A Novel Concept of Dummy Heat Sources for Heat Transfer Enhancement

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Outline

Introduction

- Thermal management of electronics becomes challenging in recent times due to miniaturization.
- Faster rate of heat dissipation from electronic equipment is must for its safe and reliable operation.
- Chip level power density has increased enormously.
- To handle such high levels of heat flux, air cooling techniques like natural and forced convection air cooling, Foam based cooling, jet impingement cooling and liquid cooling are getting increasingly popular.
- These techniques are widely used in many engineering applications viz. space, aircraft, military, biomedical and in almost all electronic gadgets.

Review of Literature

Author	Key Findings
Choi et al [1]	Identified effects of conduction through the substrate play an important role in heat transfer from PCB (Numerical).
McEntire et al. [2]	Performed experiments on flush heat sources to measure convective heat transfer and found that heater temperature strongly affected by flow structures
Hajmohammadi et al. [3]	Studied optimal configuration and spacing of heat source array to maximize heat transfer (Experimental).
Tye-Gingras et al.[4]	Optimized triggering time of discrete heaters and showed position of heater can decrease overall thermal resistance (Numerical).
da Silva et al. [5]	studied optimal distribution of heat sources on a wall with natural convection and showed that optimal distribution of heaters are not equidistant.

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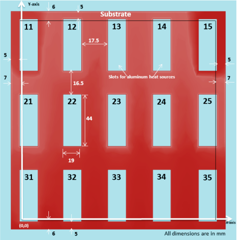
Author	Key Findings
Hadim A. [6]	Studied force convection in fully and partially porous channel-with localised heat sources and indicated that as Darcy number decreases, heat transfer increase significantly.
Rau and Garimella [7]	Investigated direct cooling of electronic components using dielectric liquid HFE-7100 and obtained local heat transfer.
Lemczyk et al. [8]	2-D thermal conduction analysis to establish an accurate effective thermal conductivity for a typical PCB.
Hotta and Venkateshan [9]	Studied natural and mixed convection heat transfer cooling of discrete heat sources placed near the bottom of a wall and showed that The size of the heat sources has a great impact on the heat transfer coefficient (Experimental).

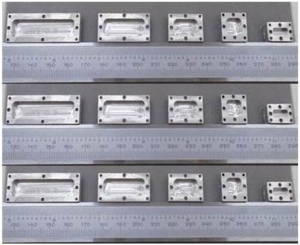
Objectives

- To find the optimal configuration of heat source array that results in enhanced heat transfer
- To study the effect of dummy heat sources on fluid flow and heat transfer .
- Investigate the local heat transfer performance of heat sources in optimal configuration with and without dummy heat sources.
- Investigate the effect of substrate conductivity on heat transfer.

Substrate boards and Heaters

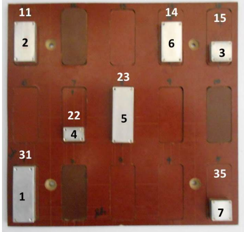


a: Substrate board



b: Heaters

31-11-15-22-23-14-35,λ=1.3



c: Heaters mounted on bakelite substrate baord

Figure 2: Substrate boards and heaters arrangement

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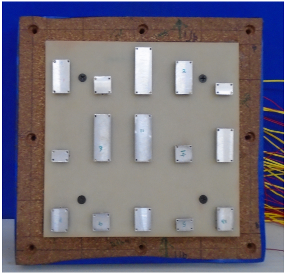
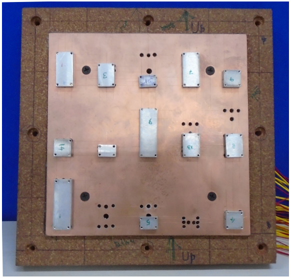
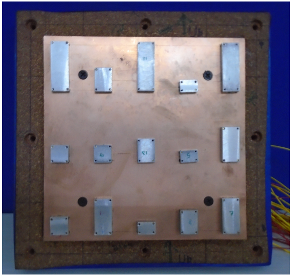


a: 8d-FR4



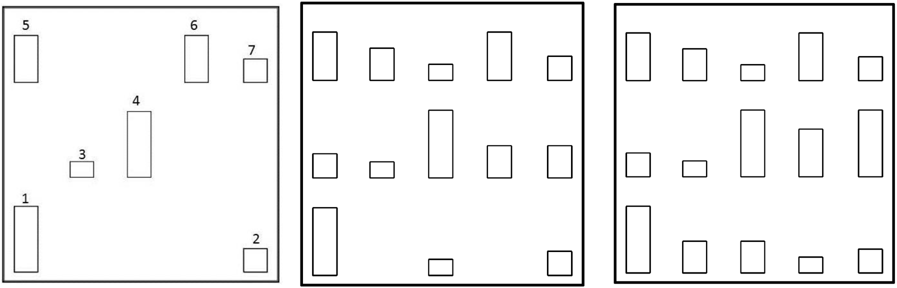
b: 6d-CCB



c: 8d-CCB

Figure 4: Substrate boards with heaters arrangement

Contd..



a: 7 heaters-No dummy b: 6 dummy c: 8 dummy

Figure 6: Optimal configurations

Experimental Set-up

Figure 7: Experimental Set-up

Numerical Modeling

- A 3-D steady state laminar forced convection conjugate heat transfer model of COMSOL 4.3b is used to solve the governing equations
- Force convection using ambient air at three different velocities of 0.6, 1.0 and 1.4 m/s is used to study effects on heat transfer and fluid flow.
- Three substrate board material FR4, Bakelite and copper clad board are used with heat flux of 1500 W/m^2

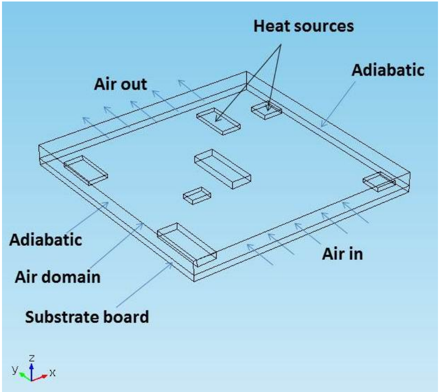


Figure 8: Simulation model

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Governing equations

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0 \tag{1}$$

$$u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z} = -\frac{1}{\rho}\frac{\partial p}{\partial x} + \frac{\mu}{\rho}\left[\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2}\right] \tag{2}$$

$$u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + w\frac{\partial v}{\partial z} = -\frac{1}{\rho}\frac{\partial p}{\partial y} + \frac{\mu}{\rho}\left[\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2} + \frac{\partial^2 v}{\partial z^2}\right] \tag{3}$$

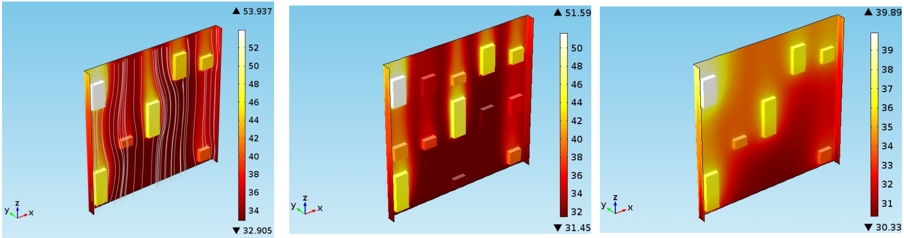
$$u\frac{\partial w}{\partial x} + v\frac{\partial w}{\partial y} + w\frac{\partial w}{\partial z} = -\frac{1}{\rho}\frac{\partial p}{\partial z} + \frac{\mu}{\rho}\left[\frac{\partial^2 w}{\partial x^2} + \frac{\partial^2 w}{\partial y^2} + \frac{\partial^2 w}{\partial z^2}\right] + F_z \tag{4}$$

$$u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} + w\frac{\partial T}{\partial z} = \alpha\left[\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2}\right] \tag{5}$$

In Eq. (4), in case of natural convection (vertical orientation of substrate board)

$$F_z = g\beta(T - T_\infty) \tag{6}$$

Results and Discussion



a: bakelite

b: 6d bakelite

c: CCB

Figure 10: Temperature plots

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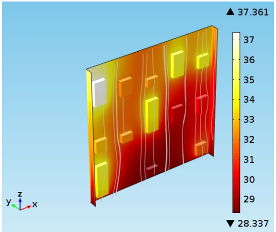
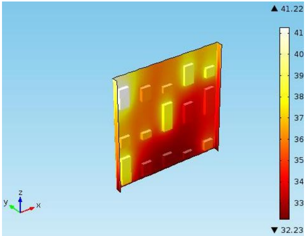
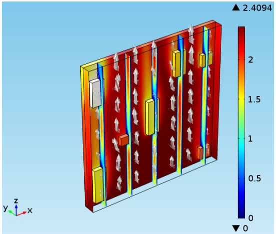


a: 6d-CCB



b: 8d-CCB



c: Velocity m/s

Figure 12: Temperature and velocity plots

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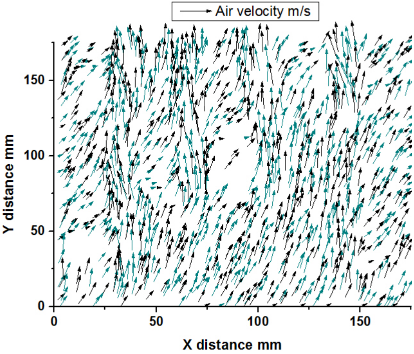
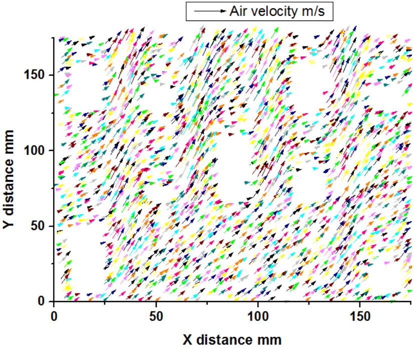


a: N0 dummy



b: 6 - dummy

Figure 14: Effect on fluid flow due to temperature

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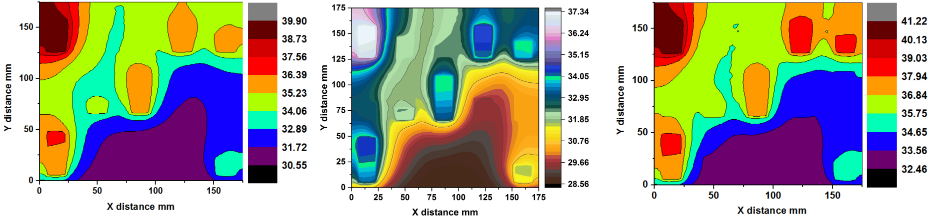

a: No dummy - CCB b: 6d - CCB c: 8d - CCB

Figure 16: Temperature contours

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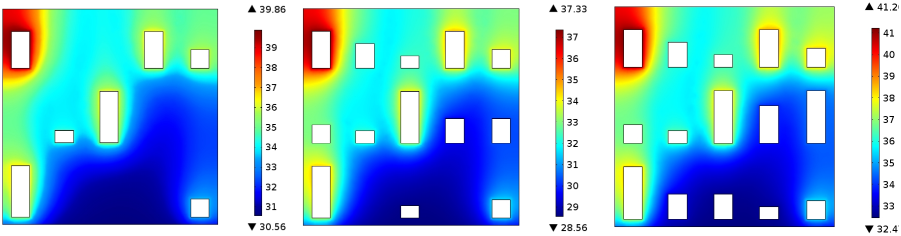

a: CCB - No dummy　　b: CCB - 6 dummy　　c: CCB - 8 dummy

Figure 18: Temperature contours for the substrate board surface

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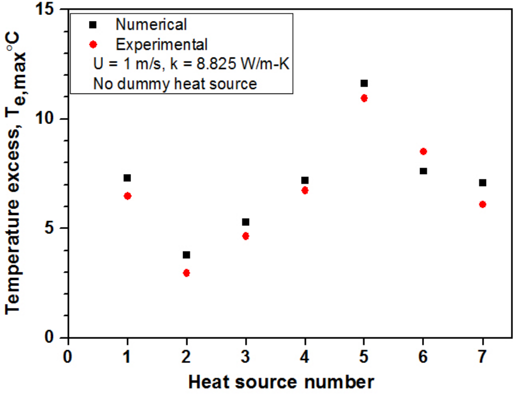

Figure 19: Comparison of experimental and numerical results

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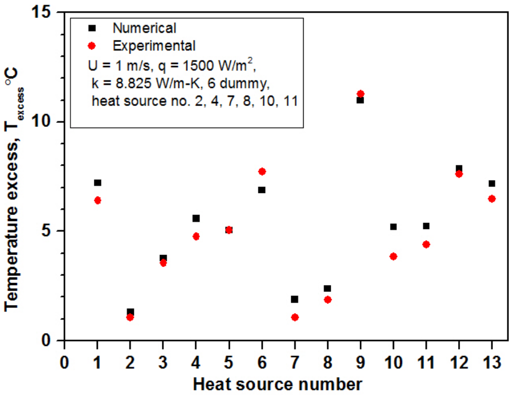

Figure 20: Comparison of experimental and numerical results

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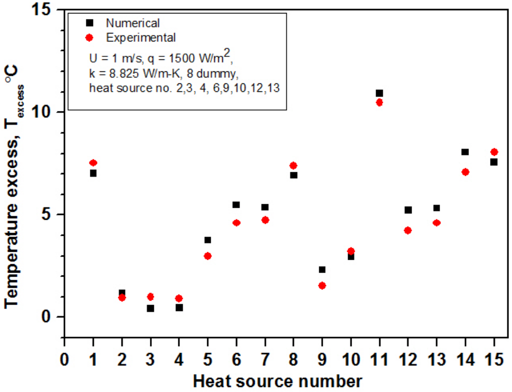

Figure 21: Comparison of experimental and numerical results

Conclusions

- Size and placement of heat sources plays a crucial role
- The configurations with six dummy heat sources is optimal
- The use of dummy heaqt sources shows increase in rate of heat dissipation
- CCB substrate board material results in enhanced heat transfer
- Substrate board can be tailored for a specific need

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Thank You !