Design and optimization of an Internal Combustion Engine Heat recovery system using a Thermoelectric Generator

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Rencontre Utilisateurs GT Simulation système 0D/1D
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Context

Why Marine application?

**High economic challenge**

> Maritime shipping is highly sensitive to bunker fuel costs
> A fuel consumption reduction of 1 % ↔ 50,000$ saving on a trip between Europe and Asia
> Fuel consumption and speed are related to a third power function

![Ship operational cost chart](chart.png)

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Context

Why Marine application?

Environmental constraints

> New IMO (International Maritime Organization) regulations
> A 10% reduction in speed corresponds to a drop in emissions of approximately 27% per unit of time or 19% per unit of distance.

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# Heat recovery systems

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Thermoelectric generator (TEG)

Thermoelectric module

- Direct conversion of temperature difference to electric voltage using the Seebeck effect
- A thermoelectric module consists of two dissimilar thermoelectric materials joining in their ends: an n-type; and a p-type semiconductors. The module must be designed such that the two thermoelectric materials are thermally in parallel, but electrically in series.
TEG model

Why the need of simulation?

> Marine engine are not adapted for laboratory scale test bench's

SEYMOUR, Ind. – Cummins Inc. QSK95 engine with around 3 MW output.

Man-Diesel 12K98MC engine
Two-stroke propulsion engine (around 68 MW output)
TEG model

Why choosing GT-Suite?

Multi parameters performance simulation
- Engine performance
- Heat exchange characteristics
- Electric circuit adaptation
TEG model

Experimental characterization

> TEG on the test bench
> Measurements:
  - air mass flow, temperature and pressure
  - electric voltage and current
TEG model

Component: TEM

- Seebeck coefficient $f(T)$
- Internal resistance $f(T)$
- Thermal resistance $f(T)$
- Load variation $f(T)$
Component: Heat exchanger

Hot Side Heat exchanger

Cold Side Heat exchanger
TEG model

Compatibility in GT modeling

> Compatible Heat exchanger modeling
> Easy alternation between application (Automotive/Marine/Hot air)
> Possible data base creation of different commercially available TEM’s
> Testing TEM’s multiple configuration (Series/ Parallel/ Standalone)
TEG model

Real time monitoring

> Thermal and electrical components real time performance variation

> To a third power function
TEG model

Results example

- Parameters: $T_{\text{hot}} = 673K$, $q_{m_{\text{hot}}} = 60$ kg/h
- Middle lane: 2 TEM  Right and Left lines: 3 TEM
- Electrical performances defined in two different electrical configurations (series or a parallel connection)
- Thermal performance: Temperature difference between the hot side and cold side heat exchangers
Conclusion

> Description of an electric Thermo-Electric Generator (TEG) with GT-Suite

> Experimental characterization and modelling

> First results obtained

> Integration of this new model in different simulation code (marine and automotive) of internal combustion engine
  • Run simulation
  • Define new efficiency of the system
Thank you!