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An Experimental Study of Heat Exchanger Based on Metal Foam, Fin, and Thermal Interface Material (TIM)

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INTRODUCTION

Open-cell metal foam and heat exchangers are two promising cooling solutions where, their combination may have the ability to reach significant heat transfer potential. Brazing is one of the method to join metal foam and base plate. However, the cost is high. Thus, developing a heat exchanger based on fins and metal foams that include TIM (to increase efficiency) by tightening it together can be a less expensive alternative.

METHODS AND MATERIALS

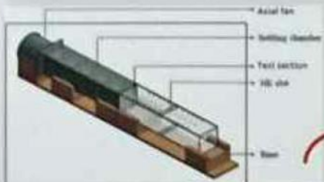
Development of Compact Heat Exchanger

A heat exchanger housing was designed to hold metal foams and fins together to develop a compact heat exchanger. A compact heat exchanger was developed with aluminium plates and open-cell metal foams placed side by side inside an aluminium housing.

Figure 1. (a) Smooth channel, (b) Fin heat exchanger, (c) Fin metal foam heat exchanger

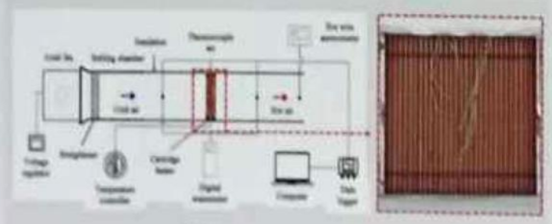
Development of Wind Tunnel

A small-scale wind tunnel was designed and built in-house to measure the heat transfer and pressure drop characteristics of a compact fin metal foam heat exchanger. The cooling was supplied by an axial fan used as a coolant fluid in the channel. The heat exchanger with the two cartridge heaters was then inserted into the test section. The test was set and run at 70°C.



Computer-aided model of the wind tunnel

Wind tunnel developed in-house



(a) (b)

Figure 2. Test rig details: (a) Schematic diagram of the experimental setup, (b) Photo of a heat exchanger in the test rig.

RESULT & DISCUSSION

The Reynolds number is defined as:

$$\mathrm{Re} = \frac{\rho V D h}{\mu}$$

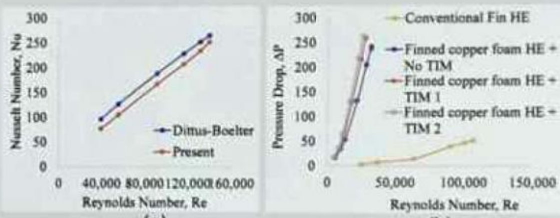
The velocity range tested was 0.3 to 3 m/s, corresponding to the Reynolds number in the range of 40, 000 to 150, 000.

Temperature drop,

$$\Delta P = P_{\mathrm{in}} - P_{\mathrm{out}}$$

The overall heat transfer coefficient and the Nusselt number is defined as,

$$h = \frac{\dot{m} C_P (T_0 - T_{in})}{A(T_w - T_{in})} \qquad Nu = \frac{h D_h}{k}$$



(a) (b)

Figure 3. (a) Experimental validation of rectangular duct for Nusselt number (b) Pressure drop across the conventional fin heat exchanger and fin copper foam heat exchanger.

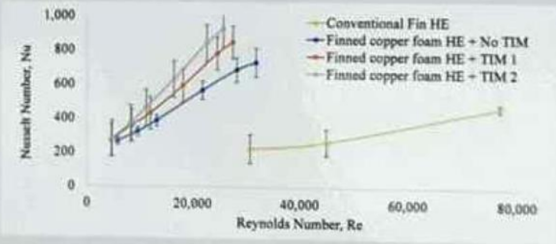


Figure 4. Average Nusselt number versus Reynolds number across the conventional fin heat exchanger and fin copper foam heat exchanger

CONCLUSIONS

- Copper foam heat exchangers increase the Nusselt number due to their larger surface area and resulting in higher heat transfer between solid and fluid phases.
- The use of TIM between the aluminium fins and copper foam has a significant impact on the heat exchanger's heat transfer performance. The TIM fills the air gaps between the surfaces and reduces thermal resistance at the interface, increasing the heat exchanger's heat transfer rate.
- Higher thermal conductivity TIM improves heat transfer performance in the fin copper foam heat exchanger. Higher thermal conductivity materials lose more heat per unit area and, quicker heat dissipation, allowing for greater heat transfer through the material in the heat exchanger.

REFERENCE

Hamadouche, A., Nebbali, R., Benahmed, H., Kouidri, A., & Bousri, A. (2016). Experimental investigation of convective heat transfer in an open-cell aluminum foams. Experimental Thermal and Fluid Science, 71, 86-94.