Numerical Study on the Thermal Performance of Embedded Heat Pipes for CPU Cooling

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Abstract

Thermal management of central processing units (CPU) becomes more challenging in the development and production of high performance computers with faster and smaller size CPUs. Heat pipes are two-phase cooling devices with an effective thermal conductivity over 200 times higher than that of a copper heat sink. In addition, heap pipes have light weight, low cost and the flexibility of many different sizes and shape options which can be embedded into the metallic heat sink to provide more efficient thermal management. In this project, CFD was used to study a heap pipe embedded CPU cooler. The simulated results is validated with the experimental data for the same CPU cooler. Golf ball fans were also introduced to replace the stock fans in the CPU cooler to enhance the heat transfer and lower the operating temperature. The detailed distributions of temperature, velocity, and pressure were used to analyze the performance of the CPU cooler in both cases and found the golf ball fans are more effective than the stock fans.

Introduction

Heat is generated by all CPUs during operation. Slower processors only used passive heat sinks, however with faster and more power consuming processors, it is no longer possible to ignore thermal management. The goal is to make sure that the heat generated is dissipated into the ambient environment while holding a safe operating temperature.

The maximum limited temperature that can be borne by silicon chip in electronic components is 120ºC, with a normal operating temperature of under 70ºC. The reliability of electronic components drops by 10% for each increase of 2ºC in normal operating temperature. The high temperature is a major factor in shortening the life of the electronic components and malfunctioning. As a result, it is necessary to keep the operating temperature of such components below 70ºC.

To accommodate with such requirement, a combination of a heat sink embedded with heat pipes and an airflow by a fan is often used. The heat pipes are used due to their higher effective thermal conductivity that is over 200 times higher than that of a copper heat sink. Majority of CPU coolers contain heat pipes and heat sinks with bases made of Copper and fins made of Aluminum.

Heat pipes are the most common passive, capillary-driven of two-phase systems. Two-phase heat transfer involves the liquid-vapor phase change (evaporation and condensation) of a working fluid. The heat pipe is filled with a small quantity of working fluid. The main idea of heat pipes is based on an evaporation and condensation processes. At the hot side, the working fluid is evaporated and at the cool side it condensates again.

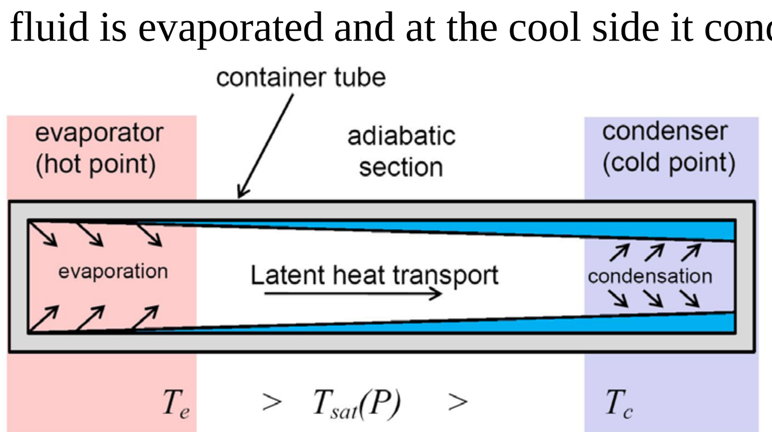

Fig. 1. Heat pipe mechanism

The fan noise is another aspect that has to be handled carefully. Fan noise is strongly dependent on the rotational speed of the fan. Sound power level is directly proportional to the 5th power of the rotational speed. Therefore reducing the fan rotational speed from 1500 RPM to 1000 RPM has advantageous acoustic effects in which the noise level decreases by nearly 9 dB (5 dB difference in sound level is noticeable).

Problem Specification

This study involves the thermal performance of a heat pipe embedded in the Noctua NH-D15 CPU cooler, which is a CPU cooling system comprised of a finned heatsink, a heat pipe, and two fans. The model was simulated in SolidWorks Flow Simulation. The stock fans will be replaced with a Golf fan in a second simulation with a reduced . The CPU chip is attached to the base plate of the module.

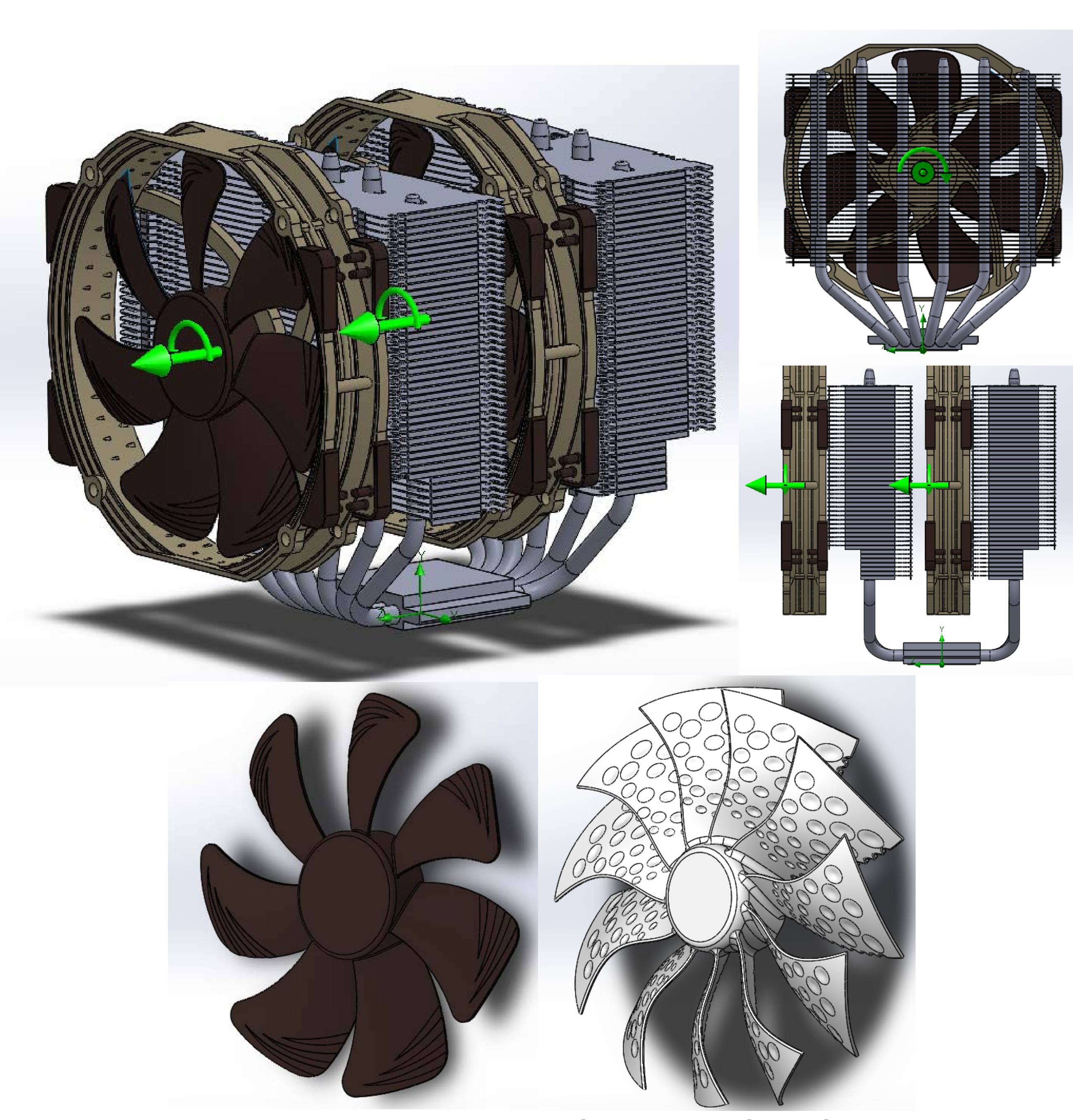

Fig. 2. CPU cooler, stock fan, and golf ball fan

Table 1. Design Parameters

Noctua NH-D15: Specifications	
Height (with fan)	165 mm
Width (with fan)	150 mm
Depth (with fan)	161 mm
Material	Copper (base and heat-pipes), aluminum (cooling fins)
Fan compatibility	140x140x25 mm
Weight	990 g (+160 g for each stock fan)
Fin count	46
Fin thickness	0.42 mm
Fin spacing	1.91 mm
Fan Specifications	
Stock fan rotational speed	1500 RPM
Golf fan rotational speed	1000 RPM

Mesh Cells	
Total Cells	580,264
Fluid Cells	373,248
Solid Cells	207,016

CFD Simulation

The CPU power is set to 100W in this case study and simulated as a surface heat generation source. Heat pipes have an effective thermal resistance of 0.3 K/W in most of the commercial CPU coolers. The fans were set to 1500 RPM for the stock fan & 1000 RPM for the golf ball fan. They were simulated via a rotating region in an outward direction.

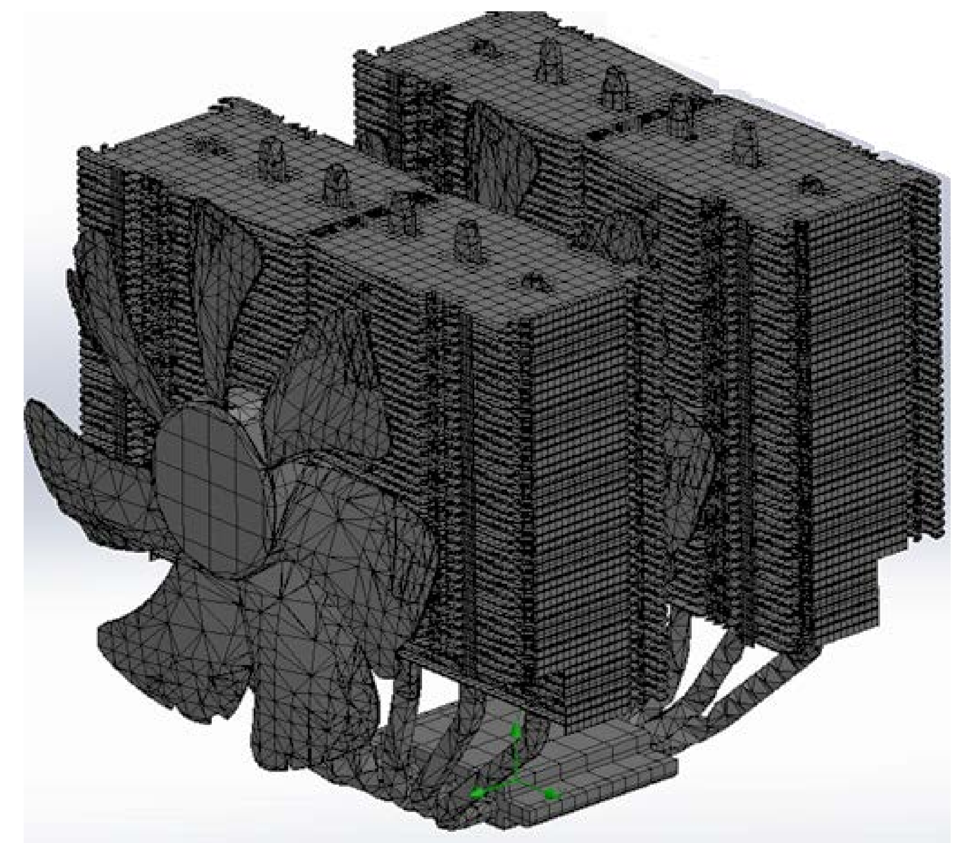

Fig. 3. Computational mesh

Simulation Results

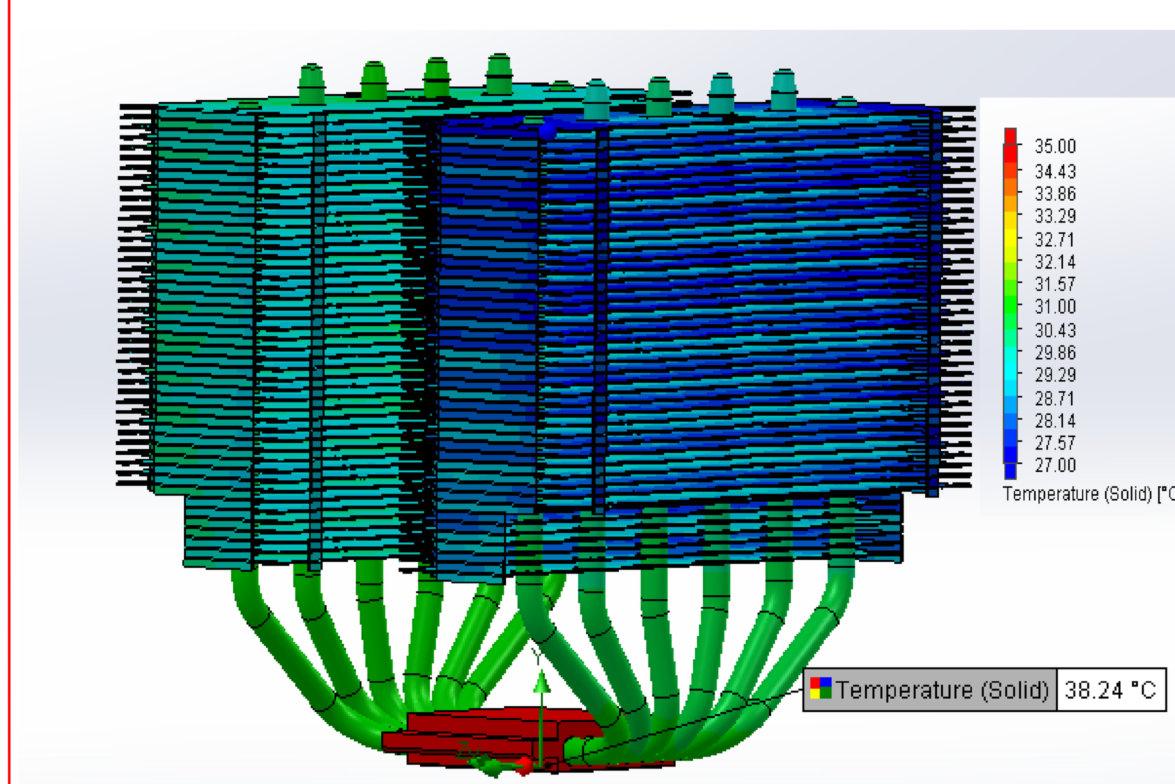

Fig. 4. Temperature distribution using stock fans

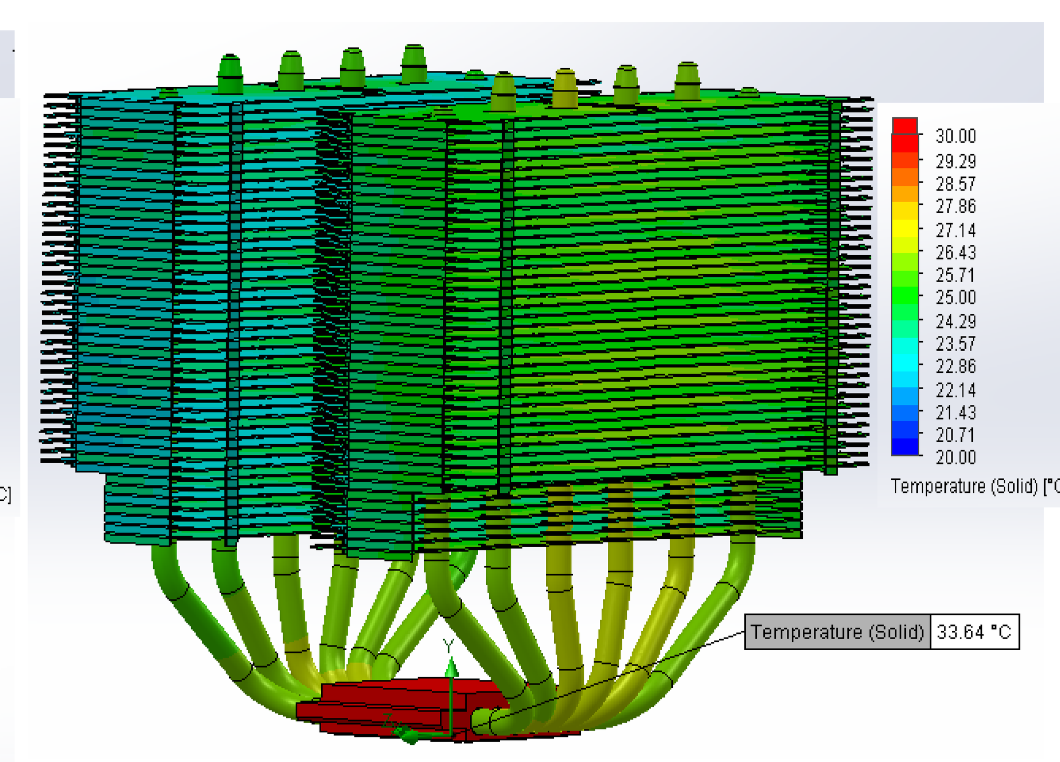

Fig. 5. Temperature distribution using golf ball fans

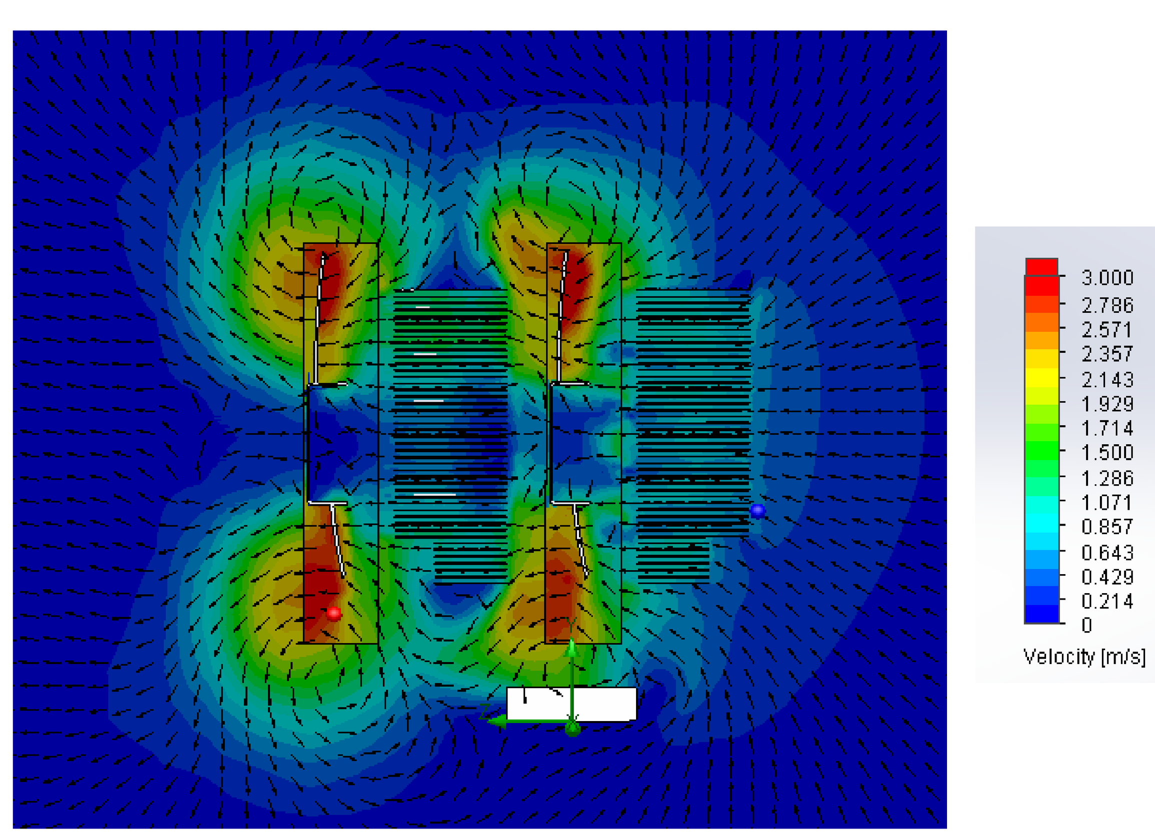

Fig. 6. Velocity distribution with vectors using stock fans

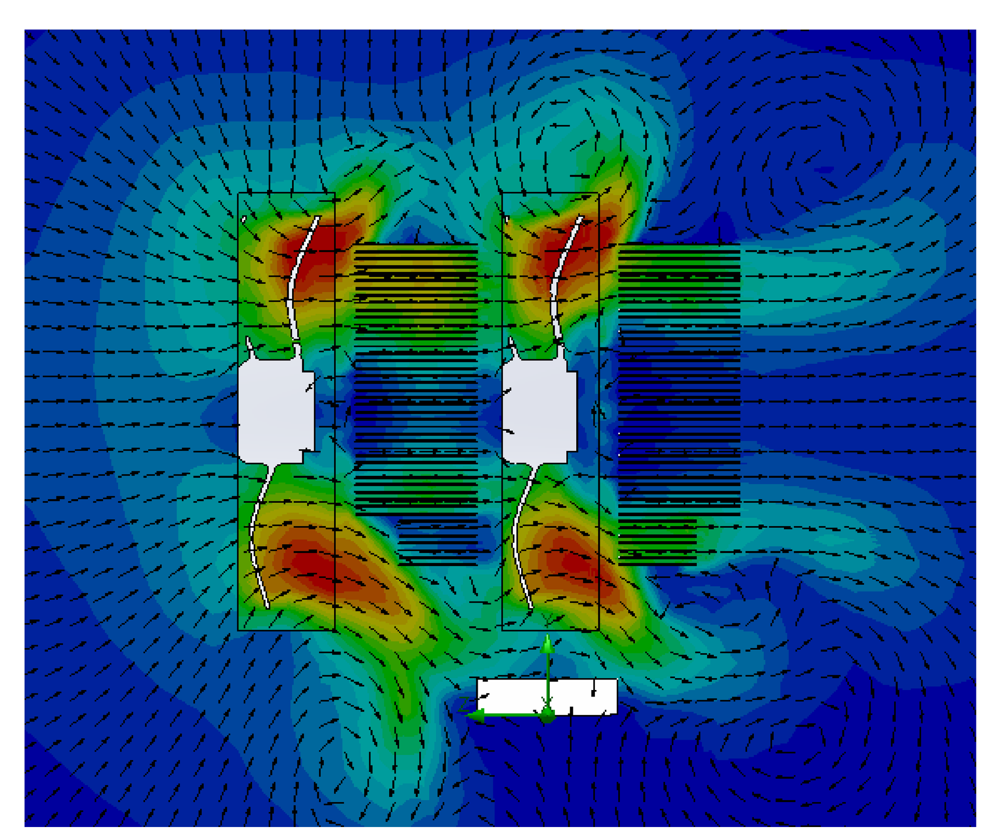

Fig. 7. Velocity distribution with vectors using golf ball fans

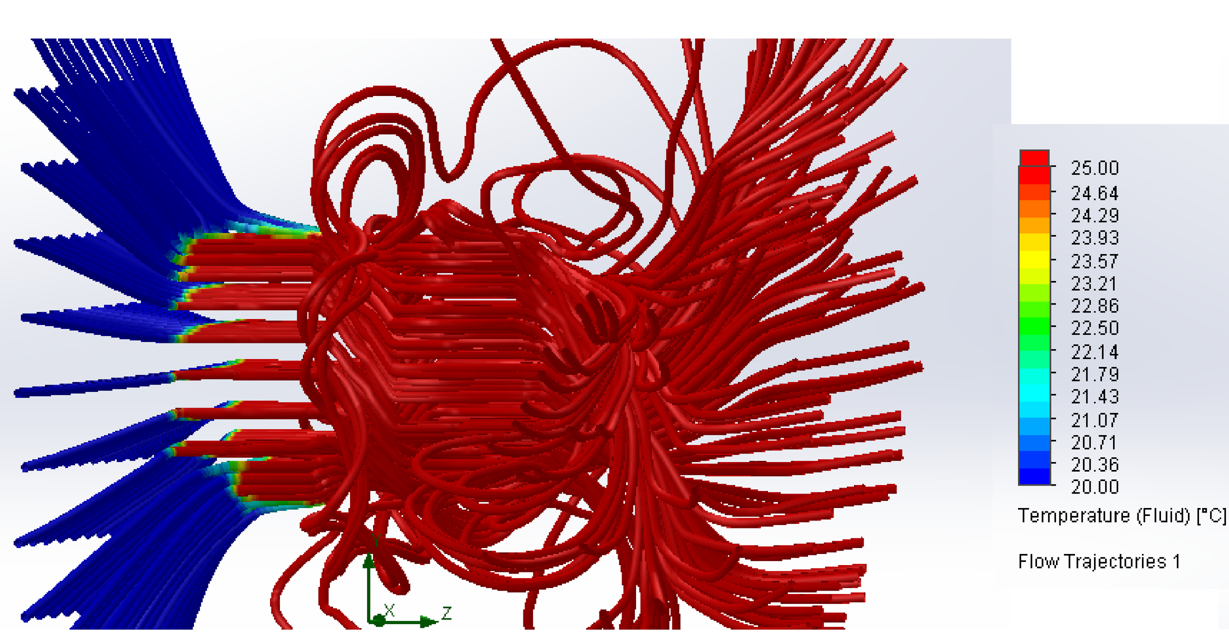

Fig. 8. Fluid Temperature flow trajectories using stock fans

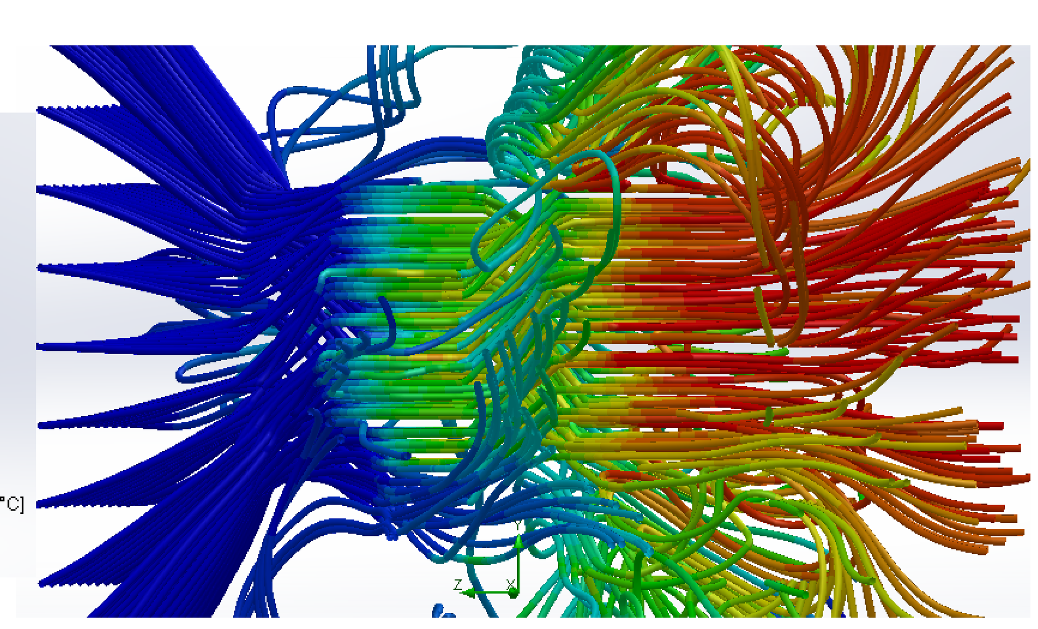

Fig. 9. Fluid Temperature flow trajectories using golf ball fans

Conclusion

In this study, the heat transfer and fluid flow of a 3D model of the Noctua NH-D15 CPU cooler was simulated with SolidWorks Flow module. The maximum temperature is close to the experimental result. Heat pipes are found to be effective to spread heat from the CPU chip to the metal heat sink which is then further cooled by the CPU fans. The temperature and flow patterns of the stock fans were compared with those of the golf fans. The results show that the dimpled texture and the increased number of the blades for the golf fans were able to achieve nearly the same temperature with a much lower RPM, thus reducing power consumption and noise levels.