IDENTIFYING POTENTIAL BINDING AGENTS FOR UTILIZATION OF WASTES AND RENEWABLE RESOURCES AS FUELS OR MATERIALS

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The following is a procedure developed at the University of North Texas for identifying potential binding agents for the utilization of wastes and renewable resources as fuel materials. This procedure is being used for other materials which will be described in the extended paper for book publication.

The goals were to find six low-cost, environmentally acceptable binders for preparing pellets of densified refuse derived fuel (RDF). The binders had to be capable of being used with RDF to produce a pellet that could be produced in a more stable fashion than with water alone. The pellet produced had to be chemically and biologically stable and had to be capable of being stored for up to six months prior to being used as a fuel.

Over 100 potential binders were considered including glues, natural starches and celluloses, adhesives, waste liquors, fly ashes, dusts, hydraulic cements, reaction cements precipitation cements, etc.

The densification fabrication technique used must remove the pores between the RDF particles (accompanied by shrinkage of the component), combined with growth together and strong bonding between adjacent particles. The following criteria must be met before densification of the RDF can occur:

* A mechanism for material transport must be present
* A source of energy to activate and sustain this material must be present.

The primary mechanisms for transport are diffusion and viscous flow. Heat is the primary source of energy, in conjunction with energy gradients due to particle-particle contact and surface tension.

Much progress in understanding densification techniques has been achieved since 1935. Now densification is studied by plotting density or shrinkage data as a function of time and by actual examination of the microstructure at various stages of densification by using scanning electron microscopy, transmission electron microscopy, and lattice imaging.

Densification mechanisms may include vapor phase, solid phase, liquid phase, and reactive liquid phenomena. Probably the most applicable of these to RDF are solid phase mechanisms, although other forces are undoubtedly present. Diffusion will be important. The differences in free energy or chemical potential between the free surfaces of particles of RDF and free points of contact between adjacent particles will be important. The control of temperature and particle size for densified RDF will probably be extremely important, but control of time less important. Particle size distribution may be of critical importance. Particle shape will also be important.

Other processes are also available to achieve densification, deposition of a solid phase, or strong bonding. These types of processes include hot pressing, reaction densification, chemical vapor deposition, liquid particle deposition, and cementitious bonding. All of these processes were considered during the course of this project and in the pilot-plant phase. The application of pressure during densification of RDF might provide the following processing and property advantages:

- Reduction of densification time,
- Reduction of densification temperature,
- Minimization of residual porosity, and
- Higher strengths than can be achieved through pressureless densification, due to the minimization of porosity and grain growth

The RDF was obtained from Madison, Wisconsin; Ames, Iowa; and Monroe County, New York. It was determined in our laboratory that the three sources of RDF were similar and behaved in approximately the same way to binders. The RDF was minus one inch in particle size. The RDF was first dried in the oven for several hours to remove as much moisture as possible at 100°C. Once dried, the RDF was suitable for preparation with binders and follow-up tests.

The preparation involves the weighing of a desired quantity of the dried RDF, usually 30 to 40g, and adding to it 5 percent by weight of water. For those binders that are in liquid form, no water is added. All of these components are mixed and the binder-RDF mixture chopped and reduced in particle size with a food processor. The RDF/binder mixture is then placed into a stainless steel die and formed into pellets by a Carver laboratory pellet press using 5,000 lb of pressure. The pellets produced range in weight from 1 to 1.5g. The process of making the pellets takes about 30-45 minutes. After the pellets are produced, various tests are conducted according to design protocols and a binder rating system.

For example, the durability test is conducted in order to determine the durability of the pellets when subjected to handling. Two pellets are weighed by difference and placed into a ball mill jar with then ceramic stones. The jar is allowed to tumble for ten minutes. After this specified time, the two largest remaining pieces are reweighed. The percent durability is calculated using the following formula, with 100% being the ideal:

$$\% \text{ Durability} = \frac{\text{weight of largest RDF pieces}}{\text{weight of RDF pellets}} \times 100$$

Another example is the water sorability test, which helps to determine the quantity of water that the pellets absorb within a given time frame (in this case, 24 hours). The pellets should absorb as little water as possible in order to further enhance their endurance potential. Two pellets are weighed into a petri dish (W_w) and their weight obtained by difference (W_p). Twenty-five milliliters of water are added, and the pellets are allowed to absorb water for one hour. Actually, the pellets remain on each side for 30 minutes in order to ensure equal water absorption, thus resulting in a total of one hour. The pellets are then placed into a desiccator with a constant 100% relative humidity and maintained for 24 hours; and the petri dish is then placed into an oven at 100°C to dry. Following the 24 hour period in the environmental chamber, the pellets are removed and reweighed (W_t). The percent absorbed water is calculated using the following formula, with the lower percentage being most favorable:

$$\% \text{ Absorbed Water} = \frac{W_t - W_w}{W_p} \times 100$$

The overall study was divided into two sections, a preliminary study and a laboratory study. The preliminary study was designed to reduce the number of binders that would be investigated in the laboratory study to approximately 50. In order to accomplish this, a series of protocols was developed for the preliminary study and the laboratory study in order to evaluate the potential binders discussed previously. The protocols were subjected to peer review early in the project and modified in some instances.

The preliminary study was divided into two parts. They were binder cost and environmental acceptability, rated at 60 points and 40 points, respectively, for a total of 100 points. Cost was considered to be the more important aspect of a suitable binder. This is because the RDF is a low-cost binder with a low-cost material. This would only make sense if the binder could be used in very low concentrations, and none of our studies indicated that this was possible. The environmental acceptability part was broken into three segments - toxicity, odor, and emissions - rated at 10 points, 10 points and 20 points, respectively.

The laboratory study was divided into 11 segments; binder dispersability, binder Btu content, binder ability to wet, binder ash content, pellet weatherability (including in the ice box at 32°F and in the environmental chamber at 110°F), pellet water sorability, pellet caking, pellet ignition temperature, moisture content, durability, and aerobic stability. These were considered to be in two parts, the first four segments being binder properties and the last seven segments being pellet properties. The binder properties were rated at 7 points per segment, and the pellet properties were rated at 9 points per segment (with the exception of weatherability, which was rated at 9 points each for the ice box test and the environmental chamber test).

The above concepts were also subjected to peer review, and comments generally favored this approach. Protocols for each study were developed and will be discussed in the extended paper.

Worksheets were prepared listing point values for the various binder and pellet properties identified previously. The sheets are arranged in order from the binder having the highest rating to the binder having the lowest rating. In some cases, binders with low preliminary study ratings were tested in the laboratory study, in order to evaluate different types of binders.

The top six binders were carbon black, calcium hydroxide, free lime, cement kiln dust, limestone and lignite fly ash. Further pilot plant work at Jacksonville Naval Air Station in Florida indicated that calcium hydroxide was the best binder. The above procedure, with some modifications, is being used with other solid waste problems. These will be briefly discussed in the extended paper.