Integrating Prior Information in Cylinder Pressure Modeling and Interpretation

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Project Overview

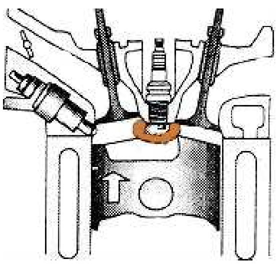
Today's vehicles are under strict legislative requirements regarding emissions and thus need proper control and diagnosis functionality to secure operation within the prescribed limits. A key characteristics is the interplay between modeling and information fusion, using information from in-vehicle sensors, databases, as well as communicated information from other vehicles and infrastructure. The core of the project is in information integration. One particularly interesting area is systematic and efficient analysis of combustion engine data. These have a direct impact on the performance and selection of control strategy. The data is very informative but to get reliable results, it is necessary to also combine the data with information from experts. Recent results concern the development and evaluation of systematic methods that combine traditional measurements with a parametric description obtained from expert knowledge in a systematic way. These methods have been applied to the problem of analyzing combustion engine data.

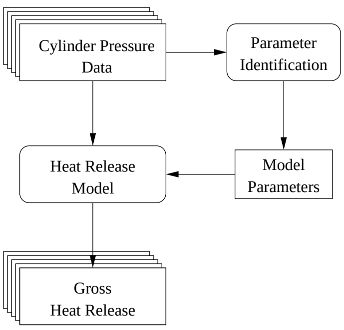
Problem outline

Control of the combustion process is very important since it directly influences both emissions and efficiency.
Predictive models (mixing, turbulence etc) are not yet reliable, analysis of engine data is an important tool. Measure cylinder pressure make *Heat release analysis*. The goal is to have a systematic method that answers the important questions

- How was the fuels chemical energy converted to thermal energy and work?
- What is the position and speed of combustion?

Setup





A thermodynamic model is necessary for data extraction.

- First law analysis of cylinder contents gives ODE

$$dp = \frac{dQ_{ch} - \frac{\gamma}{\gamma-1}\, p\, dV - dQ_{ht}}{\frac{1}{\gamma-1}V + \frac{V_{cr}}{T_w}\left(\frac{T}{\gamma-1} - \frac{1}{b}\ln\left(\frac{\gamma-1}{\gamma'-1}\right) + T'\right)}$$

- Parameter identification for each cycle. Many parameters, identifiability problem.
- Much data. Time consuming to analyze.
- Systematic analysis.

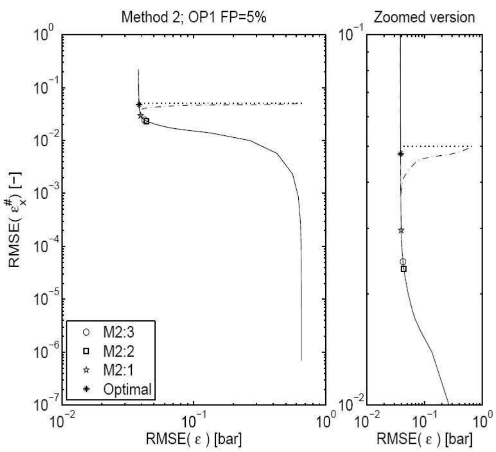
Prior knowledge – Regularization

Parameter vector x with prior knowledge data $x^\#$.
Prediction error method with regularization

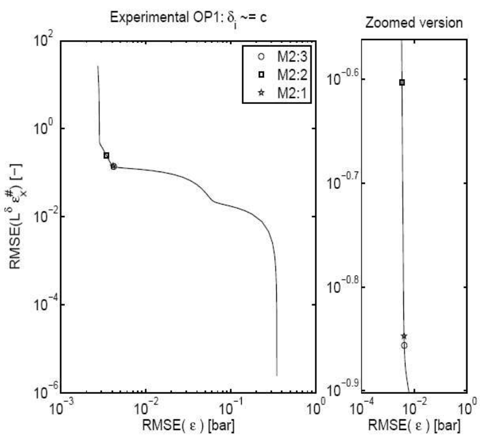
$$W_N = \frac{1}{N}\sum_{i=1}^{N}\left(p(\theta_i) - \hat{p}(\theta_i, x)\right)^2 + (x - x^\#)^T \delta (x - x^\#)$$

Here δ is a diagonal matrix and it integrates the prior knowledge. Two choices for δ; all equal $\delta_i = \delta_0$, uncertainty of parameter i $\delta_i = \delta_0 \frac{1}{2\,N\,\sigma_i}$.

How to select δ_0? Hansens L-curve.
Three corner finding methods investigated in [1].



Experimental results Not the true model structure available. Corner is detected but not as clear as in simulation.



References

[1] Marcus Klein, *Single-Zone Cylinder Pressure Modeling and Estimation for Heat Release Anaysis of SI Engines*, PhD Thesis, September, 2007.