Analysis of Heat Transfer in a Complex Three Dimensional Structure Fabricated by Additive Manufacturing

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Introduction: The goal of this study was to create a three dimensionally designed biomedical device with multiple functionalities and analyze its simulated heat transfer.

- The device would be fabricated through additive manufacturing; specifically electron beam melting (EBM).
- EBM has a feature size constraint of 1 mm (acceptable for this design) and is only capable of manufacturing titanium alloys [2]; a biocompatible metal commonly used in the medical implant market [1].
- Silicon IC chips are used as attached functional elements.

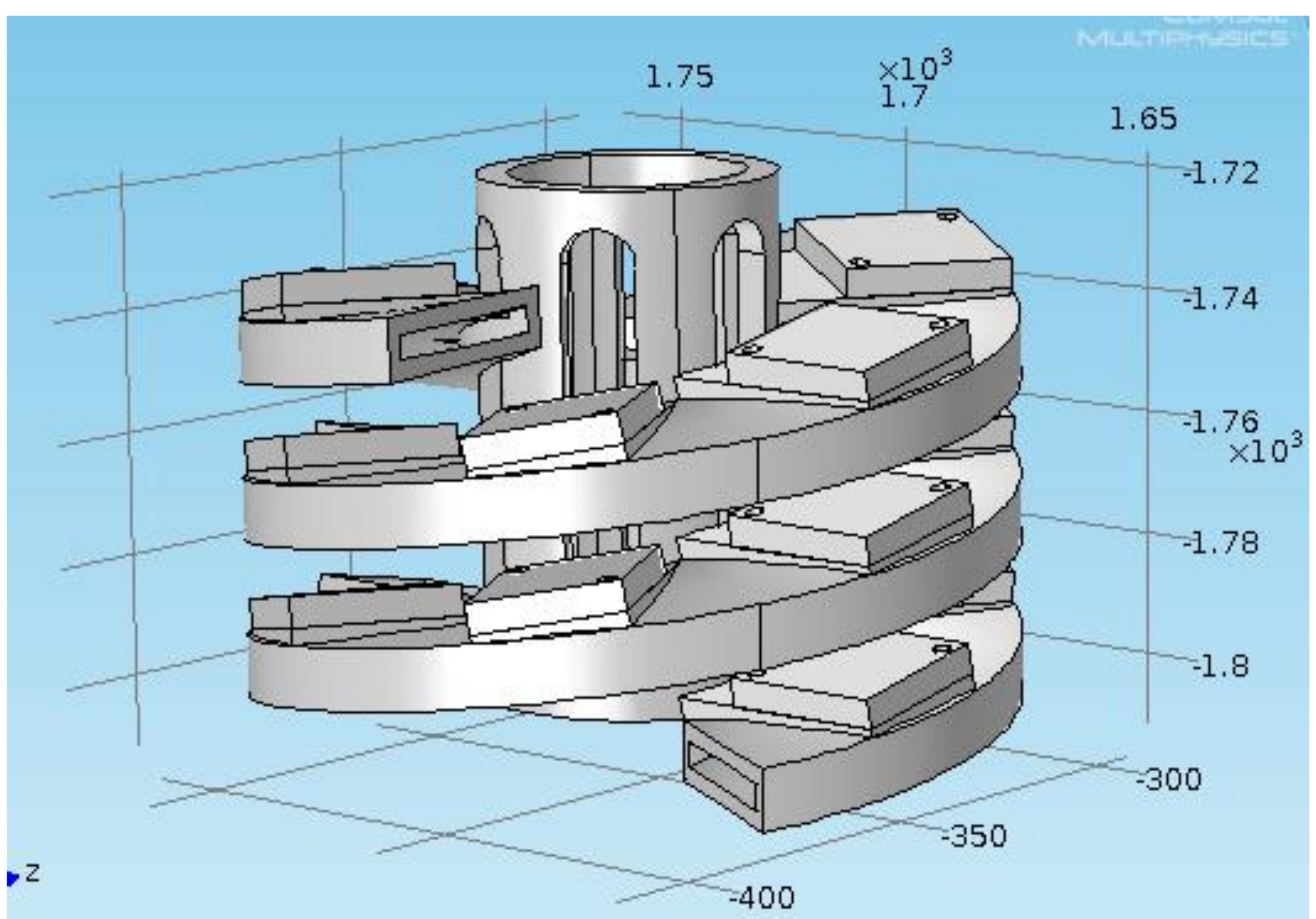

Figure 1. Heat Sink Channeled, Helix-Shaped Structure

Computational Methods:

- The design was simulated to test its functionality in a way similar to that of a heat sink channel [3].
- It contains three separate domains (see figures 1 and 2)
  - A helix shaped titanium body with channels running through the center of each vessel
  - 16 silicon chip components that generate heat (each having the same power consumption)
  - Water running through each channel for cooling
- The water had a starting temperature of 283 K while the power dissipated from the silicon chips as well as normal inflow velocity of the water were modified to see how they affected the output temperatures

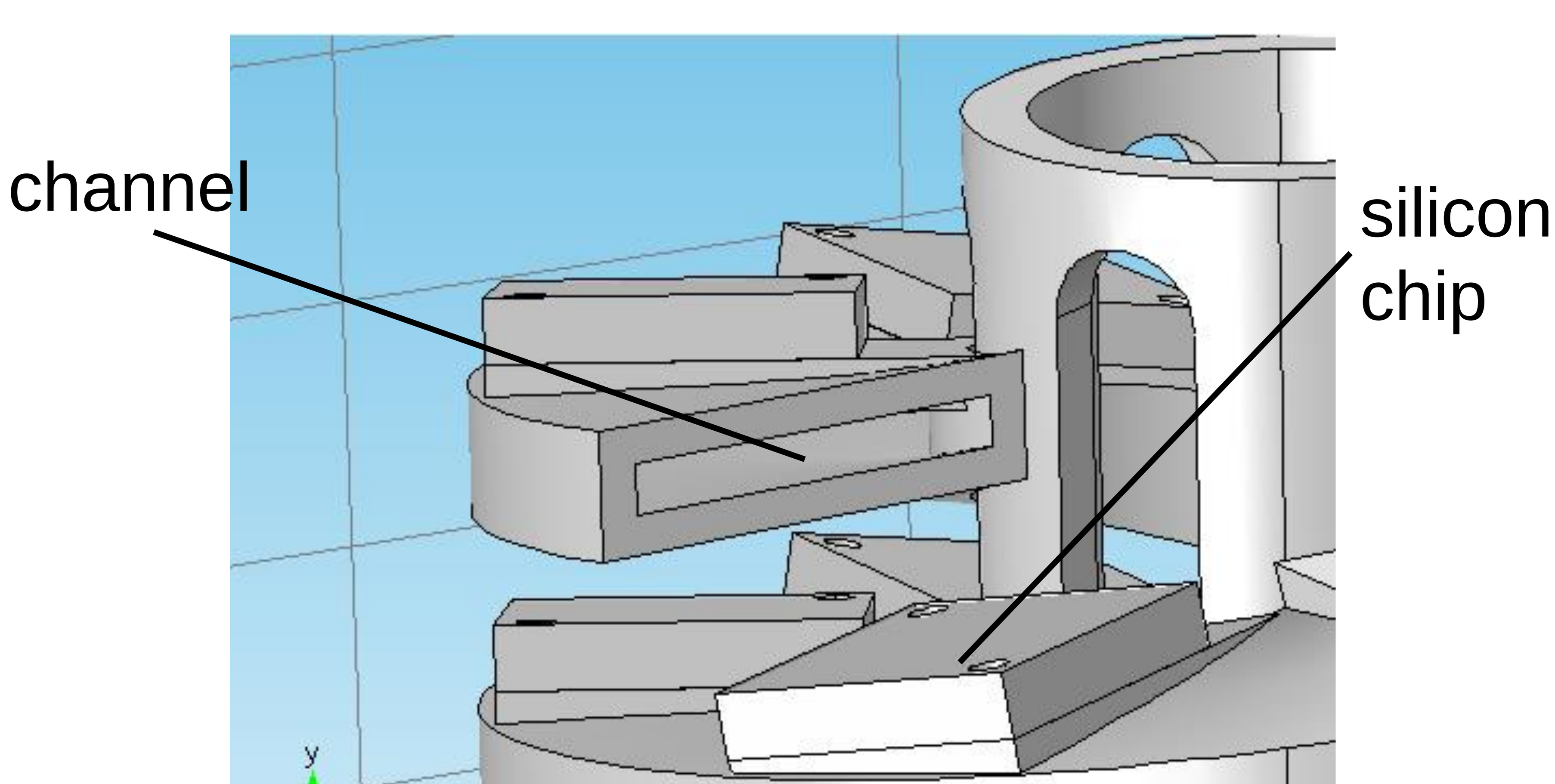

Figure 2. Diagram of the Water Channel Opening and Silicon Chips

Results:

- The volume temperature in figure 3 shows temperature highest at the bottommost located heat sources (silicon chips).
- The water in the channel as well as the titanium show an increase in temperature moving down the structure.
- In figure 5, there is a decreasing exponential relationship and in figure 6, a linear relationship.

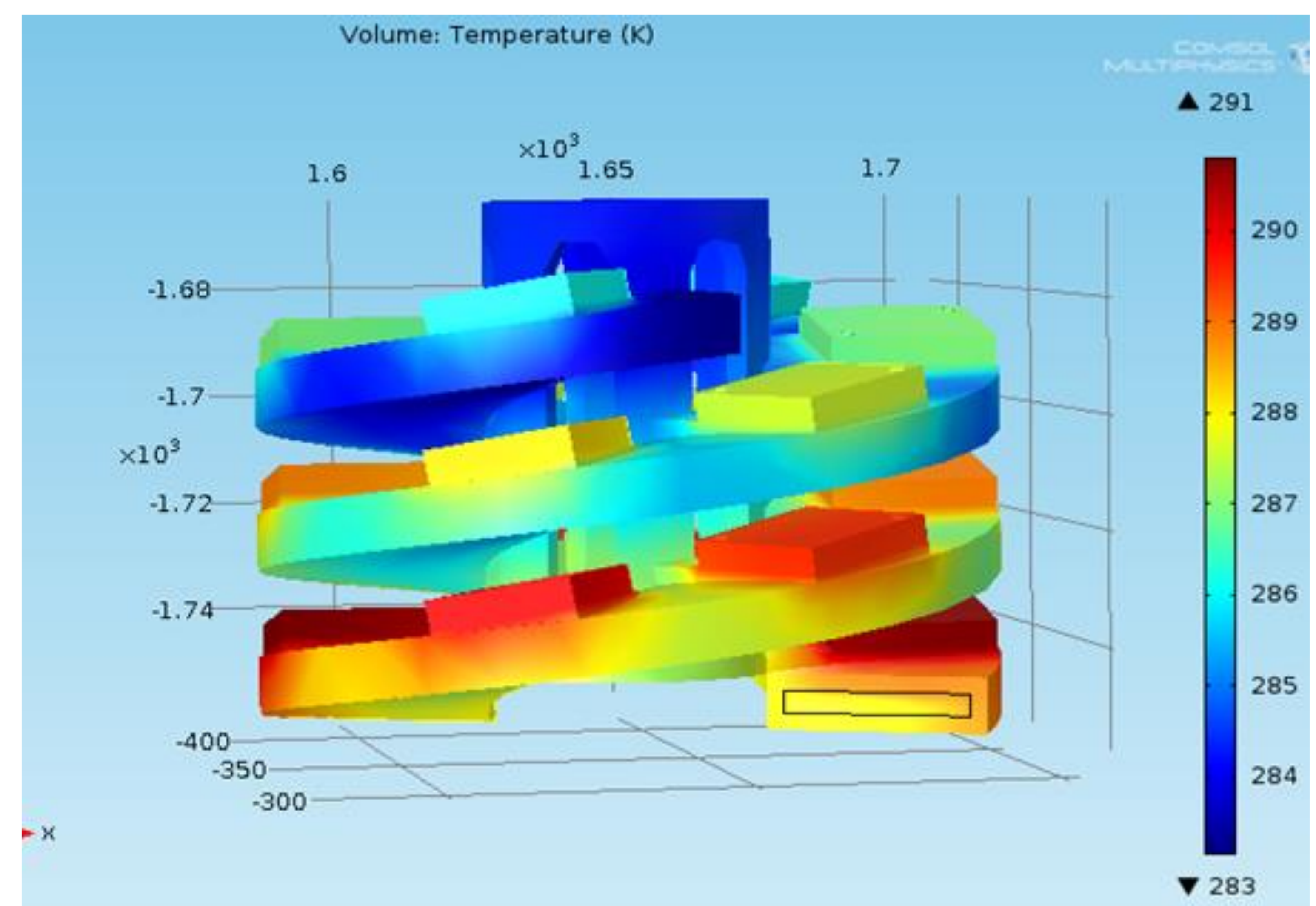

Figure 3. Volume Temperature of Heat Sink Channel (.005 m/s normal inflow velocity; 25W power)

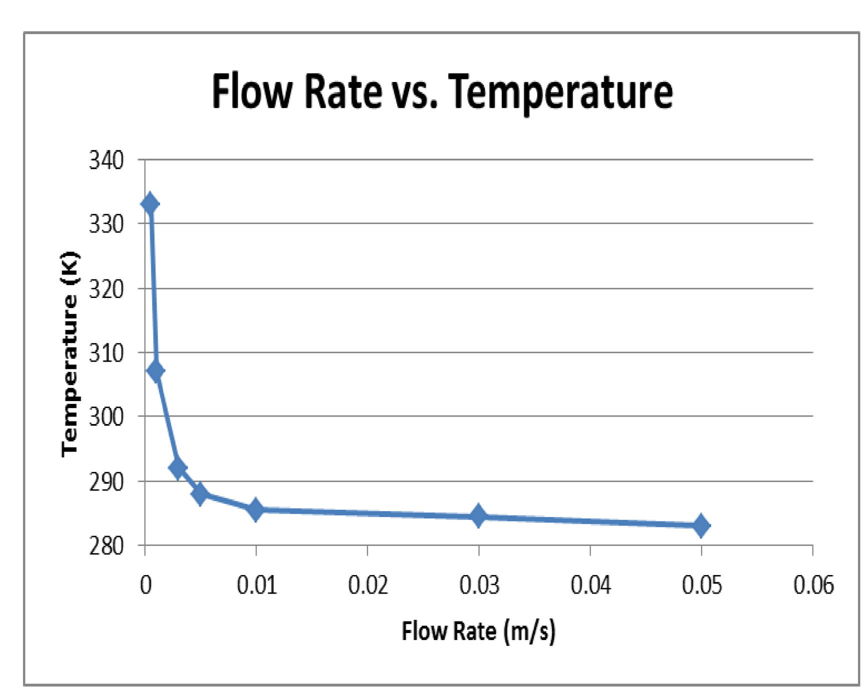

Figure 5. Normal Inflow Velocity vs. Output Temperature (25W power)

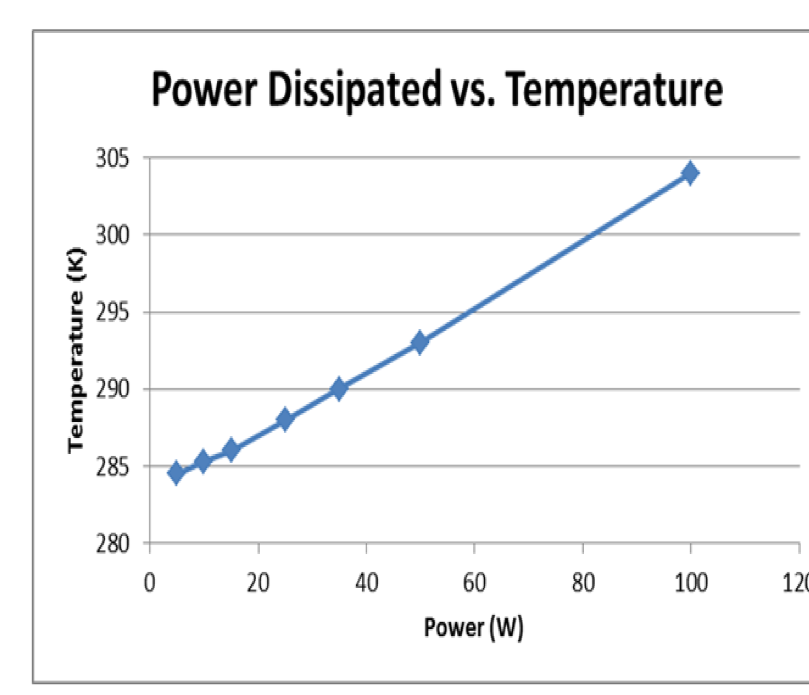

Figure 6. Total Power Dissipated vs. Output Temperature (.005 m/s normal inflow velocity)

Conclusions: It was determined from this simulation that:

- As flow rate increased, the output temperature was lower.
- The output temperature increased with increasing power from the system.

From these observations, we can conclude that the devise design and characteristics can be optimized through this COMSOL analysis.

References:

1. Xiang Li and Chengtao Wang. "Fabrication and Characterization of Porous Ti6Al4V Parts for Biomedical Applications Using Electron Beam Melting Process." Materials Letters 63. 2009: 403-05.
2. "Electron Beam Melting." Additively.com - 3D Print Your Parts.
3. Weilin Qu and Issam Mudawar. "Analysis of three-dimensional heat transfer in micro-channel heat sinks." International Journal of heat and mass transfer 45. 2002: 3973-3985.