Abstract
Our aim was to explain and predict the partial saturation of glass-fiber wicks during wicking of oil for combustion. We used Richard's equation for this purpose. In the proposed novel approach, the properties such as capillary pressure and relative permeability were determined directly from the wick microstructure using the state-of-the-art software GeoDict. No fitting parameters were used. The accuracy of the proposed simulation was tested by comparing its predictions with the results of a wicking experiment. The good agreement highlighted the power and the accuracy of our proposed microstructure using the state properties such as capillary pressure and relative permeability were determined directly from the wick as a function time and space.

Introduction
The rate of fluid transport in partially saturated porous media has been one of the most challenging problems in porous media studies. It finds application in areas including moisture migration in soils and tissues, drying of food, burning of wicks, etc.

The Washburn (1) equation, which is based on sharp front models, is applicable for predicting the absorption of liquid into porous media and is known to have a satisfying correlation with the experiments. However, under partial saturation when the liquid front between liquid and air is not distinguishable, it is unable to predict the height of the wicking liquid into porous media. In the case of glass-fiber wicks, partial saturation occurs due to upward pumping of liquid by fiber clusters.

The generated geometries were used to obtain the relation between the capillary-pressure and medium's saturation by using the Full Morphology (FM) Method which is a quasi-static geometric approach for obtaining a capillary-pressure and relative permeability as a function of saturation($S_{w}$). In the FM method, the void spaces in a given porous structure are filled with spheres which represent the non-wetting phase. These spheres are also superimposed and interconnected, thus establishing a continuous wetting phase. The different radii of the spheres correspond to different predetermined capillary-pressure values. By maintaining connectivity to the non-wetting phase reservoir and their placement limited by void size, the insertion of different sized spheres corresponding to different pressures represents the drainage pressure in the medium. For each incremental pressure, the wetting or non-wetting phase saturations can be measured based on the change in structure's void space occupied by the spheres.

Numerical simulations obtained from Mathematica and COMSOL solve the Richard's equation along the wick axis after using appropriate initial and boundary conditions. The results describing saturation distribution are compared with experimental results and are shown in Figures 6 and 7. It is clear that there is a good correlation between the numerical solutions and the experimental result.

Results

The Richard's equation was solved numerically in one dimensionally domain in two different ways. Mathematica and COMSOL were used to solve the equation for saturation ($S_{w}$) distribution along the wick axis.

Conclusion

- Moisture moves in a diffusive (instead of piston-like) manner during imbibition in a glass-fiber wick due to local inhomogeneities.
- Richard's equation can be employed to predict saturation distribution and liquid mass uptake in such problems.
- Good agreement observed between experimental results and numerical predictions.
- Partial saturation of wicks can explain some deficiencies (such as fuel leakage caused by partially saturated wicks) in the performance of wick based torches.

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