Student: Arash Ahmadi  
Professor/Sponsor: Professor Carlos Fernandez-Pello  
Mentor: Dan Murphy  
Research Project Title: Scale model building smoke viewing  
Abstract:  
Scale model building smoke viewing have been completed to address a significant barrier to the technical problem of accounting for wind in naturally ventilated atria or malls for different sizes of buildings. The purpose is to validate this model for different scales of buildings. This exercise is also intended to validate the uncertainty associated with the effects of wind on smoke control systems utilizing passive or natural ventilation methods in atria and malls for different sizes of buildings. The scaling technique can validate or provide an alternative to CFD models. The effect of external wind upon heat and mass transport due to fires in a naturally ventilated atrium is investigated using scaled physical models in an atmospheric boundary layer wind tunnel. Utilizing SolidWorks to design parts and assemblies of the building; Construction of the scaled buildings was done using Polycarbonate plastic. Specific change was made on the program which was intended to analyze the data and pictures taken from the experiments to increase the efficiency of data analysis. Development of an experiment to figure out what fuel should be used to create heat needed in each building based on their size. Scale models were validated against reduced scale physical models. These issues are relevant to design of smoke control systems in naturally ventilated buildings and demonstrate the ability of scaled physical models using modern visualization and experimental techniques to complement and validate numerical fire modeling.

Student: Khanh Trung Do  
Professor/Sponsor: Professor Carlos Fernandez-Pello  
Mentors: Casey Zak and James Urban  
Subarea: Combustion  
Research Project Title: Fuel Bed Ignition by Heated Particles: An Experimental and Phenomenological Study  
Abstract:  
According to the National Fire Protection Association of the United States, "outside and other" fires, or wildland and wildland urban interface, has caused more than $500 million dollars in property damage and killed 55 civilians in the year 2010 alone. Many of these fires are allegedly ignited by heated particles generated by power line interactions, welding and other sources of hot particles. However, there has been relatively little research on the ignition of fuel beds by hot particles. Our research focuses on the study of ignition of powdered cellulose fuel beds by hot metal particles. Stainless steel, brass and aluminum spheres, whose diameters ranges from 1.59 mm to 12.7 mm were heated to temperatures between 773 and 1373K in a furnace and immediately dropped onto cellulose fuel beds with moisture contents of 1.5% and 4.5%. The effects of varying particle diameter, temperature and thermal conductivity and fuel bed moisture content on flaming ignition propensity are discussed. Additionally, high-speed videos taken of three ignition events are presented and used in conjunction with phenomenological arguments to develop a description of the ignition process. The results of our works so far suggest that ignition of fuel beds by hot particles is a very rapid surface phenomenon that
most strongly depends on particle size and temperature, with a possible dependence on fuel bed moisture content.

Before the ignition process occurs, the biomass must be broken down by pyrolysis. The products of this process are H2, CO, CH4, C2H4, levoglucosan, and a small amount of other hydrocarbon. Depending on the temperature, the ratio of the products will differ. As increasing the temperature, the amount of H2 increases while the percent of methane and levoglucosan decrease.

**Student:** Felix Sebastian Frank  
**Professor/Sponsor:** Professor Carlos Fernandez-Pello  
**Mentor:** Daniel Murphy  
**Subarea:** Combustion  
**Research Project Title:** Effect of Wind on Fires Inside Naturally Ventilated Buildings

**Abstract:**  
A team from the Combustion Lab conducted scaled wind tunnel experiments to analyze the effect of wind on fires inside naturally ventilated atria or malls. Motivation of this experiment was to get a clear picture of the different hot gas layers and exhaust vent flows which develop in such a situation. Plenty of measurements were taken with the Schlieren digital photography, however, due to the fact that the analysis of the Schlieren data was only possible one-by-one, time constraints obviated the examination of the data. Consequently, we needed a way to efficiently assess the data. Therefore, we programmed a script, based on PIVlab, which is able to analyze complete packs of data all at once. This major improvement enables us to use the Schlieren digital photography in the future as a very efficient tool for the analysis of general fluid flows.

A second emphasis lies on the validation of the scale model technique. Scale Modeling is an engineering theory that is used to analyze systems where calculations and computer simulations are not reliable or at least very time-consuming. The theoretical approach is to build a downscaled version of the original system while maintaining the same geometry, kinetic and kinematic. Non-dimensional analysis delivers a proof for the similarity between these systems, as long as the governing parameters are kept constant when scaling down the reality. However, in practice, there have to be variations regarding the numerous non-dimensional parameters. As a result the theory of scale modeling needs to be validated to prove that an application is justifiable. Building various sizes of the same geometry and conducting experiments with exactly the same data proves the applicability and secures the competitive ability of scale modeling compared to the in business primarily used computer simulations.

**Student:** Zachary Hammond  
**Professor/Sponsor:** Professor Robert Dibble  
**Mentor:** Dr. Hunter Mack  
**Research Project Title:** The Addition of Hydrogen Peroxide to Methane Fueled HCCI Engines Through Numerical Simulation

**Abstract:**  
Although Homogeneous Charge Compression Ignition (HCCI) has proven to be an attractive internal combustion technique in attaining low emissions and high fuel efficiency, its ignition process remains dependent on chemical kinetics thus making it difficult to control. One promising approach to
controlling combustion timing in HCCI uses two fuels to drive combustion. This study proposes that hydrogen peroxide may be a suitable additive to introduce as a means of control because of its role as a critical oxidizer in the initiation of thermal ignition, and its effect on indicated mean effective pressure and ignition timing. The authors employed hydrogen peroxide as a means of control by studying the effects of directly injecting a hydrogen peroxide solution into the combustion chamber of an HCCI engine through numerical simulation. A single cylinder of a methane fueled HCCI engine was modeled with MATLAB using the Cantera 2.0 flame code toolkit, the GRI-Mech 3.0 chemical reaction mechanism, and a single zone slider-crank engine model. The numerical simulation was used to develop relationships between the amount of hydrogen peroxide injected, the start of injection timing, the intake temperature, and the combustion timing.

It was found that the addition of hydrogen peroxide provided a significant advance in combustion timing. In small concentrations, hydrogen peroxide could induce combustion of methane under conditions that would otherwise result in a misfire. While holding intake temperature and SOI constant, varying the amount of hydrogen peroxide allowed for the control of combustion timing. To expand the range in which the injection of hydrogen peroxide provides a beneficial effect on combustion, injection timing was also utilized as an ignition control parameter. An advance in SOI while holding injected mass and intake temperature constant produced an advance in combustion timing. The use of hydrogen peroxide as a secondary fuel in HCCI can provide control over combustion timing while retaining the factors that make HCCI an attractive technique. The simulations showed that the addition of hydrogen peroxide has a slightly positive effect on the emissions of NOx and other emissions. The simulations also showed that addition of hydrogen peroxide has no discernible effects on peak pressures within the cylinder, which is important considering high peak pressures can damage the engine.

This preliminary experiment shows that hydrogen peroxide may be effectively introduced as a means of control in HCCI combustion. The application of internal injection of hydrogen peroxide has the potential to negate some of the difficulties associated with controlling the combustion event and expand the range of combustion regimes at which HCCI operates. This can be achieved while maintaining low emissions and peak in-cylinder pressures.

Student: Harlan Kuo
Professor/Sponsor: Professor Carlos Fernandez-Pello
Mentor: Daniel Murphy
Research Project Title: Advanced Diagnostic of Scaled Compartment Fires

Abstract:
Compartment fires are areas where a flame is present in an enclosed space with one or more outlets. Analysis on such environments is needed to determine whether structures, such as large atriums, are safe enough to allow people to evacuate unharmed in the case of a fire. The computational models such as the Fire Dynamics Simulator can take immensely large resources and computer hours to calculate larger rooms making scaled modeling a much more attractive method of providing the needed analysis. Scaled modeling when combined with Particle Image Velocimetry and Background Oriented Schlieren produce a full set of data needed to verify if the room is safe. The objective of this research is to scale and model an atrium fire in a wind tunnel with similar conditions as to what an actual atrium must be tested in to be considered safe. A scaled down atrium will be placed in a wind tunnel seeded with droplets and the atrium will have a heat source seeded with aluminum oxide powder. A Nd YAG laser is used to illuminate the local area allowing for a camera to take measurements of the velocity field. A
special pattern is then placed behind the atrium and imaged to detect for perturbation in the air due to refractions caused by hotter air generating a temperature field of the area as well. These combined measurements will produce all the relevant data to the model. This methods promises to be cheaper and faster than computational models of comparable accuracy.

Student: Eric Olson  
Professor/Sponsor: Professor Robert Dibble  
Mentor: Dr. Hunter Mack  
Sub Area: Combustion  
Research Project Title: Investigating the use of Compressed Natural Gas in a Variable Displacement Spark Ignition Engine

Abstract:  
With the number of vehicles on the road today the need for improved emission control is readily apparent. The modern spark ignition engine is designed to be most efficient when operated at full load, but normal operating conditions rarely achieve this type of loading. Instead, most engines operate at loads significantly lower than their designed capacity, which increases their contribution of harmful exhaust emissions to the environment. In order to overcome partial-loading conditions, industry has developed "Variable Displacement" engines that dynamically deactivate certain cylinders and effectively lower the displacement of the engine, which allows the remaining functional cylinders to operate at nearly full-load conditions.

This research utilizes Dynamic Skip Fire (DSF), which is the newest in Variable Displacement Technology developed by Tula Technology Inc. DSF technology shuts down individual cylinders for improved performance under partial-load conditions. In addition to utilizing variable displacement, lowered emissions can also be achieved through the use of alternative fuels, such as Compressed Natural Gas (CNG). CNG offers favorable engine-fuel properties, so CNG-fueled vehicles produce lower levels of all pollutant emissions than either conventional or reformulated gasoline and diesel fuels. The goal of this research is to operate a Dynamic Skip Fire equipped GM L94 6.2 Liter V8 on Compressed Natural Gas to determine the overall improvement to emissions achieved through this coupling.

The first phase of the project was the construction of an engine test cell and the breaking in of the engine. Specific tasks assigned to the undergraduate assistants included fabrication of brackets and mounting hardware in the student machine shop, wiring and calibration of sensors between the interior of the test cell and the controlling computer system, and installation of the heat exchanger for the fuel delivery system. Once the engine test cell construction was completed, a start-up procedure was developed and the engine was test fired. A series of runs were then conducted to break in the engine, and data was collected and analyzed to verify that frictional losses would not interfere with future experiments. These preliminary tests have been completed, and the engine will now begin to collect data for examination into the benefits of DSF run on CNG.

Student: Tuong-Vi Tran  
Professor/Sponsor: Professor Carlos Fernandez-Pello  
Mentors: Casey Zak and James Urban  
Sub Area: Combustion
Research Project Title: An experimental and phenomenological study of powdered fuel bed ignition by heated particles

Abstract:
Since ancient times, wildland fires have been a threat to both human life and property as well as the environment. Many fires are allegedly ignited when incandescent particles, among them are hot metal particles from electrical arcing of power lines or welding, land in combustible fuels beds, such as saw dust or forest floor. So far, there has been little research done about the impact of hot metallic particles on cellulose fuel bed, thus our research aims to discover a better understanding of this ignition pathway to assist regulatory agencies in predicting causes of wildland fires, as well as preventing it from happening. The experiment was setup so that a metal particles, such as aluminum, stainless steel or brass spheres, get heated inside a furnace until they reach the desired temperature, then are promptly withdrawn from the furnace and drop onto a fuel bed, whose properties were also being measured. The variety of particle mass, diameter, temperature, and material as well as thermal conductivity and fuel bed moisture content were discussed and analyzed. This research is continuing from Fall 2012, using the same methods but also adding the use of thermocouples, implemented on the spoon that holds the particle, to ensure it reaches desired temperatures. High-speed videos captured the moment when the spheres landed into the fuel bed, thus enabling us to determine whether it is flaming, non-flaming or smoldering ignition as well as study their ignition behaviors. Our work so far has indicated the trend that separate the combinations of mass and temperature where a certain metal particle will ignite the fuel bed from those where the fuel bed was not being ignited at all. We concluded that the ignition of a fuel bed is a rapid phenomenon that strongly depends on particle mass and temperature.

In Fall 2013, our research continued using the same methods but focusing on perfection the ignition curve for steel, copper and brass particle. Instead of using the relatively small, less than 3.18 mm, and relative big, larger than 10.5 mm, we conduct tests based heavily on metal ball with diameter ranges from 3.96 mm to 7.92 mm. Our work so far has indicates that the ignition trend we predicted based on relative small and large particles also hold for medium size particles. We also did experiment with aluminum particles using same method but dropping on a barley hay fuel bed instead of cellulose. Our results so far indicated that aluminum particle fully ignite at higher temperature when dropping on barley hay fuel bed due to barley hay's moisture content is larger than cellulose's.

Student: Michael Wiley
Professor/Sponsor: Professor Robert Dibble
Mentor: Russell Labrie
Sub Area: Combustion

Research Project Title: Benefits of Dynamic Skip Fire (DSF) for Improved Natural Gas Engine Performance

Abstract:
Over the past two semesters I have had the privilege of working in the Combustion Analysis Lab alongside a select group of graduate and undergraduate students on the "Benefits of Dynamic Skip Fire (DSF) for Improved Natural Gas Engine Performance" project. At its heart, this project's purpose was to demonstrate the possible "fuel economy gain, which results from the combination of Dynamic Skip Fire technology and compressed natural gas"[1]. While the main objective of the project was realized, the data that was collected during the testing phase came at a time prior to the completion of the engine's break-in. As a result, the conclusions drawn from this data needed to be verified in order to assess their
validity. It was this task that myself and the other members of the research team set out to begin this semester.

This semester started out with myself and the other members of the team becoming familiar with the start up procedures and data acquisition system for the engine we would be working with, a refurbished General Motors 6.2L V8. Once familiarized, our task was to run the dynamometer and data acquisition system in order to map the engine's parameters (focusing especially on the Friction Mean Effective Pressure) at specific engine conditions. The goal was to conduct these tests in order to fully break-in the engine with the intent of using FMEP as a guide to track when full engine break-in had occurred. At this point in time, the data acquisition portion of our project remains incomplete. Hopefully the research team and I will be able to continue our research during the summer.