Shape optimization of pin fins in heat sinks using genetic algorithm

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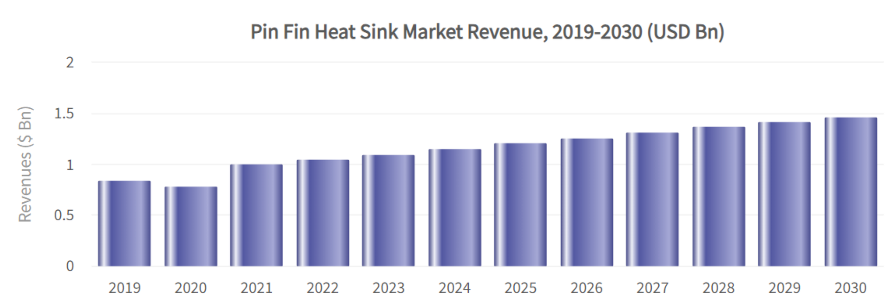
Introduction

► Pin fins serve as heat sinks, commonly used in cooling electronics like semiconductors. They offer a high surface area-to-volume ratio, making them effective for heat transfer in a compact form. Efficient heat dissipation in limited spaces prevents overheating in electronics and potential chip damage.

► Semiconductor chips generate substantial heat during operation. Heat is transferred from the chip to the heat sink via thermal interface material. The heat sink then dissipates this heat into the surrounding environment, maintaining safe operating temperatures.

► Genetic algorithms mimic natural selection to optimize shapes or geometries for specific applications. Engineers and designers utilize genetic algorithms to explore a wide range of shapes efficiently. The method aids in finding solutions that offer maximum performance for various applications.

Research questions



► What are the optimal shapes of pin fins that minimize flow pressure drop and maximize heat transfer performance under different heat loads (heat flux = 10, 50, 100 W/cm^2)?

► How can the thermal and hydraulic performance of the pin fin array be improved by changing Genetic algorithm parameters such as population size, generation size, and crossover rate?

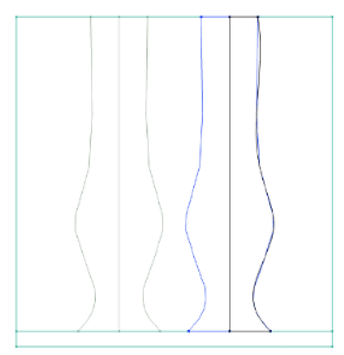
► Can heat transfer performance and pressure drop of pin fin array be enhanced by optimizing the shapes of all pins in different forms?

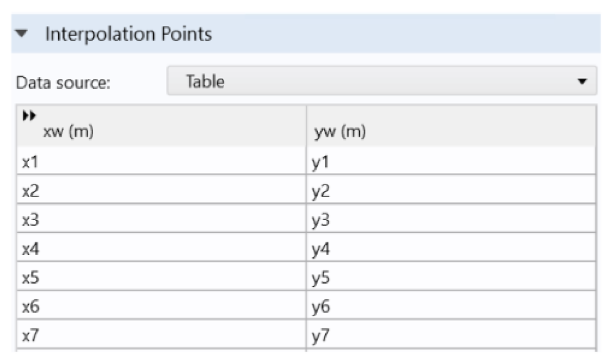
Methodology

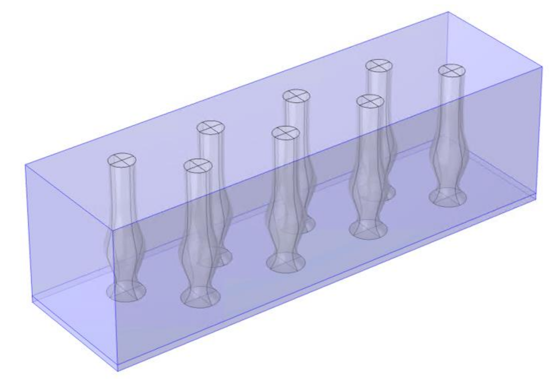
The objective of this research is to discover effective shapes of pin fins that are different from conventional circular cylindrical shapes using a genetic algorithm (GA).

► **Finite element model for pin fin heat sink (comsol model)**

This study employs MATLAB R2023a in conjunction with the MATLAB Global Optimization Toolbox to construct the optimization program for the genetic algorithm.

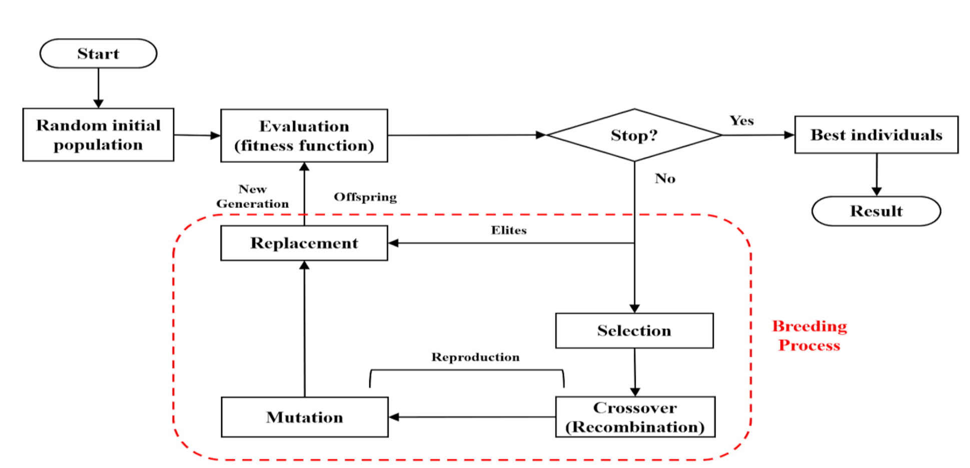


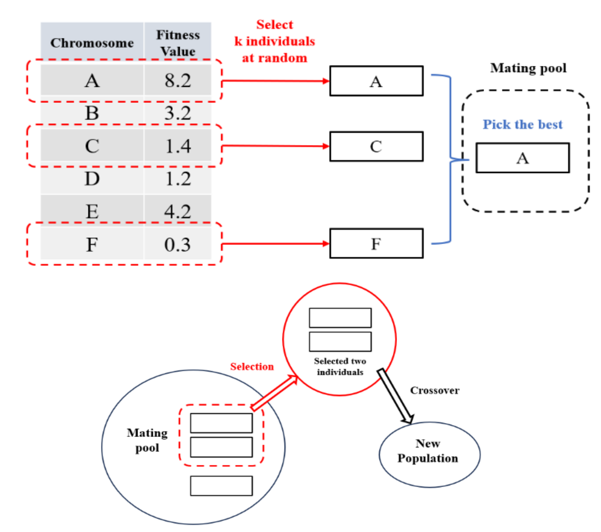




To achieve precise design specifications, engineers decided to employ the 7-point control interpolation curve. Subsequently, they initiated the implementation of a revolving transformation to fashion a curved pin fin, leveraging the intricate details of the generated curve. After runing the simulation, calculate the average temperatue of heated surface and pressure drop.

► **Genetic algorithm for pin fin design (MATLAB)**





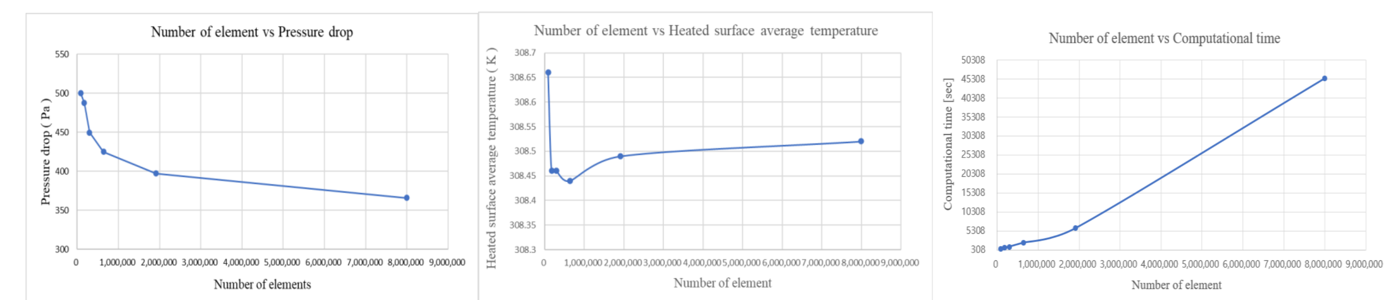
The fitness function employed in this study:

$$F = \lambda T + \Delta P$$

λ represents the weighting factor applied to the average temperature of the heated surface in Kelvin, while ΔP signifies the pressure drop across the channel in Pascal. These two parameters are derived through computational fluid dynamics (CFD) simulations conducted using COMSOL Multiphysics 6.0. MATLAB calculates the fitness value and transfers it to the main code.

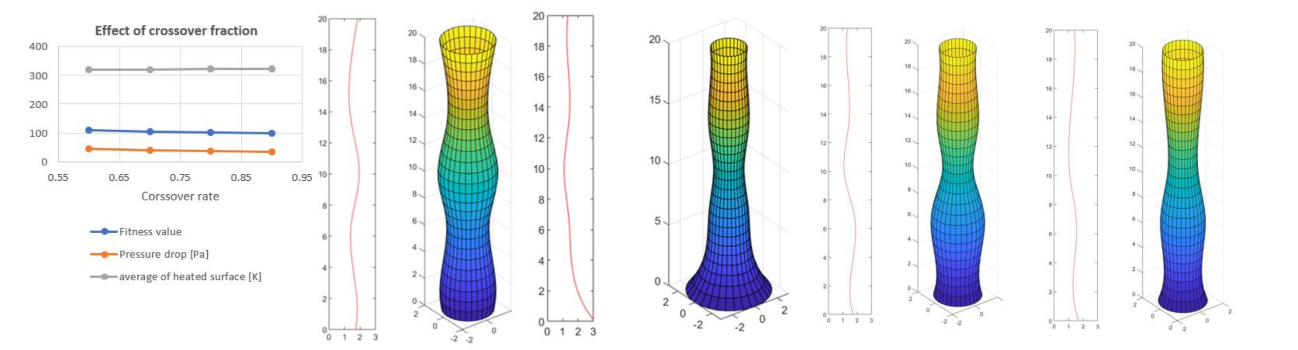
Result & Discussion

► Identifying the point where mesh refinement's impact becomes negligible is crucial in determining the optimal mesh size for the problem. Choosing this size strikes a balance between computational accuracy and efficiency.



► Following the analysis, it was observed that after the fifth mesh size, the difference in average temperature and pressure drop amounted to 0.01% and 6.5% respectively. However, the computational time experienced a substantial increase of 179%. Therefore, the mesh size of 637,650 (4th element size) would be the preferable choice.

Cross fraction	0.6	0.7	0.8 (Origin)	0.9
Best fitness value	108.6856	104.0585	103.345	98.5017



► As I increased the crossover rate from 0.6 to 0.9 in increments of 0.1, both the fitness function and the pressure drop exhibited a decrease of 9.4% and 24.9% respectively.

► The average temperature of the heated surface demonstrated a slight decrease of 0.8%.

Acknowledgements

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