BIOENERGY ASSOCIATION

WOODENERGY

Woody biomass fuel drying for forced drying options

Introduction

Extracting useful heat energy from wood involves processing the wood in a combustor or a gasifier. Prior to combustion it can be left to dry naturally or dried in a fuel dryer. The amount of energy able to be extracted depends on the processing equipment design, the calorific value of the material, and its moisture content.

Many wood waste combustion units are designed to burn reasonably wet wood. However, there is a practical limit on the moisture content of the fuel for each system.

Some combustor designs can cope with high moisture content material while others are better suited to handling only dry fuel. Wood waste from freshly harvested trees, with a 60% moisture content measured on a wet basis[1] (mcwb) is around the maximum moisture content that standard grate boilers are designed for.

Advantages of pre-drying:

Pre-drying of wet woody biomass for fuel can provide the following advantages:

- improved energy conversion efficiency;
- more stable combustion;
- ability to utilise fuel too high in moisture for an existing combustor design;
- ability to use less expensive combustion systems for fuels of higher moisture content (but there is a trade-off here since drying the fuel can have a cost); and
- lower stack emissions.

Some fluidised bed combustors cope with higher moisture contents and are more tolerant of fuels with varying moisture content.

Gasifiers usually require a dry fuel around 20% mcwb though larger capacity fluidised bed design can cope with wetter fuels. All combustion systems work better with a consistent and low moisture content fuel source.

In many situations the pre-drying of wood fuel prior to combustion or gasification provides a number of advantages to the user.

This information sheet examines the issues surrounding the pre-drying of woody biomass for combustion by both natural and forced means.

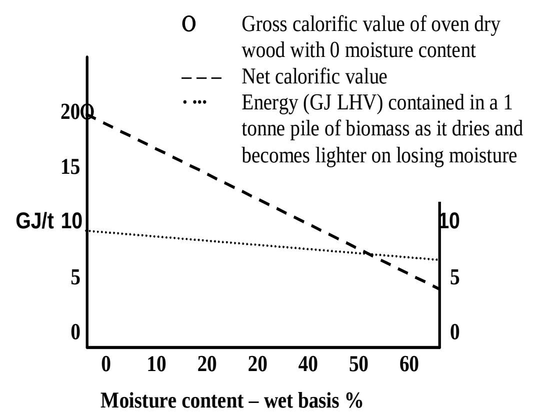

Figure 1: Moisture Content and Calorific Value (Source: Refs 2 & 3)

[1] Wet basis is commonly used for biomass, not dry basis which is used more for wood products.

Energy in wood

Broadly speaking the amount of energy available per kilogram of totally dry wood is very similar (19-22 GJ/t) for all wood species. What varies is the density of the wood (kg/m3) and its moisture content.

When fuels of high moisture content are burned, much of the energy released during the combustion process is used to drive the moisture out of the wood. The energy contained in this moisture can be recovered from the flue gas using condensing steam boilers, but this is seldom done in New Zealand. Therefore, in most biomass combustion systems the higher the moisture content of the fuel the lower the combustion system output of heat. The net calorific value (or lower heat value), being the energy available after complete combustion without recovery of the moisture from the flue gas varies with moisture content of the wood biomass (Figure 1).

On a unit weight basis one tonne of wood of a lower moisture content contains more net energy than one tonne of wood of a higher moisture content. However dry wood is less heavy than wet wood. Hence as a pile of wet wood chips dries down, the total available energy contained in the pile rises only slightly. At 60% mcwb a 1 tonne pile of wood chips has a heating value of around 6.3 GJ. If dried to 20% mcwb it would then weigh 0.5 tonne and contain 7.45 GJ of available energy around only 18% more net calorific value. This is demonstrated in Figure 1 above.

Moisture content

Moisture content (mc) of woody biomass is commonly expressed as either dry basis (mcdb) or wet basis (mcwb) and normally expressed as a percentage. It is important to know which moisture content measurement definition is being used when quoting or using moisture content percentages.

In practice, the moisture content of wet wood is determined by weighing a sample, oven drying it at around 90°C until constant weight is achieved, then weighing it once dry. The difference between the wet weight and the oven dry weight is the moisture content.

Dry basis mc (mcdb)%

$$= \frac{\text{(Total weight of wet wood)} - \text{(oven dry weight of wood)}}{\text{(Oven dry weight of wood)}} \times 100$$

Wet basis mc (mcwb)%

$$= \frac{\text{(Total weight of wet wood)} - \text{(oven dry weight of wood)}}{\text{(Total weight of wet wood)}} \times 100$$

For a sample of wood, the definitions of the two methods are shown

Wet weight 11.2 kg
Oven dry weight 6.3 kg

Moisture content dry basis = $\frac{(11.2- 6.3)}{6.3} \times 100$=77.8%

Moisture content wet basis = $\frac{(11.2-6.3)}{11.2} \times 100$ = 43/4%

Fuel preparation

All biomass combustion units have a limit on particle size as do fuel dryers. It is normally possible to use the same comminution and screening equipment for size reduction and grading to classify the material prior to drying. The drying process will benefit from reduced and consistent particle size in all dryer designs. It is also normally beneficial to keep different fuel streams separate and blend them only just prior to feeding into the combustion unit.

Thus, routing only wet fuel through the dryer is possible which minimises the size (hence cost) of the unit and reduces the risk of fire.

Fuel drying

Drying principles

There are three primary requirements for drying fuel; a source of heat, a method of removing evaporated water and some form of agitation to expose fresh material for drying. Typically, moisture content of trees at harvest is around 60% mcwb. Depending on piece size, time of year, atmospheric humidity and whether covered or not, the moisture can drop naturally to around 20-30% mcwb within 3 to 6 months after harvest.

It is possible to dry fuel naturally by leaving it in the forest prior to collection or by laying it out in the open to allow moisture to evaporate. In New Zealand, this is not usually an option due to the space required, labour cost (for turning), loss of mass due to degradation, and inconsistent final moisture content. Mechanical drying can be used but this requires capital equipment and operating costs. An evaluation of the trade off of costs versus moisture content reduction and subsequent energy output benefits has to be undertaken on a case by case basis.

Types of dryers

Direct and indirect designs of dryers are available based on how the heat is provided.
In direct dryers - the heating fluid (normally air) comes into direct contact with the biomass material being dried.
In indirect dryers - the material being dried is separated from the heat source by a heat exchange surface but is more expensive than direct designs so is not in common use in New Zealand. Hence this information sheet will principally deal only with direct drying. There are three main types of direct dryers.

Rotary dryers

Wet biomass usually in the form of wood chips, bark pieces, or sawdust, is interfaced directly with hot air inside a rotating insulated drum (Figure 2).

The drum tumbles the biomass particles to promote mixing as the material moves from one end to the other. The hot air and the biomass normally flow co-currently (in the same direction) so that the hottest air comes into contact with the wettest material.

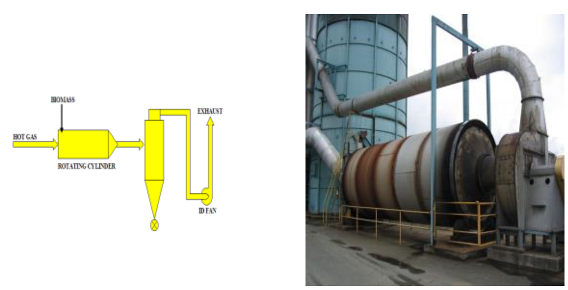

Figure 2: Rotary Dryer Schematic

Rotary dryers can be single, double or triple pass. Because the biomass particles are mechanically stirred and exposed to a larger retention time than flash dryers, rotary dryers can accept a fairly wide range of particle sizes and still achieve high rates of dryness in a single pass. Triple pass dryers require a more uniform and smaller particle size than a single pass unit but can achieve lower moisture contents. Fire risk in rotary dryers is higher than in flash dryers due to hotter inlet temperatures and drier biomass produced.

After passing through the dryer the biomass particles are separated from the moisture-laden air via a cyclone, or other particulate separation device (e.g. bag filter). Fuels suitable for drying in rotary dryers include wet sawdust, chips or bark. Moisture content can be reduced from 60% to around 15% mcwb.

Flash dryers

Wet biomass particles are conveyed through a duct and mixed with a high velocity hot air stream (Figure 3).

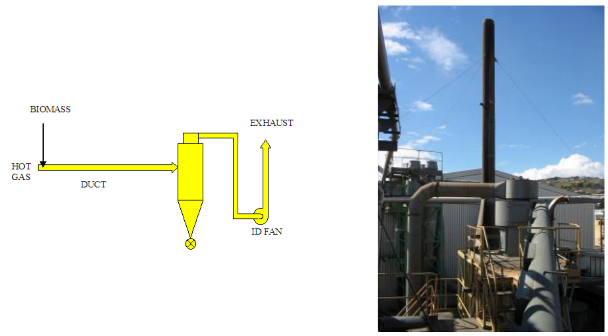

Figure 3: Flash Dryer Schematic

Drying takes place during this process and the solid particles are separated in a cyclone. The exhaust gas is vented direct to atmosphere or routed through a scrubber or other device to remove particulate matter.

Flash dryers are simple, relatively easy to operate and control but have greater electricity consumption than rotary dryers. Because the biomass is conveyed in the gas stream it needs to have a fairly consistent, small particle size.

The retention time of the material in the dryer is normally less than 30 seconds. Therefore, the ability to dry wet sawdust material down to very low levels of moisture content is limited but a risk of fire still exists.

Typical fuel for drying in a flash dryer would be wet sawdust. When its moisture content might be reduced from say 60 to 45 % (wet basis). In NZ this drying process is often included in a drying loop using boiler flue gas emissions through which the wet sawdust passes prior to being fed into the boiler. A comparison of rotary dryers with flash dryers is given (Table 1 below).

Superheated steam dryers

Superheated steam is interfaced with the wet biomass normally in a tube similar to a flash dryer. Because of its superheat the steam remains above saturation temperature and does not condense on the surface of the cooler biomass. Moisture from the biomass material is driven off creating a large amount of steam but at a lower temperature. Excess steam is removed and the remainder reheated and recycled back into the dryer. This type of dryer is not common in New Zealand and is not covered in detail in this information sheet.

Summary of advantages/disadvantage of flash dryers vs rotary dryers

	Flash Dryer	**Rotary Dryer**
Requires small particles <50 mm	Yes	No
Requires uniform size	Yes	No
Reduction in moisture content	Low	High
Ease of control	Easy	More difficult
Power requirement	High	Low
Fire risk	Medium	High
Capital cost	Low	High
Maintenance cost	Low	High
Source: Ref. 1		

Table 1

Dryer emissions (Ref. 1)

Fuel dryer's exhausts will emit a range of substances, some of which may be considered harmful and require controls. If boiler flue gas is used as a dryer heat source the exhaust may contain sulphur dioxide, nitrous oxides, carbon monoxide, unburned hydrocarbons and particulate matter (dust) from the wood.

The dryer itself may create "blue haze" emissions which are caused by the condensing of resins and organic acids after the exhaust gas leaves the exhaust. In general blue haze emissions are a problem in dryers with high operating temperatures (typically above 260°C).

In New Zealand the largest concern is normally with emissions of particulate matter (PM). In most cases dryers' exhausts are fitted with cyclones and these are normally accepted as an adequate means of PM control. Other more sophisticated controls for PM include bag filtration wet scrubbers. Removal of blue haze emissions is more difficult and the best available control technology is wet electrostatic precipitators

Case study

A sawmill had been operating for around 10 years and was kiln drying a significant quantity of the total sawmill timber output. The drying energy was provided by a wood waste combustion unit with a fixed grate. More timber drying capacity was required but a new energy system was considered too costly and the existing unit was running at maximum output.

Figure 4

The unit burned all the dry shavings also produced on site and a proportion of the wet sawdust produced. There was a limit to the quantity of wet sawdust which could be burned due to the furnace grate configuration.

The flue gas temperature was however around 230°C and the plant manager recognised that this waste heat could be used to dry the wet sawdust. Supplying the combustion unit with the same mass of dryer fuel would provide more available energy at a higher temperature. (Less energy would be used in drying the moisture from the fuel.)

A study indicated that the plant manager was correct and he decided to use a rotary dryer due to previous experience in drying feed. A suitable second-hand Heil three-pass rotary dryer was sourced from the USA and the system was designed locally (Figure 4 above).

Other benefits included:

- more stable combustion; and
- less wet sawdust to dispose,

All other equipment required (fan, ductwork, cyclones and fuel conveyors) were designed and manufactured in New Zealand. The implementation of the drying system increased the usable output from the combustion system by 25%.

Economics

The economics of drying woody biomass for fuel is complex due to the variables involved. Each situation must be examined on a case by case basis to determine if a fuel dryer should be added to an existing plant or be included with a new combustion system.

Capital cost

The following statements will be true in most situations and may help determine the economic sense of inclusion of fuel drying.

- A fuel dryer will add to the capital cost of a combustion system
- If more energy is required from nab existing system, and an excess of fuel is available, the addition of a fuel drying "loop" utilising flue gas may prove less expensive than adding another combustion unit.
- The inclusion of fuel drying in a new combustion system will allow the use of a more common, simple and less expensive furnace grate/combustion technology.

Operating cost

The major operating cost of a fuel dryer will usually be the fuel handling cost. The other operating costs to consider are electricity and maintenance. Rotary dryers tend to be more expensive to own and operate than flash dryers (Table 1).

Control, operation and maintenance

Control

Controls can be simple or complex depending on the consistency of final moisture content required. If the incoming moisture content of the biomass fuel varies dramatically, the resultant final moisture content from a dryer with simple controls will vary too. Final moisture content variation will be much reduced with more technical controls. It is important that the fuel requirements of the combustion system are known as it is preferable to integrate the dryer controls with those of the combustion system, to produce fuel of the desired quality.

Operation

Operation of a fuel dryer is typically automatic. The energy plant operator can monitor the dryer's performance along with other normal duties and typically no manual intervention is required. A fuel dryer will normally operate with a water vapour plume from its exhaust.
Fire is an operational risk with both flash and rotary dryers so depending on the assessed risk with the particular dryer type, a fire detection system and/or extinguishing system should be installed.

Maintenance

Rotary dryers

Maintenance of the driving mechanism (typically a chain or gear) and the rollers is required though this is easy for well-designed units. Lifting bars for agitation of the fuel inside the dryer is designed for long life and requires infrequent maintenance. As with flash dryers the main fan will require some maintenance especially if located before the main cyclone.

Flash dryers

Flash dryers can suffer from a build-up of material in the drying tube. Access hatches are normally fitted and this build up should be regularly removed, usually every 2 to 4 weeks. The dryer tube itself is subject to abrasion but with good design will last many years without maintenance. Normally the only moving part of the dryer is the main fan and if it is located after the main cyclone, very little maintenance is required.

Conclusion

The use of naturally dried woody biomass or a dryer to dry fuel prior to combustion will improve energy efficiency and reduce air emissions.

Two main dryer types are in fairly common use in New Zealand.

Rotary dryers can cope with a large material size range and will dry fuel down to low levels of moisture content. However, they are more expensive than flash dryers and present a greater fire hazard.

Flash dryers are the less expensive and are easy to control. However, they require smaller and more consistent biomass material size and do not dry the fuel down to as low levels of moisture content.

The addition of a fuel dryer (normally utilising a flue gas drying loop) to an existing combustion system can increase the usable heat output of the combustion system.

References

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