Numerical Simulation of Pressure Infiltration Process for Making Metal Matrix Composites

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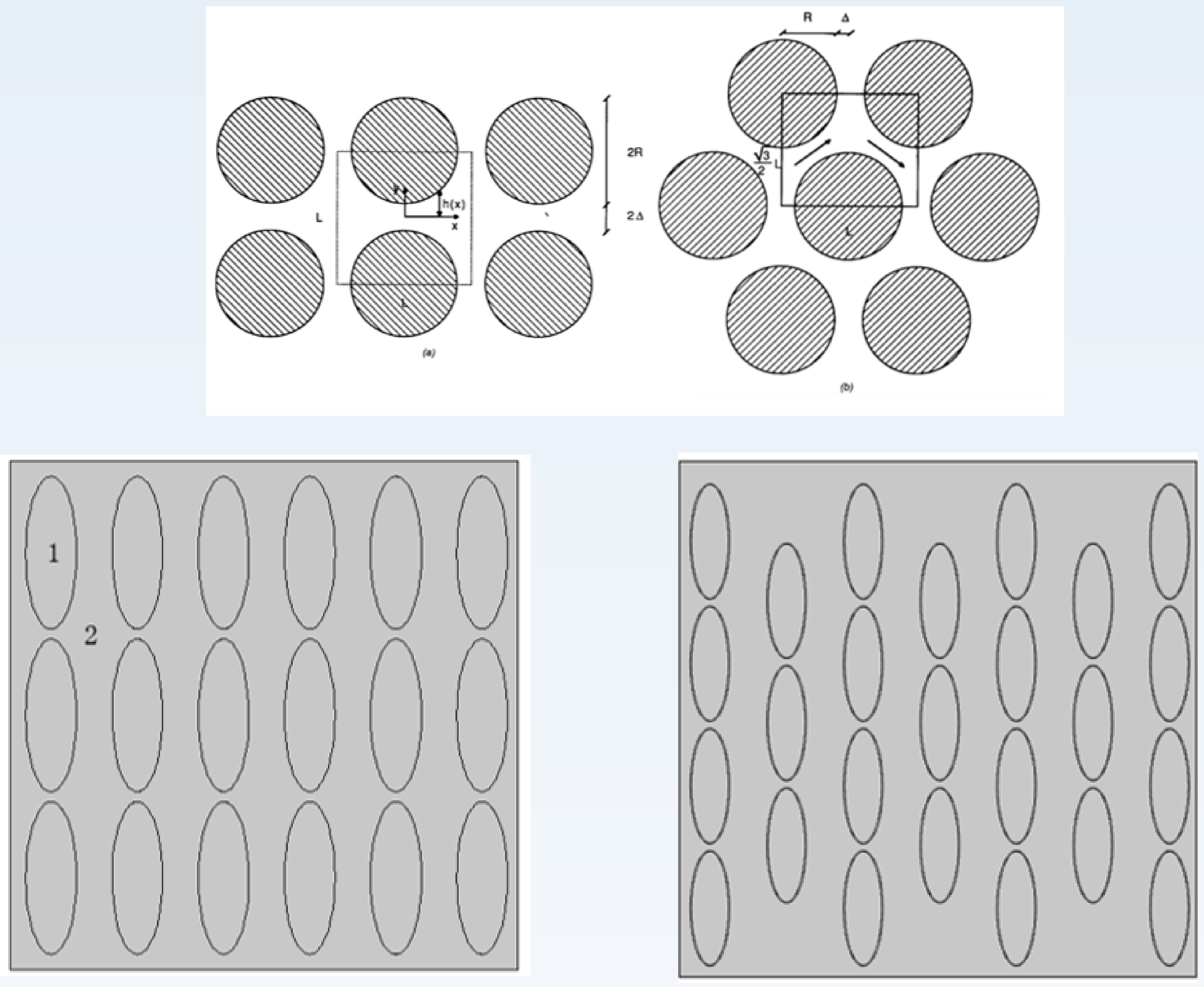
Introduction

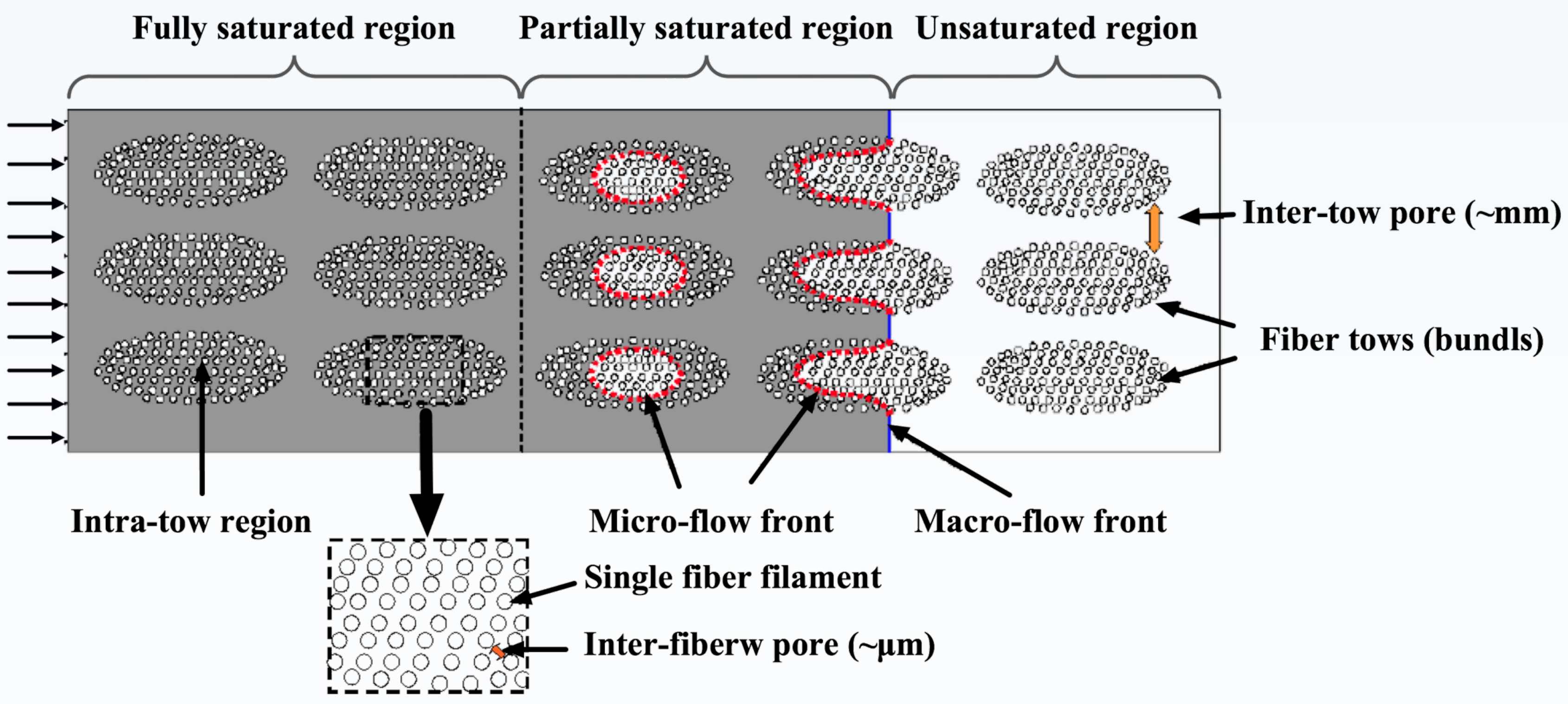
Metal matrix composites (MMCs) are widely used in the development of materials for aerospace, electronics, optical instruments, and so on, due to their good mechanical properties which include low density, high Young's modulus, high wear and fatigue resistances, etc. The fabrication of the MMCs mainly consists of two stages: infiltration and solidification, which have great influence on the properties of MMCs. We mainly focus on the infiltration process under different fiber arrangement condition. The areas where pores appear at high frequency are estimated during pressure infiltration process, which make a great effect on optimizing the manufacture of MMCs.

Model

I. Rough schematic of the typical unsaturated flow pattern observed in dual-scale mats



II. Detailed schematic of the typical unsaturated flow pattern observed in dual-scale mats



Mathematical Model

Darcy equation

$$v = -\frac{K}{\mu}\frac{\partial P}{\partial x}$$

Continuity equation

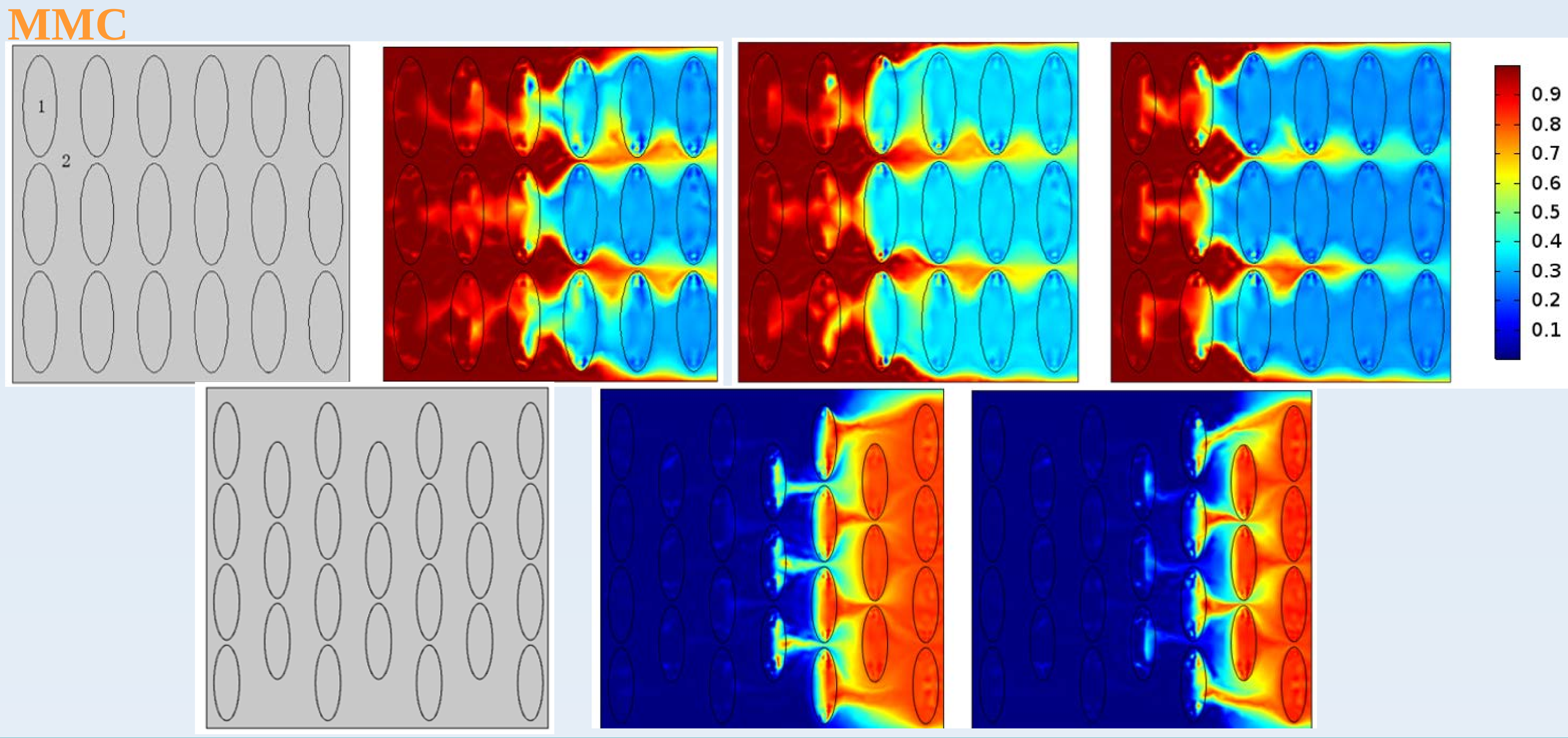
$$\frac{\partial(\rho_L \emptyset)}{\partial t} + \nabla(\rho_L u) = 0$$

VOF equations

$$\frac{\partial F}{\partial t} + \frac{V}{\emptyset}\cdot \nabla F = 0$$

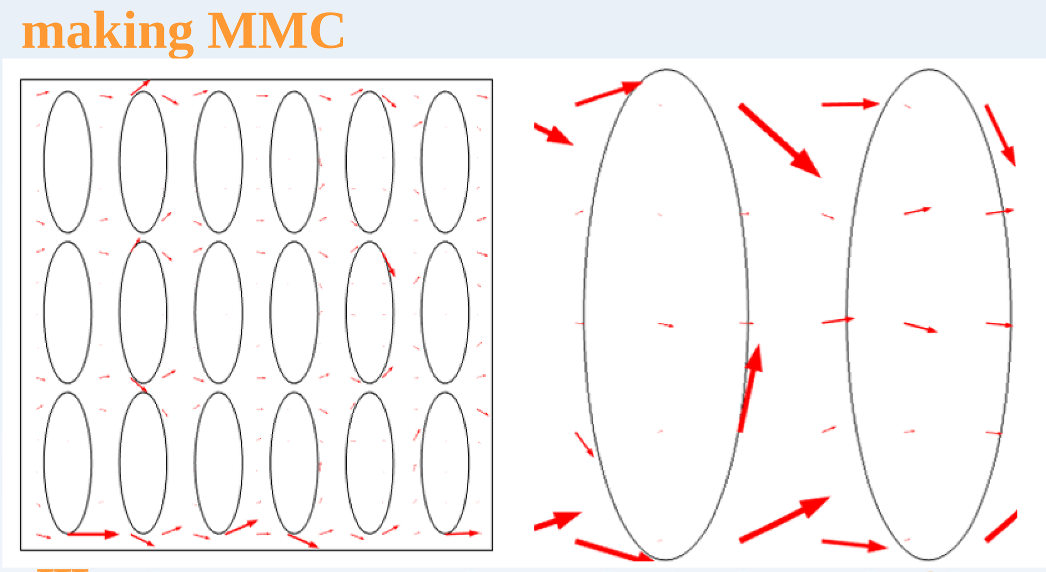
Results and Discussions

I. The effect of dynamic viscosity on pressure infiltration process for making MMC



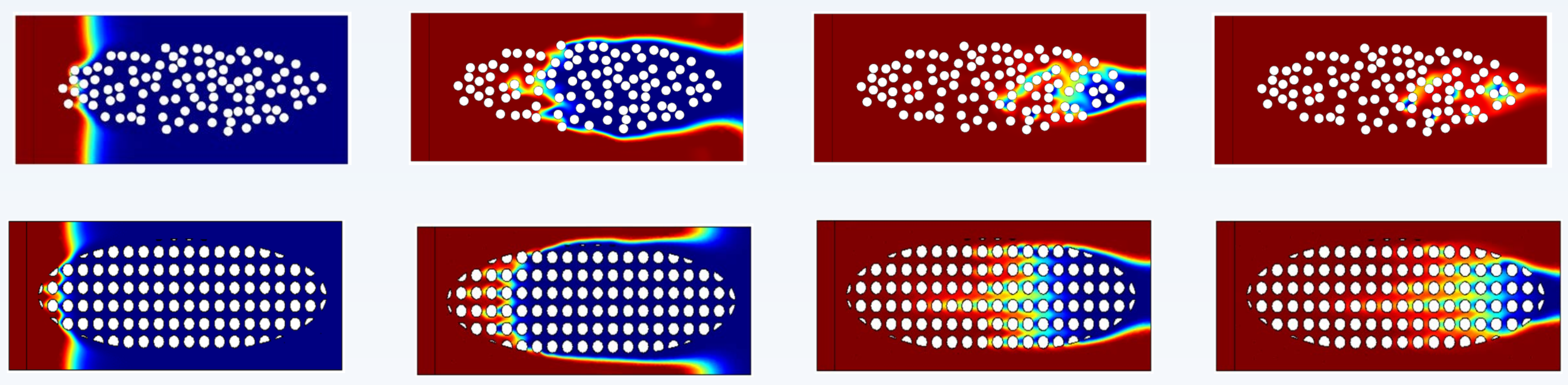
It is clearly observed the flow front between the fiber bundles was far ahead of that within the fiber bundles. To a certain extent, the existence of fiber bundles blocks the flow of metal liquid. The places where there are no fiber bundles, metal liquid can flow unimpeded. In the inner part of the fiber bundle, the phenomenon of air wrapping or air gap is more likely to occur, which has adverse effects on material properties.

II. The velocity vector arrowhead during pressure infiltration process for making MMC

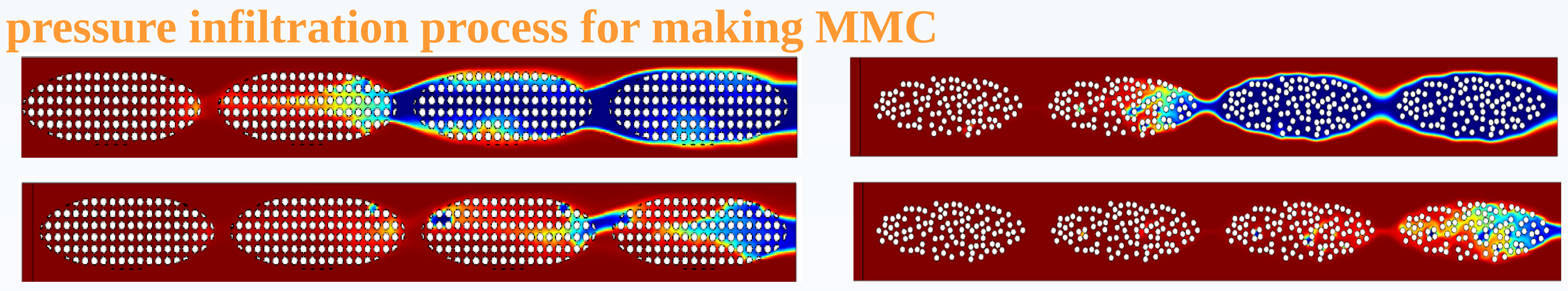


The percolation behavior between fiber bundles and in fiber bundles is different. It can be seen that velocity vector arrowhead between fiber bundles is much larger than that of metal fluid in fiber bundles, which can be obviously seen in the local magnification. And the larger the arrow means the greater velocity.

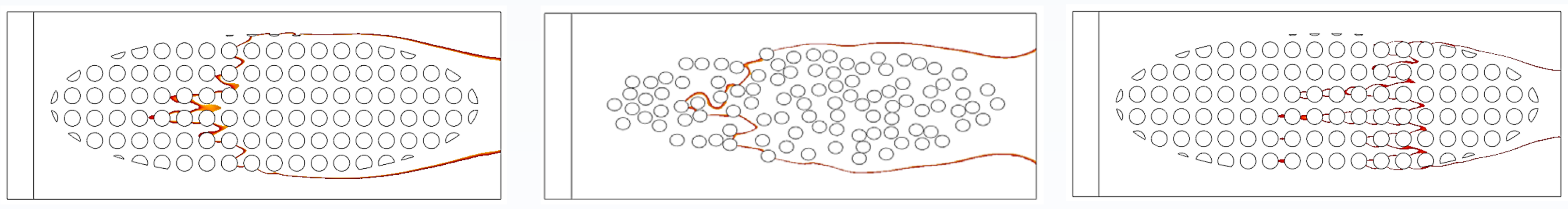
Ⅲ. Flow patterns through single-scale fiber mats and Porosity formation during pressure infiltration process for making MMC



Ⅳ. Flow patterns through dual-scale fiber mats and Porosity formation during pressure infiltration process for making MMC



Ⅴ. The shape of the flow front at the different pressure when t= 0.3ms (left: sparse, right: random)



Conclusions

In infiltration simulation, the pressure inlet is set on the left of the model and the outlet is set at the right end of the model. The metal melt will be pressed into the mold with the pressure inlet. The infiltration condition of MMCs is optimal when the fiber arrangement is ideal, with only a few air pores produced. And the air pores can even be eliminated with the process of pressure infiltration process for making MMCs. Therefore, products with better performance can be obtained.

In the case of random arrangement of fibers, the places where distance among single fiber is too close or even bonded will block the flow of fluid and more easily produce voids, which have adverse effects on the products. Therefore, the fiber preform should be arranged as ideal as possible, avoiding single fibers are set to be too close or bonded.