Design of an Experimental Device for the Analysis of the Influence of Sound Waves on the CPU Cooling Process - Part II

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Abstract— *The article describes the calibration procedures and the creation of a series of initial data packages as a basis for comparative experiments in the process of increasing the efficiency of CPU air cooling in the case of commonly available types of coolers. It then describes the course of the experiment, the input parameters and the data obtained from the calibration of the basic model at different power settings of the fan mounted on the DeepCool AG200 air cooler. The output of the article is a model of cooling performance based on fan speeds and ambient operating temperature.*

Keywords— ***CPU, TDP, cooling process.***

I. INTRODUCTION

With the development of CPUs and with the annual increase in their computing power, there is also an increase in the amount of heat generated during their operation. The heat generated during CPU operation is one of the limiting factors of their maximum computing performance. To remove heat from the surface of the CPU, various methods were gradually introduced, from passive aluminium coolers to coolers with forced air flow provided by a fan, to water circuits that transport the generated heat using a heat-carrying medium to larger coolers located outside the CPU area, where the heat is removed to surroundings. Increasing the area of water coolers results in taking up larger areas on the computer case. This procedure of enlarging the heat exchange surface is unsuitable for portable PCs. For this reason, there has recently been a re-development of air coolers with heat pipes, where there is an effort to increase their performance using methods of disrupting the boundary layer of the flowing air in the ribs, to increase the removal of heat to the surroundings.

II. THEORETICAL FOUNDATION OF THE CALIBRATION MODEL

To create a suitable calibration model, against which it would be possible to relate the results of experiments for disruption of the boundary layer of flowing air, it is necessary to create a package of comparative data. As the basis of the experiment described in the previous article, a block of aluminium with dimensions of 85x58x16 mm was used, in which there are 3 heat sources with a total joint power of 150W, which simulated the operation of the CPU. Thermometers are placed in the volume of the aluminium block and on its surface to determine the average temperature of this block at different power settings of the heating elements and the cooler. A DeepCool AG200 air cooler with a total cooling capacity of TDP 100W is placed on the surface of one of the largest surfaces.

In the design of the experiment, a cooling performance measurement system was used at different power settings of the fan given by its speed. The amount of heat that needed to be removed was determined by the voltage and current supplied to the heating elements. If we know the voltage and current supplied to the heating elements, we can determine the heat output dissipated by the cooler to the environment at the point, when the temperature of the aluminium block stabilizes. Due to the insulation used, we can neglect the removal of heat to the surroundings in other ways than cooling with the use of a cooler. By changing the speed of the fan, the amount of air that passed through the heat exchange plates of the radiator changed and thus also the amount of energy that was transferred to the air. At each setting of the speed and the amount of heat supplied by the heating bodies, the temperature of the aluminium block stabilized, where the amount of heat supplied to the body was equal to the amount of heat removed, as shown in Figure 1.

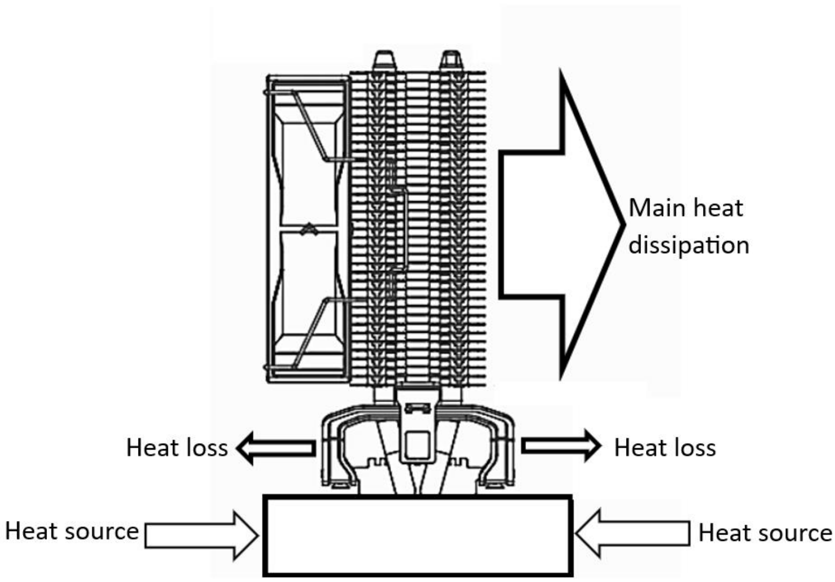

FIGURE 1: Temperature flow through the experimental device

III. BOUNDARY CONDITIONS

Due to the simple possibility of observing and comparing changes during individual experimental modifications of the cooling device, it is necessary to maintain the same boundary conditions during the entire duration of the experiment. One of the main boundary conditions that can have a significant impact on the obtained data is the ambient temperature. When the ambient temperature changes, there is a change in the temperature differential between the heat exchange surfaces and the flowing air and the parameters associated with the heat flow. This will subsequently cause an increase or reducing the cooling performance of the device. To eliminate these undesirable effects, it is necessary to perform a partially idealized experiment. The device is in an open room with a floor area of 3x8 m, in which the temperature is maintained at 22°C. Considering the size of the room and the relatively small heating power of the experimental equipment, it is possible to assume that the temperature in the room is stable. In the case of placing the experimental device in a computer case, as it is commonly used, there would be significant temperature fluctuations during the experiment and the need to create conversion coefficients relating to the actual temperature in a small space.

An important boundary condition for the possibility of comparing different power settings of the fan, or the influence of elements to increase the cooling efficiency, is the possibility of a stable setting of the heat flow that the cooler is supposed to remove. For this purpose, a laboratory source with adjustable voltage and current output was used. With the ability to accurately regulate and record voltage and current, it is possible to accurately reproduce the heat output delivered to the heated block of aluminium that represents the simulated CPU.

The last condition for the reproducibility of the created calibration model is the possibility of regulating the fan speed. The original fan supplied by the manufacturer of the DeepCool AG200 cooling device is connected to a laboratory power supply that regulates the supplied voltage, which controls the speed of the fan. The speed of rotation is recorded using a recording device that is connected to a digital tachometer built directly into the fan. Thanks to the connection between voltage and revolutions, it is then possible to easily regulate the speed of rotation of the fan based on the change in voltage without the need to detect the current revolutions.

IV. PROCEDURE OF MEASUREMENTS AND EVALUATION OF RESULTS

An Arduino MEGA microcontroller was used to record the measured data, which then sent the obtained and processed data to the computer. Dallas DS18B20 digital sensors on the surface in the number of 7 pieces and 3 pieces of NTC 10k thermistors in the core of the aluminium block were used to record the temperatures. Temperature data was recorded approximately every second and then these temperature values were averaged. Averaging temperatures enabled a better comparison of measured data and prevented inaccuracies caused by local heating of one of the thermometers.

To determine the efficiency of cooling the aluminium block using air cooling, a system of comparison of the maximum temperatures achieved at precisely defined heat outputs of heating elements and fan speeds while maintaining the same value of the ambient temperature was used. A gradual increase in the power of the heating elements was carried out according to the selected schedule, always after reaching a stabilized temperature of the aluminium block at the specified fan speed. The measured data subsequently created a table of dependences of the maximum temperatures achieved with respect to the fan speed and the power of the heating elements.

Increasing the thermal output of the heating elements was carried out by changing the voltage and current values on the laboratory power source. In tab. 1 shows the measured maximum stabilized temperatures of the aluminium block with respect to the heat output supplied to the aluminium block and the speed of the fan.

TABLE 1
DEVELOPMENT OF TEMPERATURES DEPENDING ON THE SPEED OF THE FAN AND THE HEAT OUTPUT OF THE HEATING ELEMENTS

	Thermal performance	9W	16W	24W	36,6W	49,7W	64W	81W	99W
		Temperature (°C)							
Fan speed	1450 rpm	27,12	29,73	33,43	39,13	44,96	50,92	58,46	66,89
	1750 rpm	26,142	29,31	33,1	38,32	43,96	49,78	57,32	65,41
	2100 rpm	26,04	29,05	32,36	37,41	42,84	48,53	55,71	63,27
	2325 rpm	25,88	28,73	32,15	36,62	41,74	47,45	54,46	61,61
	2575 rpm	25,64	28,59	31,93	36,40	41,50	46,92	53,84	60,71
	2800 rpm	25,74	28,38	31,62	36,29	41,26	46,52	52,94	59,84

The course of measurements was carried out at an ambient temperature of 22°C ± 0.5°C. From table 1 and fig. 2 there is a linear change in temperature with respect to the change in fan speed and heat output. According to the assumption, with increasing revolutions, the average and maximum temperature of the aluminium block decreased due to the increasing cooling power, which increased with the increase in the speed of rotation of the fan and thus also with the increase in the volumetric flow of cooling air. The increase in fan speed was realized by increasing the supply voltage by 1V at each measuring step.

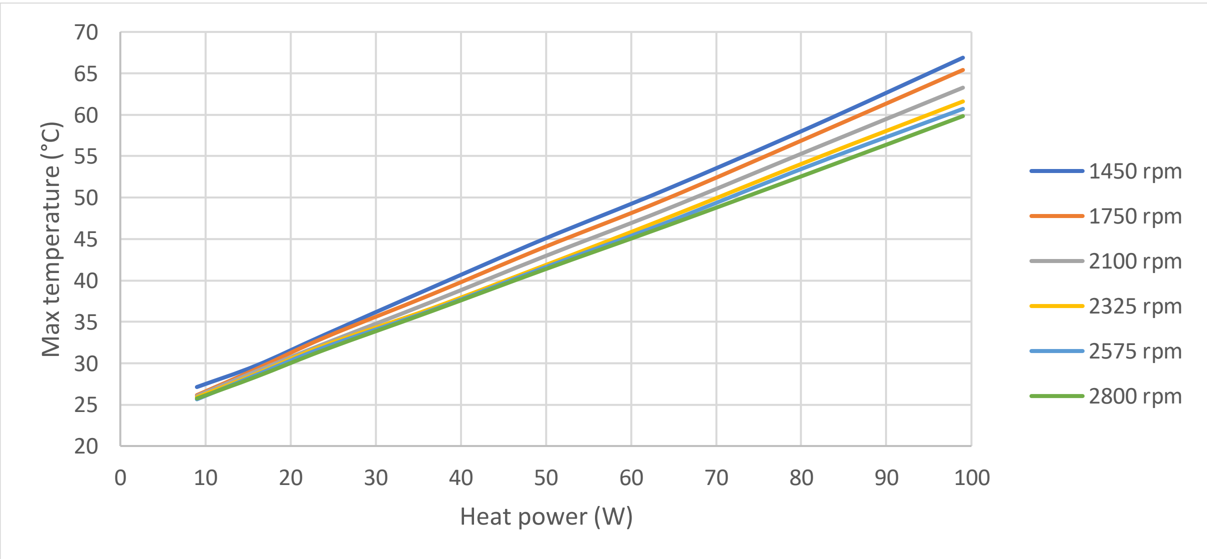

FIGURE 2: Dependence of the temperature change on the heat output of the heating elements and fan speed

If only the maximum heat output of 99 W and the effect of the change in speed on the maximum temperature reached in the aluminium block were monitored, it would be possible to determine a linear temperature drop with respect to the fan rotation speed. A change in speed will cause a change in the speed of air flow through the body of the cooler, which will also increase the amount of heat transferred to the environment while maintaining the same temperature difference between the air inlet and outlet. The linear decrease in temperature is shown in fig. 3.

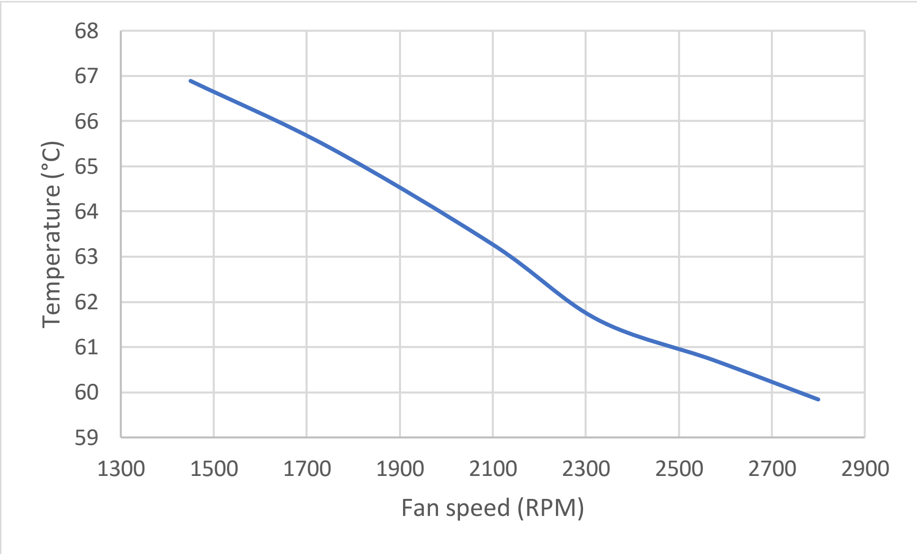

FIGURE 3: Change in the maximum temperature reached with a change in fan speed

During the experimental measurements, a recording was made of the overall course of temperature change and subsequent stabilization. Due to different powers and stabilization times, the data set was modified and shown in fig. 4.

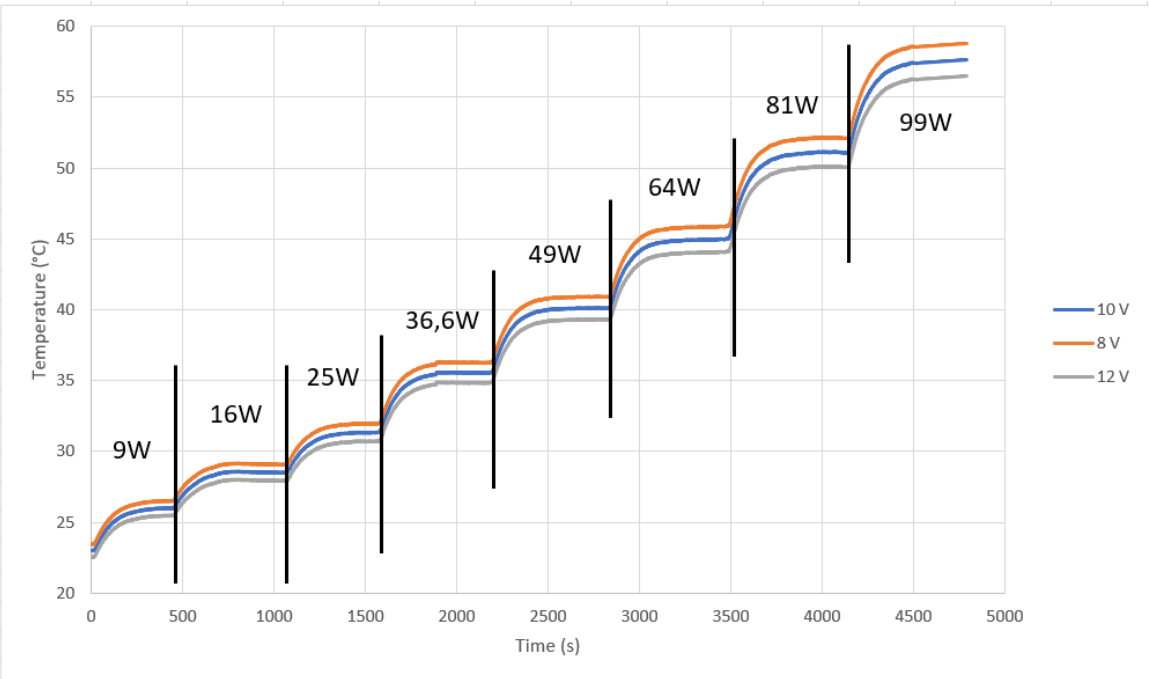

FIGURE 4: Change in maximum temperature with different heat outputs of heating elements and fan speed over time

As can be seen from the given dependence, there is a significant decrease in the maximum reached temperature of the aluminium block with respect to the speed of the fan. From the obtained data forming the comparison package, it is possible to predict the resulting maximum temperature at known fan speed and ambient temperature at the specified thermal performance of the heating elements (simulated CPU).

V. CONCLUSION

The creation of a comparison and calibration model is an essential basis when dealing with increasing the efficiency of CPU cooling using air cooling devices. Without the creation of a reliable comparative model against which it would be possible to relate the results measured during the process of increasing the efficiency under different operating conditions, it is not possible to accurately determine the change in cooling performance due to the use of innovative methods of increasing the cooling performance.

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