DESIGN AND PERFORMANCE EVALUATION OF AN IN-FIELD BIOMASS CUBER

By

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ABSTRACT

In the past biomass had been our main source of controllable energy, burning forest materials for heat, light, and cooking. Today, the resources still exist for biomass to become a substantial contributor to our energy future, especially in the form of crop residues and perennial grasses. One of the many challenges impeding the use of biomass for energy is its inherent low bulk density and the associated high transportation and processing costs. Therefore, the primary goal of this research was to increase the density and improve the handling properties of biomass feedstocks for more efficient energy production, especially in relation to co-firing biomass for electrical or heat generation.

The current system of densification involves packaging the biomass into large round or square bales which require repeated handling and processing, substantially adding to the cost of biomass. For this research a mobile in-field cubing machine was modified to create cubes of biomass to be burned simultaneously with coal for electricity or heat generation. Directly creating biomass cubes at harvest would eliminate many steps involved with the handling of bales, hopefully reducing the cost of creating energy from biomass. Cubing produces a flowable feedstock that can be transported and handled with the same equipment currently in place at most coal burning facilities, limiting the capital transition costs necessary to implement a co-fire electricity generation system.

A test fixture was designed and fabricated to control the die surface temperature and resistance pressure, while measuring parameters such as applied force and friction force.

Laboratory experimental results showed that as the surface temperature of the die block increased, the friction created at the interface between the material and the die decreased. Reed canarygrass cubes were formed at 12% (w.b.) and 70 MPa resistance pressure and resulted in a reduction in friction from 34 to 17kN when the die surface temperature was increased from 50 to 150°C. Friction force decreased from 23 to 9 kN when die temperature increased from 50 to 150°C when switchgrass was cubed at 13% (w.b.) moisture and 145 MPa resistance pressure.

Friction is used to create the required back pressure to consolidate the material in an in-field cuber, so regulating the die temperature to 50°C could improve the performance of the in-field cuber by increasing consolidation back pressure. However, there would be a corresponding increase in energy required to form cubes. The higher die temperatures also reduced cube density because the higher temperature cubes had a longer cooling period which allowed for more relaxation. However, the elevated die temperatures did improve cube durability in some cases.

During the formation of switchgrass cubes, resistance pressures in excess of 145 MPa did not appear to increase cube durability and counter-intuitively reduced the dry density in some cases when the pressure was increased to 170 MPa. Increasing the resistance pressure from 70 to 120 MPa during the formation of reed canarygrass cubes increased the durability but did not affect the final density in this range of resistance pressure. However, when the pressure was increased from 80 to 110 MPa during the formation of switchgrass cubes, final cube density increased significantly. The increase in resistance pressure was also found to increase friction across most experiments due to the Poisson effect, which increased the normal force of the cube against the walls of the die.

Crop moisture above 16 – 17% (w.b.) significantly reduced cube durability and density for both reed canarygrass and switchgrass. It was found that when moisture was between 10 to 16% (w.b.), increased moisture resulted in greater wall friction, but as moisture level continued to increase, friction was reduced presumably due to a lubrication effect. Field experiments using reed canarygrass showed similar results where material above 16% (w.b.) produced reduced cube quality.

Polymer and lignosulfonate binders added in solution were found to have no effect on the measured parameters in these experiments. It is likely that any benefit of the minute level of binder added was mitigated by the water added by the solution. Calcium oxide added to the material increased density, cube durability, and the wall friction. Reed canarygrass cubes formed at 22% (w.b.) with the addition of 1% of DM calcium increased durability from 14 to 65% and density increased from 303 to 390 kg/m^3. In the same experiment the force transmitted into the block, by means of friction between the material and the die surface, increased from 20 to 27 kN.

Low density polyethylene (LDPE) added in powder form at the rate of 6 to 17% of DM reduced the friction force while simultaneously increasing the resulting cube durability. However, the lower bulk density of LDPE caused a reduction in cube density at the greater application rates.

The laboratory test fixture work showed that improved cube properties could be obtained by lowering die temperature and adding calcium oxide as an amendment. The in-field cuber was modified with a die cooling system using ambient temperature water and system to apply lime to the material just before the die ring. Although these modifications did improve the performance of the in-field cuber, the fraction of material formed into cubes and the durability of the cubes was almost always less than desired. The spatial variability of moisture in the windrow made it very difficult to optimize the cuber operating parameters so that a continuous production of cubes could be produced for a sustained period.

In summary, much additional work would need to be conducted to improve in-field biomass cube production to a commercially viable system. Further experimentation of the effects of binders, and more specifically lime addition could be conducted. Also, material conditions could be examined further to determine an ideal particle size and die temperature for each moisture level. Lastly an improved handling and cooling system could be implemented to improve cube quality.