Design Guidelines for a Piezoelectric Micro-Blower Fansink

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Forced air cooling using a fan is widely used to cool electronic equipment. In recent years, office automation equipment such as printers, and a variety of mobile devices have undergone massive improvements in multi-functionality and performance, coupled with miniaturization. As a result, the thermal design has become more challenging. There is no space to implement an additional fan for cooling. However, forced air cooling is needed to achieve the required cooling performance and prevent overheating. To address this, a number of small air cooling devices have been developed in recent years.

In this study, we investigated the practical use of a small air-cooling device for use within the narrow gaps found in densely packed electronics. The device is an ultra-compact piezoelectric micro-blower that is thin enough to be installed in the gaps between parts and develops a high enough pressure to generate sufficient flow rate. The blower is 20mm x 20mm and just 2mm thick, yet is able to supply 1L/min of air with a jet speed of almost 20m/s. This was investigated in conjunction with a heatsink, optimized using FloTHERM® to get the best thermal performance from the blower.

In recent years, the implementation of micro air movers in narrow spaces has been reported, including, micro fans [1] and piezo fans [2-4]. These devices have dimensions sufficiently small to be considered, but the resulting airflow would be minute, and perhaps adversely affected by the system air flow, limiting the benefits. This study focusses on the use of an ultra-thin piezoelectric micro-blower recently developed by Murata [5] to be 2mm or less (see Figure 1), to cool an attached heatsink. The purpose of the study is to develop design guidelines to maximize the heat transfer from the heatsink structure.

The piezoelectric element attached to the air chamber is vibrated by applying an alternating voltage (nominally 26kHz) to cause expansion and contraction of the air chamber. Air is drawn in during expansion, and forced out as a jet during contraction, entraining air from the flow passage. The study first looked at how

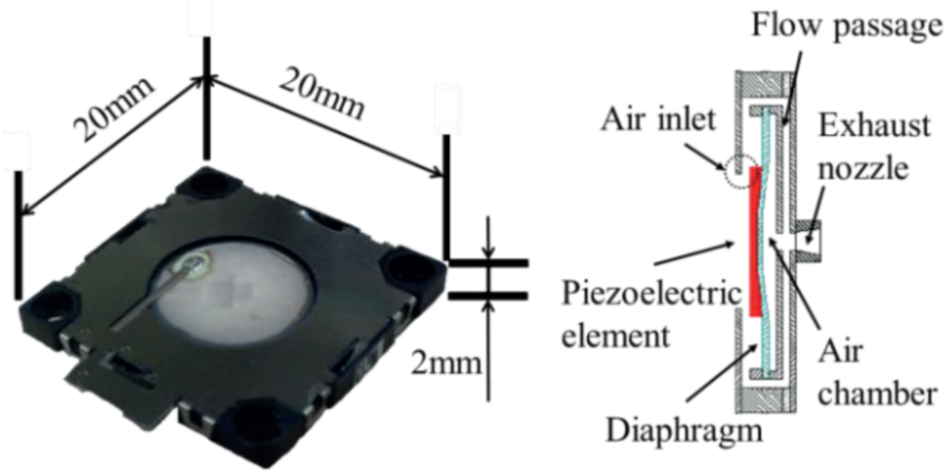

Figure 1. Murata's High-pressure Ultra-thin Microblower.

the flow performance was affected by installing a baffle plate to simulate nearby densely packed electronics. It was found, that provided the distance to the baffle is 1mm or more, there is very little restriction in the flow rate, pointing to the suitability of the device for use with narrow channels.

Having shown that the flow rate does not change even in the presence of very limited available flow space, the next stage was to investigate how the heat transfer enhancement resulting from the jet can be used to greatest advantage by numerical analysis using FloTHERM. This study considered a heatsink that had the same footprint area as the blower, to initially optimize the fin shape. For this a model was constructed as shown in Figure 2, to capture the design of future planned experimental work. The base of the heatsink was uniformly heated, with the base of the heatsink and the heater set into a 150mm x 150mm horizontal acrylic block. An identical acrylic block was set 5mm above, with the blower airflow modeled as a laminar fixed velocity directly above the center of the heatsink. The flow rate was set to 750 mL/min to make allowance for the system pressure drop, with an inlet air temperature of 20°C and a heat source of 1W applied uniformly within the heater.

To investigate the effectiveness of the blower, the cooling performance was also measured with the blower turned off for several heatsink

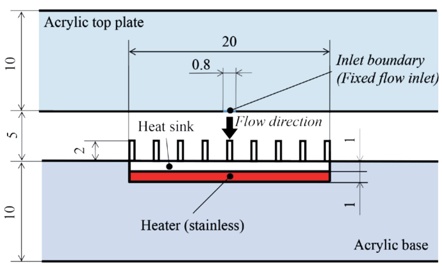

Figure 2. Dimensions (in mm) of the FloTHERM Model

designs, and the assembly cooled through a combination of natural convection, conduction and radiation. This caused an additional increase in the heatsink temperature rise by around 30°C in all cases, showing that although the flow through the blower is small, its effect on cooling the heatsink is large, providing confidence that the full study of heatsink geometries would be worthwhile.

Once the effectiveness of the blower was confirmed, attention turned to studying the influence of the fin shape on the performance of the heatsink. Heatsinks primarily extend the surface area available for cooling, so the hope was that the heat transfer could be increased by switching from an extruded fin heatsink to a pin fin heatsink, which were originally designed for use with impinging flows, and increasing the number of fins. By investigating 10 different heatsink designs in addition to the original extruded fin heatsink, it was found that an in-line arrangement of fins was superior to a staggered

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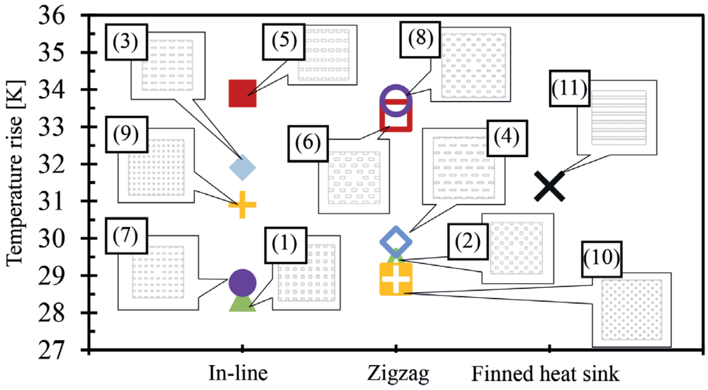


Figure 3. Performance of Different Heatsink Geometries

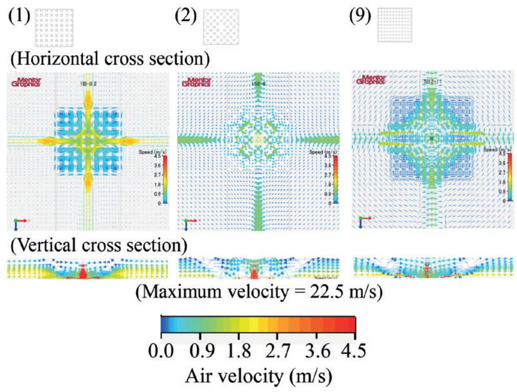


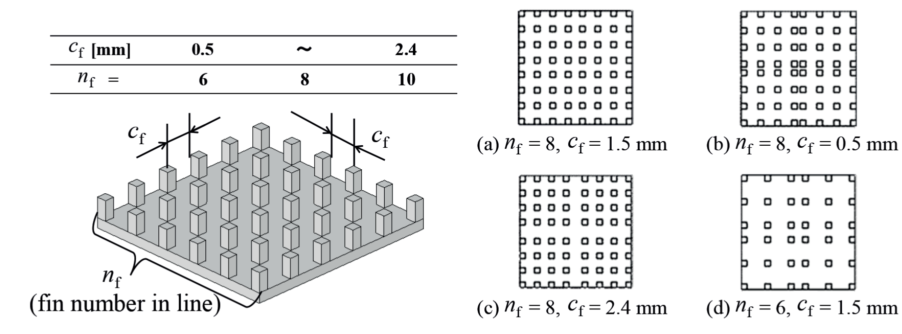
Figure 4. Differences in Flow Field Arising from Different Heatsink Designs

arrangement, as shown in Figure 3, in which heatsink #1 shows the lowest temperature rise above ambient.

It is worth noting that heatsink #9 with the finest fins, each having a cross-sectional dimension of 0.5mm x 0.5mm showed worse performance than heatsink #1 with 1.0mm x 1.0mm fins in the same in-line arrangement. For this reason the flow distribution within the heatsink was then investigated. For this part of the study, heatsinks 1, 2 and 9 were considered. Of these, heatsink #1 gave the highest rate of heat transfer and heatsink #9 the lowest.

From the flow vectors shown in Figure 4, it is evident that heatsink #1 has the highest velocity in the channels between the fins extending from the jet out to the sides of the heatsink, with the flow being ducted in those directions due to the alignment of the pins. The narrower channels in heatsink #9 increase the flow resistance and so act to reduce the flow velocity, causing the flow to spread more uniformly within the fin array. One key difference between heatsink #1 and heatsink #9 is that the latter has a row of pins across the base in line with the centerline of the jet, whereas heatsink #1 has a central gap. The staggered arrangement in heatsink #2 partially breaks up the jets, again reducing the flow velocity and leading to more uniform flow within the finned region.

From this, it was concluded that the main contribution to heat transfer is due to the boundary layer flow forming on the base of the heatsink, and the action of the fins to duct the flow and hence preserve its velocity provides a key to future heatsink designs. To further optimize the design it was decided to investigate how the fin gaps influence the cross flow. For this study the 3mm tip clearance above the heatsink fins shown in Figure 1 was reduced to zero by lowering the top acrylic down to the fin tips. The central fin gap size was varied from 0.5mm to 2.4mm, and the number of fins in each direction set to be six, eight, or ten, with the spacing between the other fins changed as required. Samples of the designs are shown in Figure 5 along with the results, which show that the key parameter affecting the performance of the heatsink is the size of the central gap, with the results more weakly affected by the spacing between the other fins, with the larger fin spacing resulting from using only six pins in each direction showing the best performance.



9 fin conditions for optimal fin spacing verification of the jet occurs site

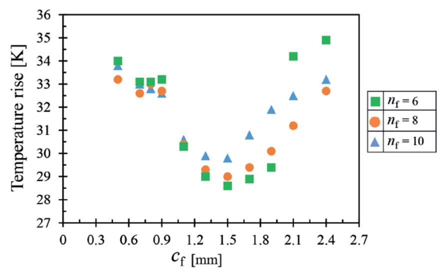


Figure 5. Influence of the Center Gap Spacing on Heatsink Cooling Performance

By way of conclusion, this work has shown the viability of using a commercially available piezoelectric micro-blower with a customized heatsink design to cool densely packed electronics as found in the latest office automation products and mobile devices. Design guidelines for the heatsink have been developed to maximize the heat transfer from the heatsink by optimizing its design for the impinging flow. Further work is planned to experimentally verify the results of this study. There is also scope to optimize the shape of the fins and their layout beyond the rectangular cross section studied so far to further enhance the flow through the finned region by considering a radial arrangement with circular and elliptical fins.

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