Abstract

Biochar produced through pyrolysis is commonly used in agricultural settings and has recently gained popularity as a carbon sequestration method. Most small-scale pyrolysis reactors use the combustion of biomass or propane as a heating source for biochar production. Pyrolyzing biomass can be carbon negative when using waste feedstocks by converting up to 50% of the carbon to solid biochar[1]. However, for small-scale batch producers of biochar these values are harder to achieve with simpler, low-cost reactor designs. Further, these pyrolysis reactors have lower efficiencies and can require more combustion. Based on calculations for emissions of biochar with different heating sources, concentrated solar power (CSP) can avoid 1.67-1.92 kg of carbon dioxide (CO_2) emissions, compared to an open flame setup. This research explores the use of CSP as an alternative heating source for small-scale pyrolysis.

In this work, a parabolic dish solar concentrator, measuring 1.77 m^2 in reflective area, was investigated for potential biochar production. First, the parabolic dish was calibrated with water on a partially cloudy September morning in Northern New Jersey, reaching a maximum flux of 0.232 kW/ m^2. Two pyrolysis reactor prototypes were assembled with differences in reactor material, wall thicknesses, and position relative to the concentrator. A reactor made of two 28-oz aluminum tomato cans (prototype 1), demonstrated the ability to produce biochar with CSP, but with significant radial and axial thermal gradients. A new rotary reactor was designed with a 56 oz stainless-steel reactor vessel, with multiple temperature measurements along the central axis and a force sensor to track mass loss during pyrolysis (prototype 2). The force sensor was successfully calibrated, demonstrating its ability to monitor the mass loss and therefore track reaction progress.

Wood shavings were used as the pyrolysis feedstock, ranging from 45.7-107.9 grams per run. Pyrolysis was estimated to have been 40.3-74.9% complete, resulting in 9.6-41.9 grams of biochar. Heating rates at the wall of prototype 2 were 14.5% of those at the wall of prototype 1, showing the effect of reactor material and thickness on heating rates. The rates were 200% as fast as those in the center, showing the resistance to heat transfer within the reactor. The CSP system had an efficiency of 26.1-56.4% for the water calibration, and 5.5% for the pyrolysis reactor. An energy analysis was conducted and demonstrated that most of the heat loss was due to convection and radiation. From the energy analysis, the enthalpy of pyrolysis was calculated to be 2.7-2.9 MJ/kg, which is in good agreement with literature values for a similar feedstock and pyrolysis temperature.

The cost for the reactor components, aside from instrumentation for data collection, was less than $225. The reactors proposed were successfully able to produce biochar on a small-scale, and a new method for collecting mass data with a force sensor was able to track pyrolysis progression. The solar pyrolysis setup encountered issues with thermal gradients, which will be discussed in further detail in this thesis. This reactor design is an inexpensive and easy to assemble option for small-scale users that also allows them to decrease the emissions associated with biochar production.