Comparative analysis of numerical models of plate-fin heat sinks with forced convection for thermoelectric energy generation

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1. Introduction

- Thermoelectric generators (TEGs) are solid state devices that transform heat into electrical energy by means of the Seebeck effect.
- The efficiency of TEGs highly depends on the design of its heat transfer system. The design of the heat sink at TEG's cold side is essential to obtain high values of power generation.
- Common heat sinks employed in TEGs are plate-fin heat sinks. Many researchers have proposed models to predict both the hydraulic and thermal behaviors of plate-fin heat sinks but none has been applied to a system with TEGs.
- Here, we apply 6 numerical models of plate-fin heat sinks applied to a TEG system and compare their predictions with experimental data.

2. Experimental set up

- Open-circuit wind tunnel. Test zone: 500 mm long and 41x41 mm inner cross-section (Fig. 1). Cones with honeycombs at both ends.

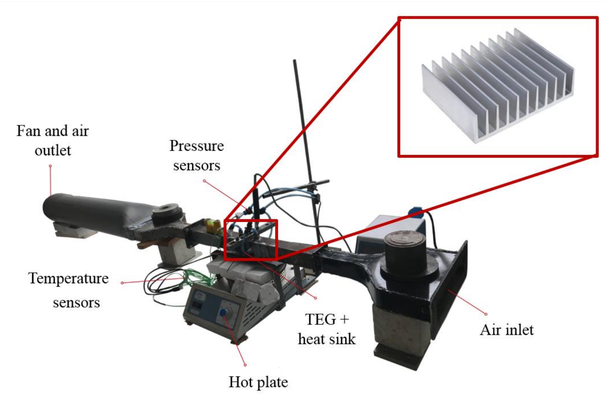

Fig. 1. Experimental set up.

- Two aluminum finned heat sinks tested. Forced convection without bypass (heat sink occupies the entire cross-sectional area of the test zone) and with bypass (heat sink occupies a fraction of the cross-sectional area) (Fig. 2).

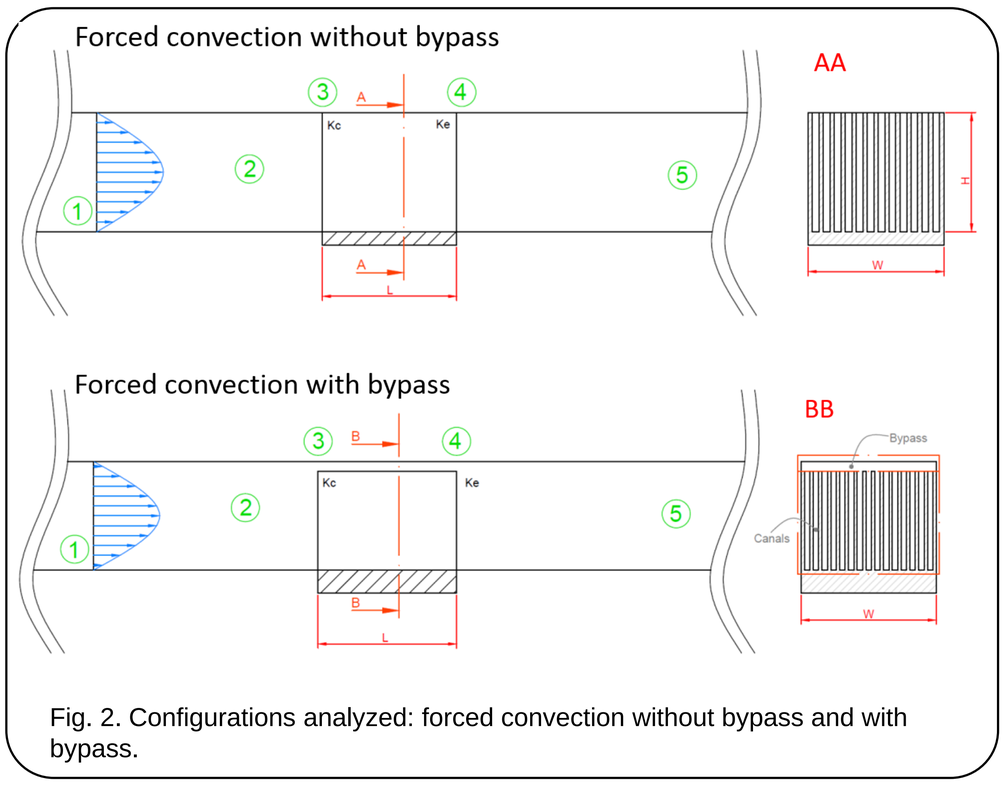

Fig. 2. Configurations analyzed: forced convection without bypass and with bypass.

- Hot plate (Selecta Combiplac) controlled by a PID. It heats a rectangular aluminum block in contact with a ceramic slab 3 mm thick of known thermal conductivity (Macor, Corning Inc.).
- TEG H-199-14-06-L2 of Crystal Ltd. located above the ceramic slab and below the heat sink and just outside the test section.
- Data acquired: ceramic slab as well as TEG hot and cold sides temperatures (type K thermocouples), TEG voltage and intensity, air pressure loss across the heat sink (Sensirion SDP610-125 Pa) and flow velocity in the square duct (Veloport 2.0).

3. Numerical models

- A total of 6 numerical models of plate-fin heat sinks are analysed (Table I).

Table I. List of numerical models analyzed.

Ref.	Configuration	Flow regime	Hydraulic model	Thermal model
[1]	No bypass	Laminar	✓	✓
[2]	Bypass	Laminar	✓	✓
[3]	No bypass / Bypass	Laminar	✓	✗
[4]	No bypass	Laminar	✓	✗
[5]	No bypass	Laminar/Turbulent	✓	✓
[6]	Bypass	Laminar	✓	✓

- Objective variables: pressure drop through the heat sink Δp and its thermal convective resistance R.
- Some models of Table 1 have been modified in order to accept no bypass/ bypass cases and/or to include the thermal model.

4. Results

- Experimental data obtained with hot plate temperature equal to 250ºC and different air velocities. The flow within the fins is always laminar.
- Differences with respect to the experimental data are shown in Figs. 3 and 4 for non-bypass and bypass configurations, respectively.

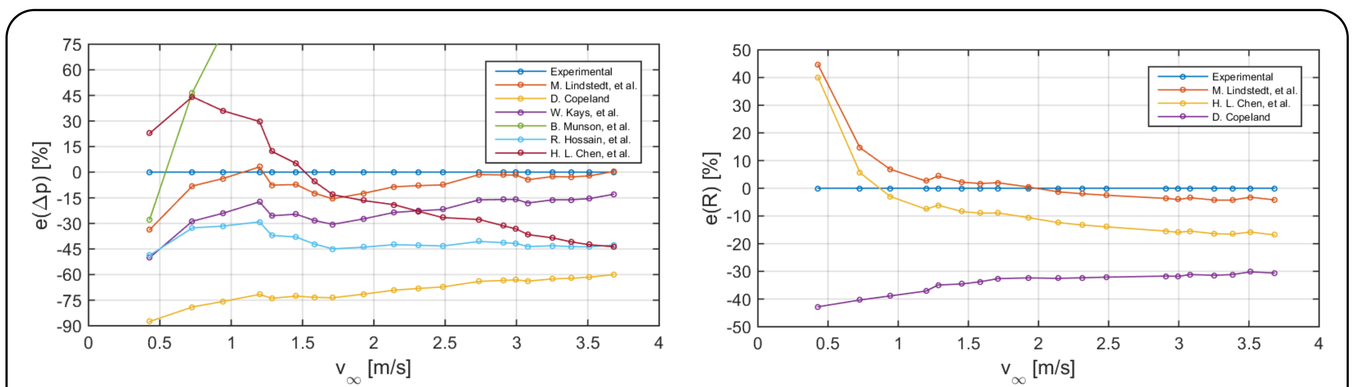

Fig. 3. Relative differences between modelled and experimental data of pressure drop (left) and termal convective resistance (right) for different air average velocity in the duct v_∞. No bypass case.

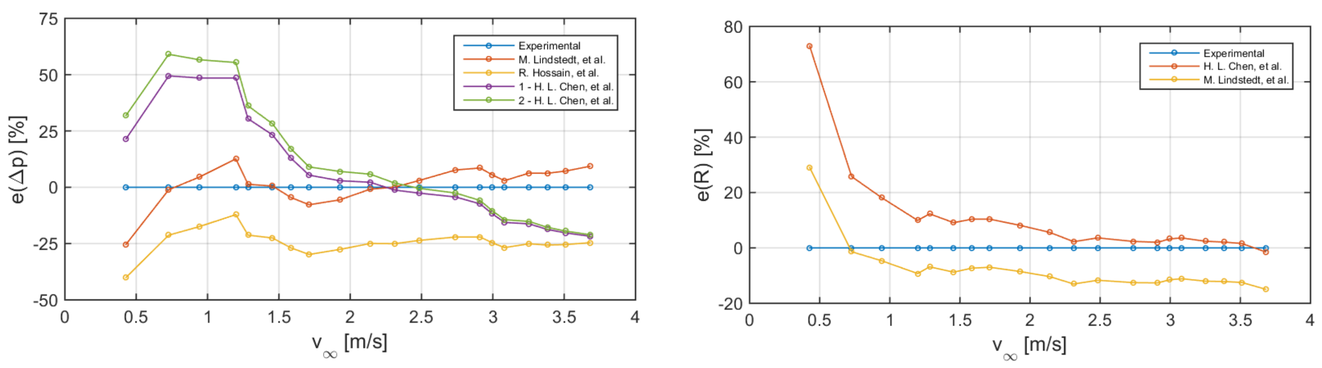

Fig. 4. Relative differences between modelled and experimental data of pressure drop (left) and termal convective resistance (right) for different air average velocity in the duct v_∞. Bypass case.

5. Conclusions

- Hydraulic and thermal models of plate-fin heat sinks under forced convection have been analysed when applied in a TEG.
- The Lindstedt and Karvinen [5] formulation is the most accurate one for both hydraulic and thermal models, with discrepancies below 12% in the majority of working conditions evaluated.

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