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PROFILE HIGHLIGHTS

Academic

- Developed and taught courses in thermal-fluid sciences - mechanical engineering (US)
- Mentored more than 45 undergraduate, 4 MS and 1 PhD students in projects (US)
- Proposed and conducted research sponsored by NASA on microgravity combustion and sponsored by Cummins Inc. on EGR (Exhaust Gas Recirculation), cooling and waste heat recovery (US)
- Published more than 30 journal/ conference publications as well as 2 patents in the areas of thermal-fluid sciences, biomedical engineering, food science, combustion & engineering education (US)
- Led ABET accreditation process in developing methods for student learning assessment (US)

Entrepreneurship/ Industry

- Awarded Pre-seed Support for Funding by IIT, Patna Incubation Centre (India) – see attachment to the end of the CV
- Co-Founder and Chief Product Officer of an Ed-tech startup, and an IoT startup (India)
- Five years in a Technical Leadership position in engine design & development with Fiat Chrysler Automobiles-US (FCA-US)
- Training, mentoring and recruitment with FCA-US
- Consulted for a startup, performed patent searches, reviewed business plans (US)

Citizenship Status: United States national with Overseas Citizenship of India (OCI) card

CURRENT APPOINTMENTS

Vishnu Educational Development and Innovation Centre — **Hyderabad, India**

Dean and Organizational Coach — Jul 2017 – present
Professor, Sri Vishnu Engineering College for Women — Jul 2017 - present

- Advised educational institutions on research practices, curriculum development, laboratory development, faculty development, use of technology in education etc.
- Developed and conducted workshops on student engagement in the classroom, project-based learning, curriculum design and research methods with content customized for faculty from various disciplines of engineering

Indo-Universal Collaboration for Engineering Education (IUCEE)

Core Team Member — Sep. 2013 – 2017
Expert Panel Member — Aug. 2010 – present

SELECTED WORKSHOPS / COLLOQUIUM DEVELOPED & CONDUCTED (2011 – present)

20 unique Workshop offerings with (total participant count > 1200 faculty)

1. Lab Redesign Workshop (Jan 2020, planned)
2. Inspire-Impact-Introspect Level 1 Workshop Batch 17, (Sep 11 – 13, 2019, 31 participants)

3. Closing the Loop on Outcome-Based Education Batch 1 (Aug 19 – 20, 2019, 32 participants)
4. Course and Curricular Design Workshop ME/ CE (Aug 6 – 8, 2019, 21 participants)
5. Leadership in Teaching and Learning, Batch 2, (July 31 – Aug 2, 2018, 28 Department Heads and Deans)
6. Think-Technology-Transform Level 1 Workshop Batch 2, (May 2 - 4, 2018, 30 participants, as co-facilitator)
7. Advanced Research Techniques Workshop Batch 1, (Apr. 25 – 27, 2018, 30 participants, as co-facilitator)

INDUSTRY EXPERIENCE

Vigilare Innovations Pvt. Ltd. **Chennai, India**

Advisor Nov 2016 – Jun 2017

- Provided direction for mechanical design of an IoT product

IntelliEd Innovations Pvt. Ltd. **Chennai, India**

Co-Founder, Chief Product Officer Jun 2016 – Jun 2017

- Set strategy directions for product based on customer (parent and student) feedback
- Managed a team of animators, script writers, programmer and a marketing manager
- Selected and developed script for technical content in multiple fields in simple language
- Developed various product features aimed at school students
- Improved process efficiency and effectiveness to meet production timelines

Fiat Chrysler Automobiles (FCA-US) **Auburn Hills, MI**

Technical Specialist, Powertrain Jan 2011 – May 2016

- Identified & systematized training needs, reviewed course content for Chrysler Powertrain
- Recruited students from Universities and mentored them for Chrysler Powertrain
- Primarily led hardware systems development as a senior engineer (combustion)
  - Tested various V6 gasoline engine technologies and demonstrated ~6% improvement in fuel economy and ~15% improvement in torque performance
  - Provided technical guidance to a team of 5 dynamometer test and analysis engineers, 3 engine & flow simulation engineers and 5 test cell operators
  - Proposed, developed and monitored dynamometer/ simulation test plans during proof-of-concept to production phases of the high volume (500,000 units per year) V6 gasoline engine for the Chrysler Pacifica, Jeep Grand Cherokee, and Dodge Durango
  - Developed processes and methods for utilizing flow bench and simulation data (from GT-Power, Star-CD and CONVERGE) to guide hardware direction
  - Studied effects of compression ratio, intake and exhaust ports, combustion chamber and piston top geometries, VVT/ VVL/ VVA (Variable Valve Train/ Lift/ Actuation), EGR (Exhaust Gas Recirculation), GDI (Gasoline Direct Injection), intake, and exhaust systems on engine & vehicle fuel economy, torque performance and emissions
- Supported corporate decisions for technologies aimed at meeting Corporate Average Fuel Economy (CAFÉ) 2025 and CARB (California Air Resources Board) and EPA (Environmental Protection Agency) emission standards
- Improved the time duration, measurement uncertainties of test & measurement processes

ACADEMIC EXPERIENCE

Indiana University - Purdue University Indianapolis **Indianapolis, IN**

Assistant Professor of Mechanical Engineering Sep. 2002 – May 2010

- Supervised and trained undergraduate / graduate students on industry and research projects involving design of experimental equipment for teaching and research
- Demonstrated feasibility of a heat recovery Rankine cycle for heavy duty truck diesel engines with a 4% improvement in brake thermal efficiency as part of an industry project
- Consulted for a medical device startup
- Developed & taught graduate and undergraduate courses in thermal fluids including innovative teaching practices

Mid Infrared Sensing, Diagnostics and Control Consortium, **West Lafayette, IN**
Maurice J. Zucrow Laboratories, Purdue University

Post-Doctoral Research Associate March 2000 – August 2002

- Coordinated and led technical multidisciplinary projects involving food science, biomedical engineering, mechanical engineering and aerospace engineering departments in mid infrared diagnostics
- Conducted patent searches, filed invention disclosures, technical reports, prepared business plans, startup and research funding proposals
- Made major purchase decisions / trained personnel in use of FTIR and optical equipment
- Supervised, mentored and trained graduate students

Department of Aerospace Engineering, University of Michigan **Ann Arbor, MI**

Graduate Research Assistant July 1995 – March 2000

- Managed a research laboratory for optical diagnostics of combustion generated soot
- Developed a fuel system, soot sampler and a laser-based optical scattering system
- Contacted vendors for equipment purchase decisions and ongoing maintenance

RESEARCH/ PRODUCT INTERESTS

- Environmental Health Sensors, Environmental Monitoring
- Engineering education, Artificial Intelligence and Technology Tools for Education

TEACHING / TRAINING INTERESTS

- Air Pollution – Dynamics and Sensors and Systems, Emission Monitoring, Air Pollution Mitigation
- Effective Teaching, Curriculum and Course Design, Problem Solving, Innovation

EDUCATION

University of Michigan **Ann Arbor, MI**

Ph.D. in Aerospace Engineering May 2000

Dissertation topic: Optical Properties of Soot Emitted from Turbulent Diffusion Flames

University of Michigan **Ann Arbor, MI**

M.S. in Aerospace Engineering May 1997

Indian Institute of Technology (IIT) **Madras, India**

B.Tech. in Aerospace Engineering May 1995

Project topic: Optimization of Solid Rocket Performance Using Incremental Analysis - ISRO (Indian Space Research Organization) consultancy project.

SELECTED AWARDS/ HONORS/ CERTIFICATIONS

1. IGIP (International Association for Engineering Pedagogy) Certified Educator (since March 2019)
2. Heartfulness Meditation Certified Trainer (since October 2018)

3. Invited to be Associate Editor, Journal of Engineering Education Transformations (since October 2018)
4. ASEE (American Society for Engineering Education) Honorable Mention, 2009
5. Trustees TERA (Teaching Excellence Recognition Award) Award, 2008
6. Fourth Place (among 8 finalists) Burton D. Morgan Entrepreneurial Competition, 2002
7. Selected to represent India at the London International Youth Science Fortnight, 1991

STUDENT AWARDS

1. J.M. Abshire, "Comparisons of Model Predictions with Measurements of Microgravity Laminar Diffusion Flame Shapes," AIAA Annual Region III Student Conference, Paducah, KY, **Graduate Presentation Award - First Place (2003).**

STUDENT SUPERVISION

Graduate Students

Ph.D. students

1. 'Simulations of Normal and Inverse Laminar Diffusion Flames under Oxygen Enhancement and Gravity Variation', Pramod Bhatia , Ph.D. (ME), Purdue University, West Lafayette (PUWL), Thesis submitted, May 2008. – Thesis Advisor
2. 'Wave Rotor Performance Analysis and Numerical Study of its Transient Heat Transfer', Hongwei Li, Ph.D. (ME), PUWL, May 2009. – Thesis Committee Member
3. 'Detection of Pathogens in Food using FTIR Spectroscopy', Yash Burgula, Ph.D. Food Science, PUWL, Aug. 2006. – Thesis Committee Member

MS students

4. 'Waste Heat Recovery System for Diesel Engines – Design and Concepts Evaluation', William Donelson, MSME, IUPUI, Report submitted May 2007 – as Thesis Advisor
5. 'Effect of Oxygen Enhancement and Flame Configuration on Radiation and Flame Structure', Manish Saini, MSME, PUWL (Purdue University, West Lafayette), Thesis submitted, Aug 2006– as Thesis Advisor
6. 'Laminar Diffusion Flame Shapes Under Earth-Gravity and Micro-gravity Conditions', Jason Abshire, MSME, IUPUI, Thesis submitted, July 2004 – as Thesis Advisor
7. 'Design of a Multifluid Heat Exchanger', Sang Bae Park, MSME, IUPUI, Thesis submitted, Dec 2003 – as Thesis Advisor
8. 'Exhaust Gas Cooling in Modern Truck Engines', John Bowman, MSME, IUPUI, Report submitted, July 2005. – as Thesis Committee member
9. 'Numerical Analysis of Hot Gas Injection and Premixed Flame Propagation in a Channel', Dhruv Baronia, MSME, IUPUI, Dec. 2006. – as Thesis Committee member
10. 'Computational Prediction and Design of Fuel-Air Mixing in a Combustion Wave Rotor', Arnab Banerjee, MSME, IUPUI, Nov. 2005. – as Thesis Committee member
11. 'A Probability Density Function Based Monte Carlo Scheme for Two-Phase Flow Simulation', Jie Huang, MSME, IUPUI, Oct. 2004. – as Thesis Committee member
12. 'The Development of a CFD Chemistry ODE Solver for Ethylene Fuel', Keith Bandi, MSME, IUPUI, July 2004. – as Thesis Committee member
13. 'The Effectiveness of High Pressure in Fuel-Air Mixing and Design of Flow Passage', Snehaunshu Chowdhury, MSME, IUPUI, Dec 2003. – as Thesis Committee member
14. 'Infrared Sensors for Rapid Identification of Select Food-borne Pathogens', Daniel Khali, MSME, PUWL, Dec 2003. – as Thesis Committee member
15. 'Statistical Design-of-Experiments in the Investigation of the Wave Ejector', Tao Geng, MSME, IUPUI, Nov 2003. – as Thesis Committee member

As Non-Thesis Graduate Project Advisor

1. 'Experimental Demonstration and Measurement of Combustion-Generated Tonal Noise', Eisuke Tanabe, MSME, IUPUI, Project Report submitted, May 2009.

Selected Undergraduate Research Projects (31 undergraduate students in projects - 6 teams and 7 as independent study)

1. "Technical Evaluation and Social Aspects of the Creation of Green Building Rating Systems", MURI (Multidisciplinary Undergraduate Research Initiative) Principal Mentor, Team of 2 BSME students, 2 BS Architectural Technology students, and 1 BS Informatics student, with co-mentors Dr. David Jan Cowan (Architectural Technology) and Dr. Tim Koponen (Public Affairs), May 2009.
2. "Redesign of a Fin Experiment", Project Advisor, Capstone Design Project, Team of 4 BSME students, December 2008.
3. "Ergonomic Redesign of Flame Diagnostics Setup", Project Advisor, Capstone Design Project, Team of 4 BSME students, May 2006.
4. "IUPUI Moonbuggy Team", Project Advisor, Capstone Design Project, Team of 4 BSME students, May 2006.
5. "Flame Sheet Location using SiC Filaments", Project Advisor, Independent Study/ Honors Project, 2 BSME students, May 2005.
6. "Design of a Two Axis System for Radiation Flux Measurements", Project Advisor, McNair Scholarship, 1 BSME student, December 2004.
7. "Design of a Soot Sampling System for Diffusion Flames", Project Advisor, Independent Study, 1 BSME student, December 2004.
8. "Redesign of Existing Residential Heating Equipment to Meet ASHRAE Standards 62.2 P", Project Advisor, Capstone Design Project, Team of 3 BSME students, December 2004.
9. "Cooling System for a Planar Chromatograph", Project Advisor, Independent Study, 1 BSME student, December 2004.

PROFESSIONAL MEMBERSHIPS

- Member, ASME (American Society of Mechanical Engineers), 2019 - present
- Member, SAE (Society of Automotive Engineers), 2011 – 2018
- Member, ASEE (American Society of Engineering Education), 2005 – 2010
- Member, ASHRAE (American Society of Heating Refrigeration and Air-conditioning Engineers), 2008 – 2010
- Member, USGBC (US Green Building Council), Indiana Chapter, 2008 - 2010
- Member, Combustion Institute, 2003 – 2010
- Member, AIAA (American Institute of Aeronautics and Astronautics), 2003 – 2010
- Member, SPIE (Society of Photonics and Instrumentation Engineers), 2001

SELECTED WORKSHOPS/ TRAINING ATTENDED

- AVL Microsoot Analyzer – Jan '12
- Combustion and Emissions in Internal Combustion Engines – SAE Course, Mar '11
- Waste Heat-to-Power Workshop, Irvine, CA, Feb '06
- Seventh International Microgravity Combustion Workshop, Cleveland, OH, Mar '03

SELECTED INDUSTRY PROJECTS

The following list includes the sequence of tasks involved in the development and production readiness of a high volume (about 1,000,000 units per year) V6 gasoline engine.

1. "Evaluation of Fuel Economy and Torque Performance of Various Vehicle Applications of the V6 Engine", 2013 – 2015
2. "Evaluation of Impact of an Active Valve Exhaust System for Improving Scavenging Performance of a V6 Engine", 2013 - 2014

3. “Evaluation of Effect of Production-Level Geometric Tolerances on the Combustion Performance of the V6 Gasoline Engine”, 2013 – 2014
4. “Evaluation and Selection of Combustion Chamber and Compression Ratio for a V6 Gasoline Engine”, 2012 – 2013
5. “Development and Selection of Valve Train for a V6 Gasoline Engine”, 2012 – 2013
6. “Engine Fuel Map Generation and Target Setting Based on Vehicle Level Targets”, 2012
7. “Proof-of-Concept Investigation and Evaluation of Engine Technologies for a V6 Gasoline Engine Upgrade”, 2011 - 2012

SELECTED SPONSORED PROJECTS (Total = ~$457,000 funded)
Title, Sponsor, Participation, Institutional Budget / Total Budget, Duration, Role, and Affiliation)

1. “Technical Evaluation and Social Aspects of the Creation of Green Building Rating Systems”, MURI (Multidisciplinary Undergraduate Research Institute) Grant, $7,500, May 2009 – Feb 2010
2. “Oxygen and Fuel Jet Diffusion Flame Studies in Microgravity Motivated by Spacecraft Oxygen Storage Fire Safety”, PI, $70,819+1 MS student support/$390,000, Oct 2003 - May 2007 (Co-PIs: Jay Gore, Purdue Univ., Peter Sunderland, Univ. of Maryland)
3. “Flame Shapes of High Oxygen Flames under Normal and Low Gravity Conditions” New Faculty Development OPD (Office for Pro1fessional Development, IUPUI) Grant, PI, $10,000/$10,000, Mar 2003 – Mar 2004
4. "Infrared Sensors for Rapid Identification of Biological Foodborne Contaminants" CFSE (Center for Food Safety Engineering), Purdue University, Co-I, $2,200/$184,237, Jan 2003 – Dec 2004. (PI: Dr. Lisa Mauer, Department of Food Science, Purdue University, West Lafayette, IN).
5. “Design Modification Of A Gas Furnace To Meet ASHRAE (American Society of Heating Refrigeration and Air-Conditioning Engineers) Standard 62.2” – Undergraduate Student Project Grant, Mentor, $5,000, Fall 2004 (Co-Mentor: R. Pidaparti, IUPUI)
6. “Mid Infrared Absorption of Glucose in Biological Fluids”, Purdue Research Foundation Trask Innovation Fund, $ 55,000, Co-PI, Mar 2002 – Mar 2003 (PI: J.P. Gore, Purdue Univ.)

INDUSTRY PROJECTS (Total = $143,000)

7. “Thermal and Fluid Sciences Laboratory”, UTC (United Technologies Corporation)-Carrier Grant, Mentor, total $72,000, May 2008, 2007, 2005, 2004
8. “Waste Heat Recovery System for Diesel Engines – Design and Concepts Evaluation” Cummins Engine Company, PI, $71,000, Sep 2005 – Oct 2007
   The goal of the project was to identify heat sources on a heavy duty truck diesel engine and demonstrate technical feasibility of a heat recovery Rankine cycle. The project involved the development of empirical models for and estimation of the size of a phase change heat exchanger, simulation of Brayton and Rankine cycles using thermodynamic properties from NIST-REFPROP with the goal of obtaining a brake thermal efficiency for the engine. A 4% improvement in brake thermal efficiency was demonstrated.

PROFESSIONAL SERVICE

- Associate Editor, Journal of Engineering Education Transformations, 2018 - present
- Core Team Member, Indo-Universal Collaboration for Engineering Education, 2013 - present
- Expert Panel Member, Indo-US Collaboration for Engineering Education, 2010 - present
- Invited Reviewer, Oak Ridge Associated Universities Ralph Powe Faculty Enhancement Program, 2018, 2019
- Invited Reviewer, JEET (Journal of Engineering Education Transformations), 2018

- Invited Reviewer, ASEE (American Society of Engineering Education) Conference 2015 - present
- Invited Reviewer, ICTIEE (International Conference on Transformations in Engineering Education), 2014, 2015, 2016, 2017

- Faculty Advisor, AIAA, 2003 – 2009
- Affiliate Director (IUPUI), INSGC (Indiana Space Grants Consortium), 2003 – 2008
- Grand Awards Judge, ISEF (Intel International Science and Engineering Fair) 2006
- Session Chair (Globalization), FIE (Frontiers in Education) Conference, San Diego, CA, 2006
- Reviewer, ASEE – Recent Trends, 2005 - 2007
- Reviewer, ASME (American Society of Mechanical Engineers) - Internal Combustion Engine Division, Spring Technical Conference, 2003

Key Publications and Patents

1. P. Bhatia, V. R. Katta, S. S. Krishnan, Y. Zheng, P. B. Sunderland and J. P. Gore (2012) "Simulations of Normal and Inverse Laminar Diffusion Flames under Oxygen Enhancement and Gravity Variation," *Combustion Theory and Modeling*, Vol. 16, pp. 774 – 798.
2. S. S. Krishnan, M.K. Saini, Y. Zheng and J.P. Gore (2012), "Radiation Properties of Oxygen-Enhanced Normal and Inverse Diffusion Flames," *American Society of Mechanical Engineers (ASME) Journal of Heat Transfer*, Vol. 134, No. 2, 022701 (2012), DOI:10.1115/1.4005076
3. S. S. Krishnan and R. Nalim (2009) "Project-based Learning in Introductory Thermodynamics," 2009 ASEE Annual Conference and Exposition, Austin, TX. – **Honorable Mention (Mechanical Engineering Division) –** *Outstanding Contributions to Mechanical Engineering Education Session.*
4. S.S. Krishnan, J.M. Abshire, P.B. Sunderland, Z.-G. Yuan and J.P. Gore (2008) "Analytical Predictions of Laminar Diffusion Flame Shapes in Microgravity and Earth Gravity," *Combustion Theory and Modeling*, Vol. 12, No. 4, pp. 605- 620.

Patents

5. Gore, J.P., Singh, R.K., Tay, A., and Santhanakrishnan, S. (2007) "Method for Measuring the Amount of an Organic Substance in a Food Product with Infrared Electromagnetic Radiation," US Patent no. 7,288,768, Issue Date: October 30, 2007.

Attached below is the first page of the Sensor Proposal Submitted and Approved for Incubation by IIT Patna followed by 5 key publications and patents:

NAME OF THE APPLICANT :	Sivakumar Krishnan
MOBILE NUMBER :	9566124528
E-MAIL ADDRESS :	ss.krishnan@gmail.com
CITY :	Chennai, Tamil Nadu
DATE OF APPLICATION :	March 27, 2017
ABSTRACT :	The product proposed is a sensing device that provides high quality information to asthma patients to help them alleviate or prevent the occurrence of their symptoms, thus improving their quality of life.
SECTOR :	Healthcare
STAGE :	Idea

1. Value proposition (highlighting the innovation)

Asthma patients typically have little knowledge of the environments in which they live either at home or commuting or at work.

Certain environments trigger asthma in asthma patients. If the patient knows about these specific environments and the environmental factors in advance, they can choose to avoid these environments or environmental factors and thus be prevented from experiencing asthma symptoms.

AirSense - Value Proposition to the Customer

AirSense is a device that tracks the environmental conditions for individuals with impaired lung function e.g., asthma patients and maps these with the occurrence of their symptoms.

AirSense combines several functions to deliver high quality information to the user.

- Customer will experience an improvement in quality of life due to intelligent decisions to promote healthy environments and lifestyles and manage asthma symptoms.
- Potentially life saving
- Crowd sharing of data creates a platform where asthmatic users help each other. For example, certain locations can be avoided by other users once it is known that there is a large probability of symptom occurrence in those locations.

Combustion Theory and Modelling
Vol. 16, No. 5, 2012, 774–798

Taylor & Francis
Taylor & Francis Group

Simulations of normal and inverse laminar diffusion flames under oxygen enhancement and gravity variation

P. Bhatia[a]*, V. R. Katta[b], S. S. Krishnan[c], Y. Zheng[d], P. B. Sunderland[e] and J. P. Gore[d]

[a]*Mechanical and Automobile Engineering Department, ITM University, Gurgaon 122017, India;* [b]*Innovative Scientific Solutions, Inc., Dayton, OH 45440, USA;* [c]*Department of Mechanical Engineering, Purdue School of Engineering and Technology, IUPUI, Indianapolis, IN 46202, USA;* [d]*School of Mechanical Engineering, Purdue University, West Lafayette, IN 47907, USA;* [e]*Department of Fire Protection Engineering, University of Maryland, MD 20742, USA*

(*Received 21 July 2011; final version received 12 January 2012*)

Steady-state global chemistry calculations for 20 different flames were carried out using an axisymmetric Computational Fluid Dynamics (CFD) code. Computational results for 16 flames were compared with flame images obtained at the NASA Glenn Research Center. The experimental flame data for these 16 flames were taken from Sunderland *et al.* [4] which included normal and inverse diffusion flames of ethane with varying oxidiser compositions (21, 30, 50, 100% O_2 mole fraction in N_2) stabilised on a 5.5 mm diameter burner. The test conditions of this reference resulted in highly convective inverse diffusion flames (Froude numbers of the order of 10) and buoyant normal diffusion flames (Froude numbers ~0.1). Additionally, six flames were simulated to study the effect of oxygen enhancement on normal diffusion flames. The enhancement in oxygen resulted in increased flame temperatures and the presence of gravity led to increased gas velocities. The effect of gravity-variation and oxygen enhancement on flame shape and size of normal diffusion flames was far more pronounced than for inverse diffusion flames. For normal-diffusion flames, their flame-lengths decreased (1 to 2 times) and flames-widths increased (2 to 3 times) when going from earth-gravity to microgravity, and flame height decreased by five times when going from air to a pure oxygen environment.

Keywords: microgravity; diffusion flames; ethane; global; steady state

Nomenclature

0g_IDFxx	Inverse diffusion flame under microgravity with oxidiser composed, respectively, of xx and (100 - xx) mole% of O_2 and N_2.
0g_NDFxx	Normal diffusion flame under microgravity with oxidiser composed, respectively, of xx and (100 - xx) mole% of O_2 and N_2.
1g_IDFxx	Inverse diffusion flame under earth-gravity with oxidiser composed, respectively, of xx and (100 - xx) mole% of O_2 and N_2.
1g_NDFxx	Normal diffusion flame under earth-gravity with oxidiser composed, respectively, of xx and (100 - xx) mole% of O_2 and N_2.
υ	Kinetic viscosity.
D	Burner inner diameter.

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http://www.tandfonline.com

Radiation Properties of Oxygen-Enhanced Normal and Inverse Diffusion Flames

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Indiana University-Purdue University
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J. P. Gore
School of Mechanical Engineering,
Purdue University,
West Lafayette, IN 47907

Radiative heat transfer in oxygen-enhanced inverse flame configurations is an important area of study for fundamental combustion research and for terrestrial and spacecraft fire safety. Motivated by this, heat flux distributions, total radiative heat loss and spectral radiation intensities were investigated experimentally for oxygen-enhanced normal and inverse laminar ethane diffusion flames with increasing heat release rates. The oxygen mole fraction in the oxidizer was varied as 21%, 30%, 50%, and 100% with coflowing normal and inverse flame burners used to stabilize the flames. The inverse diffusion flames were essentially nonluminous while the normal diffusion flames with identical heat release rates were highly luminous. Oxygen enhancement led to reduced flame lengths, increased luminosities and increased total radiative heat loss and spectral radiation intensities for both normal and inverse diffusion flames. Using flame length as the characteristic length parameter, the normalized radiative heat flux distributions for flames approximately collapsed together, further establishing the effectiveness of the single point radiant output measurement technique. Radiative heat loss fractions of normal and inverse diffusion flames with varying oxygen concentrations in the oxidizer are compared. The radiation spectra of all flames included significant contributions from gas radiation from carbon dioxide and water vapor and the radiation spectra of the high oxygen concentration flames included contributions from soot radiation. [DOI: 10.1115/1.4005076]

Keywords: combustion and reactive flows, radiative heat transfer, experimental techniques

Introduction

Flame radiation originates from emission of energy by hot gaseous molecules such as carbon dioxide and water vapor and hot soot particles. For most flames, most of the radiation occurs in the near infrared spectral range ($0.8 \sim 10\ \mu$m). Radiation from gaseous molecules concentrates in spectral bands corresponding to specific energy transitions, whereas continuum radiation is emitted by the soot particles [1]. Radiative heat transfer in oxygen-enhanced inverse diffusion flame configurations is an important area of study for fundamental combustion research as well as for fire safety. Motivated by these considerations, a number of researchers have studied the radiative heat loss for various flame and flow configurations.

Markstein and coworkers [2,3] conducted measurements of radiative heat loss for buoyant laminar and turbulent hydrocarbon-air diffusion flames, with increasing heat release rates. In their study, measured radiation flux was used to calculate the total radiant energy from the flames under the spherical isotropic emission assumption. They reported that the radiant emission from both turbulent and laminar diffusion flames were governed by a single parameter, the smoke point flame length, and that no other specific information of fuel chemistry were required to characterize their radiant properties.

Gore and Skinner [4] reported measurements of radiative heat flux and soot volume fraction for laminar and turbulent diffusion flames burning mixtures of methane (CH_4) and acetylene (C_2H_2) with air. The radiative heat loss fractions for both laminar and turbulent flames varied linearly with mass fraction of CH_4 in the fuel. The radiative heat loss fractions for the turbulent flames with C_2H_2 content were found to increase more rapidly than those for the laminar flames.

Zheng et al. [5,6] implemented spectral radiation intensity measurements for various nonsooting turbulent diffusion jet flames. The experimental data were of value in the evaluation of radiation models that are increasingly being used in combustion simulations. Also, their work indicated the importance of spectral radiation intensity measurements at chord-like paths for the understanding of turbulent-radiation interactions.

Sivathanu and Gore [7,8] conducted coupled soot kinetics and radiation calculations in hydrocarbon-air diffusion flames. They concluded that the local radiative heat loss cools the flame and therefore, strongly influences the soot nucleation, formation and oxidation rates. Further, for strongly radiating flames, the relationships between temperature and mixture fraction were found to vary significantly at different locations and affected the soot kinetics processes. Kaplan et al. [9,10] and Smooke et al. [11] developed numerical models for simulations of axisymmetric hydrocarbon-air diffusion flames. Recently, Bennett et al. [12] conducted simulations of oxygen-enhanced axisymmetric laminar methane flames and Katta et al. [13] conducted simulations of an ethylene-air inverse diffusion flame (IDF). The results from these models further confirm that radiative heat loss changes the overall temperature, species concentration, and/or soot volume fraction distributions in the flame.

Shaddix et al. [14] studied steady and pulsed sooting IDFs. They measured OH and polyaromatic hydrocarbon (PAH) laser induced fluorescence, soot laser induced incandescence (LII), and soot thermal emission at 850 nm and found the relative positions of different structural features to be very similar in the normal diffusion flames (NDFs) and the IDFs. The OH signals from the NDFs and the IDFs were reported to be identical, while the PAH and the soot concentration signals from the IDFS were smaller than those from the NDFs. The near infra-red radiation was found to be approximately 25% lower for the IDFs when compared to

[1]Corresponding author.

Contributed by the Heat Transfer Division of ASME for publication in the Journal of Heat Transfer. Manuscript received May 20, 2009; final manuscript received August 22, 2011; published online December 9, 2011. Assoc. Editor: Walter W. Yuen.

AC 2009-1911: Project-Based Learning in Introductory Thermodynamics

Sivakumar Krishnan, M. Razi Nalim

Abstract

The sophomore year is a critical decision point for engineering students. In freshman year, they might have been given exciting introductions to engineering design and applicable science by faculty dedicated to teaching. In sophomore year, they encounter traditional lecture presentation of challenging engineering science courses, probably by faculty more dedicated to research than undergraduate teaching. This may present either a threat or opportunity for retention of students. Introductory thermodynamics is usually such a 'gateway' course that must introduce to students both a new branch of science and an unfamiliar abstract method of scientific reasoning. Test scores, surveys, and classroom assessments indicate that many students did not really understand the laws of thermodynamics until the end of the course, if at all, even if they could apply the 'formulae'. A supplemental or alternative approach such as project-based learning may be very useful.

This paper describes a design project in a mechanical engineering program at an urban research university. It was initially supplemental, but became a framework for alternative presentation of thermodynamics in a problem-based learning approach. The design project is intended to apply key topics in thermodynamics to a familiar domestic problem of heating, ventilation, and air conditioning (HVAC) system design for a residential application, based on manufacturer's specifications, second-law principles, and actual climate data. Students work in small teams of 2-3.

The project is assigned and discussed at the beginning of the semester, so that it naturally motivates the learning of needed concepts throughout the semester. Teams were given annual climate data for different locations and defined home insulation, infiltration, and heat source properties. They were required to perform an energy audit and equipment thermodynamic performance evaluation to select specific units appropriate to the calculated heating and cooling loads. They recalibrate manufacturer ratings of the chosen units for local climate, and calculate the average cost of heating and cooling as well as the lifetime cost of the systems. This involved identifying the vendor and obtaining the necessary performance and cost data from them. Discussions were encouraged among the teams using an online discussion forum. Each student team was required to submit a final project report at the end of the semester and present their data.

This project was implemented for a number of years by four different instructors. This holistic design and teamwork experience at the sophomore level appears to have given students a springboard benefit in the curriculum that persists into later courses and professional practice. Direct and indirect assessments of the project-based method were conducted and the results will be presented in the paper. The design project is assessed based on classroom presentations and a written report with technical analysis, design process, and professional conclusions. It is intended to continue restructuring the course syllabus around this project in the future.

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Analytical predictions of shapes of laminar diffusion flames in microgravity and earth gravity

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Flame shape is an important observed characteristic of flames that can be used to scale flame properties such as heat release rates and radiation. Flame shape is affected by fuel type, oxygen levels in the oxidiser, inverse burning and gravity. The objective of this study is to understand the effect of high oxygen concentrations, inverse burning, and gravity on the predictions of flame shapes. Flame shapes are obtained from recent analytical models and compared with experimental data for a number of inverse and normal ethane flame configurations with varying oxygen concentrations in the oxidiser and under earth gravity and microgravity conditions. The Roper flame shape model was extended to predict the complete flame shapes of laminar gas jet normal and inverse diffusion flames on round burners. The Spalding model was extended to inverse diffusion flames. The results show that the extended Roper model results in reasonable predictions for all microgravity and earth gravity flames except for enhanced oxygen normal diffusion flames under earth gravity conditions. The results also show trends towards cooler flames in microgravity that are in line with past experimental observations. Some key characteristics of the predicted flame shapes and parameters needed to describe the flame shape using the extended Roper model are discussed.

Keywords: flame shapes; Roper model; microgravity; inverse diffusion flames; oxygen enhanced

Nomenclature

C	coupling function $= (f - f_a)/(f_0 - f_a)$
d	burner diameter
D	mass diffusivity
f	$\bar{\nu}X_F - X_{O2}$
Fr	Froude number $= u_0^2/gd$
g	acceleration owing to gravity on earth $= 9.81\ m/s^2$
I_0	Bessel function

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Method for measuring the amount of an organic substance in a food product with infrared electromagnetic radiation
Patent number: 7288768
Abstract: A method for measuring the amount of an organic substance in a food product with infrared electromagnetic radiation.
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Inventors: Jay P. Gore, Rakesh Singh, Abdullatif Tay, Sivakumar Santhanakrishnan

Description

This application claims priority under 35 U.S.C. §119(e) to U.S. Provisional Patent Application Ser. No. 60/396,851 entitled "METHOD FOR MEASURING THE AMOUNT OF AN ORGANIC SUBSTANCE IN A FOOD PRODUCT WITH INFRARED ELECTROMAGNETIC RADIATION" which was filed on Jul. 18 2002 by Jay P. Gore et al. which is expressly incorporated by reference herein.

TECHNICAL FIELD OF THE INVENTION

The present invention generally relates to a method of measuring an amount of an organic substance contained within a food product. The present invention particularly relates to a method of measuring the amount of an organic substance contained within a food product utilizing a limited number of selected infrared wavelength bands.

BACKGROUND OF THE INVENTION

Adulteration of food products, involving the replacement of high cost ingredients with lower grade and cheaper substitutes can be very attractive and lucrative for a food manufacturer or raw material supplier. The adulteration of food products is not only a major economic fraud, but can also have major health implications to consumers. In the 1980s, more than 400 deaths and 20,000 casualties occurred from the disease known as "Spanish toxic syndrome," caused by the consumption of adulterated oil. Therefore, the detection of adulteration is of importance.

Olive oil production is a big business subject to serious attempts at fraudulent marketing of low-quality or adulterated oils. There are various methods for extracting the oil that yield different quality grades. Extra virgin olive oil is obtained from the olive *Olea europaca sativa* H by purely mechanical means, and the lower grade oils are obtained by solvent extraction, heat treatment, esterification, or refining. The composition of the oils is based on the fatty acids present in the tri-acyiglycerols and their location on the glycerol backbone. This composition varies not only with the type of oil and extraction method but also with geographical origin and meteorological effects during the growth and harvest of the olives. This variation can be used for oil authentication and the identification of adulteration. Various physical and chemical tests have been used to establish the authenticity of olive oil and to detect the level of adulterants in it. UV spectroscopy based on 208-210 and 310-320 nm has been widely used to detect the adulteration of virgin with the refined olive oil. A second derivative spectrometry method was reported to be able to detect the adulteration at a level of 6%.

Analysis of fatty acid profile after methylation using gas chromatography (GC) has been reported for the quantification of seed oils in olive oil. HPLC analysis of the fatty acid and triglycerides composition was also studied for detection of adulteration of olive oil. Nuclear magnetic resonance (NMR) analysis and a spectroflourometric methods have also been reported for detecting the adulteration of olive oil.

However, a drawback to some of these conventional methods of analyzing oils is that they are destructive and time-consuming, involving the hydrolysis and methylation of the resulting fatty acids. In addition, some of these approaches loose any information associated with the location of the fatty acids on the original glycerol backbone. Accordingly, authentication of the constituents of a food product is a major challenge in food product analysis.

Therefore, in light of the above discussion, it is apparent that what is needed is a method of measuring an amount of an organic substance contained within a food product that addresses one of more of the above discussed drawbacks.

SUMMARY OF THE DISCLOSURE

In one illustrative embodiment, there is provided a method of measuring an amount of an organic substance contained within a food product. The organic substance has an infrared absorption spectrum which includes a set (n) of wavelength regions. Each of the wavelength regions substantially correspond to an absorption band of the absorption spectrum. The