DEVELOPMENT OF A MODEL FOR THE PROMOTION OF ENERGY EFFICIENCY IN AN AUTOMOTIVE INDUSTRY PAINT-SHOP

I. Malico, F. Zdanowski, F. Pécurto, F. Steinmetz Alvarez, P. Canhoto, R. P. Lima

Motivation

The automotive industry faces technological challenges to improve its sustainability under the pressure of economic and environmental requirements. One of the most cost-effective ways of reducing energy costs is through the implementation of energy efficiency measures. Typically, paint-shops include the most energy intensive processes in a vehicle assembly plant (Fig. 1). They consume both electricity and fuels to drive the different equipment (e.g., fans and pumps), to dry and condition the air in the painting line and to oxidize the Volatile Organic Compounds (VOC) in the exhaust.

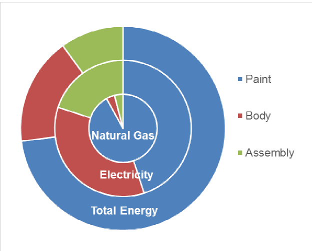

Fig. 1 – Illustrative breakdown of the energy consumption in a vehicle assembly plant

Objectives

To assist in the promotion of energy efficiency in paint-shops of vehicle assembly plants, a 0D model that simulates the network of thermal equipment in paint and cataphoresis facilities is being developed and is presented in this work aiming to provide a tool for the simulation of this part of the industrial plant.

Since one of the most important energy consumers is the VOC incinerator, which generates process heat and helps controlling the emissions of such components, its operation is modeled with more detail, using a Computational Fluid Dynamics (CFD) model. This results in a set of accurate simulations which will then be integrated with the global simulation model of the peripheral equipment network that assures the correct operation of the paint-shop.

The model presented in this work is being developed and tested for a real paint shop in a vehicle assembly plant located in Portugal, EU27.

Paint and Cataphoresis Facilities

- Heat exchangers with internal combustion chamber (GC1, GC3)
- Heat exchangers that use flue gas from the incinerator (GC2, GAN)
- Damper for fluid flow control and partition
- Ducts (pressure drop and heat loss are considered)
- Incinerator of VOC (Fig. 3):
  - Thermal Recuperative Incinerator (TRI)
  - Nominal Power: 1000 kW
  - Fuel: Natural Gas
  - Average fuel mass flow rate:

    54 kg/h
  - Largest energy consumer in the paint-shop

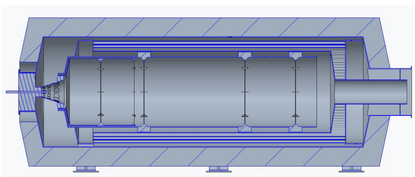

Fig. 3 – Section view of the TRI

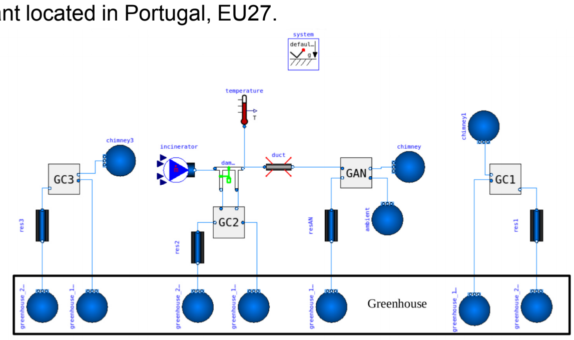

Fig. 2 – Model of thermal equipment network in OpenModelica

0D Model of the network of thermal equipment

- One step combustion process in the GC1 and GC3 air heaters.
- Efficiency method for heat exchanger analysis (0D model with adjustable parameters).
- Transient model developed in OpenModelica 3.2.3 (Buildings and ThermoPower libraries).

CFD Model

The TRI is being simulated with the use of a Computational Fluid Dynamics (CFD) model for a variable set of operating conditions.

Transport equations: Steady, 3D, RANS, mass, linear momentum, energy and species.

Closure Models:

- Realizable k-ε turbulence model with a near-wall modelling approach
- Non-premixed combustion of CH_4+air described by a 1-step reaction
- Finite-rate/eddy-dissipation model for combustion
- Discrete ordinates method to model radiation

Numerical Model:

- Ansys/Fluent 2022 R1
- SIMPLE
- Second-order discretization

Integration of the CFD and 0D models

- CFD: CFD Simulations of the TRI under different operating conditions
- Stat: Development of a surrogated model for the TRI using statistical methods
- ∫: Integration of the surrogated model with the 0D model
- 0D: Simulation of the network of thermal equipment using the 0D model

Conclusions

This work presents first simulations of the equipment network of a paint-shop located in a vehicle assembly plant. The model is being developed and validated and will allow a detailed description of the process, assisting in the promotion of energy efficiency measures.

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Mechatronics Engineering Department, University of Évora, Largo dos Colegiais
7000 Évora, Portugal
imbm@uevora.pt

VIP198