Introduction

• The dynamics of incomplete combustion events (e.g., misfires and partial burns) was investigated on a cyclic basis using the cumulative heat release (HR).

• Symbol sequencing was done on an energy basis. This provided insight into the differences in the dynamics when operating in the misfire or partial burn regime.

Background

• Increased dilution either from excess oxidizer or combustion products causes combustion to become more strained, and incomplete combustion events (i.e., misfires and partial burns) start to occur. These events cause combustion instabilities and create a dilute limit.

• Heat release will alternate from low to high or high to low as combustion becomes more strained. These patterns represent a higher energy cycle being followed by a misfire or vice versa and are caused by the feed-forward mechanism present in the residual gases.

• Symbol Sequencing is a common technique to investigate patterns between engine cycles.

Experimental Setup

• 2.0 L GM Ecotec LNF Engine
• Spark advance from 30° BTDC to 70° BTDC
• 2000 RPM and 4 bar BMEP (no dilution)
• Fixed fueling
• 20% EGR or 2.160
• Approximately 5000 cycles for each data set

Data Analysis

Partition limits used for symbol sequencing

\[
\begin{align*}
HR_{\text{final}} & < HR_{\text{CE10}} \quad \text{Misfire (0)} \\
HR_{\text{CE10}} & < HR_{\text{final}} < HR_{\text{CE10},\text{exp}} \quad \text{Partial Burn (1)} \\
HR_{\text{CE10,exp}} & < HR_{\text{final}} < Q_{\text{inel}} \quad \text{Nominal (2)} \\
Q_{\text{inel}} & < HR_{\text{final}} < HR_{\text{CE10}} \quad \text{Above Nominal (3)} \\
HR_{\text{final}} & > HR_{\text{CE10}} \quad \text{High Energy (4)}
\end{align*}
\]

where \( Q_{\text{inel}} \) is the energy in and CE is a combustion efficiency. \( HR_{\text{CE10}} \) corresponds to the HR value at 10% CE.

The level of determinism was quantified using the Euclidean norm. Resampling the data removed the time dependency.

\[
\| f \| = \sqrt{\sum_{k=1}^{N} (f_{\text{original}} - f_{\text{resample}})^2}
\]

where \( f \) is the frequency and \( N \) is the number of sequences.

Results

• The decreased sensitivity could be due to a difference in the level of and/or a difference in composition between the two dilution methods.

• Misfires are typically followed by high-energy cycles while partial burns were typically followed by above-nominal cycles.

• Repeated partial burns appear to be stochastic.

• Results suggest dynamics are in fact different when operating in the misfire or partial burn regime. The misfire regime appeared to be less stochastic.

• Changes in spark advance are more apparent with lean dilution than high EGR.

Conclusions

Acknowledgments

Experimental data was provided by researchers in the Fuels, Engines, and Emissions Research Center (FEERC) at Oak Ridge National Laboratory (ORNL). The authors wish to thank Dr. Charles Finney from Oak Ridge National Laboratory for his expertise and technical advice related to the symbol sequencing analysis.

This work was funded in part by the US Department of Energy’s Vehicle Technologies Office under the guidance of the Advanced Combustion Engine Research and Development program managed by Gurpreet Singh and Michael Wiesmuller.

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