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Design and Thermal Analysis of Pine Needle Charcoal Briquette

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ABSTRACT: The work represented in this paper focuses on the design and thermal aspects of the pine needle charcoal briquette. Different types of briquette samples are manufactured based upon their composition, ratio of the constituents, design and physical structure. The samples are compared upon these parameters by performing proximate analysis and water boiling tests. The briquette, having clay as the binder and the ratio six to four of pine char with the clay, is taking the least ignition time. The briquette, having cow dung as the binder with ratio four to six with the pine char and having nineteen holes, is having the longest life among all the considered types of the briquettes. The specific fuel consumption is observed better for the briquette with cow dung as binder with the ratio three to seven of the pine char and having thirty three holes. The briquette, with nineteen holes and having clay as the binder in the ratio three to seven with the pine char, takes the least time to boil the water and the briquette, with nineteen holes and having clay as the binder in the ratio four to six, takes the longest time to boil the water. Thus, this article provides an insight for design considerations for pine needle briquetting to improve their efficiency.

Keywords: Pine Needle Briquette; Proximate Analysis; Water Boiling Test; Ignition Time & Specific fuel consumption.

INTRODUCTION: The use of the biomass offers an environment friendly way for producing clean and sustainable fuels. Chir Pine, *Pinus roxburghii*, is a very common tree in Northern India. In rural households, the wood of pine trees is used for cooking, whereas pine needles/leaves (figure 2) are used for animal shelter or used for preparing fertilizers etc. The pine trees (figure 1) shed their leaves every year in the months of January, February, March and April. These leaves have about 70% of mean volatile matter content. It is a fact that most of the pine needles remain unutilized and thereby accidently cause forest fires during summers.

Figure 1: Pine trees.

Figure 2: Pine leaves.

These forest fires cause release of harmful gases into the atmosphere, thus affecting the flora, fauna & the atmosphere. It also affects the fertility of the soil, as no vegetation is feasible under the dry pine leaves. The systematic use of pine needles can control the forest fires, save biodiversity and at the same time can be utilized for developing Pine Needle Briquettes (PNB). Carbonization of pine needles in least oxygen / in the absence of oxygen is done at best carbonization temperature of 600 degree Celsius. This process involves the conversion of an organic substance into carbon through pyrolysis. This also includes removal of harmful gases at the initial stage.

PNB are rich in calorific value, have improved handling and storing operations, reduces the transportation costs and makes it available for variety of the applications. The pine needle briquette charcoal is considered as an advanced fuel due to its clean burning nature. Also, it can be stored for longer periods of time. Hence the pine needles or leaves can be used as an alternative to the wood charcoal by converting into the briquettes.

MATERIALS AND METHODS:

Design: For preparing the fuel briquette, firstly the design of the mould is prepared, which is to be used in the manufacturing of the briquette. The briquette mould (figure 3) consists mainly of three parts. All the three parts of the mould are placed over one another in a certain pattern.

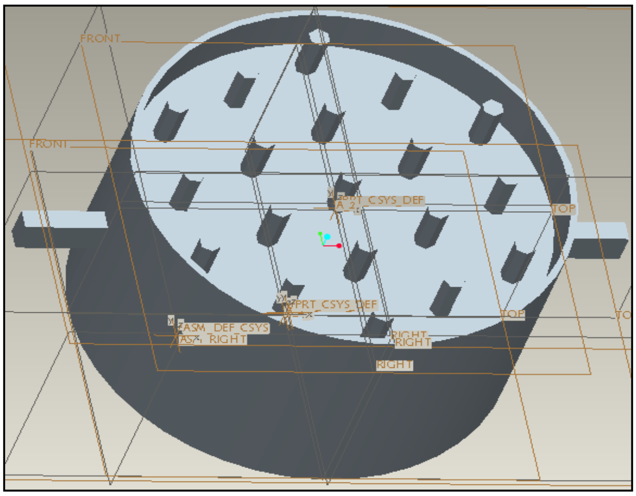

Figure 3: Briquette mould.

Two types of the briquette mould are designed using the Pro/E software, Mould 1 having nineteen holes (figure 4) and Mould 2 having thirty three holes (figure 5).

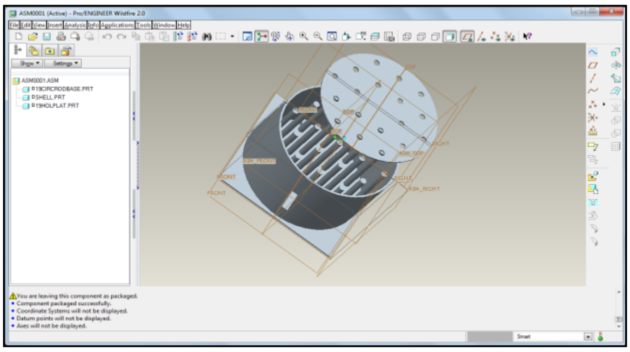

Figure 4: Mould 1.

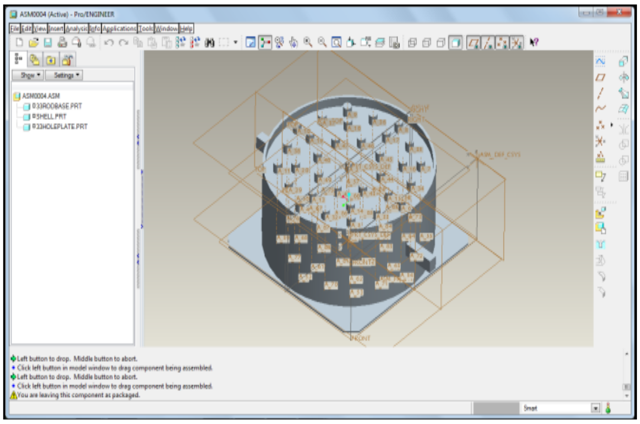

Figure 5: Mould 2.

Procedure: The material which is required to be used for preparing the briquettes consists of mainly these components: one drum charring unit (figure 6), pine needles as the biomass, some dry leaves, grass or paper. The biomass is then carbonized (burning in the low supply of air) for three to five hours (figure 7) and thus, twenty five to forty percent of the biomass char is obtained.

Figure 6: Drum charring unit and pine char.

Figure 7: Burning the biomass.

Proximate analysis: The moisture content, ash content, volatile matter and fixed carbon are determined using the proximate analysis (figure 8) of the material.

Figure 8: Proximate analysis.

Briquette preparation: The biomass char is mixed with the binder, which can bind the mixture of the char obtained in the form of the briquette or a brick. Here it is mixed in two types of ratios:

(1) 7:3 that is pine char to the binder ratio.
(2) 6:4 that is pine char to the binder ratio.

The binder can be of different types. Here, the binder used is of two types:

(a) Clay
(b) Cow dung

The material mixing is done manually (figure 9) and is rammed into the moulds when the mixture is finally prepared.

Figure 9: Mixing the material.

Mould fabrication: After the design preparation, these moulds are fabricated in the workshop using various operations like cutting, welding, filing, drilling etc. The final mould is shown in figure 10. The mould consists of a base plate, a cylindrical pipe and a circular plate.

Figure 10: Mould.

After that the mixture is put inside the mould and is rammed to have proper packing.

Figure 11: Prepared briquettes.

The different parts of the mould are then disassembled to obtain the desired PNB. The final PNB thus prepared are having nineteen and thirty-three holes as shown in figure 12. Available literature suggests a L/D ratio of 0.6 for preparing these PNB samples.

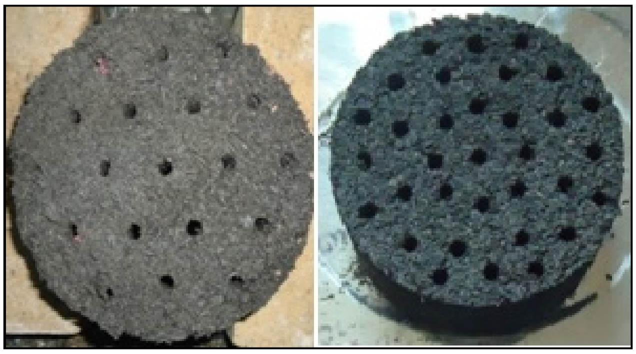

Figure 12: Briquettes.

Eight types of PNB samples were prepared as shown in Table 1. These samples were varied in their concentration ratio, and in terms of number of holes.

Table 1: Briquette samples composition.

Sample	Char	Binding material	Mould Type
1	1kg	435g clay	19 circular
2	1kg	435g clay	33 circular
3	1kg	435g cow dung	19 circular
4	1kg	435g cow dung	33 circular
5	1kg	666g clay	19 circular
6	1kg	666g clay	33 circular
7	1kg	666g cow dung	19 circular
8	1kg	666g dung	33 circular

Water boiling test: This test measures the time taken by each briquette type to boil an equal volume of the water under identical conditions. This test also compares the cooking efficiency of the briquette samples. By performing this test, other fuel properties of the briquettes like burning rate and specific fuel consumption are also found.

The burning rate can be calculated as the ratio of mass of the fuel consumed (in grams) to the total time taken (in minutes).

$$Burning\ Rate = \frac{Mass\ of\ fuel\ burnt}{Total\ time\ taken}$$

The specific fuel consumption shows the ratio of mass of the fuel briquette consumed (grams) to the quantity of the boiling water (liters).

$$\text{Specific fuel consumption} = \frac{\text{Mass of fuel burnt}}{\text{Quantity of boiling water}}$$

RESULTS AND DISCUSSION:

Proximate analysis: According to the proximate analysis, the sample with pine char and clay is the best among the all considered samples in the briquette production.

Water boiling test: The water boiling test is performed using each of the briquette samples. Different parameters are based upon it.

Ignition time: Each of the samples is ignited and water is boiled upon it.

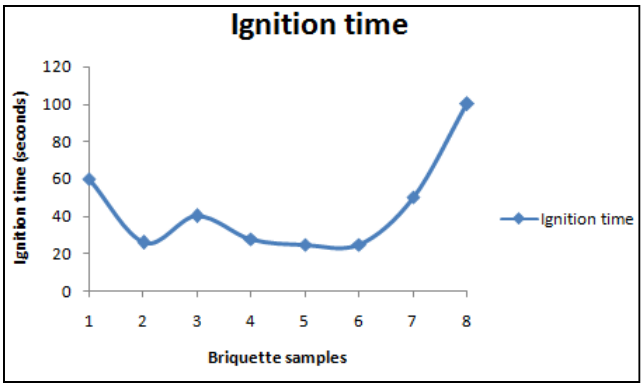

Figure 13: Ignition time of briquettes.

Thus, it is clear from the study of the ignition times of the different briquette samples (figure 13), that the samples having clay as the binder with ratio six to four exhibit the best ignition properties.

Table 2: Results of the proximate analysis

Sample	Moisture (%)	Volatile matter (%)	Fixed carbon (%)	Ash content (%)
Pine char	4	0.66	2.66	92.66
Pine char + cow dung	4.66	7	2.33	86
Pine char + Clay	3	17.33	2.33	77.33

During proximate analysis, the mixture of pine char and clay exhibits highest mean value of volatile matter; also it shows least ash content. Whereas, the mixtures of pine char and cow dung have significant volatile matter, but creates pollution.

Burning rate: The burning rate for various samples is shown in figure 14. The burning rate is least for the sample having the mixture of pine char and the cow dung with ratio six to four of nineteen circular holes. For better efficiency, the burning rate must be less. Thus, the seventh type briquette is the best among the all based on this parameter.

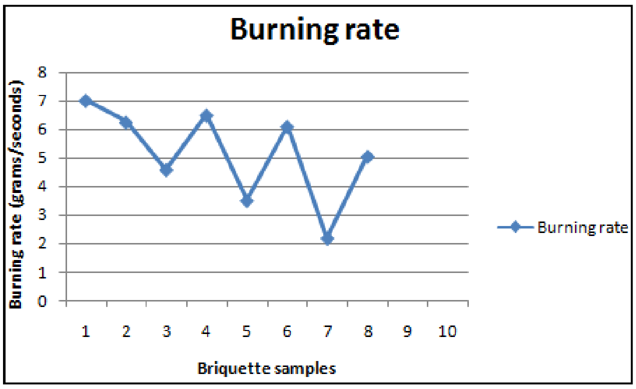

Figure 14: Burning rate characteristics.

Specific fuel consumption: The specific fuel combustion for various samples are shown in figure 15. The specific fuel consumption is least for the third sample which is having the mixture of the pine char and the cow dung in the ratio seven to three and having nineteen circular holes in it. The specific fuel consumption should be less for the efficient burning of the fuel briquette. Thus, it is clear that the third sample is the best among all the briquettes based on this parameter.

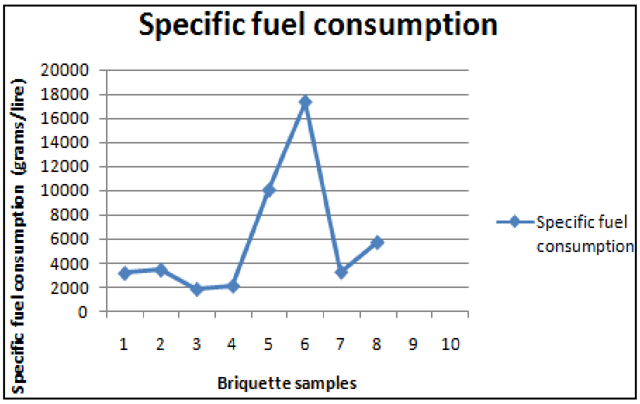

Figure 15: Specific fuel consumption characteristics.

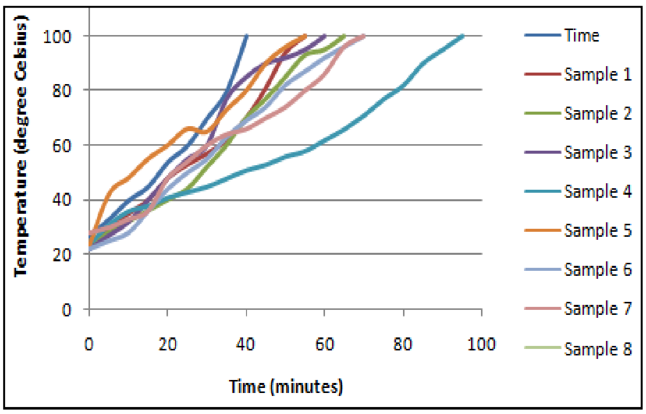

Figure 16: Temperature variation characteristics.

Temperature variation: It is clear from the figure 16 that the sample with nineteen circular holes with clay as the binder in the ratio seven to three is fastest to boil the water. Sample five, that is the briquette with nineteen holes and clay as binder with the ratio six to four takes the longest time to boil the water. Briquette using clay as a binder in more proportion takes more time for water boiling than other briquette samples. The reason is the higher percentage of clay briquettes and the non-combustible behavior of the clay.

CONCLUSION: In the present work, an environment friendly energy source is focussed from waste pine leaves. Design and thermal aspects of PNB are considered. The briquettes are prepared while blending with various binders and tested upon various parameters. By the results, it is clear that if one requires a good amount of heat intensity, briquettes with cow dung as binder and more holes briquette can be preferred. But, at the same time, the specific fuel consumption is more. The PNB with clay as binder are able to retain the heat for a longer time but with lesser intensity. It is preferable in the applications like cooking. It is also clear that if briquette having greater number holes is used, it is emitting greater amount of heat but for a shorter time as compared to the briquette having lesser number of holes which emits lesser amount of heat for longer time. Thus, a suitable type of briquette can be chosen based upon the needs.

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