IUPUI

CENTER FOR RESEARCH AND LEARNING

INDIANA UNIVERSITY–PURDUE UNIVERSITY INDIANAPOLIS

Multidisciplinary Undergraduate Research Institute

MURI Project Proposal Form

Section I: Proposal Cover Page

Date of submission: 04/22/2015

Proposed project title:

Investigation of plasma-assisted turbulent jet ignition for rapid combustion applications

Principal Mentor	
Name: Razi Nalim	Title: Professor
Phone number: 317-278-3010	Email: mnalim@iupui.edu
Department: Mechanical Engineering	School: Engineering & Technology

Co-Mentor	
Name: Dr. Afshin Izadian	Title: Assistant Professor
Phone number: 317-274-7881	Email: aizadian@iupui.edu
Department: Engineering Technology	School: Engineering & Technology

Co-Mentor	
Name: Mohammad Ebrahim Feyz	Title: PhD student
Phone number: 317-261 1743	Email: mofeyz@iupui.edu
Department: Mechanical Engineering	School: Engineering & Technology

Co-mentor	
Name: Ali Tarraf Kojok	Title: MS student
Phone number: 843 986 6340	Email: altarraf@iupui.edu
Department: Mechanical Engineering	School: Engineering & Technology

Stipend is requested for the three co-mentors only.

Please note that preference will be given to projects that include mentors from multiple disciplines.

Section II: Student Request Page

Total number of students requested: _____6_____
(Note: The total number of students must exceed by two the number of mentors)

Total Number of freshmen and/or sophomores to be recruited: _____1_____
(Note: Preference will be given to projects that include at least one freshman and/or sophomore)

Disciplines or majors of students (preference will be given to projects that include at least two disciplines or majors): _Engineering Technology, Mechanical Engineering, Physics, and Electrical Engineering

Skills expected from students: Fluid mechanics, plasma physics, thermodynamics, general laboratory skills, data acquisition & control, circuit design and fabrication

Names of students you request to work on this project.

(Mentors are invited to recommend students that they would prefer to work on the proposed project. Please provide an email address and a rationale; for example, a student may have an essential skill, may already be working on a similar project, or may be intending to apply to graduate school to pursue the same area of research.)

The Center for Research and Learning will consider the students requested below, but cannot guarantee placement of specific students on teams.

Name of Student:	**Student's Email:**	**Rationale:**
1) Not yet identified		
2)		
3)		
4)		
5)		
6)		

Section III: Proposal

1. Research Objective & Significance

1.1. Introduction

In combustion-driven machines, a significant challenge is to reliably ignite the mixture of air and fuel [1]. An appropriate ignition process must ensure ignition in the desired temporal and spatial point. Often ignition is achieved by an electric spark (in piston engines, for example) in which chemical reaction begins as the temperature reaches a sufficient level and a flame kernel is initiated [2]. Spark ignition may be ineffective in a hostile environment [4], for instance, in pulse detonation engines and supersonic combustors. Typically, spark ignition works for slower combustion processes (above 20 ms time scales) as in piston engines [5]. Formation of the flame kernel by spark ignition is sensitive to surrounding fuel-air ratio, turbulence intensity and features of the flow near the spark plug [6].

Turbulent jet ignition (TJI) is sometimes used to rapidly ignite air-fuel mixture in combustion chamber with harsh environments and fast ignition requirements such as wave rotor combustors (WRC) and scramjets [7]. For these applications, combustion must be initiated and completed rapidly (< 20ms time scale) [8]. In TJI, a pilot portion of air and fuel are combusted in a pre-chamber. After the combustion products reaches certain temperature and builds up enough pressure in the pre-chamber, the hot and highly turbulent exhaust gases are discharged through one or more small orifices into the main chamber which contains air-fuel mixture [9].

Experiments and computer simulations at IUPUI's Combustion & Propulsion Research Laboratory (Fig. 1) with funding from the National Science Foundation (NSF) illustrate the evolution of the ignition by TJI. It is observed in Fig. 2 that as the hot turbulent jet penetrates into the main chamber, it ignites the air-fuel mixture around it in quite fast manner. TJI enables very fast burn rates due to the ignition system producing multiple, distributed ignition sites, which consume the main charge rapidly and with minimal combustion variability [10]. The main features of the TJI are; (a) fast ignition speed, (b) high penetration into the air-fuel mixture, (c), lower sensitivity local flow features.

Ignition by hot turbulent jet occurs because of two main thermal and chemical factors acting in parallel. The unburnt air-fuel mixture adjacent to the turbulent jet is ignited primarily due to [11]: (a) transport of energy from jet to unburnt mixture mainly by convection and radiation and (b) transport of chemical active radicals from the jet to the unburnt air-fuel mixture. The former factor can heat up the mixture and initiate the exothermic chemical reactions which can lead up to the kernel formation. The latter factor can facilitate the faster occurrence of chemical reactions by adding active and intermediate radicals such as OH, H, O atoms.

The use of low calorific fuels and lean fuel/air ratio to meet environmental regulations thas increased. Also, the use of natural gas has increased due to its relatively low cost. These approaches require ignition of a fuel-air mixture with low reactivity. TJI still may still fail or require too much time to ignite mixtures with lower reactivity, especially at cold starting conditions. Nalim et al [12] showed that TJI can have a great performance for rapidly igniting the H_2-air mixtures while it is not efficient enough for igniting CH_4-air mixtures which inherently has lower chemical reactivity. This proposal is focused on an idea by which the active radical content of the hot turbulent jet can be improved and thus the TJI effectiveness for ignition would be enhanced.

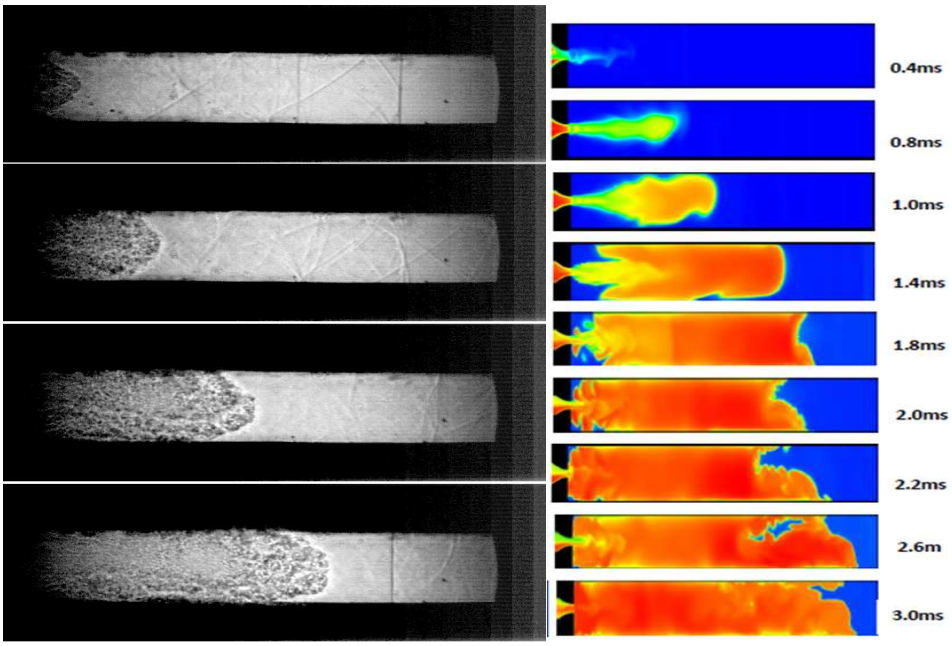

Fig.1 The evolution of combustion after injection of the hot-turbulent jet; Flow visualization (Left) and numerical simulation (Right) (Courtesy of CPRL, IUPUI)

1.2. Plasma-assisted TJI

Plasma is a state of matter that is caused by exciting the gas molecules via applying extremely high electrical energy which produces a mixture of electrons, ions, and other active atoms and radicals from the gas molecules [13]. Plasma can acts as an effective ignition source [13] for combustible mixture, and pulsed plasma jets are potential ignition sources for lean-burning combustion engines. The plasma can be considered as an intensive production source of radicals and ions which can initiate the combustion process. The plasma arc (the gap between anode and cathode) is relatively small. Like a spark, the plasma ignition still may fail in applications which require rapid and penetrative ignition source i.e. WRC, transonic and supersonic engines [14,15]. The proposal aims to integrate the benefits of plasma as a major generator of active radicals and ions with TJI.

Figure 2 is a schematic of a preliminary concept in which the radicals and ions produced by the plasma arc (time step 1) are torched into the main chamber via the turbulent jet (time step 2). Thus, plasma-assisted TJI combines these features and may achieve more effective ignition for low reactive fuel-air mixture (for example mixtures with high percent of methane or high excess air).

2. Specific Objectives of project

For realization of plasma-assisted TJI, some initial questions must be answered in order to evaluate the feasibility of this novel idea. This project will provides an initial assessment of the concept. Tasks assigned to individuals or subgroups of the MURI team are shown with the timeline below:

Tasks		Month						
No.	Description	1	2	3	4	5	6	7

1	Literature review and primary studies about TJI and plasma							
2	Specifying the plasma type and characteristics that fit our application							
3	Design and fabrication of the electrical components							
4	Modification of the current WRC rig for plasma torch installation							
5	Conducting the experiments and evaluating plasma effectiveness							
6	Post-processing of the data and preparation of the final report							

Based on the results of this MURI project, it is planned to prepare a competitive proposal for external and internal funding. The proposal may be submitted to the NSF, sponsor of current TJI work at CPRL, or to other agencies or businesses. Dr. Nalim has a strong record of external funding from numerous agencies and from industry (see CV appended).

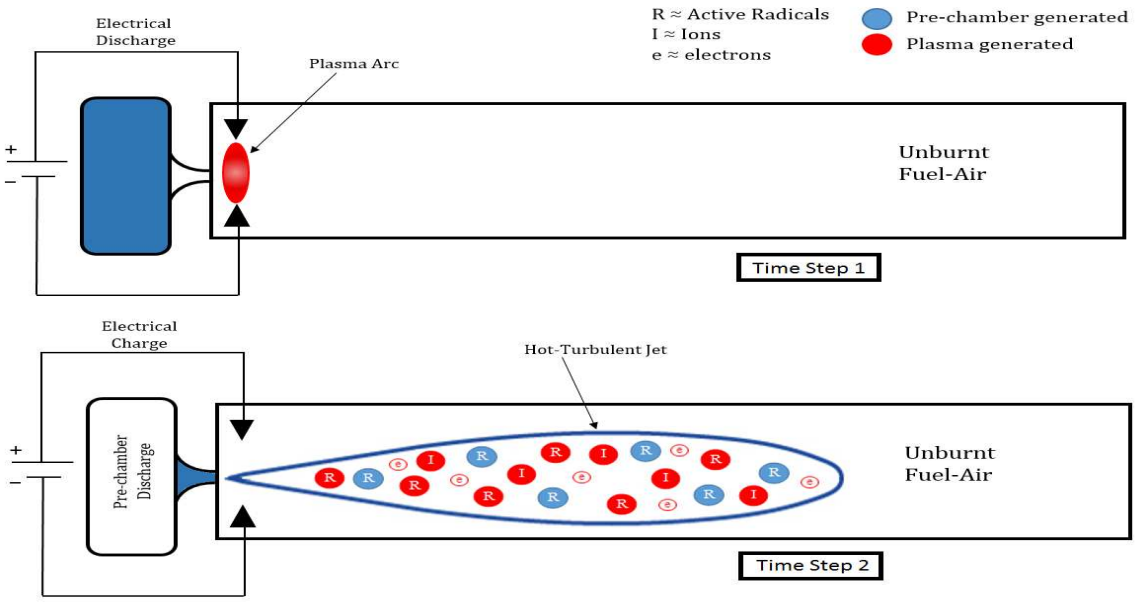

Fig.2 Concept for a pulsatile plasma-assisted TJI
(Time steps 1 and 2 occurs repetitively for every combustion cycle)

3. Resources and facilities

CPRL includes a wave rotor ignition test rig (Fig. 3) consists of two combustion chambers namely: the pre-chamber and the main chamber. The hot combustion products from a pre-chamber are discharged into the main chamber in the form of a highly turbulent-hot jet which can ignite the fuel-air mixture in the main chamber. Pressure transducers, Schlieren imaging, and high speed videography through a full-length quartz window record ignition, flame propagation and shock wave interactions. Cantera is an open source and object-oriented software tool for problems involving chemical kinetics, thermodynamics, and transport processes, available to MURI students as

designated. The students will have access to the machine shop at the School of Engineering & Technology for manufacturing and machining the components. The Energy Systems and Power Electronics Laboratory can assist the students to put into practice their electrical knowledge by designing the circuits via computer software and fabricate them.

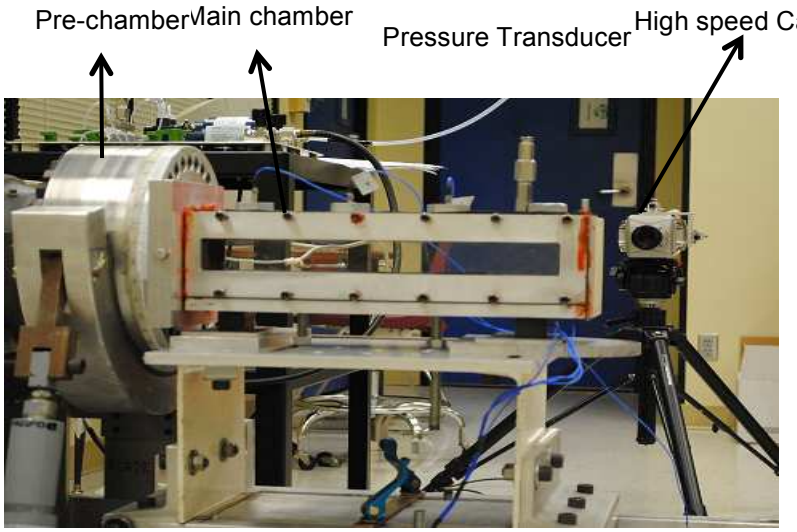

Fig.3 Wave rotor ignition rig at CPRL (Courtesy of CPRL, IUPUI)

4. Opportunities for Undergraduate students

Due to the interdisciplinary nature of the plasma assisted TJI, the students with different training and skills are required. The project requires knowledge in Physics, Electrical Engineering, Mechanical Engineering, and Engineering Technology. The students involved in the project will get exposure to a research topic that is being developed in leading research organizations and industries (NASA, NSF, Rolls- Royce, U.S. Department of Energy). The students will learn to apply their knowledge gained through the courses in series of mathematical, computer and experimental procedures. Moreover, by working with graduate students and faculty as a team, they will gain team skills and collaborative tasks required for a successful career in the future.

5. Tasks for Students and Mentors

Tasks are described above in the timeline. The proposed work will require skills in

- Physics: Identifying the properties of plasma arc and key parameters
- Electrical Engineering: Design and implementation of the plasma generation circuit
- Mechanical Engineering: Design the fixture and plasma jet and modification of the ignition rig.
- Engineering Technology: Fabrication of components and assembly of the system. Project management, safety inspection and training.

The mentor, Prof. Razi Nalim, Director of CPRL, will be responsible for overall guidance for the co-mentors and the MURI students. He will ensure that each co-mentor is involved in guiding the students as needed. Additionally, Dr. Nalim will ensure appropriate milestones for the work. The co-mentor Mohammad Ebrahim ('Moh') Feyz would be responsible to prepare a thorough guideline and strategy for the students in their respective scope of work. Also he would assess each phase of progress to make sure it is aligned with the objectives of project. The co-mentor Dr.

Afshin Izadian would be providing inputs on the electrical issues of the rig design and providing the group with appropriate trainings if necessary. The co-mentor Ali Taraf Kojok would be responsible for familiarizing the students with manufacturing processes and giving ideas for better implementation of the new components into the test rig.

6. Plan for effective communication and deliverables

The project communication infrastructure and time management will be implemented through the following process:

6.1. Weekly meetings to discuss and review the progress of the work carried out and also to address the difficulties that students are facing during the course of research
6.2. Students will perform background research in the literature and technical publications related to turbulent jet ignition and plasma ignition and sharing their findings, insights and questions
6.3. Students will contact external suppliers and other researchers to obtain the best materials for the project, and to seek advice from professionals under the guidance of their mentors
6.4. Preparation of the report for each step of the project
6.5. Preparation of the results in form of a manuscript ready for publication

7. Benefits and Outcomes

The outcome of the project would be establishment a successful configuration for integrating plasma with the current TJI system. Students will learn more about practical aspects of engineering in a collaborative environment. Upon the achievement of this goal, TJI can be successfully employed for rapid ignition of fuel-air mixtures with low reactivity such as syngas combustion or ultimately lean combustions. With knowledge gained from the proposed study, useful information for understanding of combustion processes in industrial applications under various operating conditions can be obtained. Subsequent to the completion of this project, it would have the potential to be participated in the national competitions and grant opportunities.

8. Budget

A total equipment budget of $ 2000 is requested to purchase the material and equipment. The primary estimation of the items needed are as follows: Circuits, boards and electrical material, Fixture components with machining, Plasma torch (off-the-shelf), Controls (electrical and mechanical)

9. Risk Management

No risk requiring special oversight are involved in the proposed research.

10. *Center for Research and Learning generally shares the text of funded proposals on the web so that prospective students can learn about available MURI projects. Please let us know if it is OK with you to post your proposal on the CRL MURI webpage by checking one of the following answers:*

☒ **YES**

Section IV: References/Bibliography (insert 1-2 pages as needed)

1. Ballal. D. R, A General Model Of Spark Ignition For Gaseous And Liquid Fuel-Air Mixtures, Symposium (International) on Combustion, 1981
2. Heywood JB. Internal combustion engine fundamentals. Mc Grow Hill Book Company; 1988.
3. Atzler, F., F. X. Demoulin, M. Lawes, Y. Lee, and N. Marquez. "Flame speed oscillations in combustion of two-phase mixtures." Revista Técnica de la Facultad de Ingeniería. Universidad del Zulia 30, no. 1 (2007).
4. Cordier, M., A. Vandel, G. Cabot, B. Renou, and A. M. Boukhalfa. "Laser-induced spark ignition of premixed confined swirled flames." *Combustion Science and Technology* 185, no. 3 (2013): 379-407.
5. P. Akbari and M. R. Nalim (2009) Review of Recent Developments in Wave Rotor Combustion Technology, Journal of Propulsion and Power, Vol. 25, No. 4, pp. 833-844.
6. Li, Suhui, Xiaoyu Zhang, Di Zhong, Fanglong Weng, and Min Zhu. "Syngas Spark Ignition Behavior at Simulated Gas Turbine Startup Conditions."*Combustion Science and Technology* 186, no. 8 (2014): 1005-1024.
7. Bilgin, M., 1998, Stationary and Rotating Hot Jet Ignition Flame Propagation In a Premixed Cell, Ph.D. Thesis, University of Washington, Seattle, Washington.
8. Weber, R., (1997) A Pressure-Wave Machine with Integrated Constant-Volume Combustion, Swiss Energy Research Report 1977–1997, National Foundation of Energy Research, Switzerland, Project No. 426, pp. 142–153
9. Nalim, M. R., and Pekkan, K., "Internal Combustion Wave Rotors for Gas Turbine Engine Enhancement," ASME Paper IGTC-2003-FR-303, 2003
10. Paxson, D. E., "Numerical Simulation of Dynamic Wave Rotor Performance," *Journal of Propulsion and Power*, Vol. 12, No. 5, 1996, pp. 949-957
11. Akbari, P., Nalim, M. R., and Müller, N., (2006) A Review of Wave Rotor Technology and Recent Developments, Journal of Engineering for Gas Turbines and Power, Vol. 128, No. 4, pp. 717–735.
12. Elharis, T.M., Wijeyakulasuriya, S.D., Nalim, M.R., "Analysis of Deflagrative Combustion in a Wave-Rotor Constant-Volume Combustor," *49th AIAA Aerospace Sciences Meeting*, Orlando, FL, 2011.
13. Koleczko, Andreas, Walter Ehrhardt, Stefan Kelzenberg, and Norbert Eisenreich. "Plasma ignition and combustion." *Propellants Explosives Pyrotechnics* 26, no. 2 (2001): 75-83.
14. Starikovskii, A. Yu. "Plasma supported combustion." *Proceedings of the Combustion Institute* 30, no. 2 (2005): 2405-2417.
15. Li, Ting, Igor V. Adamovich, and Jeffrey A. Sutton. "Investigation of the effects of non-equilibrium plasma discharges on temperature and OH concentrations in low-pressure premixed flames." In *Proc. AIAA SciTech, 52nd Aerospace Sciences Meeting (National Harbor, MD, 13–17 January 2014)*, pp. 2014-0664. 2014.

Section V: CVs/Resumes

M. RAZI NALIM, P.E., Ph.D.

Professor & Associate Dean, IUPUI School of Engineering & Technology
Director, Combustion & Propulsion Research Laboratory, IUPUI
http://www.iupui.edu/~meengr/cprl/

Professional Education

Indian Institute of Technology, Kanpur, India	Mechanical Engineering	B.Tech., 1983
Cornell University, Ithaca, NY	Mechanical Engineering	M.S., 1985
Cornell University, Ithaca, NY	Aerospace Engineering	Ph.D., 1994
NASA Lewis Research Center, Cleveland, OH	Combustion & Turbomachinery	Post-doc, 1994-1997

Experience: 5 yrs industry, 3 yrs government, 17 yrs academic

- 2013-present, Chief Scientist, Aerodyn Combustion, LLC, Indianapolis, IN.
- 2014-present, Associate Dean for Research, School of Engineering & Technology, (IUPUI), IN.
- 2010-2013, Associate Dean for Research & Graduate Programs, Purdue School of Engineering & Technology, (IUPUI), IN.
- 2008-2010, Associate Chair of Mechanical Engineering, IUPUI, Indianapolis, IN.
- 2004-2008: Graduate Chair of Mechanical Engineering, IUPUI, Indianapolis, IN.
- 1997-present, Assistant/Associate/Full Professor, Mechanical Engineering, IUPUI, Indianapolis, IN.
- 1994-1997, Research Associate, NASA Lewis Research Center, Cleveland, OH.
- 1994, Project Engineer, CFD Research Corporation, Huntsville, AL.
- 1985-1989, Manager - Research Programs / Research Staff Engineer, Diesel and Gas Engineering Co., Beaver Dams, NY.

Selected & Recent Publications

- A. Karimi, M. Rajagopal, R. Nalim, "Traversing Hot-Jet Ignition in a Constant-Volume Combustor," *ASME Journal of Engineering for Gas Turbines & Power*, vol. 136, No. 4, 2014.
- V. Kilchyk, R. Nalim, & C. Merkle, "Scaling Interface Length Increase Rates in Richtmyer-Meshkov Instabilities," *ASME Journal of Fluids Engineering*, vol. 135, no. 3, 2013.
- M.R. Nalim, Z.A. Izzy, & P. Akbari, "Rotary wave-ejector enhanced pulse detonation engine," *Shock Waves*, vol. 22, no. 1, pp. 23-38, 2012.
- A. Karimi, M. Rajagopal, R. Nalim, "Traversing Hot-Jet Ignition in a Constant-Volume Combustor," ASME Paper GT2013-95797, IGTI Turbo Expo, San Antonio, TX, Jun 2013.
- R. Helfenbein, R. Nalim, M. Rajagopal, "Faculty Perceptions of Project-Enhanced Learning in Early Engineering Education: Barriers and Benefits," FIE 2012, Seattle, WA, Oct 2012.
- R. Nalim, M. Rajagopal, R. Helfenbein, "Project-Enhanced Learning in Engineering Science Education," FIE 2012 Workshop, Seattle, WA, Oct 2012.
- P. Snyder & R. Nalim, "Pressure Gain Combustion Application to Marine and Industrial Gas Turbines," ASME Paper GT2012-69886, IGTI Turbo Expo, Copenhagen, Jun 2012. (Best paper award)
- V. Kilchyk, R. Nalim & C. Merkle, "Laminar Premixed Flame Fuel Consumption Rate Modulation by Shocks and Expansion Waves," *Combustion & Flame*, vol. 158, no. 6, pp. 1140-1148, June 2011.
- H. Li, M.R. Nalim & C. Merkle, "Transient Thermal Response of Turbulent Compressible Boundary Layers," *ASME Journal of Heat Transfer*, Vol. 133, 2011.

- V. Kilchyk, R. Nalim & C. Merkle, "Baroclinic Vortex Sheet Production by Shocks and Expansion Waves," *Shock Waves*, vol. 20, no. 5, 367-380, 2010.
- Yu Matsutomi, Scott E. Meyer, Sameera Wijeyakulasuriya , Zuhair Izzy, M. Razi Nalim, Masayoshi Shimo , Mike Kowalkowski and Phil H. Snyder, "Experimental Investigation on the Wave Rotor Combustor," AIAA 2010-7043, 46th Joint Propulsion Conf., Nashville, TN, 2010.
- P. Akbari, & M. R. Nalim, "Review of Recent Developments in Wave Rotor Combustion Technology," *AIAA Journal of Propulsion & Power*, v. 25, no. 4, pp.833-844, Jul-Aug 2009.
- V. Kilchyk, R. Nalim, & C. Merkle, "Shock and Expansion Wave – Laminar Flame Interaction," 6th International Colloquium on Pulsed and Continuous Detonations, Moscow, Russia, Nov 2008.
- Sameera D Wijeyakulasuriya & M. Razi Nalim, "Gas Injection Strategies in Confined Subsonic Cross Flow for Wave Rotor Fueling," AIAA 2008-4867, 44th Joint Propulsion Conf., Hartford, CT, 2008.
- P. Akbari, M.R. Nalim, S.D Wijeyakulasuriya, & N. Mueller "Wave Disk Engine for Small-Scale Power Generation," AIAA 2008-4879, 44th Joint Propulsion Conf., Hartford, CT, 2008.
- P. Akbari, M.R. Nalim, & P.H. Snyder, "Numerical Simulation and Design of a Combustion Wave Rotor for Deflagrative and Detonative Propagation," 42nd Joint Propulsion Conf., AIAA Paper 2006-5134, Sacramento, 2006.
- M.R. Nalim, "Assessment of Combustion Modes for Internal Combustion Wave Rotors", *ASME J. of Engineering for Gas Turbines & Power*, v.121, April 1999.
- M.R. Nalim & D.E. Paxson, "A Numerical Investigation of Premixed Combustion in Wave Rotors". *ASME J. of Engineering for Gas Turbines & Power*, v.119, p.668, 1997.

Selected Research Grants & Contracts at IUPUI

1. National Science Foundation via Aerodyn Combustion LLC, "Wave Rotor Constant-Volume Combustion for Energy Efficiency and Greenhouse Gas Abatement in Gas Turbine Engines," Small Business Technology Transfer (STTR) project, in negotiation 2015, co-PI for IUPUI, $100,000 ($225K total award)
2. NASA Aeronautics Research Institute, "Hybrid Wave-Rotor Electric Aero-Propulsion (HyWREAP)", $200,000, PI, 2013.
3. National Science Foundation, "Transient Jets and Re-Ignition for Energy Efficiency Gains from Confined Combustion," $328,120, PI, 2012-2015.
4. National Science Foundation, "Implementation, Dissemination, Barrier Identification and Faculty Training for Project-Enhanced Learning in Gateway Engineering Courses," $200,000, PI, 2010-2012.
5. Rolls-Royce Corporation, "Methods Development for Wave Rotor Combustor Design," PI, $212,254, 2009-2010.
6. Rolls-Royce North American Technologies 'Liberty Works,' "Wave Rotor Combustion Rig Design, Analysis, and Test Support," PI, $491,708, 2007-2008.
7. Rolls-Royce North American Technologies 'Liberty Works,' "Wave Rotor Combustion Rig Test Article Procurement," PI, $136,072, 2006.
8. NASA Glenn Research Center (subcontract via Allison Advanced Development Co.), "CVCCE Technology Utilizing Wave-Rotor Configurations – Seals Development," PI, $68,197, 2004 - 2005.
9. State of Indiana 21st Century Research & Technology Fund, "Expansion of Propulsion and Power Center of Excellence," co-PI $1,608,881 total, PI for IUPUI $366,526 grant via Rolls-Royce Allison, 2004-2007.
10. Cummins Inc., "Engine Cooling System Design and Evaluation", PI, $101,877, 2003-2005.
11. State of Indiana 21st Century Research & Technology Fund, "Advanced Propulsion and Power Institute: Innovative Propulsion and Systems and High-Fidelity Computer Simulation," co-PI for $2,000,000 total grant, PI for IUPUI grant via Rolls-Royce Allison of $252,832, 2001-2002.
12. Dresser-Rand, "Two-Stroke Engine Flow Simulation, Phase I & II," $78,360, PI, 2000-2002.
13. Defense Advanced Research Projects Agency (subcontract via Allison Advanced Development Co.), "Wave Rotor Detonation Engine Performance," $79,574, PI, 2001-2002.
14. Blue Operations-LLC (Amazon.com founder Jeff Bezos), "Wave Rotor Engine for Space Propulsion" $14,943, PI, 2001.

Afshin Izadian, Ph.D.

Assistant Professor, Department of Engineering and Technology,IUPUI
http://www.engr.iupui.edu/~aizadian/

Affiliation:

- Director of Energy Systems and Power Electronics Laboratory, Purdue School of Engineering and Technology, Indianapolis
- Assistant Professor at Purdue School of Engineering and Technology
- Approved Graduate Faculty at Purdue University West Lafayette
- Research Member at Energy Center, Discovery Park, Purdue University
- Research Faculty at Richard Lugar Center for Renewable Energy
- Affiliated with Integrated Nanosystems Development Institute (INDI)

Education:

- Postdoctoral Researcher, University of California at Los Angeles (UCLA), 2009
- PhD, Electrical Engineering, West Virginia University (WVU), 2008
- MS, Electrical Engineering, Iran University of Science and Technology (IUST), 2001

Publications:

Awarded Patents

Afshin Izadian, US Patent 8,878,384 Central wind turbine power generation Awarded: Nov. 04, 2014,

Book, Book Chapter, CD Proceeding

1. IEEE EIT, USB Proceeding on Electro-Information Technology, ISBN: 978-1-4799-4313-5, 2014.
2. IEEE EIT, USB Proceeding on Electro-Information Technology, ISBN: 978-1-4673-5207-9, 2013.
3. IEEE EIT, CD Proceeding on Electro-Information Technology, ISBN: 978-1-4673-0818-2, 2012.

Journals

J-2014

1. Majid Deldar, Afshin Izadian, Sohel Anwar, "Modeling of a Hydraulic Wind Power Transfer Utilizing a Proportional Valve," IEEE Transactions on Industry Applications, Accepted, In Press 2014.
2. Masoud Vaezi, Afshin Izadian, "Piecewise Affine System Identification of a Hydraulic Wind Power Transfer System", IEEE Transactions on Control System Technology, accepted with minor revisions, 2014.
3. Amardeep Singh, Afshin Izadian, Sohel Anwar, "Adaptive Nonlinear Model-Based Fault Diagnosis of Li-ion Batteries," IEEE Transactions on Industrial Electronics, 2014. Accepted.

4. Amardeep Singh, Afshin Izadian, Sohel Anwar, "Model Based Condition Monitoring in Lithium-Ion Batteries," ELSEVIER, Journal of Power Sources, 2014. Accepted.
5. Afshin Izadian, Sina Hamzehlouia, Majid Deldar, Sohel Anwar, "Hydraulic Wind Power Transfer System: Operation and Modeling,"IEEE Transactions on Sustainable Energy, 2014, Vol. 5, Issue 2, Pp 457-465, April 2014.

J-2013

6. Afshin Izadian, "Self-Tuning Fault Diagnosis of MEMS," IFAC, Journal of Mechatronics, vol. 23, issue 8, pp. 1094–1099, Dec. 2013.
7. Afshin Izadian, Nathaniel Girrens, Pardis Khayyer, "Renewable Energy Policies, A Brief Review of the Latest U.S. and E.U. Policies," IEEE Industrial Electronics Magazine, vol. 7, issue 3, September 2013.
8. Afshin Izadian, "Controllable Lenses for Photovoltaic Energy Generation Enhancement," IEEE Transactions on Electron Devices, Journal of Photovoltaic, vol. 3, no. 3, pp. 1113-1117, July 2013.
9. Sina Hamzehlouia, Afshin Izadian, Sohel Anwar, "Modeling and Control of Hybrid-Hydraulic Electric Vehicles," Advances in Automobile Engineering Journal, vol. 2, issue 1, February 2013.

J-2012

10. E. Yildiz, M. Farooqi, S. Anwar, Y. Chen, A. Izadian, "Nonlinear Constrained Optimization of Hybrid Electric Vehicles," Invited, Journal of Automotive Safety and Energy, vol. 3, no. 1, pp. 64-70, October 2012

Mohamad Ebrahim Feyz

799 W. Michigan Street, Indianapolis, IN 46202-5160 CPRL, ET 109	Email: m.e.feyz@gmail.com mofeyz@iupui.edu	Phone: 317- 261 1743

Graduation:

M.Sc. in Mechanical Engineering, Division of Energy Conversion, Fersowsi University of Mashhad-2013 (GPA: 3.7); ***Thesis Topic:*** *Thermodynamic Analysis of the Effects of Fuel-Air Equivalence Ratio on the Operation of a Premixed-Low Swirl Burner*

B.Sc. in Mechanical Engineering, Fluid and Heat Physics, Fersowsi University of Mashhad-2010 (GPA: 3.5); ***Thesis Topic:*** *Exergy and Fuel Economy Analysis of an EGR-Equipped Diesel Engine*

Journal Publications:

- ✓ "Experimental Investigation of the Exhaust Gas Recirculation Effects on Irreversibility and Brake Specific Fuel Consumption of Indirect Injection Diesel Engines", M. Ghazikhani, M.E. Feyz, A. Joharchi, 2010, *Journal of Applied Thermal Engineering*
- ✓ "Effects of Altitude on the Soot Emission and Fuel Consumption of a Light-Duty Diesel Engine", M. Ghazikhani, M. E. Feyz, O. Mahian, 2013, *Journal of Transport*
- ✓ "Exergetic Performance of a Cylindrical Methane-Air Microcombustor under Various Inlet Conditions", M. E. Feyz, J. A. Esfahani, 2013, *Int. Journal of Exergy*
- ✓ "Effect of a New Wet Soot Absorber on Soot Removal of a Diesel Engine ", M. Ghazikhani, M.E. Feyz, I. Khazaee, A. Ghazikhani, M. J. Mahmoudzadeh, 2013, *Journal of Scientia Iranica*
- ✓ "Parametric assessment of a low-swirl burner using the exergy analysis", M.E. Feyz, S.I. Pishbin, M. Ghazikhani, S.M.R. Modarres Razavi, 2015, Energy

Conference/ Proceedings Publications:

- ✓ "Experimental Study of Natural Gas Fuel Temperature Influence on Radiation Enhancement and Emission ", M. Javadi, M. Moghiman, P. Nikuieian, M. E. Feyz, *Proceedings of the ASME2010 Biennial Conference on Engineering systems Design and Analysis, July 12-14, 2010, Istanbul, Turkey*
- ✓ "Development of an Analytical Model to Predict Flame and Wall Temperature of a Radial Micro-combustor", J. A. Esfahani, M. E. Feyz, M. Kimiaghalam, *The 2nd International Conference on Engineering and ICT , February 2010, Melaka, Malaysia*
- ✓ "Analytical Investigation on the Effects of Exhaust Gas Recirculation (EGR) on in-cylinder residual gas mass fraction in an IDI Diesel Engine ", M.ghazikhani, M.E.Feyz, P. Nikuieian, *The Sixth International Conference on Internal Combustion Engines, November 17-19, 2009, Olympic Hotel, Tehran, Iran.*

- ✓ "Experimental Study on the Effect of Splashing Wet Precipitator on the Restriction of Soot Emission From Diesel Engines",*18th Annual International Conference on Mechanical Engineering-ISME2010,11-13 May, 2010, Sharif University of Technology, Tehran, Iran*
- ✓ "Effect of Using EGR on In-Cylinder Irreversibility of an IDI Diesel Engine", M.ghazikhani, M.E.Feyz, *The Sixth International Conference on Internal Combustion Engines November 17-19, 2009, Olympic Hotel, Tehran, Iran.*
- ✓ "Experimental Investigation on the Effect of EGR on the Second Law Efficiency in Diesel Engines", M. Ghazikhani, M.E. Feyz, A. Joharchi, *The Seventh Annual International Conference of Mechanical Engineering (ISME),Iran ,Tehran, Tehran University, March, 2009.*
- ✓ "Analytical Study On the Effects of EGR on the Performance of Exhaust in Diesel Engines", M.ghazikhani, M.E.Feyz, P. Nikuieian, *The Sixth Annual Student Conference of Mechanical Engineering (STU2008), Iran ,Tehran , Amir Kabir University, January 2008.*
- ✓ "Numerical Study On The Effects Of Bubble –Tube Relative Diameter On The Performance Curve Of An Air-Lift Pump", M.E.Feyz, M.Kimiaghalam, *The Seventh Annual Student Conference Of Mechanical Engineering (MEC2009), Iran ,Mashhad , Azad University, October 2009.*

Experience:

- ✓ Research assistant at combustion and propulsion research lab, IUPUI (present)
- ✓ Research assistant in Internal Combustion Engines and Heat Pumps laboratory at FUM (2008 -2014)
- ✓ Technical advisor of Shar-Babana baking company (2011)
- ✓ Technical advisor of Raad Mashhal company (2009)

Research Tasks:

- ✓ Preparation and Operation of Low-Swirl Burner Test Setup
- ✓ Assembling and Implementation a Diesel Engine with High Pressure-Loop EGR
- ✓ Preparation of a Test Bed for Wet Soot Absorber Filter Compatible with Transportation Diesel Engines
- ✓ Experimental and Numerical Evaluation of the Effects of Methane Dissociation on Flame Radiation of a Burner
- ✓ Providing an Analytical Model to Predict Flame Temperature of a Premixed Radial Micro-Combustor.
- ✓ Numerical Simulation and Entropy Study of a Methane/Air Cylindrical Microcombustor
- ✓ Thermo-Economic Analysis of a Small Scale Steam Power Plant
- ✓ Design and Numerical Analysis of a Patented Centrifugal Pump Impeller
- ✓ Design, Manufacturing and Analysis of an Absorption Chiller for Domestic Applications (*in progress*)

Ali Tarraf Kojok

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Summary

Combustion and propulsion researcher, entrepreneur launching two start-ups, avid tinkerer, experienced manager responsible of teams of up to 100 employees, industrial machine designer building an air compressor

Selected Accomplishments

- Design and optimization of a torch ignitor for a wave rotor combustor
- Attracted and delivered sales orders of up to 100,000 $ at Randaplast
- Built a creditworthy relationship with a Chinese plastic supplier, while developing the plastic additives market at Randaplast

Skills

- Business Development & Management
- Mitsubishi industrial robot programming
- Rockwell Automation PLC programming
- Fluent in French, and Arabic
- Solidworks, ProEngineer,AutoCAD
- Matlab, Labview, PSpice
- West Africa company start ups
- Plastics extrusion, and blowing
- Caterpillar forest products

Education

Purdue School of Engineering and Technology (IUPUI),
Master of Science in Mechanical Engineering, **Expected graduation May 2016**

- Assistant in the Combustion & Propulsion Research Lab
- Partial tuition Mechanical Engineering department MS Thesis award for 2014-2015

American University of Beirut (AUB), (ABET accredited)
Lebanon, June 2009

- Bachelor in Mechanical Engineering
- Minor in Business

Professional Experience

AT Works – Start up, assembling air compressors & plastic cutting machines **Ghana, January 2014 – June 2014**

- ***CEO & CTO***
- Designed and built a screw type air compressor, with an automatic pressure regulating control system
- Sold two units at very competitive price compared to world class manufacturer (Atlas Copco, Ingersoll Rand)

John Bitar Co. – Leading manufacturer of timber & veneer in West Africa **Ghana, August 2012 – August 2013**

- ***Forest & Logistics manager***
- Managing 100 employees in forest & transport operations delivering 4000m^3(logs/month)
- ***Forest coordinator***
- Managing forest operations in 5 different locations using 10 Caterpillar forest machinery

Randaplast Gh. LTD – Start up, in plastics recycling **Ghana, August 2011 – June 2014**

- ***Partner***

• Developed a market for plastic additives, achieving record sales, & creditworthy relationship with a Chinese supplier

- ***CEO & Chief Engineer***

• Starting up a plastic recycling company, achieving 20 % growth in one year

SCCI – Leading plastics compounds producers in West Africa **Ivory Coast, November 2009 – August 2011**

- ***Plant Manager***

• Managing 49 employees in production and quality control teams, producing 24,000 Tons of plastics per year

- ***Industrial Engineer***

• Maintenance of 50 machines, like extruders, mixers, chillers, compressors

Consolidated Contractor International Company (CCIC), **Qatar, June 2008 – September 2008**

- Engineering Intern – Ras Gas Expansion project phase 2 (1 Billion $), rotation in the following departments: Planning, Piping, Instrumentation, Structural and Equipment

Private Tutor, Tutoring two high school students in math and sciences throughout 2008

Events & Organizations

Professional memberships, ASME, AIAA
Outdoor Festival, Organizing an estimated 10,000 attendees festival at the AUB university campus
Lebanese Red Cross, Run for Aids, Driving awareness, Blood donation, and Free lunch campaigns
Fairs & Conferences, Asia Mould 2013 (China), West Africa Clean Energy & Environment Exhibition 2013 (Ghana)

Section VI: Support Letters

None

Section VII: Appendix

Title of Past MURI Project: Design of optical diagnostic system for Wave Rotor constant volume combustor
Date Awarded: 2013. ***Date Completed:*** May 2014
Description of Project: Reviewed & determined the best optical diagnostic method for advanced flame imaging based on cost and needs of the wave rotor combustor. Designed optical system and discussed effectiveness. Prepared the list of equipment, purchase, assembled and tested the Schlieren system using a light source. Conducted experiments with the WRC rig to visualize flow with density gradients.
Mentors Involved in Project: Manikanda Rajagopal, Razi Nalim
Students Involved in Project: Kok Hwang Chow, Zhen Wei Yong and Fatin Baharuddin
Description of Basic Project-related Student Learning Outcomes: Research poster and research paper submitted to MURI. Learned physical optics, fluid dynamics, research skills.

Title of Past MURI Project: Thermodynamic Cycle Analysis for Wave-Rotor-Combustor-based Combined Cycle
Date Awarded: 2012. ***Date Completed:*** May 2013
Description of Project: Investigated the potential of the wave rotor combustor using thermodynamic cycle analysis. Used EES code to compare performance of simple Brayton cycle with wave rotor combustor in recuperated engines, work producing combustor, and combined cycle power plant application. Compared overall specific fuel consumption, specific work, and efficiency. Measured pressure data and high-speed images from an experiment were analyzed, and MATLAB programs were developed to identify flame edges and estimate the propagating flame velocity.
Mentors Involved in Project: Manikanda Rajagopal, Razi Nalim
Students Involved in Project: Brian Knip, Michael David, Jessica Collins, Arash Edalatnoor
Description of Basic Project-related Student Learning Outcomes: Research paper submitted to MURI. Learned thermodynamics of real gases, image processing, research skills.

Title of Past MURI Project: Design of Safe Electrical System for Wave Rotor Igniter Experiment
Date Awarded: 2012. ***Date Completed:*** August 2012
Description of Project: Analyzed the combustion process inside a rotating and enclosed chamber, involving pressurized flammable gasses, electrical motors, a spark ignition system, and high-speed rotating components. Improved system safety and performance: automation of the spark ignition system, all systems from a single control location, installation of safety features which included a brake and an emergency stop system. Diagnosed and repaired electrical systems. Examined, replaced, reconfigured, and tested ignition system for safe, consistent, and reliable operation. Configured drive motor and motor controller system for high speed shaft rotation of 3,500 RPM. Researched and tested sensors and methods to accurately monitor the shaft angular position at high speeds with real time data analysis.
Mentors Involved in Project: Manikanda Rajagopal, Razi Nalim, Afshin Izadian
Students Involved in Project: Kyung-Hoon Bang, Kenneth Wayne Lee, Golnaz Mortazavi
Description of Basic Project-related Student Learning Outcomes: Research paper submitted to MURI. Learned electro-mechanical system safety, pressure and combustion safety, research skills.

Title of Past MURI Project: Experimental Investigation of Ignition Delay Times of Ethylene-Air Mixtures Ignited by Hot Gaseous Jets
Date Awarded: 2010. ***Date Completed:*** Aug 2010
Description of Project: Experimentally studied ignition delay times of different mixtures of ethylene-air using a single-channel constant volume combustor test rig. Ignited different mixture fractions of ethylene-air using a hot combustion gas jet. Obtained high frequency pressure transducer data and high-speed video images obtained to correlate ignition delay time and experimental variables.
Mentors Involved in Project: Razi Nalim, Indika Perara

Students Involved in Project: Matthew Bixler, Inthiquab Farook, Arash Pourtaherian
Description of Basic Project-related Student Learning Outcomes: Research paper submitted to MURI. Learned data acquisition, combustion experimentation, research skills.

Title of Past MURI Project: Optical Diagnostics Design for a Novel Engine Combustor
Date Awarded: 2008. ***Date Completed:*** Aug 2008
Description of Project: Designed a Schileren system to detect gases and using a high speed camera and Labview program.
Mentors Involved in Project: M. R. Nalim, G. Vemuri, B. Froelich
Students Involved in Project: Dara Navaei, Diana Vasquez, Nojan Aliahmad, Prince Bedell
Description of Basic Project-related Student Learning Outcomes: Research paper submitted to MURI. Learned data acquisition, optical methods, research skills.

Section VIII: Signature

Name and Signature of the Principal Mentor:
(typing in the full name suffices as signature for electronic copies)

____Mohamed Razi Nalim_____April 22, 2015__
Name Signature Date