



Advances in rapid compression machine studies of low- and intermediate-temperature autoignition phenomena



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ABSTRACT

Rapid compression machines (RCMs) are widely used to acquire experimental insights into fuel autoignition and pollutant formation chemistry, especially at conditions relevant to current and future combustion technologies. RCM studies emphasize important experimental regimes, characterized by low- to intermediate-temperatures (600–1200 K) and moderate to high pressures (5–80 bar). At these conditions, which are directly relevant to modern combustion schemes including low temperature combustion (LTC) for internal combustion engines and dry low emissions (DLE) for gas turbine engines, combustion chemistry exhibits complex and experimentally challenging behaviors such as the chemistry attributed to cool flame behavior and the negative temperature coefficient regime. Challenges for studying this regime include that experimental observations can be more sensitive to coupled physical-chemical processes leading to phenomena such as mixed deflagrative/autoignition combustion. Experimental strategies which leverage the strengths of RCMs have been developed in recent years to make RCMs particularly well suited for elucidating LTC and DLE chemistry, as well as convolved physical-chemical processes.

Specifically, this work presents a review of experimental and computational efforts applying RCMs to study autoignition phenomena, and the insights gained through these efforts. A brief history of RCM development is presented towards the steady improvement in design, characterization, instrumentation and data analysis. Novel experimental approaches and measurement techniques, coordinated with computational methods are described which have expanded the utility of RCMs beyond empirical studies of explosion limits to increasingly detailed understanding of autoignition chemistry and the role of physical-chemical interactions. Fundamental insight into the autoignition chemistry of specific fuels is described, demonstrating the extent of knowledge of low-temperature chemistry derived from RCM studies, from simple hydrocarbons to multi-component blends and full-boiling range fuels. Emerging needs and further opportunities are suggested, including investigations of under-explored fuels and the implementation of increasingly higher fidelity diagnostics.

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Contents

1. Introduction	3
1.1. Background	3
1.2. Measurements of autoignition phenomena	5
1.2.1. Autoignition chemistry.....	5
1.2.2. Physical-chemical interactions	6
1.3. Rapid compression machines	7
1.4. Characteristic time scales	8
1.5. Overview	9

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2.	RCM designs and configurations	9
2.1.	RCMs for autoignition chemistry / fuel reactivity studies	9
2.1.1.	Early designs	10
2.1.2.	Control of the compression phase.....	10
2.1.3.	Control of piston creep and rebound	15
2.1.4.	Control of the reacting gas.....	15
2.1.5.	Piston crevice containment.....	17
2.1.6.	Aerosol fueling and direct test chamber methods	17
2.2.	RCMs to study physical-chemical interactions	18
2.2.1.	Stratified autoignition	18
2.2.2.	Turbulence–chemistry interactions	19
2.2.3.	Knock	19
2.2.4.	Plasma-enhanced autoignition	20
2.2.5.	Phase-change induced gradients.....	20
2.3.	Summary	20
3.	Development and application of standard and advanced RCM diagnostics.....	21
3.1.	Pressure measurements	21
3.2.	Temperature measurements	21
3.2.1.	Schlieren techniques.....	22
3.2.2.	Thermocouple measurements	22
3.2.3.	Rayleigh scattering, fluorescence and absorption techniques.....	23
3.3.	Species measurements: radicals, stable intermediates and products	25
3.3.1.	Gas sampling methods	25
3.3.2.	Absorption, emission, and fluorescence spectroscopy	27
3.4.	Velocity field characterization	28
3.5.	Summary	29
4.	Autoignition regimes and modeling	30
4.1.	Definitions	30
4.2.	Modeling	32
4.2.1.	Homogeneous reactor models.....	32
4.2.2.	Non-uniform reactor models.....	34
4.3.	Summary	34
5.	Studies of physical-chemical interactions	35
5.1.	Stratified autoignition	35
5.2.	Turbulence–chemistry interactions	35
5.3.	Mild ignition.....	37
5.3.1.	Shock tube observations	37
5.3.2.	RCM measurements.....	38
5.4.	Knock.....	40
5.4.1.	Fuel structure and autoignition chemistry effects	40
5.4.2.	Flame–autoignition interactions.....	42
5.4.3.	Gas dynamic evolution	43
5.5.	Summary	43
6.	Studies of autoignition chemistry	44
6.1.	Hydrogen/syngas mixtures	45
6.2.	Linear and branched chain alkanes.....	46
6.2.1.	Methane	46
6.2.2.	Methane/hydrogen mixtures	47
6.2.3.	Methane/natural gas mixtures.....	48
6.2.4.	Ethane	49
6.2.5.	Propane.....	49
6.2.6.	Butane isomers.....	49
6.2.7.	Pentane isomers	51
6.2.8.	Hexane isomers.....	52
6.2.9.	Heptane isomers.....	53
6.2.10.	isoOctane and PRF blends	54
6.2.11.	Decane	55
6.2.12.	Summary - alkanes.....	55
6.3.	Cycloalkanes	55
6.3.1.	Cyclohexane	55
6.3.2.	Methylcyclohexane	55
6.3.3.	Propylcyclohexane	55
6.3.4.	Summary - cycloalkanes	56
6.4.	Alkenes	56
6.4.1.	Summary - alkenes.....	57
6.5.	Aromatics	57
6.5.1.	Benzene	57

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