

# Scott, Justin

## Determining Biomass Particle Properties via Digital Imaging

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### Objective

The research focus is on designing and building an imaging system capable of simultaneously determining the shape, surface area, volume, and temperature of moving biomass particles during combustion. This information is key to understanding how this alternative fuel source can be used more effectively to meet global energy needs.

### Introduction

Understanding the devolatilization and combustion of biomass (sawdust, agricultural waste, etc.) will lead to better use of this renewable fuel source. The overall goal of the project is to write a computer model that can accurately predict what will occur during biomass combustion.

The research conducted over the past year has focused on developing an apparatus capable of determining the needed data for model development. The apparatus, once completed, will consist of an entrained flow reactor, an optical measurement system, and a computer algorithm to process the needed data from the images.

### Apparatus

The reactor allows the researcher to observe biomass particles under desired experimental conditions. The design allows for variations of the reactor temperature, temperature profile in the reactor, and of the particle residence time. The reactor is designed to have a maximum heating temperature of 1300 °C. This allows for simulation of actual boiler environments. Particles are injected into a hot gas stream that carries them through the heated reactor. Eighteen view ports allow optical access to all sides of a particle at three different locations. The particle collection system, consisting of two cyclone separators, has demonstrated over a 99% collection efficiency of the charred particles exiting the reactor.

The reactor is nearing completion. Limited electrical work remains to power the heating elements. Reactor construction presented significant challenges. The high temperatures needed for the experiment required the use of silicon carbide tubes and high temperature insulation. The extreme hardness of silicon carbide made the material difficult to work with. It took three attempts by a ceramic grinding company before the pieces were properly drilled and cut. This delay set back our timetable for reactor completion by 4-6 months.

Selecting and implementing a successful optical measurement system has proved difficult. The system must be able to image three orthogonal views of the same particle simultaneously. The particle must be self illuminated in order to establish particle surface temperature from the image. We have located a system consisting of three Redlake ES 1.0 cameras that we believe will meet our needs. Forester System Engineering has worked with us to determine the feasibility of this set up and to procure the components required to make it work.

Several different setups have been considered throughout the previous year. One idea involved the use of mirrors to reflect all three sides of a particle onto one plane. The belief was that then only one camera would be needed to image all three sides. Experiments proved that it was possible to capture the images on one plane, but not without significant loss of intensity. A triple head camera unit was also considered, but the unit was not sufficiently light sensitive. After experimenting with different cameras, we believe that the ES 1.0 cameras will successfully balance sensitivity and performance. The system should be tested early January 2004.

Once the cameras are in place, many secondary systems are required to take correct volume/shape measurements. The effect of motion blur must be corrected for. The ES 1.0 has a maximum shutter speed of 127 microseconds. This means that a one millimeter (average particle length) particle traveling at 3 m/s (average particle speed) will appear to be 1.381 mm long in a shot. Faster shutter speeds are possible with different cameras, but they reduce the amount of light to a point where the particles are no longer visible. In order to make an exact correction for the length, the instantaneous particle velocity must be known.

Two alternatives are being considered to establish the instantaneous velocity. A fourth camera that takes continuous frames at a high frame rate can capture two images of the same particle, thus allowing us to calculate velocity. A double shot feature can be triggered in the ES 1.0 to accomplish the same thing. Triggering the camera can be done using a laser/detector setup. The laser light is reflected off the particle into the detector only when the particle is in the proper location. A signal is then sent to trigger the camera. The problems with this system include possible interference of the laser with the optical temperature measurement, time delay in the system, and the need to restart the system following a trigger.

The other alternative being considered allows the system to operate without constant supervision. The camera will be run in continuous mode (taking images even if a particle is not in the field of view). The images will then be simultaneously processed to determine if a particle is present in the image. The images containing particles will then be stored and the others deleted, thus freeing buffer space for the still incoming images. The downside of this method is that it will not allow us to take advantage of the double shot feature and thus require the additional camera. Determining which of these methods will succeed is the next challenge we must overcome.

## **Future Plans**

We plan to complete the apparatus and begin taking meaningful data by the end of the winter semester. Accomplishing this will require that the electrical/control systems on the heating elements be completed. The camera system will need to be installed on the reactor frame in a manner that allows for transfer of the cameras to any of the three optical levels. The camera will need to be calibrated and the algorithm written that uses Planck's law and single and two color pyrometry to determine particle surface temperature. These temperatures must then be overlaid onto the computer generated 3-D model of the particle. Once this is complete the model can be fine tuned to accurately predict combustion properties based on initial conditions.<sup>1</sup>

<sup>1</sup> Hong Lu, PhD Candidate, supervised and contributed his expertise to this project