Development of Ventilation Strategy in Diesel Engine Power Plant by Using CFD Modelling

Panu Mustakallio and Risto Kosonen
Halton Oy, Haltonintie 1-3, 47400 Kausala, Finland
E-mail: panu.mustakallio@halton.com
Ventilation of diesel engine power plant hall

- The main design target:

  • To keep everywhere the engine level temperature difference to the ambient air below 10 Kelvin

  • To keep the temperature of hall air cooling the generator as low as possible
Ventilation of diesel engine power plant hall

- Ventilation systems at present:

  • Based on mixing ventilation and relatively high airflow rate

  • The studied system uses big fans supplying the ambient air straight to the engine hall and mixing it strongly

→ The design targets are met, but energy consumption for the ventilation is quite high which is directly off from the generated electricity
Study of novel ventilation strategy utilizing displacement ventilation in two diesel engine power plant cases

- Diesel engine power plant with existing and new ventilation systems was modelled by using computational fluid dynamics (CFD) tool.
- Plant contains any number of diesel engine modules with generator and auxiliary systems including ventilation – one module was modelled from smaller and bigger plant.
CFD tool and used computational models in the diesel engine power plant simulation

• CFD simulation package: Ansys CFX 5.7

• Main computational models used:
  • Steady state calculation
  • Tetrahedral grid with 1000-1500 t elements
  • k-ε turbulence model
  • Buoyancy with ideal gas law
  • P1 radiation model
  • 2\textsuperscript{nd} order discretization
CFD model of hall space of smaller power plant with existing ventilation system

- One engine module modelled with periodic boundary conditions on both sides
- Heat loads specified on engine surfaces 253 kW
- Heat loads on generator surfaces and in generator cooling air 10 m³/s, 248 kW
- Heat loads and resistance in pipe module volume 50 kW
- 1 bigger and 2 smaller supply air fans 21+6+6 m³/s (with axial/rad./tan. velocities)
- Exhaust in the ceiling (opening)
Simulation results of smaller power plant with existing ventilation system
Simulation cases for smaller power plant with new ventilation systems

1. Ducting of warm exhaust airflow from generator to 2m height from current exhaust.

2. Displacement ventilation with low velocity units standing on the wall in the generator end of building and using supply nozzles below the displacement units as carrying jets.
   - 5 displacement units with supply air 3.4 m3/s, unit
   - 5 nozzles below displacement units with 1.0 m3/s supply from each

3. Displacement ventilation with low velocity units on both ends of building
   - 5 displacement units on the wall in the generator end of building, supply 3.2 m3/s, unit
   - 3 displacement units on the opposite wall, supply 2.0 m3/s, unit

4. Same as case 3 except ducting of warm exhaust airflow from generator to 2m height from current exhaust with directing part toward exhaust
Simulation results for smaller power plant with new ventilation systems - Temperature distribution

1. Ducting of exhaust airflow from generator
2. Displacement units in the generator end with supply nozzles
3. Displacement units on both ends
4. Displacement units and ducting with directing part
Simulation results for smaller power plant with new ventilation systems - Velocity distribution

1. Ducting of exhaust airflow from generator
2. Displacement units in the generator end with supply nozzles
3. Displacement units on both ends
4. Displacement units and ducting with directing part
Simulation results for smaller power plant with existing and new ventilation system

- Engine level temperature distribution

Existing ventilation system

→ Supply air: 33 m$^3$/s/module

4. Displacement units and ducting with directing part

→ Supply air: 22 m$^3$/s/module
CFD model of hall space of bigger power plant with existing ventilation system

- One engine module modelled with periodic boundary conditions on both sides
- Heat loads specified on engine surfaces 407 kW
- Heat loads on generator surfaces and in generator cooling air 17 m³/s, 474 kW
- Heat loads and resistance in pipe module volume 70 kW
- 2 bigger and 3 smaller supply air fans 21+21+6+6+6 m³/s (with axial/rad./tan. velocities)
- Exhaust in the ceiling (opening)
Simulation results of bigger power plant with existing ventilation system
Simulation cases for bigger power plant with new ventilation systems

1. Supply air fans at generator end rotating towards each other (rotation to same direction in first case)

2. Ducting of warm generator exhaust airflow to 2m height from generator with directing part toward exhaust

3. Same as case case 2 but with smaller airflow rate $2 \times 21 \rightarrow 2 \times 15 \text{m}^3/\text{s}$ from fans at generator end

4. Displacement ventilation with low velocity units on both ends of building
   - 7 displacement units on the wall in the generator end of building, supply $4.0 \text{ m}^3/\text{s/unit}$
   - 4 displacement units on the opposite wall, supply $3.0 \text{ m}^3/\text{s/unit}$
Simulation results for bigger power plant with new ventilation systems - Temperature distribution

1. Supply air fans at generator end rotating towards each other

2. Ducting of generator exhaust to 2m height with directing part

3. Smaller airflow rate from fans at generator end

4. Displacement units and ducting with directing part
Simulation results for bigger power plant with new ventilation systems
- Velocity distribution

1. Supply air fans at generator end rotating towards each other
2. Ducting of generator exhaust to 2m height with directing part
3. Smaller airflow rate from fans at generator end
4. Displacement units and ducting with directing part
Simulation results for bigger power plant with existing and new ventilation system
- Engine level temperature distribution

Existing ventilation system
→ Supply air: 60 m³/s/module

4. Displacement units and ducting with directing part
→ Supply air: 40 m³/s/module
- Conclusions:

  • New ventilation system was developed for power plant module.
  • In the most workable configuration, air is supplied through the low velocity units from both ends of the engine hall and cooling air circulated through the generator is directed straight to the exhaust opening in the ceiling.
  • This makes possible to reduce the supply air flow rate 30% from the current setup and distributes the supply air more uniformly.