Institute of Mechanical and Electrical Engineering

SDU

Advanced design for high temperature-difference heat exchangers using computational morphogenesis

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Background

- For modern internal combustion engines, reduction of NOx-emissions is of importance for the green transition.
- Exhaust Gas Recirculation (EGR) is commonly used for reducing emissions, by recirculating exhaust gas, cooled by the EGR-cooler.
- EGR-coolers are commonly used in the automotive industry, but not in larger scale for large four-strokes engines, due to the high temperature-differences of the hot exhaust gas and the cold air. Which may lead to reduced performance or even complete failure
- To obtain a better understanding of EGR-coolers for large four-stroke engines, simulation driven morphogenesis will be utilized to obtain a deeper insight in the thermomechanical loads due to high temperature-differences and the interaction between vibration in pressure containing structures.
- With the improved understanding of EGR-coolers, it will be possible to create designs for new applications reducing NOx-emissions or utilizing alternative green fuels.

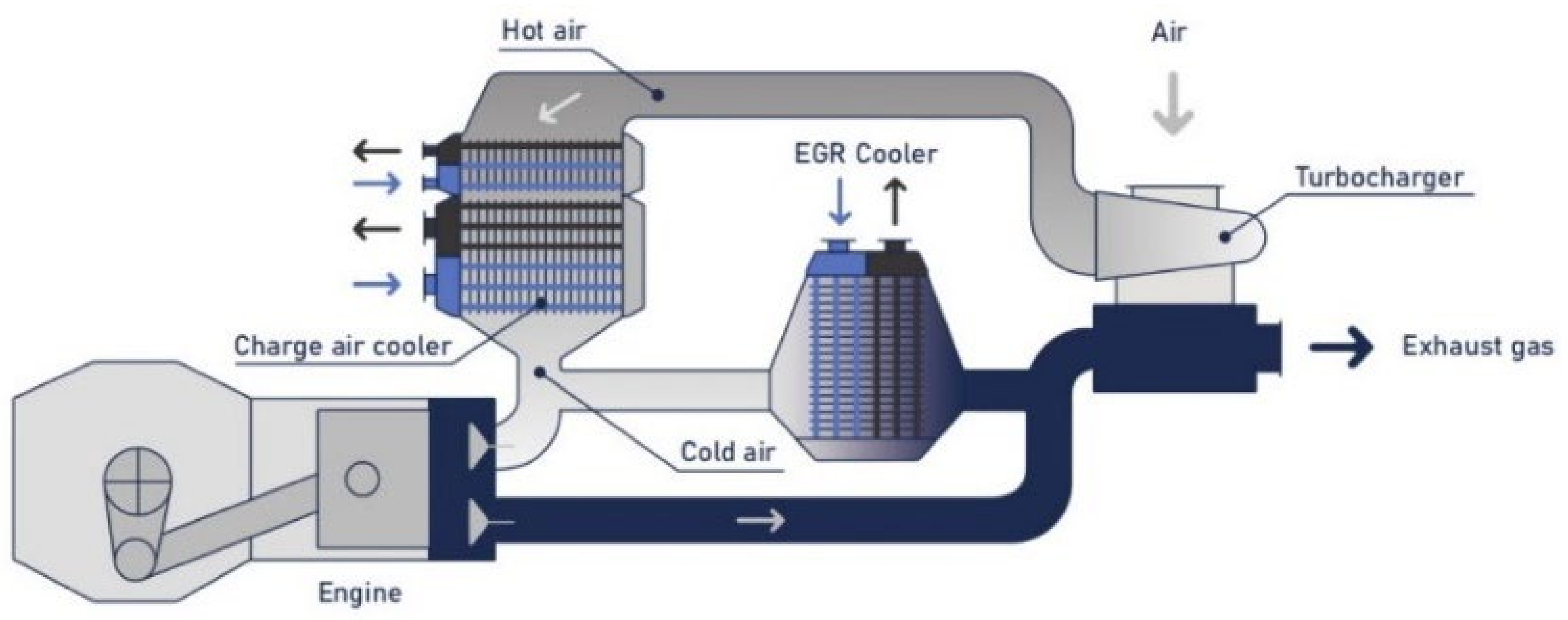

Fig. 1: Illustration of a typical EGR arrangement [1].

Research Questions

- Which topology optimization method is the best for thermomechanical problems with high temperature-differences and stress constraints?
- Can the effect from thermomechanical metamaterials be expanded to pressure containing structures and can they be utilized for heat exchanger design?
- What is the interaction between thermomechanical loads, pressure loads and vibration in the context of optimal design?
- Can thermomechanical stress be minimized through advanced design of heat exchanger's outer structure?

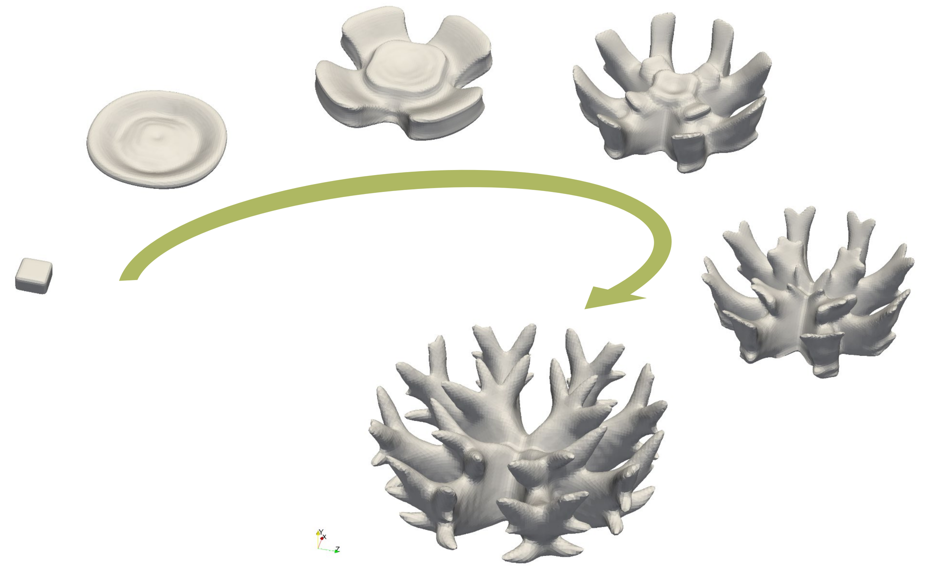

Fig. 3: Illustration of topology optimization design evolution from nothing to passive heat sink for electronics cooling [3].

Methodology

- Combining thermomechanical simulation with topology optimization to handle high temperature-differences.
- Topology optimization will be utilized to design EGR-coolers suitable for high temperature-differences.
- The optimization process consist of:
  1. Initial design
  2. Solving governing equations
  3. Check for optimal design
  4. Update design
- The Finite Element Method will be used to solve the structural and heat transfer partial differential equations.

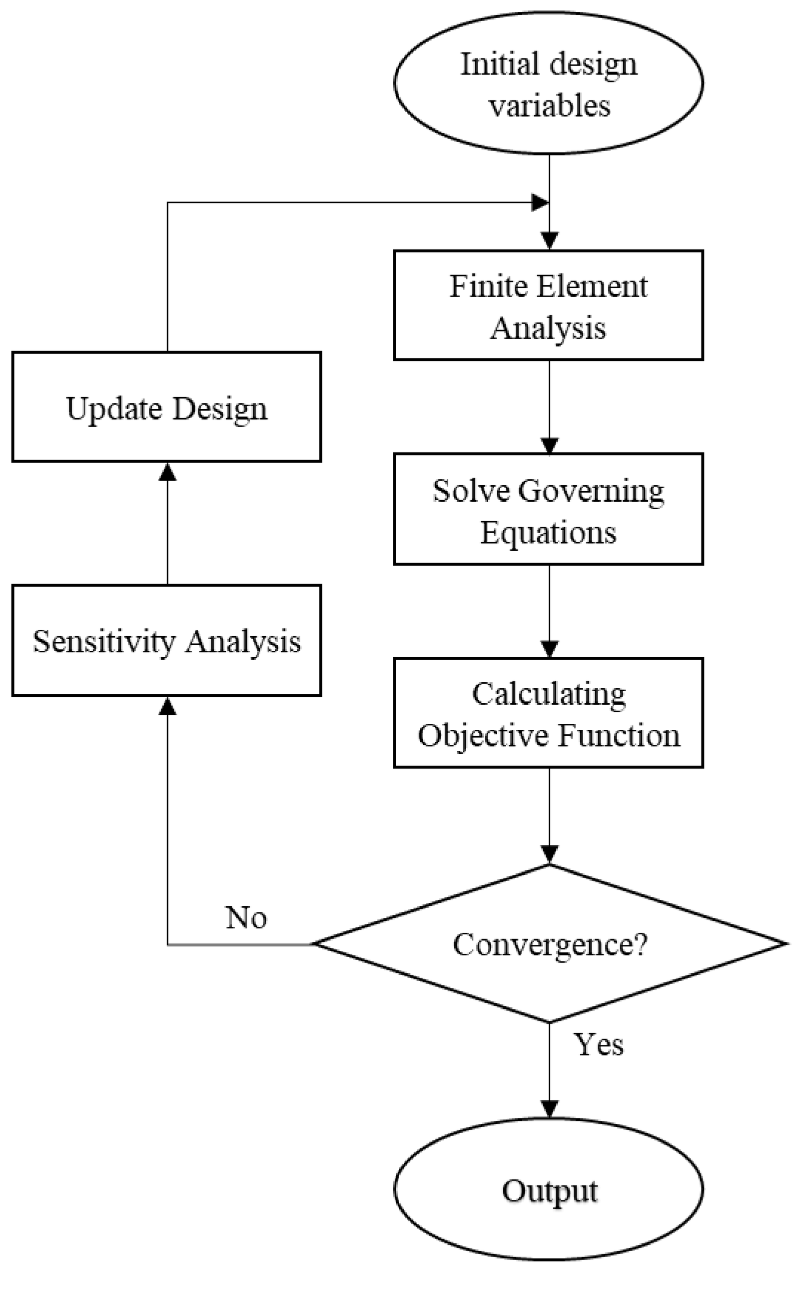

Fig. 2: Flow chart of topology optimization [2].

Challenges

- Previous high temperature-difference thermomechanical topology optimization problems, has indicated that the density method is currently not suitable for such problems.
- Performing topology optimization based comes with a high computational cost.
- The combination of thermomechanical loads, vibration loads, and vibration in topology optimization is currently an unstudied field.

References
[1] *Vestas aircoil A/S*, (2025), EGR Coolers, www.vestas-aircoil.com/products/egr-coolers
[2] *Bayat, Amirhossein* (2024), Topology Optimisation of High Heat Flux Cooling
[3] *Alexandersen et al.* (2016), Large scale three-dimensional topology optimisation of heat sinks cooled by natural convection, doi: https://doi.org/10.1016/j.ijheatmasstransfer.2016.05.013

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