Cyclic dynamics of misfires and partial burns in a dilute spark-ignition engine

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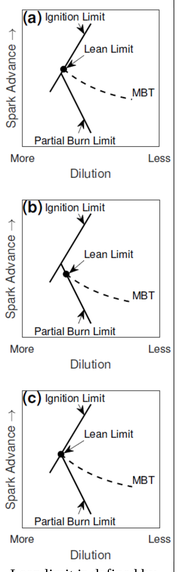
Introduction

- 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[2].
- Symbol Sequencing is a common technique to investigate patterns between engine cycles[3].



Lean limit is defined by (a) ignition limit, (b) partial burn limit, (c) ignition/partial burn limit (recreated from Quader[1]).

Experimental Setup[4]

- 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 λ=1.60
- Approximately 5000 cycles for each data set

Data Analysis

Partition limits used for symbol sequencing

	HR_{final} <	HR_{CE10}	Misfire (0)
HR_{CE10} <	HR_{final} <	$HR_{CE100,exp}$	Partial Burn (1)
$HR_{CE100,exp}$ <	HR_{final} <	Q_{fuel}	Nominal (2)
Q_{fuel} <	HR_{final} <	HR_{CE110}	Above Nominal (3)
	HR_{final} >		High Energy (4)

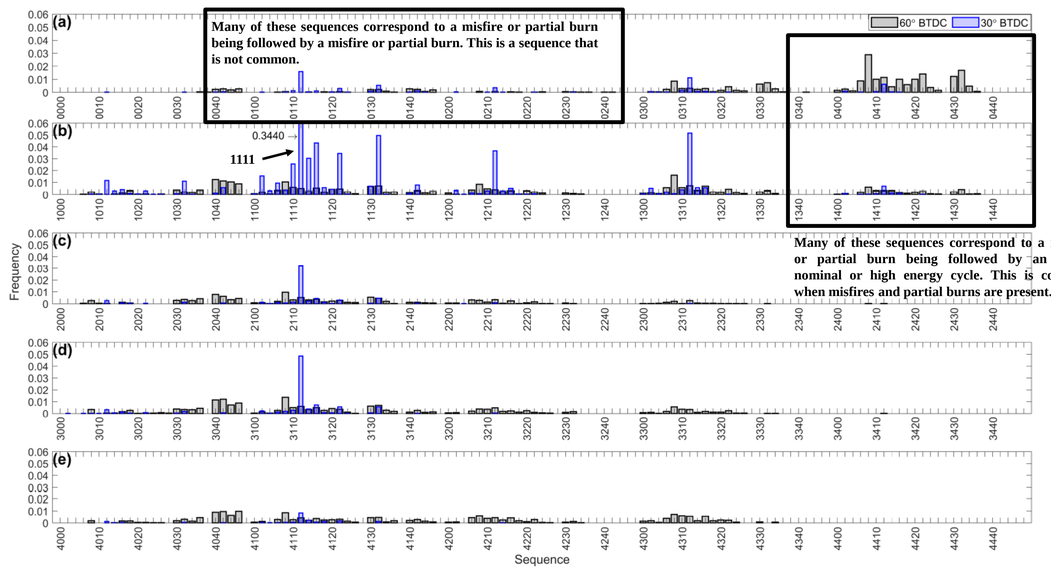
where Q_{fuel} is the energy in and CE is a combustion efficiency. HR_{CE10} corresponds to the HR value at 10% CE.

The level of determinism was quantified using the Euclidean norm[5]. Resampling the data removed the time dependency[6].

$$\|f\| = \sqrt{\sum_{k=1}^{N} \left(f_{original} - f_{resample}\right)^2}$$

where f is the frequency and N is the number of sequences.

Results

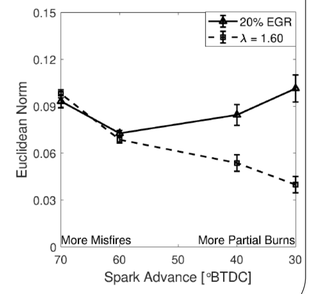


Symbol sequencing with λ=1.60 and spark advance of 60° and 30° BTDC. The subplots are for sequences (a) 0000–1444, (b) 1000–1444, (c) 2000–2444, (d) 3000–3144, (e) 4000–4444.

- Both dilution methods show similar patterns, however the patterns are more apparent in the lean dilution cases.
- The 60° BTDC case had more alternating sequences (e.g. 0404, 1040, 3040) compared to the 30° BTDC case.
- There appears to be a decreased sensitivity in the frequency of sequences with repeated partial burns when the dilution method was different. This suggests repeated partial burns may have been stochastic.
- The stochasticity of the dynamics was less sensitive to spark advance when high EGR is used as the method of dilution.

Results (continued)

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



Conclusions

- 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.

Acknowledgments

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