CFD Based Optimization of Different Types of Fractal Systems

Conference Paper · June 2023

2 authors:

Abdulmuttalib Abdulkareem Muhsen
Warsaw University of Technology

Bashar Attiya
Lehigh University

CFD Based Optimization of Different Types of Fractal Systems

Abdulmuttalib A. Muhsen[1], Bashar Hassan Attiya[2]

[1]Faculty of Power and Aeronautical Engineering, Warsaw University of Technology, Warsaw, Poland
[1,2]Haditha Hydropower Station, Ministry of Electricity, Haditha, Iraq

Abstract—**Fractal-type structures are increasingly being used in cooling systems or heat sinks. They perform better than straight (parallel)/serpentine channels. Optimizing these structures is very difficult as many parameters needed to be observed and examined carefully. This paper discusses the optimization of three different types of fractal-type structures by utilizing CFD analysis to predict the performance of optimized fractals. In this study the optimized model was created simply by increasing the number of sub-levels.**

Keywords - fractal-type structure, optimization, computational fluid dynamics, performance

I. INTRODUCTION

Optimizing the design of any fractal-type channel is a hard task, since many variables affect its geometry. Branch angle and aspect ratio play an important role during the design phase. Aspect ratio affects the formation of vortices in the fluid, causing an improvement in heat transfer efficiency. The fractal systems are mainly studied for creating heat sinks for different electronics as they provide better temperature uniformity [1-2].

In" Compact Modeling of Fractal Tree-Shaped Microchannel Liquid Cooling Systems." A technique called Flow Network Modeling (FNM) approach is utilized since the complete simulation of such systems can sometimes be very complex due to the number of fields (flow and temperature). This technique substantially improves the efficiency of analyzing different network structures and the influence of geometric variables on the performance. Element-based CFD model is constructed to validate the accuracy of this approach. It can be used along with an optimization algorithm to optimize the geometry of a fractal microchannel network. It provides an optimum geometry with a favorable total flow rate and acceptable uniformity. FNM can be expected to execute an effective and efficient analysis and optimization for other fractal microchannel networks. This method can be used with thermal analysis to predict system flow uniformity and temperature distribution. The CFD model can only validate FNM simulation in terms of velocity distribution along the channel [3]. After the model is built; then the following boundary conditions are specified:

- Pressure drop is specified as a constant value.
- Fluid is water and has constant material properties at 300 K.
- Pressure at outlets is defined as zero.

The FNM results resemble the CFD analysis outcomes. Optimization of structures with respect to most degrees of freedom leads to robustness. In the case of a radial disc, it means to distribute the imperfections related to constructal theory and not uniform distribution over an area [3].

Three independent geometry parameters determine rhombus Fractal-like Units for Electronic Chip Cooling: the branch angle and the length and width ratio under the specified external sizes. Therefore, the geometry parameters with minimum pumping power can be optimally designed by establishing the pumping power calculation method based on these independent geometry parameters and then finding the optimal branch angle and the length and width ratio through an iterative procedure, and then comparing the performance.

A triangular finned heat sink provides a faster cooling rate than other finned heat sinks at all

J. Pressure Distribution in Normal versus Optimized Irregular Fractal Geometry

The pressure drop appears to be more in the normal irregular fractal (Fig. 19) than in Fig. 20, which shows an optimized irregular fractal.

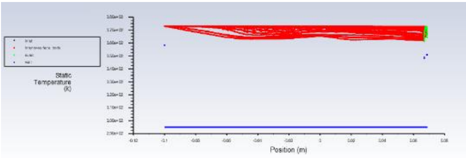

Figure 21. (normal) irregular fractal temperature plot

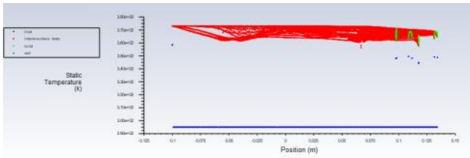

Figure 22. (optimized) irregular fractal temperature plot

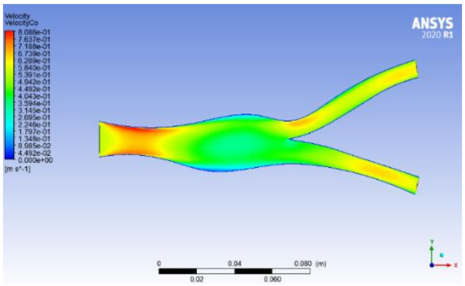

Figure 23. Irregular velocity contour (normal).

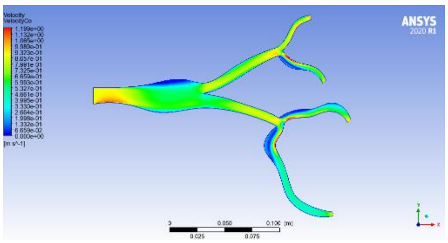

Figure 24. Irregular velocity contour (optimized).

K. Temperature Distribution Plot of Normal versus Optimized Irregular Fractal Geometry

Although the temperature does not change throughout the system, the temperature uniformity is better in normal (Fig. 21) than in the optimized one (Fig. 22).

L. Velocity Based Analysis of Normal versus Optimized Irregular Shaped Geometry

The flow uniformity of normal and optimized are shown in Fig. 23 and Fig. 24, respectively.

III. CONCLUSSION

- For Y-shaped geometry, the pressure distribution is more uniform in the normal fractal, while the temperature distribution has almost similar behavior. Flow uniformity is better in the optimized fractal.
- The pressure distribution is better in an optimized fractal for T-shaped geometry, while the temperature distribution is almost identical. Flow uniformity is better in an optimized one.
- Pressure drop is higher in optimized irregular fractal maybe because of the change in diameter, the temperature distribution is better in a normal irregular fractal, and flow is not uniform in both the cases of the irregular fractal.

REFERENCES

[1] Muhsen, A. A., & Kizilova, N. The Advanced Cooling System of Generator for Hydropower Plant. *changes*, *8*, 10.

[2] Muhsen, A. A., Attiya, B. H., & Algburi, H. A. Theoretical Analysis of Different Fractal-Type Pipelines.

[3] Chen, C., Samadiani, E., & Sammakia, B. (2011, January). Compact Modeling of Fractal Tree-Shaped Microchannel Liquid Cooling Systems. In *ASME International Mechanical Engineering Congress and Exposition* (Vol. 54969, pp. 997-1006).

[4] Arjun, K. S., & Kumar, R. (2018). Optimization of micro pin-fin heat sink with staggered arrangement. *Thermal Science*, *22* (6 Part B), 2919-2931.