RESEARCH ACTIVITIES (PI or Co-PI, career long)

ON-GOING PROJECTS

Natural Fuel Beds Ignition by Embers and Heated/burning Particles (NSF): The objective of this work is to develop quantitative predictive capabilities for determining whether or not an ember or hot particle will ignite a natural fuel beds based on particle properties, fuel bed characteristics, and ambient conditions. Firebrand (ember) and hot particles spotting is the primary vector for spread of wildland and WUI fires under dry, hot, and windy conditions that produce the most devastating fires. Whether or not an ember or hot particle is a competent ignition source depends on its characteristics (size, temperature, flaming, smoldering) and the properties of the target fuel bed. However, the conditions under which embers and hot particles can ignite spot fires are not yet quantitatively understood.

Materials Flammability in Spacecraft (NASA Space Flight Program): The project short term objective is to study the effect of “exploration atmospheres” (elevated oxygen concentration, low ambient pressure and flow velocities and low gravity) on the flammability diagrams of combustible materials used in spacecraft's (plastics, cable jackets, electronic boards, etc.), and the fire properties derived from them. The final objective is the development of a new test method that describes conditions expected in spacecraft facilities for determining the fire properties of materials to be used in those facilities. This method could provide NASA with an alternative test to rank and classify the fire hazard characteristics of materials to be used in spacecraft. The microgravity tests were approved to be conducted in the International Space Station.

Tackling CFD Modeling of Flame Spread on Practical Solid Combustibles (NSF): Project involves the development of a generalized pyrolysis model that can simulate the pyrolysis and burning of real-world materials encountered in fires. Techniques involving automated optimization by genetic algorithms are applied and further developed so that the required material properties can be extracted from existing laboratory-scale tests. A pyrolysis model is developed and coupled to an existing CFD code and used to calculate flame spread on real-world solid combustibles over a range of length scales. The research represents a step toward the development of computational tools that can be used to simulate fire development and how it is affected by the use of alternate materials. The results could aid in cost-effective fire safety design of buildings, and reduce the loss of life and property by fire.

High Efficiency Thermal Storage of Solar Energy, HELSOLAR (DOE): The projects is part of a university/industry consortium to carry out a conceptual study of a solar energy steam generation system for a power plant that uses a graphite based energy storage approach. Specifically to develop a computer model that will help to design and optimize the energy storage system, including modeling issues related to heat transfer between the cycle fluid/pipe and storage mass, stagnant inventory volume calculation and system optimization. Detailed behavior material and simulation related to properties, thermal shocks, stress, fatigue and creep in pipes.

Microwave-Enhanced Ignition (KAUST): Project studies the potential to extend the flammability limits of hydrocarbons, improve combustion efficiency, and reduce pollutant emissions by microwave –enhanced combustion. Electromagnetic fields may be an effective and efficient means of implementing advanced control strategies in energy-conversion systems such as internal combustion engines and gas turbine combustors. Experimental and numerical studies are conducted to reach the objectives of the project.

PREVIOUS PROJECTS

Smoldering and Transition to Flaming in Microgravity (NASA Space Flight Program): The objective of the project is to predict smoldering and the transition to flaming of foams, composite and cellulose materials in conditions expected in space based facilities. It includes experiments in normal gravity and in microgravity. The later are being conducted in the Space Shuttle, and were approved to be continued in the International Space Station. To date five space flight experiments have been conducted in the Space Shuttle. The results of the study are used to predict and prevent the potential onset of smoldering generated fires in ground and space based facilities.

Microgravity Production of Nanoparticles of Novel Materials Using Plasma Synthesis (NASA Ground Based Program): The overall objective of the research is to study the formation in reduced gravity of particulate of novel materials, in the nano-meter size, and of high quality, using plasma synthesis. Particular emphasis will be placed on non-oxide materials like SiC, SiN, c-BN, etc. The interest is to determine how microgravity synthesis can improve the quality and yield of the nanoparticles and synthesized powder. The particulate could be applied to the growth of nano-systems, such as MEMS based combustion systems, catalytic nano-reactors, fluidized bed reactors and heat exchangers, or to build nano-structures.

Rotary Internal Combustion Micro-Engine (DARPA/MEMS): Research aimed to develop a rotary internal combustion micro-engine of MEMS scale (mm) and of meso-scale (cm), that would be capable of delivering power using liquid fuels. Major features of such engine would be: planar (wafer) geometry, silicon based ceramic material, high temperature semi-adiabatic cycle, normal or catalytic combustion, direct rotational torque. Because liquid fuels have a much higher power density than batteries, the project aims at the replacements of batteries in cases were weight is critical. Potential applications include propulsion of small devices and portable power generation.

Carbon Monoxide and Soot Formation in Inverse Diffusion Flames (NASA Ground Based Program): The objective of the research is to experimentally and computationally study CO and soot processes in laminar, inverse diffusion flames, which is a special case of underventilated combustion. An understanding of noxious gas formation and flame soot signatures during underventilated fires in spacecraft will be obtained, a goal in line with the Human Exploration and Development of Space (HEDS) objective of achieving earlier, more sensitive fire detection systems for use in microgravity scenarios. The project has additional practical significance for predicting the composition of the intermediate products from fuel-rich zones in practical staged combustors.

Compact Fluidized Nano-particle Reactor for Photocatalytic Reduction of Carbon Dioxide to Methanol (ITRI): The objective of this project is the development of a photocatalytic fluidized bed reactor that will utilize solar UV radiation to transform atmospheric carbon dioxide

(CO_2) and water (H_2O) to methanol (CH_3OH). Methanol is a conventional fuel that can be reformed into a feedstock for a hydrogen fuel cell, or directly oxidized to produce power in an engine or heat in a furnace. The result would be a carbon neutral energy generation approach that could have the advantages of fossil fuels without the adverse impact on the environment.

Flame Spread over Solid Fuels in Opposed and Concurrent Oxidizing Flows (NIST): Research aimed to the determination of the mechanisms controlling the spread of fire in convective oxidizer flows. Includes theoretical and experimental studies of the effect of the oxidizer flow velocity, turbulence intensity, and oxygen concentration on the rates of flame spread and steady burning, of solid combustible materials. The results are used in the development of fire models and of materials flammability tests.

Ignition and Extinction of Condensed Fuels (NSF): Research includes theoretical and experimental studies of ignition and diffusion flame extinction in boundary layer oxidizer flows established over the surface of solid and liquid fuels. The results provide fundamental information about the limiting conditions of condensed fuel burning.

Liquid Fuel Spray Ignition (ARO/TACOM): Study of the mechanisms of ignition and combustion of liquid fuel droplets and sprays under supercritical conditions. The project includes theoretical and experimental tasks. The results aim to improve the combustion efficiency and reduce emissions of diesel engines and gas turbines.

Stability of Gaseous Fuel Flames (NASA LeRC): Project to study the effect of buoyancy on the stability of premixed and diffusion flames. It includes experimental studies conducted at normal and reduced gravity in the NASA 2.2 seconds drop tower. The results are used to improve our understanding of the mechanisms controlling flame propagation and stabilization.

Flight Path of Metal Particles and Embers Generated by Power Lines in High Winds (SDGE): Development of a computer code to calculate trajectories, and lifetimes of metal particles generated by power lines and embers of different sizes for various wind conditions and terrains. The results predict the potential for fire spotting by metal particles and embers in wildland fires.

Liquid Fuel Pool Fires and Boilover Burning of Fuels Spilled on Water (CNRS, France): Collaboration with LCD-ENSMA, University of Poitiers, France, to study the burning characteristics (boilover) of liquid fuel spills, particularly the conditions leading to the nucleate boiling of the sub-layer water and the subsequent explosive burning of heavy hydrocarbon fuels (diesel oil, heating oil, etc.) floating on the water.

Flame Characteristics of Solid Fuels in Microgravity Conditions and Very Small Flow Velocities (ESA/Spain): Collaboration with the ETSIA, Universidad Politecnica de Madrid, Spain to study the flammability limits, surface flame spread, flame characteristics and stability limits of the combustion of solid fuels in oxidizer mixtures in microgravity, low velocity flows. The project was approved by NASA to be conducted in the International Space Station

Flame Spread over Discontinuous Fuels in Microgravity (NASA/NEDO): Collaborative project with Tohoku University, Japan, to study the propagation of flames over discontinuous fuels in reduced gravity. The microgravity experiments are to be conducted in the JAMIC drop tower facility in Saporo, Japan

NOx reduction in Diesel Engines by Ammonia Injection (Extengine Transport Systems): Study of the feasibility and performance of adding ammonia in the exhaust manifold of diesel engines to reduce NOx emissions. The results of the project could result in the implementation of the method in stationary and moving power plants using diesel to reduce emissions.

High Efficiency, Low Nox, Natural Gas Burner (UERG): Feasibility study of a two stage, ultra-low Nox and CO natural gas burner. It consists of a first stage with a premixed flame anchored at a porous burner with a highly radiant surface, and a second stage with a lean turbulent diffusion flame. The burner could be developed for use in appliances and small boilers

Resonant Gas Burner (Osaka Gas, Japan): Project to study the feasibility and performance of a gas burner operating on a resonant vortex combustion mode. The large residence times and enhanced mixing of the resonant vortex operation could permit a lean operation of the burner that would be more efficient and produce less Nox emissions.