Sawdust Combustor

RURAL ENERGY & INFRASTRUCTURE SECTION

Mahatma Gandhi Institute of Rural Industrialization

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Introduction

In many parts of India, powdery biomass like sawdust and many agricultural residues are being widely used as fuel for various purposes. However, combustion of powdery biomass can be very inefficient and polluting when ignited in the loose form. For controlled and efficient combustion of powdery biomass, fluidized bed or entrained flow combustors have to be employed, which are conventionally used at large scale. However, for continuous mode at small scale, no efficient combustor for sawdust or other powdery biomass is commonly available. Considering the above lacuna, an NGO, Navreet Energy Research and Information (NERI) developed a coil type combustor for more efficient and controlled combustion of powdery biomass. This combustor was further improved upon at IIT Delhi.

Traditional Use of Sawdust

At small scale, powdery biomass has been used traditionally for cooking by packing sawdust in a tin and using it as a *chulha*. Improved versions of this *chulha*, which have good combustion characteristics, are also available. The major limitation of this device is that it can be used only in batch mode by packing a certain quantity of sawdust and utilizing it fully before the fresh fuel can be packed again in the same tin. In many small scale industries, the fuel is required to be burnt in a continuous mode. In pottery kilns, sawdust is used by just igniting it in the loose form in a small chamber with additions of loose sawdust at a frequency dependent upon the power required. In this mode, the combustion of sawdust is very inefficient and highly polluting. Thus, a very large quantity of sawdust is required for firing even a small quantity of pottery.

Combustion of Powdery Biomass

Any fuel, for combustion, requires oxygen which is generally provided by air. Besides, combustion needs high temperature and proper mixing between the fuel and the oxygen. For complete combustion of a fuel, there is a minimum quantity of air required. If the air supplied is less, the whole of fuel cannot be burnt and hence the heat released will be less than what the fuel can provide. If the air supplied is in excess, the heat released will be taken up by excess air along with products of combustion. As a result, the overall temperature in the combustion region will be low. If the percentage of excess air is considerably high, the temperatures attained can be so low that complete combustion cannot be favored and a considerable part of the fuel can escape as intermediate products of combustion in the form of hydrocarbons or soot particles leading to smoke. Combustion of a solid fuel involves drying and then pyrolysis of the fuel. During pyrolysis, the fuel breaks up into smaller chain hydrocarbons and char. These hydrocarbons, then, burn in the presence of oxygen to produce a flame. Char also burns to give carbon-monoxide or carbon-dioxide. Thus, for the fuel to go through the complete process of combustion, it needs enough residence time in the high temperature region.

Generally in the combustion of loose biomass, the availability of air to the burning fuel is not uniform. So, in some regions, the air available will be in excess and in the interior regions, it may be in short supply. This leads to incomplete combustion resulting in low efficiency as well as pollution. As long as the powdery biomass is burnt in a heap in loose form, proper control of air is not possible. On the other hand, combustion of such a fuel in devices like fluidized bed combustors and entrained flow combustors, results in much more uniform distribution and controlled supply of air leading to much better combustion characteristics of these devices. However, such devices are commercially available only for large scale use and hence the need for a suitable device with better combustion characteristics at small scale.

Coil type combustor

Figure 1 shows the schematic of the coil type combustor developed for combustion of sawdust. The device uses entrained flow of sawdust of particle size less than 2 mm along with the combustion air. The sawdust is fed in a hopper which has rotating blades driven by a small motor. The opening at the side of the hopper releases sawdust in the air inflow passage of a small blower. The blower forces air laden with sawdust particles through a heated coil. The rate of air flow must be less than the minimum air required for complete combustion. In that case, the passage of sawdust through the hot coil results in pyrolysis and gasification. Thus, the powdery fuel gets converted into a gaseous fuel consisting of hydrocarbons in vapors form along with some amount of carbon-monoxide, hydrogen, methane and non-combustible components viz., carbon dioxide, water vapors and ash at the coil end, a burner is fixed where the gaseous fuel is burnt in such a manner that the flame heats the coil in turn, sustaining the process of pyrolysis and gasification. Since only a small part of the heat released during combustion is used for keeping the coil hot, most of the heat can be used for any useful purpose. The combustor is insulated from the sides to reduce loss of heat.

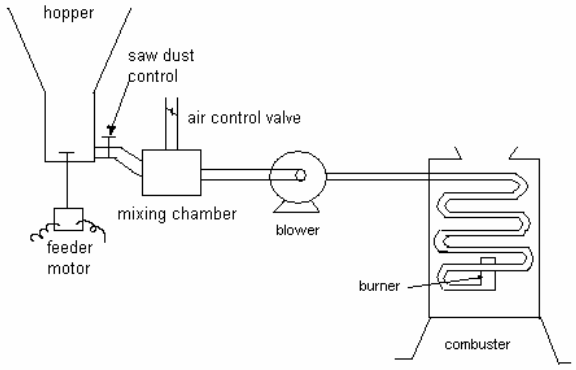

Figure 1: Schematic of the Sawdust Combustor with Accessories

The burner needs to be ignited first by first providing a flame from an external source. For using twigs or any other woody material for initial ignition, a grate has been provided at the bottom of the burner as shown in the figure 1.

The design of the combustor should be such that it allows limited supply of air for a desired fuel flow rate, which can allow better gasification in the coil, i.e., conversion to higher percentage of carbon-monoxide and hydrogen. The length and diameter of the coil tube have to be chosen so as to give enough residence time to the fuel for better gasification. The diameter of the coil and the burner size should be such that the flame is able to heat the coil effectively. The preferred material for the coil and outer casing of the combustor is carbon steel which can withstand high temperatures.

Figure 2 : The combustor developed by NERI and IITDelhi

Figure 2 gives a picture of the improved combustor developed at IIT Delhi jointly with NERI. This can use sawdust at flow rates of 4-8 kg/hr resulting in an output thermal power of 20-40 kW. Thus combustor can give a turn down ratio of about 2:1. The air flow rate can be varied by changing the blower speed as well as by changing the valve position. The sawdust flow rate changes automatically with the change in air flow rate, since sawdust is being sucked along with the air. However, it can also be controlled independently to some extent with the use of a gate at the exit of the hopper for sawdust, as shown in the figure 1.

Figure 3 shows the burner at the end of the coil for burning the gaseous products coming from the hot coil. The flame from the burner, in turn, keeps the coil hot. Figure 4 shows the flame from the burner.

Figure 3 : The coil and the burner

Figure 4 : Flame from the burner

The combustor is found to give a stable and good quality flame when the air-to-fuel ratio is between 2:1 to 3.5:1. Good quality flame is the one which looks transparent in some regions, indicating the carbon-monoxide and/or hydrogen component is considerable in the gaseous mixture. Figure 5 shows a flame which is somewhat transparent while figure 6 shows a more sooty flame. Flame due to sooty combustion of char and hydrocarbons are deep yellow in color. This is more polluting, and due to presence of un-burnt carbon, it also has less combustion efficiency. The combustor tested in IIT Delhi was found to give about 25% CO and about 9% H_2 at 2.3:1 air-to-fuel ratio. The air flow rate and sawdust flow rate need to be adjusted for getting a good flame.

Figure 5: Flame with good transparency

Figure 6: Sooty flame

The burner can be designed for a lower or higher power as well, in the range of about 5-50 kW. For lower power, the air flow rate should be lower and hence the coil tube diameter and length will be lower. With lower tube diameter, the coil diameter can also be smaller and the burner also of smaller size. The blower and the valves can also be of smaller size.

This device needs electricity for running the blower and rotating the blades for pushing the sawdust. This can act as a limitation due to non-availability of electricity in many areas. However, this limitation can be overcome by providing a hand blower and manual agitation of sawdust.

The main feature of this device is its capability to allow controlled combustion of a powdery biomass in continuous mode at small scale and a turn down ratio of about 2:1

Applications

This combustor can be very useful in any application where sawdust is being used as fuel. Thus it can find applications ranging from cooking to varieties of furnaces. It is particularly suited for small scale applications due to its range of power from 5-50 kW.

For example, pottery kilns using loose sawdust can use this combustor very effectively. The coil and the burner can be kept inside the combustion chamber of the kiln, while the hopper and blower can be outside. For this application, even the outer insulation is not required. This device will give much better control on fire inside the kiln and improve the combustion efficiency leading to savings in fuel for a given payload of pottery.

The device can also be used for cooking particularly at community level, e.g., as a *chulha* in *dhabas*. For this purpose, supports are provided on top of the combustor to keep a vessel for cooking. In this mode, the sides of the combustor must be insulated for better efficiency. Unlike the traditional sawdust stove in which a fixed amount of sawdust is packed in the *chulha*, this burner can enable continuous cooking with a reasonable control of the fire.

The device has been found to have one limitation of ash particles flying away from the flame. This will not pose a problem for a pottery kiln. However, while cooking, it should not be used in the open. Instead, it can be kept inside an enclosure so that ash particles get settled inside. This will also help in reducing the heat losses to the ambient.

Other Fuels

This device need not be limited to only sawdust. Any loose biomass pulverized to small particle size can be used as fuel in this device. Particularly dry leaves which cause a lot of pollution when burnt in loose form, can be used as an energy source in such a device.

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