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CHARACTERIZATION OF MICRO-BLOWER FOR AVIONIC PACKAGES

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Abstract - The topic of thermal management in electronic equipment has recently gained attention in research community. All electronic components and circuitry generate some quantity of heat. Development in the field of avionics results in minimizing the electronic equipment size and increase in the number of transistors used per circuit, which proportionately increases the amount of heat generation. In such cases, heat reduction is becoming a forbidden task for researchers. A piezoelectric micro-blower, which was made to cool the electronic equipment is used in the present study. Both static and dynamic characterization were found with the help of numerical simulation and experimental investigation. The performance of a micro-blower was experimentally investigated, and results were plotted. An Air-flow sensor/Anemometer is used to study the velocities coming from the blower-exit at different operating voltages. Thermal performance test was also conducted at three different alignments of heat source to observe the heat reduction capacity of blower in such alignments. Thermal contours were also captured using IR camera. Results show a significant reduction in the amount of heat generated
***Keywords*:** Piezoelectric, IR Camera, Micro-Blower, Anemometer

1. INTRODUCTION

Thermal management is essential in electronics as it increases the reliability and improves performance by removing the heat generated in such devices. In Avionic packages, the electronic equipment are placed in a hermitically sealed chamber, where the air is in static condition. Hence, we must provide forced convection by providing a fan or a blower to circulate the air available in the chamber. In general, a PCB (Printed Circuit Board) will be populated with many number of IC's, but only few IC's will generate excess heat. In such cases, we must provide a focused jet on those particular ICs, which are generating excess amount of heat, other than providing a generalized cooling on entire PCB.

So that, there is a need of today's industries for cooling products that require devices which are increasingly smaller, light in weight, consumes low power, and reduces heat generation. As per today's industrial requirements, for such application a micro-blower will be appropriate rather than a fan. The working principle of the Micro-Blower is explained in next section. A jet formation criteria for both two-dimensional and axisymmetric jets of similar application is best explained in Reference [1]

Applications of the micro-blower used in the present study include aircraft equipment, aerospace equipment, undersea equipment, power plant control equipment, medical equipment, transportation equipment (vehicles, trains, ships, etc.,), traffic signal equipment, disaster prevention / crime prevention equipment and data-procession equipment. Coming to technicality, micro-blower can be used in air pump application, spot air blowing application, Liquid sending at high pressure air, Air sucking, Blowing and Circulation application.

In the present study, two different series of experiments were conducted. First, Velocity Measurement test and then Thermal Performance test.

2. WORKING PRINCIPLE OF MICRO BLOWER

The working principle and other details of the Micro-Blower used in present study are explained in reference [2-5], but as the working principle plays the key role in understanding the present study, a brief explanation is given here

Micro-Blower works with the help of a piezoelectric element. The concept of Piezoelectricity plays a crucial role in working of Micro-Blower, which is best explained in Reference [6-10]. Constitutive equations required for actuating a piezoelectric element are given in Reference [11]. Pumping efficiency depends not only on the actuating frequency and maximum magnitude of the membrane deflection, but also on the shape of membrane deflection [12]. The piezoelectric element used in the present study is PZT-5H of 11mm in diameter. The actual Micro-Blower can be seen in fig.4 and the cross-sectional view of the micro-blower can be seen in Fig.1.

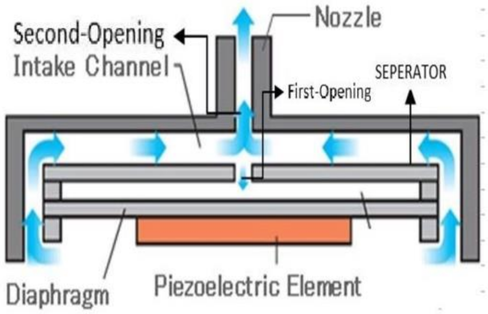

Fig.1: Cross-sectional View of Micro-Blower

The working principle of the Micro-Blower can be explained in four simple steps, (a) No-load state (b) Suction (piezo bending down) (c) Discharge (piezo return to normal state) and (d) Discharge (piezo bending up). Fig.1 is taken from reference [5]. The Micro-blower consists of a piezoelectric element, diaphragm, separator and nozzle. Diaphragm is attached to a piezoelectric element. Indirect piezoelectric effect says that the piezoelectric element will vibrate when it is given an AC voltage. As the diaphragm is also attached to piezoelectric element they will vibrate in bending fashion unlike linear motion.Table1 represents the material data for individual parts of Micro-Blower.

Table1: Materials used for Components in Micro-blower

S. No	Component	Material
1	Piezoelectric element	PZT-5H
2	Diaphragm	Nickel
3	Separator	SUS304

To study the flow physics and their effects on heat transfer, a time-averaged PIV was conducted in Reference [13].A CFD based fluid-structure interaction of the piezoelectric actuated micro-blower was modelled.

3. EXPERIMENTATION

As explained earlier, it is important to study the performance of a micro-blower, specifically, the behaviour of output velocity with respect to different input voltages and thermal performance of the micro-blower. So, in the present study two major experiments were performed. One is the Velocity measurement test and the other is the Thermal performance test. The outside dimensions of the blower are 20mm * 20mm and thickness tolerance is 1.85±0.2mm. All the experiments were performed at RCI (Research Centre Imarat, DRDO)

3.1. Velocity Measurement test:

Velocity is one of the key parameters in this work, as it decides the amount of heat that can be reduced from the heat generating component in electronic device. In the velocity measurement test by using hot-wire anemometer (UAS1500) both, longitudinal and lateral velocities coming from the exit of the micro-blower were measured. The experimental set-up for velocity measurement is shown in fig.2.

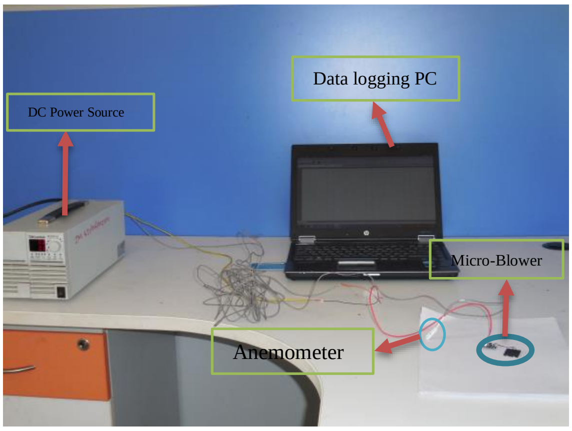

Fig.2. Experimental Set-up for Velocity Measurements

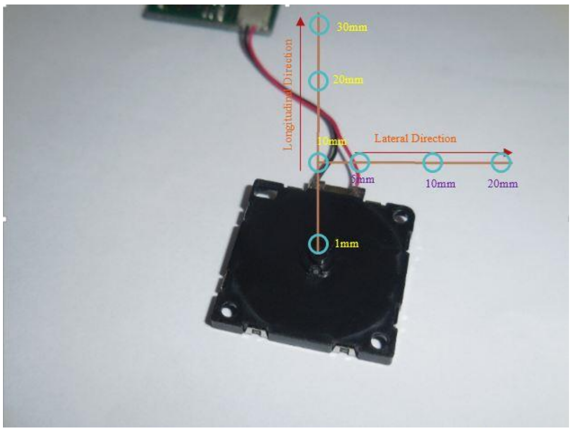

Fig.3: Pictorial representation of Longitudinal and lateral distance

By using DC power source, we can send controlled DC voltage to Driver circuit. Soldering of positive and negative wires to the Micro-Blower and driver Circuit was done by using a lead-free solder, which is maintained at 350^{0}C with a contact time of 3 seconds. This Driver Circuit will take DC voltage as input and supplies AC voltage to the Micro-blower. The anemometer is connected to a data logging PC, in which time to time velocity readings were saved in excel sheet with the help of a software. The experiment was performed at three different voltages (10V, 15V and 20V) at an ambient velocity of 0.15 m/s and an ambient temperature of 32^{0}C. Results obtained from velocity measurements are shown in table 2 and figures 4&5. Both longitudinal and lateral velocities were measured to obtain the optimum direction in which the blower can be operated. Table2 shows the longitudinal variation of velocities from the blower exit at three different operating voltages (10V_{P-P}, 15V_{P-P} and 20V_{P-P}). The micro-blower is given a square input signal and operated at 25 KHz frequency.

Table2: Longitudinal/axial Variation of velocity from blower exit

S.No	Sensor Location (mm)	Velocity(m/s)		
		10V	15V	20V
1	1	13.48	24.95	24.98
2	5	7.3	13.67	20
3	10	7	11.97	13.57
4	20	4	6.83	7.86
5	30	2	4	5.28
6	40	-	-	4.26
7	50	-	-	3.6
8	80	-	-	2.13

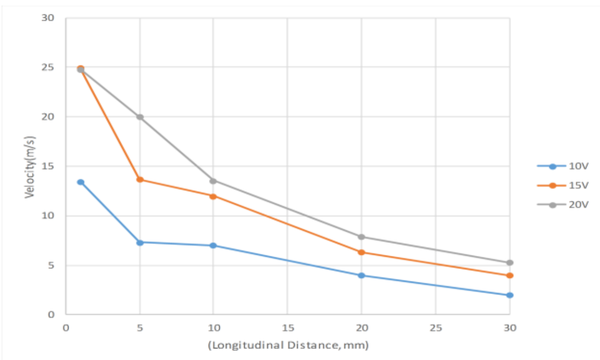

Fig.4: Longitudinal/Axial Variation of velocity from blower exit

From the Fig.4, we can clearly say that, as we move away from the blower exit in longitudinal direction, the velocity magnitude reduces and at the same time as the voltage increases the velocity coming from the blower exit also increases at one particular location. Similarly, velocity performance in the lateral direction was also observed. By tuning the longitudinal distance stable at 10mm, from that point in the lateral direction, velocity measurements were perceived at five points in a sequence. From Fig.3, it is easy to understand about longitudinal and lateral directions at the exit of the blower.

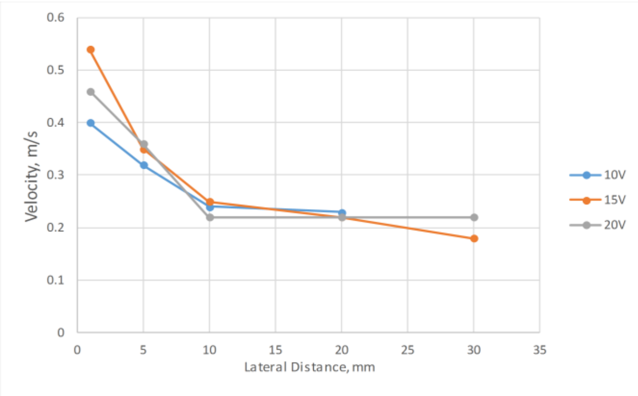

Fig.5: Lateral Variation of velocity from blower exit at longitudinal distance of 10mm

From Fig.5 it is evident that the performance of micro-blower, in terms of velocity in the lateral direction is not exciting like the velocity in longitudinal direction. At 10mm longitudinal distance from the blower exit the relation between voltage and lateral velocity is not proportional. Fig.5 shows that velocity is increasing at all the distances, when we increase the voltage from $10V_{P-P}$ to $15V_{P-P}$. But as we move further from $15V_{P-P}$ to $20V_{P-P}$, velocity reading at $20V_{P-P}$ is less than the velocity reading at $15V_{P-P}$. The difference in velocity reading can be clearly observed at 1mm and 5mm lateral distances. This is because, at $20V_{P-P}$ the fluid will be pushed out from the micro-blower with a higher pressure than at $15V_{P-P}$, so the fluid will not spread in lateral direction immediately as in case of 20V and that is the reason why velocities will come down.

3.2. Thermal Performance of Micro-Blower:

The main purpose of the micro-blower is to reduce the amount of heat generated on the electronic equipment. By performing thermal performance test, we can analyze the heat reduction capacity of the blower. In practical applications, the position of the heat generating component (any heat generating electronic equipment) is not fixed, it may be horizontal (facing up/ down) or vertically aligned depending upon the application and space constraints in the chamber.

Blower should be placed according to the direction of heat generating component. Correspondingly, the performance of the blower is not the same in all alignments. The rule of thumb is that “Every 10^0C increase in temperature reduces component life by half”. So, keeping the practical issues in view the experiment was conducted at different alignments of the heat source i.e., by placing the heat source in horizontal alignment (hater facing up & down) and vertical alignments, which can be seen in fig.6.

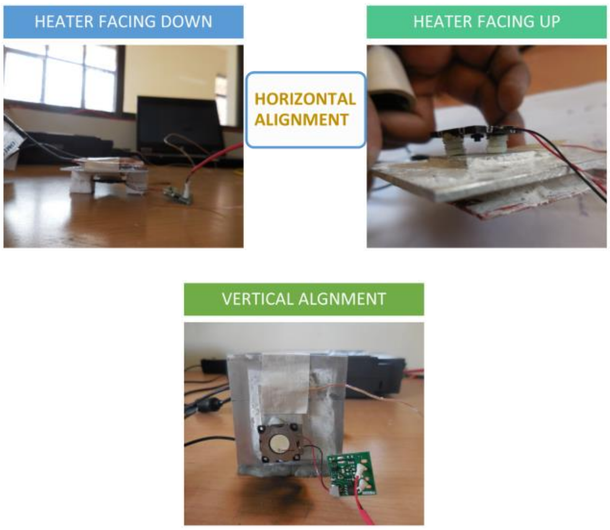

Fig.6: Different alignments of the heat source and the blower

3.2.1. Thermal Performance Test:

For thermal performance test, devices which will play key role for experiment are as follows, Nichrome Test heater of square domain, aluminum plate and Micro-Blower. The Nichrome heater will be attached to aluminum plate and a thermal paste is added in between. Thermal paste is used to provide ideal heat transfer between aluminum plate and Nichrome heater. Nichrome heater generates heat by taking 120V AC current as input and transfers heat to the aluminum plate through thermal paste. This aluminum plate is used as a constant heat source to get steady results. The attachment of Nichrome heater and aluminum plate can be seen in fig.6.

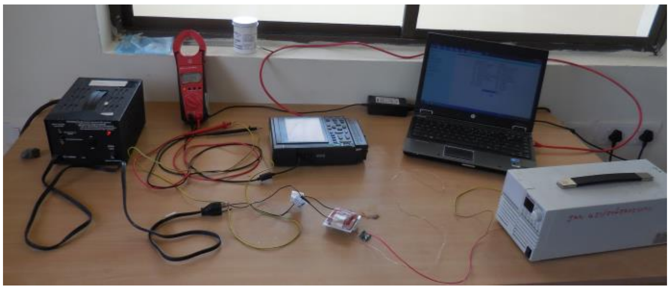

Fig.7: Experimental set-up for thermal performance test

To provide 120V constant AC voltage to the Nichrome heater, a step-down transformer is used and with the Multimeter the voltage input to the blower and Nichrome heater was constantly monitored. A Thermocouple, which is used to measure the temperature on the plate is connected to data logger and the data logger is again connected to a Data logging PC to record time to time temperature values and plots in excel sheet. Lambda power source is used to send constant DC voltage to the driver circuit of the micro-blower.

The experimental set-up for thermal performance test is shown in fig.7. Nozzle part of the Micro-Blower is focused towards the heat source. The air coming from the blower exit with specific flow-rate and velocity is directed towards the heat source and hits the heat source like a forced jet. Micro-Blower also creates turbulence in the surrounding medium, which causes generation of vortices. Generation of vortices are very much helpful in cases, when the equipment to be cooled is situated in a hermitically sealed chamber, where air in those chambers will be in static condition. Vortices formation in such cases causes better mixing of the flow and results in better heat transfer.

Once the Nichrome heater was switched ON, its temperature rises and reaches steady at 100^0C, at the same time aluminum plate also reaches 100^0C. It takes some time for the aluminum plate to reach 100^0C temperature and becomes steady. Once, if the temperature becomes study, the blower should be switched ON and the temperature drop should be observed.

Results of thermal performance test were discussed below, and graphical representations of these results were presented.

- Fig.8 shows the result of horizontal alignment of the blower, when the heater is facing upside, a maximum of 10^0C variation in temperature is observed in this alignment.
- Fig.9 shows the result for horizontal alignment of the blower, when the heater is facing down, a maximum of 5^0C variation in temperature is observed in this configuration i.e., which is half the value of temperature drop when compared to above alignment. The variation in temperature drop between two variations of horizontal alignment is mainly because of the resistance for the air flow, which is less in case of heater facing down.
- Fig.10 shows the vertical alignment of the blower, a maximum of 8.6^0C variation in temperature is observed in this arrangement.

From these results, case 1[1*] is giving the best results out of remaining alignments. When we compare case2[2] and case3[3] with case1, case 2 is having 69.44% lesser heat reduction capacity than case1 and case3 is having 49.07% lesser heat reduction capacity than case1. Hence, if the heat generating component (Integrated chip) in the chamber is placed in the direction where heat source yielded best results, there would be best possibility of reduction in temperature.

[1] Case1: Horizontal alignment and heater facing up
[2] Case2: Horizontal alignment and heater facing down
[3] Case3: Vertical alignment of the micro-blower

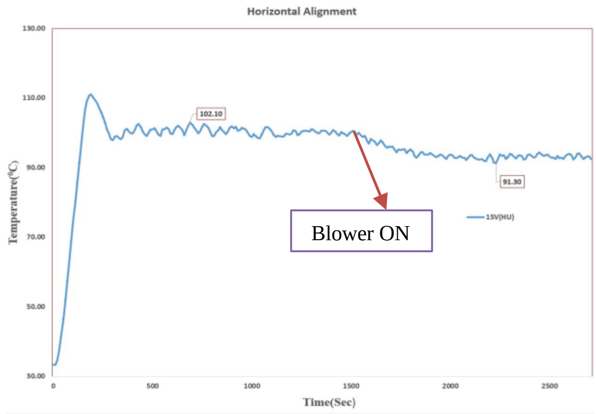

Fig.8: Temperature drop of heater for Horizontal alignment of Blower when Heater is facing up

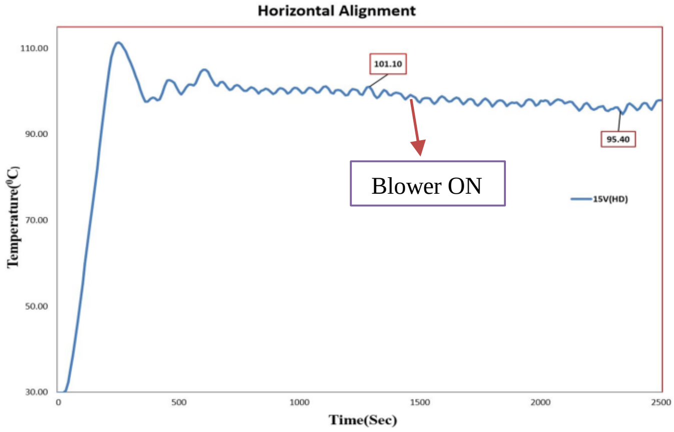

Fig.9: Temperature drop of heater for Horizontal alignment of Blower when Heater is facing down

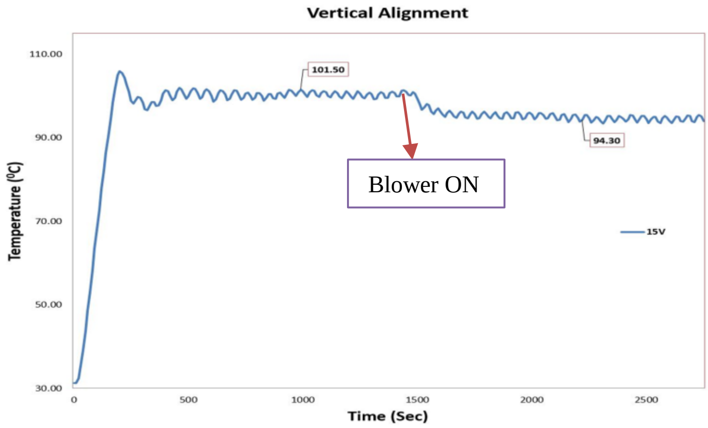

Fig.10: Temperature drop of heater for Vertical alignment of Blower

A square input signal of 15V voltage is given as an input to the micro-blower. The workplace was kept clean as the micro-blower will be affected with the dirty environment and the testing room was insisted such that, constant velocity and temperature were maintained, and no other external parameter should influence the test results.

3.2.2. Comparison of temperature drop at different voltages :

Voltage is one of the key parameter that decides the volume flow rate coming from the exit of the blower and heat reduction on the heat generating component.

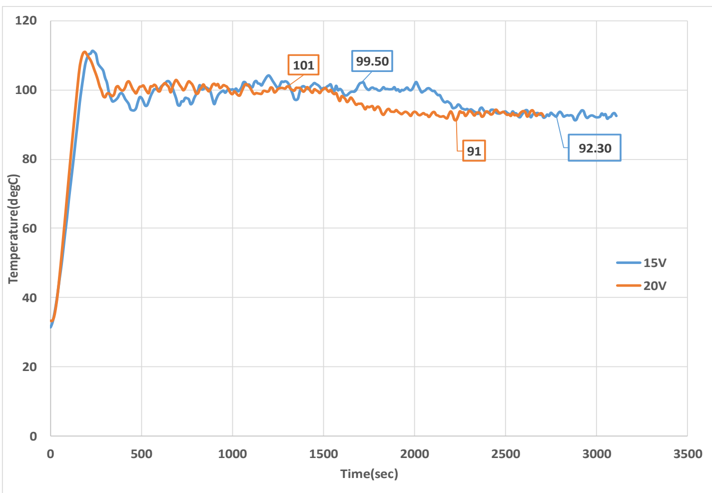

Fig.11: Comparison of Temperature drop for horizontal alignment at two different voltages (15V and 20V)

Hence to observe the effect of voltage in heat reduction instance, for an alignment thermal performance test was carried out at two different voltages. From fig.11 it is evident that maximum temperature is obtained when the input voltage is 20V. When the input voltage is increased from 15V to 20V 38.8% increase in temperature drop is observed.

3.2.3. IR images of Thermal Performance Test:

IR images are also called as thermal images captured using IR/Thermal Camera. Using thermal camera images were captured to observe the difference in temperatures when the blower is not active and when the blower is active.

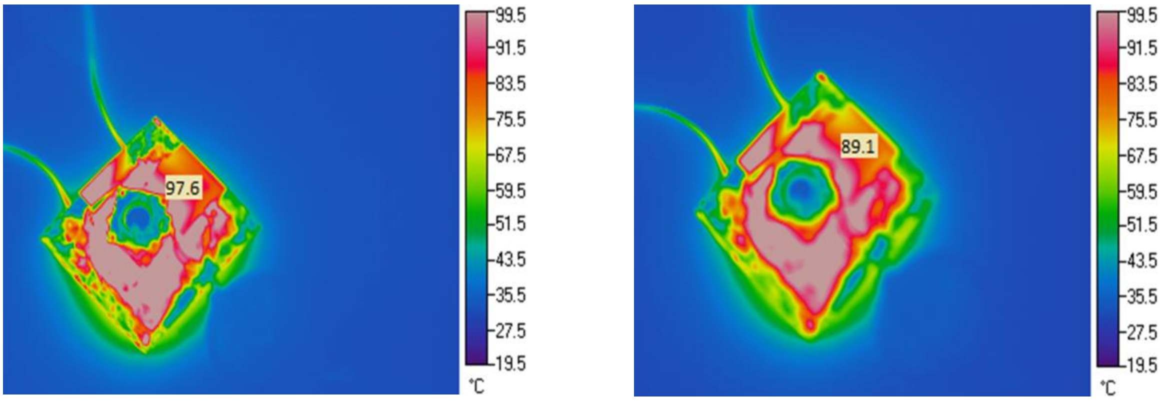

Fig.12: Thermal images captured in the cases when the blower is inactive and active

Thermal imaging is a method of differentiating the objects in distinct color codes according to temperature emitted by them or shortly can be called as thermal contours captured with camera. In the present study by using IR Camera, thermal images were captured during Thermal performance test. To observe the difference, images were captured before the test and after the test, which were shown in fig.12.

During the experiment it was observed that the temperature on the micro-blower was remained same as 32^0C even when the temperature on the aluminum plate is at 100^0C.

4. Conclusion:

In the first part of the paper both static and dynamic characterization of Micro-Blower were measured. From static characterization, stresses generated on the piezo and diaphragm for a given frequency and voltage were measured. It is found that the stresses generated in blower is within the limit. Dynamic characterization include modal analysis of the piezoelectric plate attached to diaphragm. Velocity response of the Micro-Blower for different square input Voltages signals was investigated. Both Longitudinal and Lateral Velocities were measured.

From the Velocity Measurement test, the results show an ascending order of velocities in longitudinal direction. Whereas, Velocities in lateral direction were observed very low. Also, not much variation in velocity was found with respect to voltages. In the second part of the paper, thermal performance of the Micro-Blower was noticed. Thermal performance test includes detecting the heat reduction capacity of the blower for different alignments of the heat source and for different voltage signals. It is observed that, in case1 (the horizontal alignment, when the heat generating component is facing up) the blower is having the best performance. Also, it is noticed that at higher voltages, the blower can reduce more amount of heat. So, from the velocity and thermal results perceived from the results, it is obvious to use the Micro-blower in cooling electronic equipment.

5. Scope for future work:

- This study can be proceeded further by performing the thermal performance test at elevated ambient temperatures.
- Analysis on the micro-blower should be done for different cross-sections of the nozzle.

Acknowledgment

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