Multi-Domain Motor Cooling Simulation for Enhanced BEV Efficiency and Durability

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Paper ID: 000064

SUMMARY

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1. Introduction

The modern evolution of Battery Electric Vehicles (BEVs) poses increasing demands on motor performance and thermal control, particularly under high torque loads and extended duty cycles. Efficient thermal management is critical—not only to prevent overheating and component degradation but also to enhance motor efficiency and extend operational lifespan. Recent advancements in simulation tools like MATLAB/Simulink with Simscape Driveline and Simscape Fluids enable engineers to model the complex interplay between electrical and thermal subsystems in a multi-domain environment
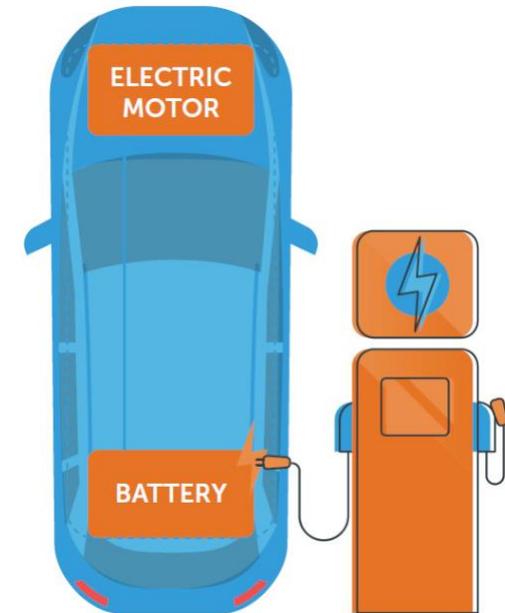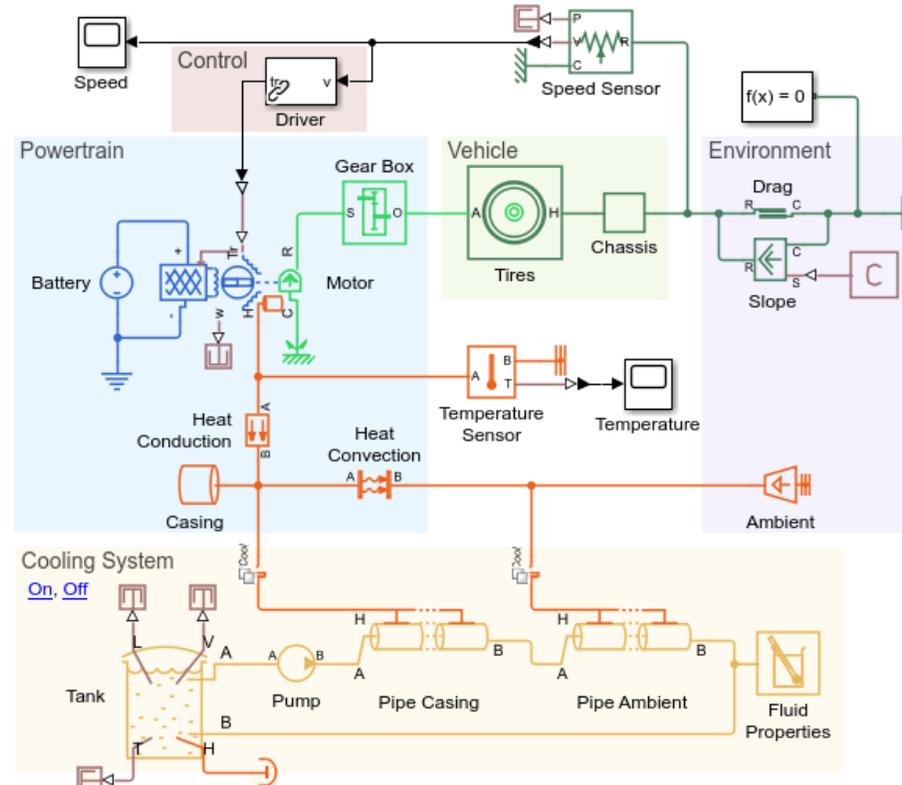
2. OBJECTIVE

The primary goal of this research is to develop and validate a robust, multi-domain simulation framework for battery electric vehicles (BEVs) that seamlessly integrates electrical and thermal models.

Battery electric vehicle with or without motor cooling system.

$$pc_p \frac{dT}{dt} + pc_p v \cdot \nabla T = \nabla \cdot (k\nabla T) + Q_{gen} - h(T - T_\infty) - \sigma_\varepsilon(T^4 - T_{sur}^4)$$
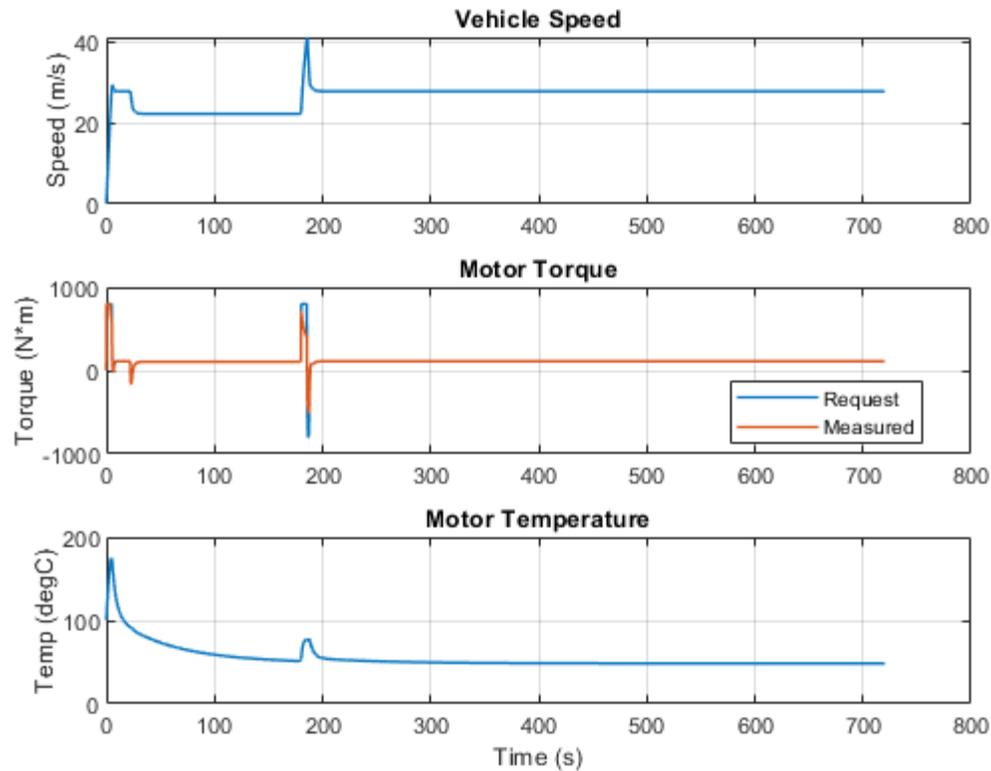
4. SIMULATION AND ANALYSIS

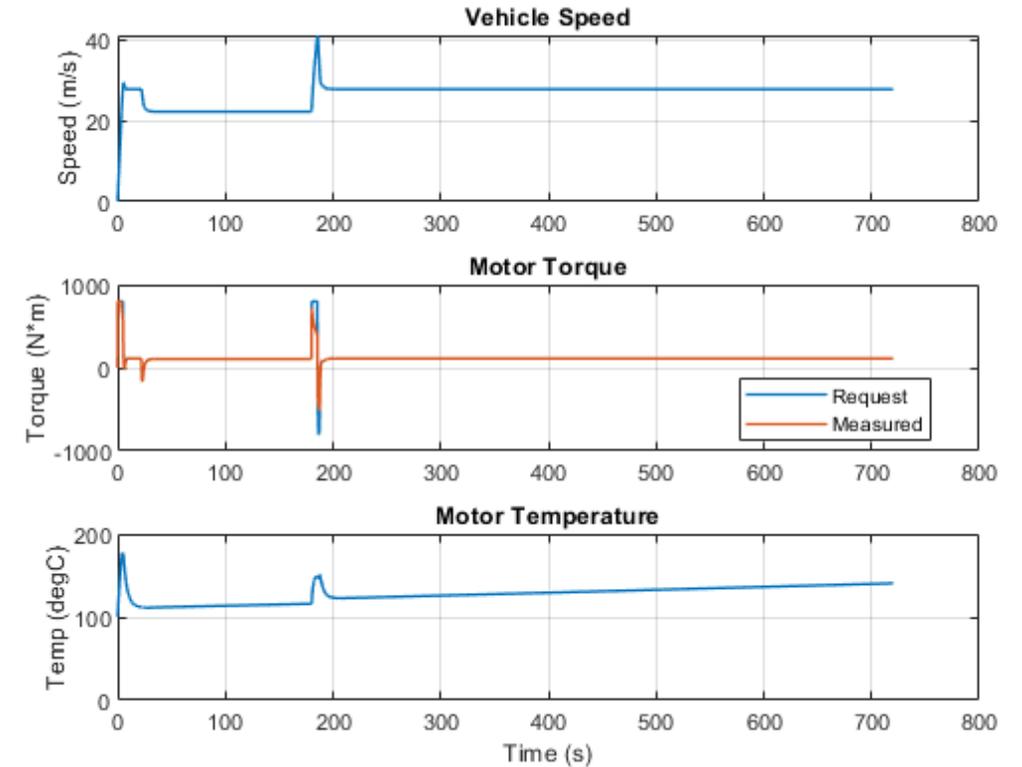Initial simulation parameters of the electric vehicle

Analyzed Parameter	Description	Initial Value	Unit
Initial motor temperature	Motor temperature before the simulation starts.	100	°C
Motor thermal efficiency	Motor efficiency before cooling influence.	90%	%
Initial vehicle speed	Initial vehicle speed at the start of the simulation.	0	m/s
Vehicle mass	Total mass of the electric vehicle.	3500	kg
Maximum motor power	Maximum power output of the motor as defined in the model.	500	kW

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With Cooling System Activated



Without Cooling System Activated

4. SIMULATION AND ANALYSIS

Simulation results for the electric vehicle with and without cooling system

Parameter	Unit	With Cooling System	Without Cooling System	Description
Peak Motor Temperature	°C	80	180	Maximum recorded temperature of the motor during operation.
Average Motor Temperature	°C	70	150	Average motor temperature over the test period.
Measured Torque (avg)	N·m	970	920	Mean torque value measured during the test cycle.
Energy Efficiency	%	92	84	Percentage of input energy converted into useful work.
Thermal Stress Level	-	Low	High	Indicates the level of thermal stress on the motor components.
Motor Longevity Estimation	Hours	5000+	<3000	Estimated operational lifespan of the motor in hours.
Cooling System Power Consumption	W	120	0	Power required by the cooling system to maintain thermal stability.
System Stability	-	Stable	Unstable (Overheating)	Overall system stability based on thermal performance.

Statistical impact of cooling on motor performance between description in Fig. 2 and Fig. 3
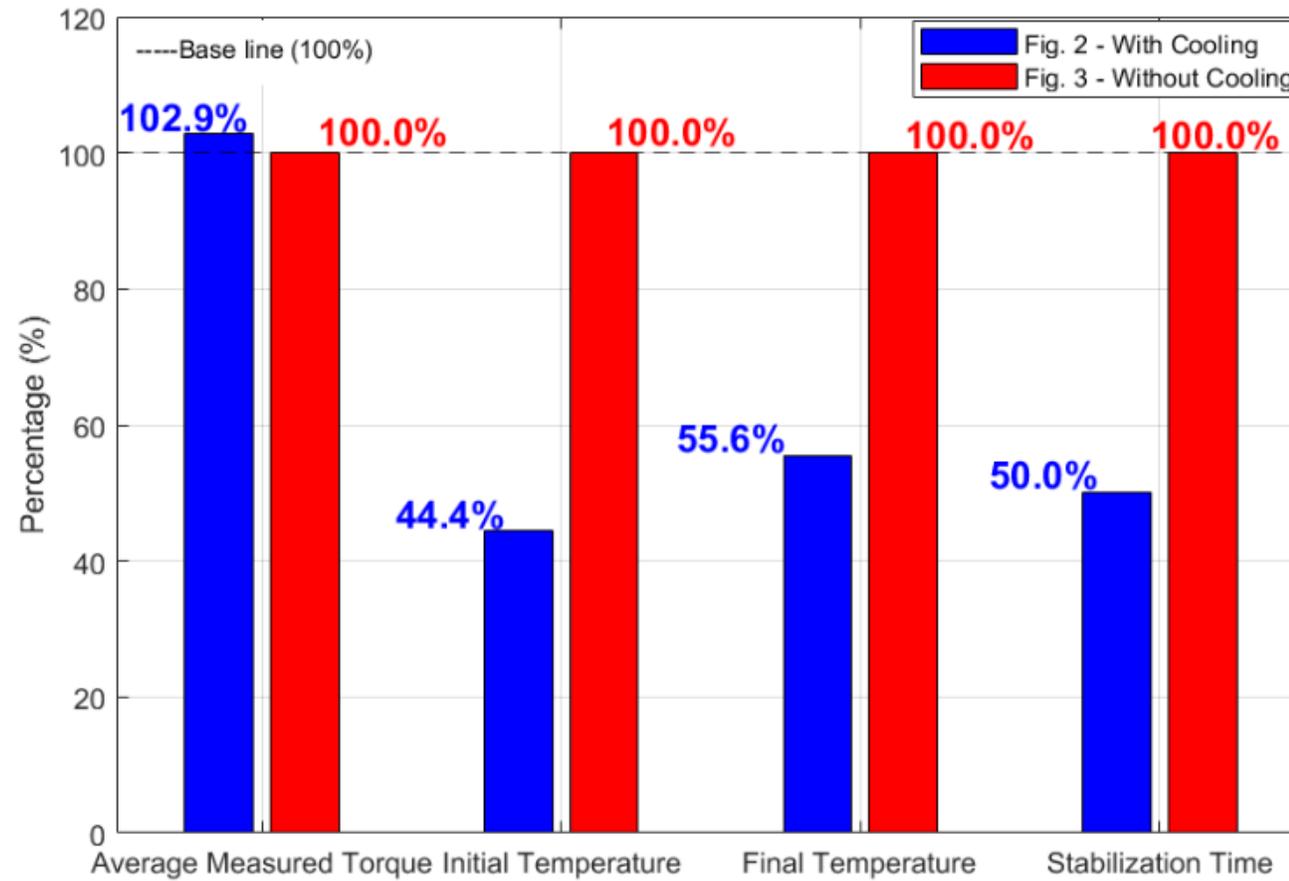
6. CONCLUSION

Our study demonstrates that the integration of an advanced liquid cooling system with an electric motor model using MATLAB/Simulink and Simscape provides a robust multi-domain simulation framework that is instrumental in addressing the critical thermal management challenges faced by battery electric vehicles (BEVs).

We can embed and test different strategies for the battery management system in order to improve the durability and efficiency.

Our model represents the physical system and works are being done to integrate AI models and advanced control strategies.

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REAL VEHICLES FOR TESTS

Renault CAPTUR, Jeep Renegade, and DAF Truck

Q&A