Flowmaster
Fluid thinking for systems engineers

Case Study

Heavy Machinery

Caterpillar & ANL

Caterpillar and Argonne National Laboratory meet sound regulations with the help of Flowmaster, at a fraction of the cost and time

When it comes to construction equipment and other heavy vehicles, engineers face common underhood thermal management design challenges including restrictive enclosures and an increasing number of different heat sources.

However, engineers of off-road machines have even greater constraints in addition to these including:

- high auxiliary loads
- severe operating conditions involving dust and debris
- wide range of altitudes and temperatures
- lack of ram air.

But the most constraining criteria for off-road machine engineers come from the need to reduce noise due to increasing sound regulations.

Separate engine compartments provide a way to suppress noise but results in higher underhood temperatures and increased cooling heat loads. The cooling system must now be designed to perform in a well-sealed enclosure with limited ventilation as shown in Figure 1.

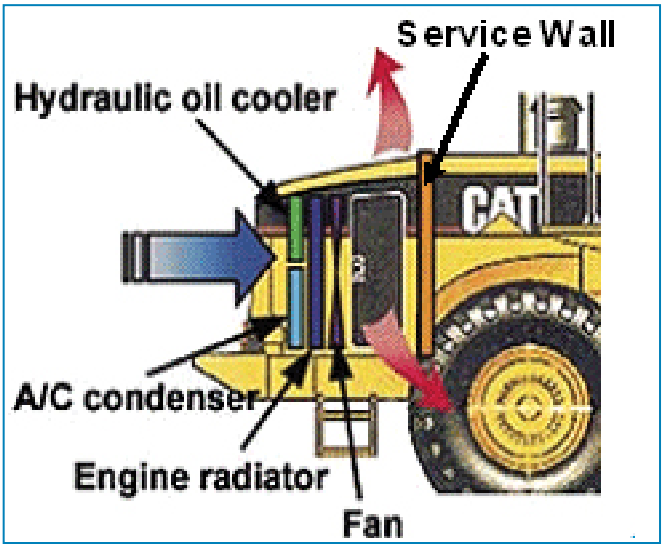

Figure 1: Typical schematic of separated engine and cooling system compartments divided by the service wall

Component life and durability is greatly reduced by high temperatures, therefore assessment of component temperatures becomes even more important with enclosed engine compartments. Traditionally, component temperature assessment is obtained by means of testing, but construction of test rigs for many different spatial configurations with many temperature sensors can be costly. In addition, cooling tests are performed at later stages of the development cycle, meaning that configuration changes are not practical. Therefore, the need for fast and accurate fluid network simulation arose to aid in the understanding of the thermal distribution in the system.

Argonne National Laboratory (ANL) and Caterpillar, Inc. were part of a Cooperative Research and Development Agreement (CRADA) to develop and validate a simulation methodology to analyze underhood thermal systems for off-road machines. The study involved the use of Flowmaster to model the thermal system of a test rig representative of an engine enclosure of an off-road machine.

The Flowmaster network comprised of the cooling air circuit, cooling water circuit, lubrication oil circuit, and the engine metal structure itself. The network took into account the thermal interactions amongst the subsystems as well as their interactions with the surrounding air and metal enclosure. This model was combined with a Star-CD 3D CFD model of the ventilation air flow inside the enclosure.

The results of this model were compared to the temperature measurements obtained from highly controlled experiments performed on the test rig. It was found that over 95% of the model temperature predictions were within a 10% error of the experimental measurements of air, fluid, and surface temperatures, thereby validating this analytical methodology. Figure 2 shows a comparison of the Flowmaster results to the experimental results for air.

With confidence in the Flowmaster simulation results, Caterpillar engineers can now analyze many different configurations and scenarios of enclosed engine compartment cooling systems before the testing phase of the design cycle. This means that with the aid of Flowmaster, engineers can now bring the best possible design for off-road machines that meet sound regulations all at the fraction of cost and time.

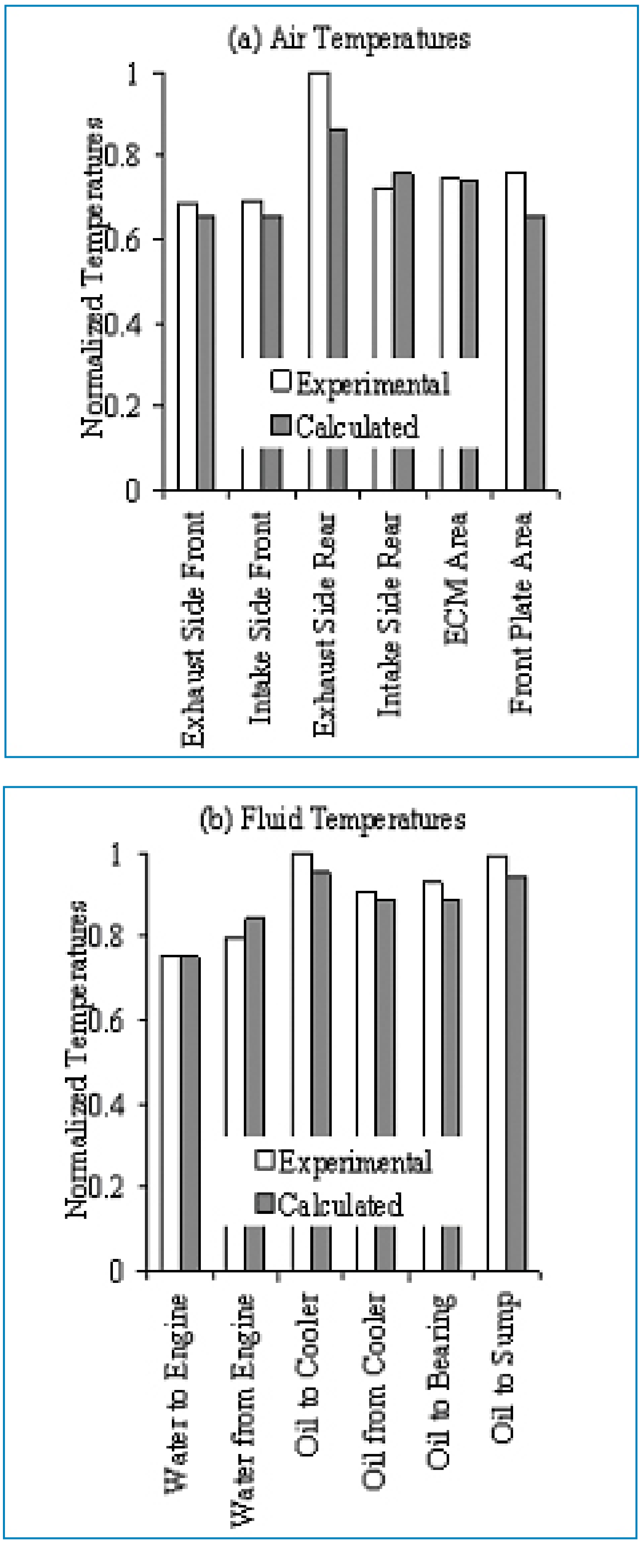

Figure 2: Comparison of temperatures between measured data and model predictions: (a) ventilation air temperatures, (b) fluid temperatures.

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