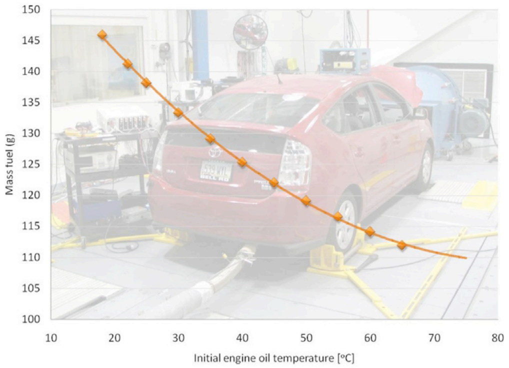
Plug-in Hybrid Engine Thermal State and Resulting Efficiency

Losses on the order of 25-40% have been observed from ambient 20° C cold starts to optimal hot temperature urban drive cycle operation in plug-in hybrid electric vehicles (PHEVs). These losses are especially critical for PHEVs, when long durations between engine operation result in reduced engine temperature. The resulting increase in fuel consumption is not well characterized and the total impact on fuel consumption is not quantified.



Modeled UDDS fuel consumption as a function of initial engine temperature. Background photo depicts test vehicle on chassis dynamometer.

The Challenge

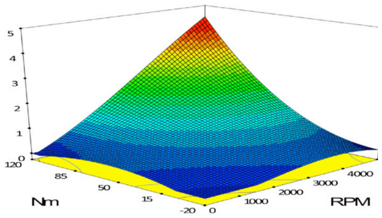
To characterize the thermal effect on PHEV fuel consumption in order to improve real world driving fuel economy.

The Solution

Response surface methodology techniques(statistical modeling) were used to characterize the thermal effect on PHEV engine efficiency. Combined with a technique for predicting the engine thermal state from its operational history, this unique methodology accurately predicts fuel consumption over a drive cycle from ambient cold start to fully operational temperature.

The Results

- Engine efficiency improved significantly with increasing engine temperature.
- Projected optimal engine temperature was ~25% more efficient than a 22° C ambient cold start.
- The initial enrichment spike during a cold start accounted for a ~3% fueling increase compared to a warm engine. Even greater accumulated losses (~20%) followed this cold start enrichment until the optimal engine temperature was reached.
- Between the range of 25 - 60°C, each 5° C increase in initial engine temperature decreased fuel consumption by 3.2% and 1.9%, respectively.
- Losses associated with the electric components, rolling losses, and transaxles were minimal relative to engine and transmission thermal losses.



Fueling rate response surface at 22°C engine temperature.

Current Work

To develop a displacement-independent engine model to be used in vehicle simulation work to account for engine thermal efficiency effects.

***"Variations in ambient temperatures and driving styles have a significant impact on fuel consumption by advanced powertrain vehicles. Understanding these efficiency losses will ultimately result in engineering more fuel-efficient vehicles,"* said Forrest Jehlik, principal mechanical engineer, Argonne National Laboratory.**