CARDIFF UNIVERSITY PRIFYSGOL CAERDYDD

School of Engineering/ Yr Ysgol Peirianneg

Modeling novel thermoelectric systems for energy recovery in steel making processes

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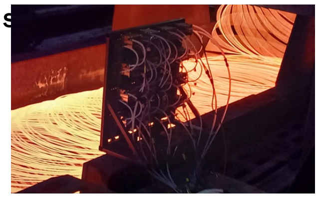
Introduction

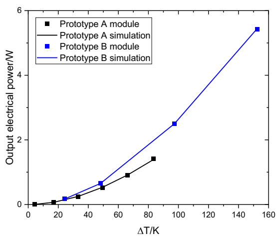
Steelmaking is an energy intensive process and is a significant contributor to greenhouse gas emissions. Thermoelectric technologies can potentially play a role through improving the efficiency of a variety of processes. The InTEGrated project develops and tests thermoelectric generator (TEGs) prototypes to recover thermal energy from furnace cooling water and radiation from hot steel products. The design of these prototypes is s numerical modelling, utilising COMSOL software.



Aims & Objectives

- Build prototypes which match expected performance based on theoretical and experimental predictions
  - **Prototype A**: heat recovery from hot water
  - **Prototype B:** heat recovery from radiant surfaces (900 ºC) with overheating protection
- Improve accuracy of the simulated models through experimental validation
- Use models as design tools to implement future designs, enhancing the optimization process of next gen prototypes

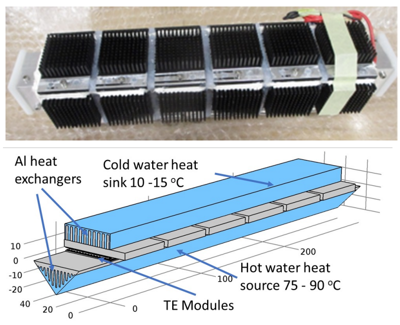
Experimental validation of TEG components



- Modules tested to determine electrical and thermal properties
- TE Material properties k,σ and α taken from data source
- Thermal and electrical contact resistance parameters fitted
- Module models build into TEG COMSOL model

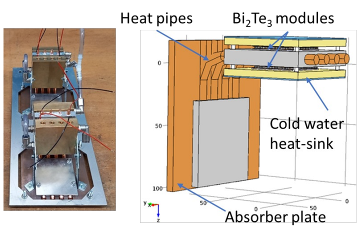
Prototypes & Models

Prototype A



- Outer casing and inlets and outlets not included in model
- ¼ model simulated to reduce computing cost
- Laminar flow is assumed at all flow rates
- Identical module characteristics assumed for all 24 modules

Prototype B



- Absorber plate ε=0.9 on side facing heat source, ε=0.5 on other sides
- Hot side components; heat losses due to radiation and convection
- Cold water heat-sink geometry simplified; same flow and velocity
- Thermal conductivity of heat pipe measured and set to 20 kW/mK in model

Experimental validation of TEG models

Prototype A

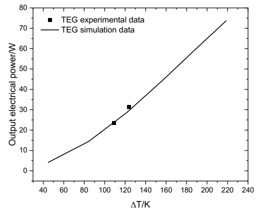
Input design parameters for ¼ model

Data	HS inlet flow/lpm	HS inlet temp/°C	CS inlet flow/lpm	CS inlet temp/°C	Electrical load/Ω
Experiment	3.66	73.7	5.61	11.01	100
COMSOL	0.92 (3.66)	73.7	1.40 (5.61)	11.01	25 (100)

Output results for ¼ model

Data	HS outlet T/°C	CS outlet T/°C	Output power/W	Current/A	Voltage/V
Experiment	57.01	13.01	10.05	0.32	31.70
COMSOL	70.87	12.76	2.52 (10.04)	0.32	7.94 (31.76)

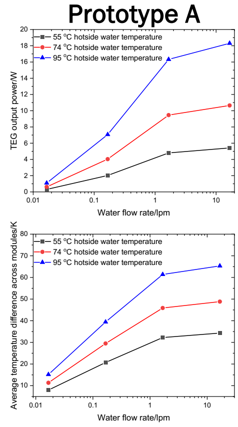
Prototype B



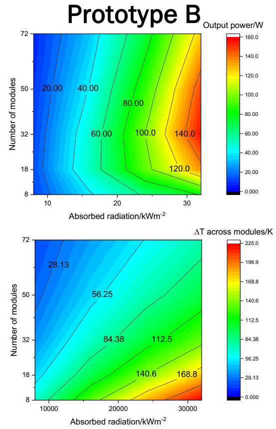
- Good agreement is achieved for both prototypes
- Two versions of Prototype B tested in lab
- Comparison with data with long term field testing at steel works will be analysed at the end of the project

Prototype simulations

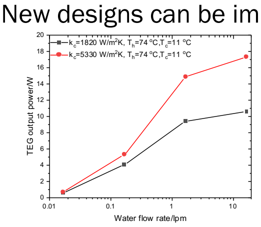
Prototype A

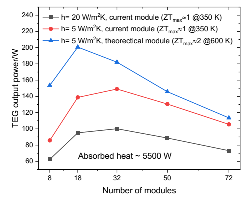


Prototype B



- Models can be used to determine the performance at different input parameters
- New designs can be implemented and tested in simulations





Conclusions

- Two COMSOL models developed and validated using data from tested Prototypes and their components:
  - Prototype A for energy recovery from cooling water
  - Prototype B for energy recovery of thermal radiation
- COMSOL models used to predict performance under different operating conditions
  - Hot water temperature and flow rate
  - Absorbed heat flux and absorber size
- Adapted COMSOL models to further optimise the design performance
  - Improved thermal contact resistance
  - Benefits of improved insulation
  - Use of different TE materials

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