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Research Paper

Investigation of a double oscillating-fan cooling device using electromagnetic force

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HIGHLIGHTS

- The characteristics of a double oscillating-fan cooling device using electromagnetic force was investigated.
- The driving current can be either DC PWM or AC within 3–12 V.
- The comparison between a double blower pair, the model and a synjet were examined.
- A 50 mm ∗ 50 mm ∗ 15 mm model can provide the flow rate of 154.89 l/min while consuming 0.65 W.
- The flow rate, sound pressure, power consumption and two thermal tests have been done.

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ABSTRACT

This study proposes a double oscillating-fan cooling device using electromagnetic force. The device consists of two oscillating-fans. It requires only one electromagnet and two fan sheets with one magnet on each of them. The electromagnet and fan sheets are situated on a base and arranged accordingly. The electromagnetic force generated by the electromagnet can actuate the fan sheets. The main advantage of the device is its simple structure because there is no bearing and motor in the device. The driving current can be either DC PWM (Pulse width modulation) or AC (Alternating current) within 3–12 V so it is compatible with most electronic devices. The dimensions of the proposed model are 50 mm ∗ 50 mm ∗ 15 mm during operation. Concerning flow rate, sound pressure, power consumption and resonant frequency tests, a comparison between the proposed model and different type of cooling devices has been completed. The result shows that the model can provide cooling ability similar to a rotary fan while consuming 40% of the power of the rotary fan. It shows not only a good cooling ability but also a great potential for structural reliability and design flexibility.

1. Introduction

Reliability of cooling devices is an extremely important issue for outdoor electronic devices. Currently, most of outdoor cooling solutions take advantage of natural convection because available axial and radial fans show degradation in outdoor environment. The reason is that the ball bearings have a low mean time to failure (MTTF) [1] due to dust, temperature, humidity and salt spray. These factors increase the friction between the shaft and the ball bearing inside the fan structure.

In previous studies, researchers proposed non-bearing cooling solution such as piezoelectric fans (PZT fans). PZT fans are a rectangular elastic sheet bonded with a PZT plate which is able to vibrate periodically by applying 50 V–100 V AC. This vibration induces airflow to improve convection heat transfer while consuming 0.08–0.15 W. The ideal application fields of PZT fan cooling technology are telecommunication equipment, LED lighting, aerospace actuators and military Electronics [2]. The fundamental concept, cooling ability, and the vibration phenomenon have been investigated thoroughly [3–5]. Recently, many studies on PZT fan array have been published. The purpose of these studies is to enhance the cooling ability of a PZT fan cooling system by increasing the fan number of the system or combining the system with a heat sink. Petroski et al. [6] optimized a heat sink by using two PZT fans. Compared with natural convection, the cooling performance of the optimized design increased by 294%. Sufian et al. [7] demonstrated the dissipation of heat generated by a light emitting diode (LED) array package using PZT fans. The result showed that the heat transfer performance was enhanced by 1.8 times by using one PZT fan and by 2.4 times by using dual PZT fans. Ma et al. [8]

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Nomenclature

L	length of the fan sheet
W	width of the fan sheet
H	thickness of the fan sheet
Y	the distance between the tip mass and the free end of the fan sheet
α	constant number concerning the structure of the fan sheet
β	constant number concerning the position of the magnet
γ	constant number concerning the position of the tip mass
ρ	the density of the fan sheet
E	the young's modulus of the fan sheet
F_{mag}	the magnetic force between the electromagnet and the magnet
K_{mag}	the stiffness of the magnetic force
K_{fan}	the stiffness of the fan sheet
K_{eff}	the stiffness of the fan sheet with the magnetic force considered
m_{mag}	the mass of the magnet
m_{fan}	the effective mass of the fan sheet
m_{tip}	the mass of the tip mass
m_{eff}	the effective mass of the oscillating-fan
T_c	core temperature of dummy heater
T_{amb}	environmental temperature (30 °C)

proposed a dual-sided multiple fans system. In this study, ten vibrating sheets were actuated by using only one PZT plate. The result showed that this design improves thermal performance 3.92 times than natural convection. However, the adhesive layer between the elastic sheet and the PZT plate shows uncertainty and degradation. Huang et al. [9] explained that the presence of glue layer contributes to the piezoceramic stiffness that influences the resonant frequency of a PZT fan. The influence of types of bonding glue and the thickness of bonding glue should be considered seriously. Shyu and Tsai [10] pointed out that the resonant frequency of a PZT fan varies as the environmental temperature changes because the stiffness of bonding glue decreases as the temperature goes up.

Except the bonding issue, an inverter drive circuit is necessary to transform low voltage DC to high voltage AC if a PZT fan is to be arranged in an electronic device.

In this study, an oscillating-fan cooling device using electromagnetic force has been proposed. The fan sheets are fixed by screws so there is no stiffness issue encountered by using glue. The driving current can be either DC PWM or AC within 3–12 V so it is compatible with most electronic devices. The flow rate and the sound pressure were also measured. Finally, two thermal tests were performed to prove its cooling ability.

2. Design of the double oscillating-fan cooling device

Fig. 1 shows the schematic view of the double oscillating-fan cooling device. It consists of two fan sheets, one basement and one electromagnet. The electromagnet is manufactured by a winding machine. The number of turns is 2000 and the coil diameter is 0.12 mm. The electromagnet is situated according to the position of the fan sheet. It receives alternating current with a specific frequency so it can generate N-pole and S-pole on both sides periodically. Fig. 2 shows the dimension of the fan sheet. L, W and H are the length, the width and the thickness of the fan sheet respectively. The fan sheet can be made of metal or plastic material. A cylindrical magnet is attached on the proper position of each fan sheet. Therefore, the electromagnetic force can be transferred to the magnet and then induce the motion of the fan sheets. Y is the distance between a tip mass and the free end of the fan sheet.

In Fig. 3, two fan sheets are stationary in the beginning. The fan sheets move toward the right side when the alternating current is positive. The fan sheets then come back to the initial position and moves toward the left side when the alternating current becomes negative. At the end of each period, the fan sheets go back to the initial position again. The fan length, width, thickness are 50 mm, 15 mm and 0.25 mm, respectively. The resonant frequency of the model is 60 Hz, which is equal to the frequency of the alternating current supplied to the model.

3. Theoretical model of resonant frequency

When the double oscillating-fan cooling device is driven under resonant frequency, it shows the maximum performance because this situation minimizes the power consumption of the device while providing maximum fan amplitude. And thus, it is crucial

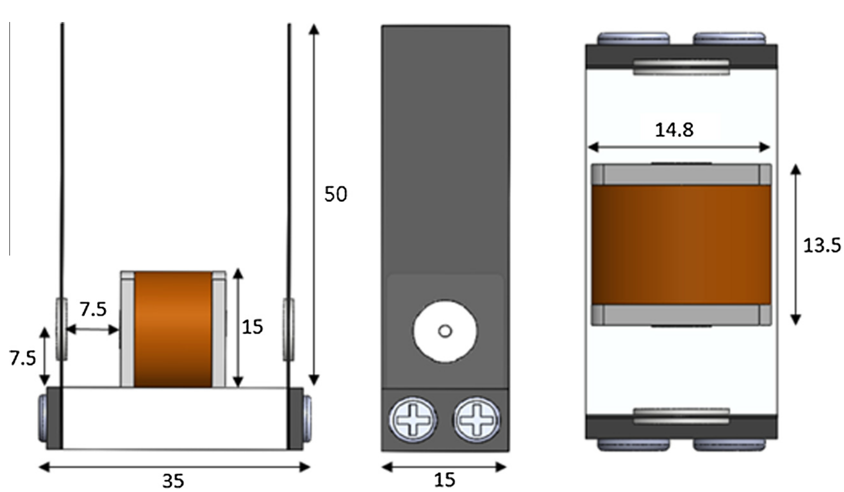

Fig. 1. Schematic view of the double oscillating-fan cooling device.