Thermodynamic Analysis of a Counter-Flow Heat Exchanger
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Objective: This project analyzes a counter-flow heat exchanger to optimize heat transfer efficiency for automotive cooling, such as truck radiators, using MATLAB. It calculates key performance metrics and evaluates fluid flow to ensure practical design.

Method: I modeled a counter-flow exchanger with water (hot fluid, engine coolant) at 80°C and air (cold fluid) at 20°C. The hot fluid flow rate is 0.5 kg/s, cold fluid 1.0 kg/s, heat transfer area initially 2.0 m^2, and overall heat transfer coefficient 500 W/m^2·K. Using MATLAB, I applied the Log Mean Temperature Difference (LMTD) method to calculate heat transfer rate (Q) and the NTU-effectiveness method to determine efficiency (ϵ). I optimized the design by varying the area, analyzed fluid flow by calculating air pressure drop, and plotted temperature profiles to visualize performance.

Results: Initially, with an area of 2.0 m^2, the heat transfer rate was 34112.53 W, with an effectiveness of 0.566. After optimizing by increasing the area to 3.0 m^2, the heat transfer rate improved to 41769.98 W, effectiveness to 0.693, cooling the hot fluid to 60.01°C and heating the cold fluid to 61.56°C. The LMTD was 27.83°C. Fluid flow analysis showed a 2.08 kPa pressure drop for air, balancing efficiency and pumping power. The temperature profiles (below) confirm counter-flow's effectiveness for cooling.

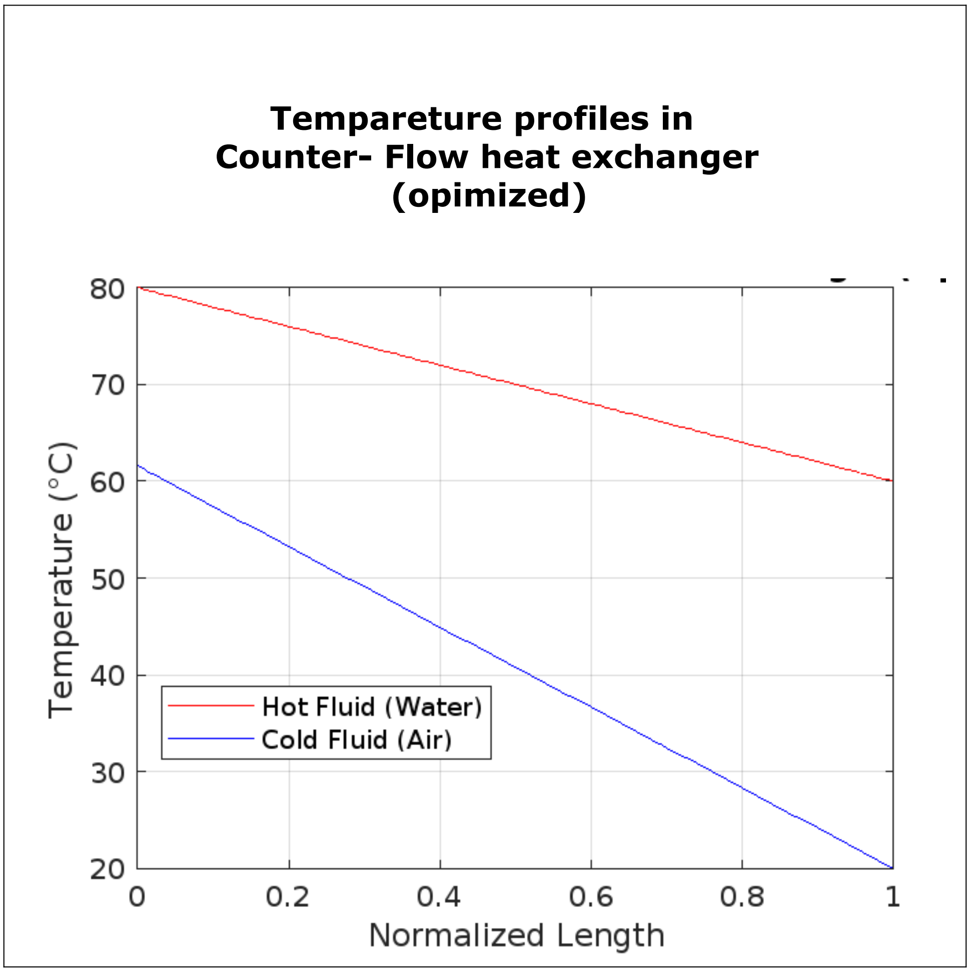

Figure 1: Temperature Profiles (Optimized, $A = 3.0\,\mathrm{m}^2$).

Conclusion: The exchanger achieved 69.3