Fall 2017-R2

ME256- Combustion

General Information:

This course provides students a solid foundation in combustion sciences and technologies relevant to current and future energy conversion devices using combustion. Topics include: Review of thermochemistry, Chemical Kinetics (explosion limits, negative temperature dependence, NOx formation), Conservation Equations for Reacting Flows, Computer modeling of combustion processes, Premixed flames, and Nonpremixed flames. Applications using advanced combustion systems for energy efficiency and low emissions will be discussed.

Lecture: T. Th 11-12:30 Etcheverry 3109

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Office Hours: Tuesday 2-3

Textbook: Warnatz, J, Maas, U., Dibble, R.W., 5-th ed. "Combustion", Springer, 2017 (draft version to be given free to class by Prof. Dibble on class website).

Other Useful Reference Books:

Glassman, I. Combustion Academic Press, 3rd Edition, 1996.
Kuo, K, K, *Principles of combustion*, Wiley, 1986.
Williams, F.A. Combustion Theory, 2nd ed. Benjamin/Cummins, 1985.
Turns, S.R. *An Introduction to Combustion*, McGraw Hill, 2nd Edition,1996.

Prerequisites:

ME40 (thermodynamics), ME106 (fluid mechanics), ME109 (thermodynamics)

GSI/READER: TBA

Grading scheme:

1) Homework (30%)
2) Midterm (30%): tentatively October 19 (Thursday)
3) Final (40%)

Topics	Text Ref. (Warnatz 5th edition)
Introduction, Fundamental Definitions	Chap. 1
Experimental Investigation of flames	Chap. 2
Review of Thermodynamics	Chap. 4
Chemkin (Computer modeling)	Handout
Chemical Kinetics, Reaction Mechanisms	Chaps. 6, 7
Chemkin Applications	Chap. 6, 7, 8
H_2-O_2 Combustion /Explosion Limits	Chap. 10
CH_4 Oxidation	Chap. 7
Combustion of higher hydrocarbon fuels	Chap. 10,11
Detonation	Chap. 10.7
Transport Phenomena /Conservation Equations	Chaps. 5,12
Laminar premixed flames	Chaps. 3 ,8
Laminar Nonpremixed Flames	Chap. 9
Opposed jet flames: computer modeling	Handouts
Turbulent Combustion	Chapters 14 & 15
Emission from combustion Nitric Oxides	Chap. 17

Assignments:

Homework: Analysis + Computer projects using Chemkin with a in-house computer facility (Linux).

Weekly schedules.

Week 1
Introduction, fundamental definition & phenomena. Brief discussions of various measurements useful for experimental investigation of flames. Reading: Chapter 1 and Chapter 2. (HW #1)

Week 2
Review of thermodynamics. Introduction of chemkical kinetics; Review of basic law and equations, type of reaction steps. Chemkin computer software. (HW #2 Chemkin equilibrium) (Chapter 4.7+ handout notes)

Week 3
Chemical Kinetics, Reaction Mechanisms. Review of collision theory. Pressure dependence , surface reactions. (HW# 3: collision frequency, estimate of pre-exponential factor). (Chapter 6)

Week 4 Reaction mechanisms: quasi-steady state, partial equilibrium. Analysis of reaction mechanisms. Chemkin , Stiffness of chemical systems (example eigenvalue analysis), computer simulation for reacting systems: Plug Flow Reactor (time dependent solutions). (HW#4: 1 analysis + 1 computer project) (Chapter 7)

Week 5
Sensitivity analysis. Auto-ignition of H_2-O_2 mixtures, CH_4-air combustion, higher hydrocarbon fuels, alcohol fuels. Spark ignition. (HW #5: computer project: sensitivity study of delay to chemical kinetic rates) (Chapter 10.3, 10.4, 10.6)

Week 6

Pathway analysis of multiple stage ignition, Low temperature combustion, intermediate temperature, and high temperature regime. Introduction to Perfectly stirred reactor (PSR). (HW #6: pathway analysis of hydrogen combustion due March 3rd) (Chapter 11+ handout notes)

Week 7

Analysis of PSR (handout). Review of shock wave and introduction to detonation waves. (HW#7 n-butane, n-heptane chemistry and PSR blowout limits)

Week 8
Properties of detonation waves (Chapter 10). Review of transport of mass and heat (Chapter 5). Definitions of diffusion velocity, Soret Durfor Conservation equations. (Hw 8: detonation & premixed flame speeds) (Chapters 3 & 8, handout)

Week 9 (Midterm)

Energy equation. Review of Premixed flames: 1-D premixed equations & solution methods. Flammability limits. Introduction to flame stretch. (hand out notes). Midterm March 17 Materials covered up to detonation (included) str. (Hw 9 1-D Diffusion).

Week 10
Continued discussions of flame stretch effect and the Marstein number. (notes): (Hw 10 flame speed & stretch)

Week 11
Nonpremxed flames: concept of mixture fraction, fast chemistry limit. Scalar dissipation rate and its importance to finite rate chemistry. (Hw 11, laminar flame structure) (Chapter 9 + handout notes)

Week 12
Jet flames, counter-flow flames. (combustion rate limited by diffusion of species). (Hw 11, opposed flame computer projects) (Chapter 12 + ppt slides).

Week 13
Introduction to turbulent combustion. (Chapters 14 & 15)

Week 14 (one day)/15
Emissions from Combustion processes: NOx, THC, soot. Control systems. Catalytic reactions: combustion & after treatment. (Chapters 17, 18)