CASE STUDY

OPTIMIZING COOLING SYSTEMS FOR ELECTRIC HEAVY-DUTY TRUCKS

REFINING EV POWERTRAIN DESIGN AND COOLING SYSTEM EFFICIENCY WITH ALTAIR CFD SIMULATION

Background Information

Effective thermal management is mandatory for the safe and reliable operation of electric vehicle (EV) trucks. An optimized cooling system design helps maintain battery, powertrain, and electrical component temperatures within safe operating ranges—ensuring performance, efficiency, and longevity of systems. By preventing overheating, thermal management systems minimize energy loss, damage, and extend the lifespan of critical components. Liquid cooling is one of the most commonly used methods, where a coolant absorbs heat and transfers it to a radiator for dissipation.

While EV's eliminate many components of traditional internal combustion engines, thermal management remains critical—especially in heavy-duty applications, which involve high power output and extended operating durations.

About the Customer

Propel Industries is pioneering the future of sustainable transportation in India with the launch of the country's first smart electric dump trucks designed for off-road applications, such as mining and construction. They have also recently introduced smart electric tractor-trailers for heavy-duty transportation. These electric vehicles offer a clean, eco-friendly alternative to traditional diesel trucks—delivering high-performance, safety, comfort, and reduced environmental impact. Propel's new EV trucks are engineered with fewer mechanical components than conventional trucks, resulting in lower maintenance costs and improved operational efficiency.

In addition to electric vehicles, Propel is a trusted leader in the crushing and screening industry. Their solutions play an integral role in both the mining and construction industries, where speed,

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efficiency, and reliability directly impact quality and productivity. Customers nationwide rely on Propel Industries for innovative, technologically-sound, and cost-effective solutions and equipment for crushing and screening operations.

Their Challenge

Electric trucks pose unique thermal management challenges due to heavier payloads while operating in rough terrain with extreme temperatures and weather conditions.

One of the most significant challenges for Propel was understanding and analyzing the flow and thermal distribution across various operational modes of the cooling system. The system included multiple subsystem components, including the radiator, pump, inverter, MCU, motor, and circuit pipe. Developing a finite element (FE) model for the entire system that captured all of its features, in addition to analyzing the transient conditions, proved to be both complex and computationally intensive.

To address these challenges early, the engineering team needed insights into overall system behavior, performance of all of the physics-driven subsystems, and the interactions between subsystems. This enabled proper sizing of key components and identification of potential design improvements—without compromising system performance targets.

A system-level simulation approach became essential to evaluate key performance characteristics such as system temperature, radiator and pump output parameters, cooling circuit design, and more.

Our Solution

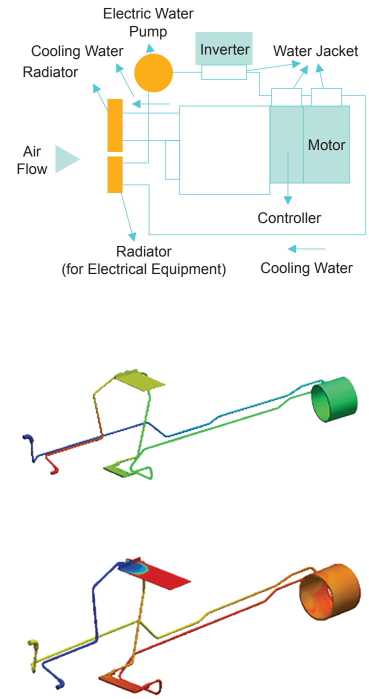
Altair solutions, including CFD, thermal, and structural analysis tools, were employed to design and simulate various physical phenomena under real-world operating conditions. The absorber unit operated in three distinct modes during each cycle: absorption, regeneration, and cooling, with a total cycle duration of five hours. The primary objective of this simulation was to analyze these modes and evaluate the thermal and flow characteristics within the system. The simulation process encompassed geometry preparation, surface meshing, volume meshing, and setting up the flow physics using Altair® HyperMesh® CFD. Altair® AcuSolve® was utilized to investigate thermal distribution under transient conditions. In this project, the thermal and flow behavior at various locations inside the absorber column was thoroughly analyzed.

To simulate the electric heavy duty truck's cooling system behavior, a cooling system model was developed encompassing various components such as the motor, control unit, inverter, and cooling circuit pipe. This model was developed using state space dynamic representation of all the key subsystems, which allowed engineers to simulate and analyze the system's behavior for different input drive cycles. The team also used key inputs such as rated parameters of the pump, a pump efficiency map, and each subsystem's heat dissipation data. The Propel team undertook a thorough validation with the physical data obtained from source. This validation increased confidence in the simulation output.

Results

The simulation results were validated against test data, achieving an accuracy of over 90%. The analysis included velocity contours and vectors, pressure contours, and temperature distribution across flow volumes. The resulting temperature distribution and pressure drop over time allowed the team to determine what cooling flow temperature would be required to prevent overheating of the inverter, MCU, and motor.

This approach significantly reduced the prototype cycle time and ensured a "first-time-right" design. By adopting this methodology, the Propel team successfully developed a robust design early in the process, minimizing iterations and substantially shortening the product development cycle. Messen Labs partnered with Altair, a leading engineering solutions provider, to leverage Altair's cutting-edge AI-powered design, simulation, and data analytics software.
This collaboration has significantly improved Propel's product development efficiency, enabling them to simulate complex product physics and drive technology innovation in their offerings.



TOP: Flow circuit considered for simulation.
MIDDLE: Pressure contour of flow interface area.
BOTTOM: Temperature contour of flow interface area