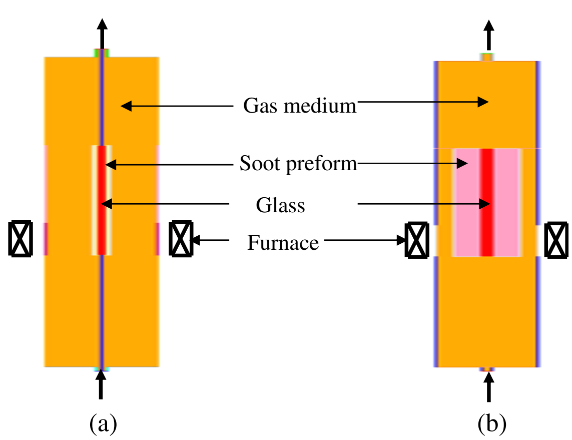

Figure 1: Sinter machine including soot preform: (a) smaller diameter preform and (b) higher diameter preform.

3. RESULTS

The validation study was carried out inside the sintering apparatus in stand by condition before discussing the soot temperature profile calculated using CFD software. The simulation result depicts that the temperate is maximum in furnace region as compared to other part of the apparatus (Figure 2(a)). The simulated temperature profile matches with the typical experimental (Figure 2(b)).

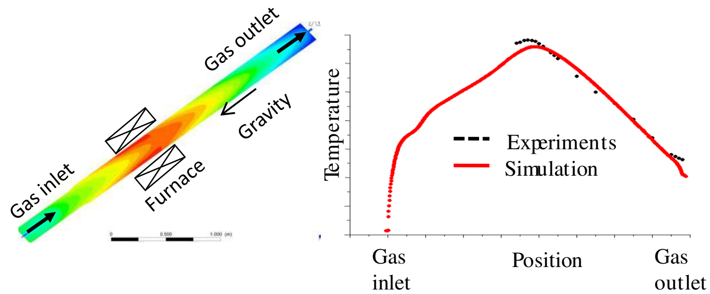

Figure 2: (a) Temperature field inside the sintering device in standby condition and (b) temperature comparison.

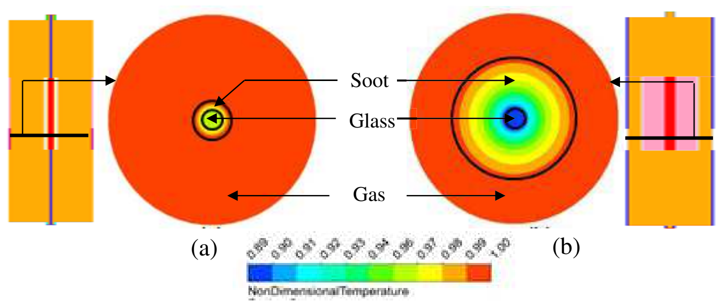

Figure 3: Temperature field in a cross section positioned at center of furnace in sintering apparatus: (a) smaller diameter preform and (b) higher diameter preform.

The temperature profile is calculated using CFD of soot preforms with two different diameters as shown in Figure 1. Temperatures are calculated using the conduction, convection and radiation equations in between the furnace muffle tube and soot preform & the conduction equation inside the soot preform respectively. The densification and gas diffusion inside the soot has not been considered in the calculation. It has been reported that the heat transfer through conduction inside the soot is faster than the gas diffusion [1].

Simulation results suggest that the temperature drop in between the furnace muffle tube and soot surface is negligible in both sizes of soot performs (Figure 3). The heat is conducted from the muffle tube to soot surface through the radiation dominantly. However, the temperature drop inside the higher diameter preform (Figure 3(b)) is 3 times more than the smaller diameter preform (Figure 3(a)) which should be considered in the process parameter settings. The heat is conducted through conduction dominantly inside the soot preform and the temperature drop increases as the soot diameter increases.

4. CONCLUSIONS

A theoretical calculation was done using Computational Fluid Dynamics (CFD) simulation software to determine temperature profile of a soot preform during sintering process. A validation study was carried out to compare the calculated temperature profile with the typical experimental data in the sintering apparatus. Simulated results suggest that the temperature drop inside the higher diameter soot preform is 3 times more than the smaller diameter preform.

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