Comparative Analysis of Energy Loss and Flow Uniformity of Different Fractals

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—**Different types of fractal structures have been proven to improve the efficiencies of many systems, and further research is being conducted. This paper is a comparative study of three types of fractals: T-shaped, Y-shaped, and irregular fractals. The main premise of the study is CFD analysis. The analysis of all fractals will determine how much energy loss happens and how much flow uniformity is present. The branching was kept to the least possible level to clearly understand how fractals behave at more minor scales. The same constant flow conditions are applied for all the fractals, and the pressure distribution, temperature distribution, and flow uniformity are found.**

Keywords - fractal shaped structures, computational fluid dynamics, flow uniformity, energy loss

I. INTRODUCTION

Fractals have been studied profusely to replace straight and serpentine channel systems in recent years. CFD analysis of a fractal-like shell for a shell and tube heat exchanger showed that the pressure drops increased as the number of bifurcations increased, and the pressure drop increased exponentially. The area of fractal shape was kept constant. The temperature increased on the shell side when the bifurcation increased, and the increment was linear. The higher number of bifurcations decreased the coefficient of performance of the fractal-like shell. This proved that the fractal-like structures are suitable while acting as a heat sink but should not be utilized in shell tube heat exchangers as the performance declines [1-3].

CFD analysis between a straight channel and fractal-shaped structure was conducted while keeping the following parameters constant between the two configurations:

- Length of a single flow path from inlet to exit.
- The convective surface area.
- The terminal hydraulic diameter.
- The applied heat flux and the required pumping power.
- All constant and temperature-dependent properties.

After the following considerations, the pressure drop in the fractal-shaped structures was 50 percent less than the one in straight channels. However, a difference in pressure drop was observed between the 3D model and the one-dimensional model of the same fractal shaped. The pressure drops slightly when the thermos-physical properties are kept constant instead of variable. This was due to less shear stress on walls caused by less viscosity of the fluid [4].

A comparison of heat transfer and pressure drop is made between fractal branching channel nets with the traditional parallel channel network. It is found that the fractal net can increase the total heat transfer rate while it reduces the total pressure drop in the fluid. Furthermore, a larger fractal dimension or a more significant total number of branching levels is found to have a stronger heat transfer capability with a minor pumping power requirement. Thus, the fractal branching channel net enhances the efficiency of a micro heat exchanger. This was done without considering the effect of

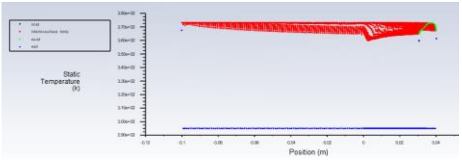

Figure 10. Y-shaped Temperature plot.

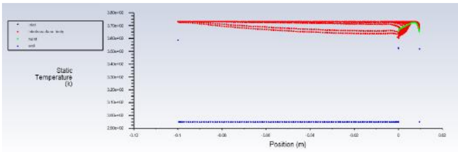

Figure 11. T-shaped Temperature plot.

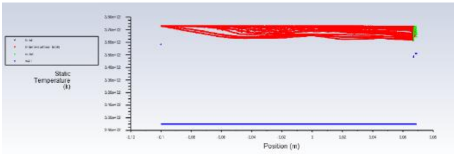

Figure 12. Irregular shaped Temperature plot.

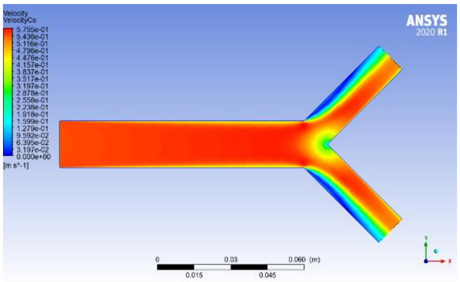

Figure 14. Y-shaped fractal (Velocity contour).

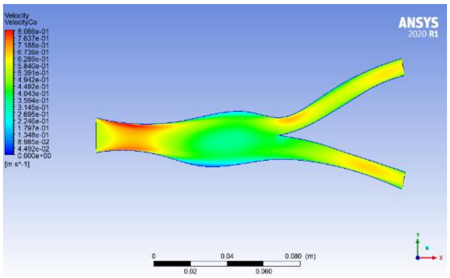

Figure 15. Irregular fractals (Velocity contour).

uniform, and the velocity appears to be lower than Y-shaped fractal but greater than T-shaped fractal throughout the simulation as shown by the velocity contours in Fig. 15.

IV. Disscusion

- As shown by the simulation, the pressure drop occurs in T-shaped fractal the most, then comes the irregular fractal and drops the least in the Y-shaped fractal.
- The temperature distribution results prove that the uniformity remains almost the same throughout the system regardless of the fractal design.
- The flow remains most consistent and uniform in Y-shaped fractals. The velocity becomes minimum at the stagnation point of the system. Finally, complete content and organizational editing before formatting. Please take note of the following items when proofreading spelling and grammar:

V. Conclusion

After analyzing the 2D models through CFD analysis, it can be stated that, for the investigated cases, the most efficient fractal system is the Y-shaped fractal as the pressure drops at its minimum, the temperature is uniform throughout, and flow uniformity is the most consistent. The Y-shaped fractal can be used in heat sinks instead of conventional channels like straight and serpentine. A 3D analysis may give us a deeper insight into what type of fractal works best in different situations, as the 2D analysis does not consider the varying fluid properties.

References

[1] Foster, N., Sebastia-Saez, D., & Arellano-Garcia, H. (2019). Fractal branch-like fractal shell-and-tube heat exchangers: A CFD study of the shell side performance. *IFAC-PapersOnLine*, *52*(1), 100-105.

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

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

[4] Alharbi, A. Y., Pence, D. V., & Cullion, R. N. (2003). Fluid flow through microscale fractal-like branching channel networks. *J. Fluids Eng.*, *125*(6), 1051-1057.

[5] Jacobs, I. S. (1963). Fine particles, thin films and exchange anisotropy. *Magnetism*, 271-350.

[6] Manshoor, B., Sapit, A., Nordin, N., Hariri, A., Salleh, H., Razali, M. A., ... & Alsayed, M. K. (2020). Simulation of fractal like branching microchannel network on rectangular heat sink for single phase flow. *CFD Letters*, *12*(2), 69-79.

[7] Yan, Y., Yan, H., Feng, S., & Li, L. (2019). Thermal-hydraulic performances and synergy effect between heat and flow distribution in a truncated doubled-layered heat sink with Y-shaped fractal network. *International Journal of Heat and Mass Transfer*, *142*, 118337.