PYROLYSIS OF WOODSHAVINGS AND SAWDUST - A REVIEW OF THE DEMONSTRATION PROJECT IN GHANA

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ABSTRACT

A demonstration pyrolytic conversion plant which produces oil, char and combustible gases from sawdust and woodshavings has been in operation in Ghana since 1980. The paper reviews the experiences and the general results of the project.

INTRODUCTION

The development and application of local renewable energy resources is becoming increasingly important in several developing countries. As the economy of Ghana is largely based on agriculture and forestry, there is great potential for using biomass as a renewable source of energy for both domestic and industrial applications.

Agricultural and forestry wastes, for example sawdust, rice straw and husks and oil palm wastes, which have high potential for collection for energy conversion, are shown in Table 1 (Chiang et al, 1976). Sawdust, in particular, is produced in large quantities by several sawmills in the Kumasi area and a few other towns in the forest zone. Its disposal often presents problems.

Most of these waste materials may be converted into alternative liquid, solid or gaseous fuels for use in existing domestic stoves, industrial kilns and, in some cases, in engines. One such conversion process is pyrolysis; the thermal decomposition of organic materials.

A pyrolytic conversion plant was set up in 1980 in Kumasi, Ghana, to demonstrate the feasibility of pyrolysis of organic wastes as an economic energy conversion process in Ghana and other developing countries. The plant currently produces char or powdered charcoal, oil, and combustible gases from sawdust and woodshavings. It was located near the demonstration brick factory of the Building and Road Research Institute with the primary aim of providing alternative fuel oil for the brick kiln.

PROJECT DESCRIPTION

Project funding and plant fabrication

The Pyrolytic Conversion Demonstration Plant, administered by the Building and Road Research Institute (BRRI), was set up with funds provided by the Bank of Ghana and the United States Agency for International Development (USAID). Some previous work on pyrolysis had been done in the USA by the Georgia Institute of Technology (GIT) (Knight et al, 1974). The Building and Road Research Institute (BRRI) made a request to the USAID for assistance to set up the Demonstration Plant as part of the research and development effort to find alternative fuel oil for brick kilns.

Feasibility studies were conducted jointly by personnel from GIT, BRRI and the Technology Consultancy Centre (TCC) of the University of Science and Technology, Ghana. It was recommended that a six-tonne per day labour-intensive pyrolysis plant be set up. Using basic designs provided by the Georgia Institute of Technology, TCC in collaboration with the BRRI and visiting engineers from the GIT, fabricated a prototype pyrolytic reactor and tested it, using sawdust as feed. Following design modifications, four pyrolytic reactors and ancillary equipment were fabricated locally, installed and commissioned. The only items which had to be imported were gas blowers, measuring instruments and an electric transformer.

The pyrolysis process and plant

Pyrolysis essentially involves the thermal decomposition of an organic material in the absence of air to produce charcoal and gases, part of which may be condensed to recover some oil. Figure 1 shows a simple flow diagram of the pyrolytic conversion process.

The demonstration plant consists of four cylindrical steel reactors and two feed dryers. Each reactor is fitted with a process air blower, condenser, demister, gas suction fan, thermocouples and pressure gauges. A mixture of sawdust and woodshavings are dried in the dryer and fed manually at regular intervals into the reactors. The process air blower supplies limited quantities of air for combustion of the bottom part of the reactor charge, to provide the heat for the pyrolysis of the remaining charge. Each reactor is equipped with a manual-operated agitator which is periodically turned to remove cavities in the reactor contents.

Powdered charcoal or char is collected into barrels beneath the reactor whilst the oil is drained at regular intervals from the condenser and demister. The incondensible gases are burned to provide heat for the feed dryers. The feed dryer is the fixed-bed type where the sawdust and woodshavings are piled on a perforated plate below which hot gases are passed to rise through the bed.

The temperature of the gas stream at the inlet of the condenser generally provides a good indication of the pyrolysis conditions inside the reactor. During plant operation, this temperature is monitored and manual adjustments of the process air flow valve are made to maintain it within the recommended range of 120-180°C.

PROJECT RESULTS

Plant performance

The design capacity of the demonstration plant is six tonne sawdust per 3-shift day or four tonne per 2-shift day, with oil and powdered charcoal yields of 18 and 25% (based on dry weight of feed) respectively (Malvar et al, 1960). To date the best performance of the plant is the conversion of 2.6 tonnes of dry woodshavings in a 2-shift day to produce 260 litres of oil and 320 kg of powdered charcoal (Hagan, 1982). The oil and powdered charcoal yields range from 6 to 13%, depending on the moisture content of the feed and how efficiently the reactor temperature is controlled.

The generally low yields of the oil and powdered charcoal may be attributed to inefficiencies in drying of the sawdust and manual process control. It has been recommended that for high oil yields the moisture content of the feed should be 10% or less. But the fixed bed dryer has proved unsuitable for drying of sawdust because the fine nature of the sawdust restricts the free passage of hot gases. Woodshavings have been dried satisfactorily in the dryer, and so currently the reactor feed consists mainly of woodshavings with some small amounts of sawdust. However, woodshavings are produced by only a few wood factories and are not as readily available in large quantities as sawdust. There is therefore a great need for the dryer to be modified to improve the drying of sawdust.

While located near a potential user, the BRRI brick factory, the plant is over 7 km from the nearest source of woodshavings or sawdust. Transport problems have caused irregularities in the supply of plant feed and increased the costs of a hitherto cheap or relatively free waste material.

The combination of inefficient feed drying, irregular supply of wet feed, low product yields and lack of funds for major repairs have made it impossible for the plant to produce sufficient quantities of the pyrolytic oil for utilisation by the brick factory.

Application of products

Pyrolytic oil

Some of the properties of pyrolytic oil are compared with those of heavy fuel oil in Table 2 (Hagan, 1982). The generally low oil yields, its acidic and tarry nature, lower calorific value and higher flash point, do not suggest that the pyrolytic oil will compete favourably with petroleum fuel oils. Its tarry and acidic properties, in particular, make it unsuitable for conventional oil burners and necessitate the use of expensive corrosion resistant storage tanks.

However, the pyrolytic oil has very good prospects as an alternative wood preservative. In preliminary field tests by Dinsey (1982), two types of pyrolytic oil, a dense type and a lighter one were compared with dieldrin, a standard termiticide. Wood blocks were treated by the immersion method and exposed to subterranean termites and fungi for nine months. Blocks were inspected at three month intervals, and mean percentage weight loss of the blocks caused by the attack are presented in Table 3.

The tests indicated no significant differences between the levels of protection against termite and fungal attack offered by the dense pyrolytic oil and 0.5% dieldrin. Further field tests are in progress.

Detailed chemical analysis of the pyrolytic oil are yet to be undertaken, but the analysis of similar products by Adamczak (1973) indicated that the dense pyrolytic oil may consist of phenols, carbonic acids, tar-oils and tar-coke. Currently most of the pyrolytic oil from the demonstration plant is sold as wood preservative at ₵ 22.00 (US $ 0.45) a litre. Considering its calorific value the oil may not be easily marketed as fuel at more than US$ 0.20 a litre.

Powdered charcoal

Powdered charcoal has been tested for domestic cooking in an adapted sawdust stove (Figure 2). The calorific value of the powdered charcoal is 23,500 kJ/kg, compared with 25,000 kJ/kg for ordinary charcoal. However in comparison with the conventional charcoal stove in Ghana, called "coal pot", the heat efficiency of the powdered charcoal stove was much lower. Further design modifications need to be made.

The powdered charcoal has been successfully converted to briquettes using cassava starch, pyrolytic oil or natural gums (from a tropical tree, *Acacia senegal*) as binders. These had satisfactory burning properties, high compressive strength and considerable resistance to abrasion and to shatter when dropped from a height. The briquettes made with cassava starch seemed most suitable for domestic cooking, the other binders producing a lot of smoke and an unpleasant odour during burning. Some of the properties of the charcoal briquettes made with cassava starch as binder are compared with those of ordinary charcoal in Table 4 (Hagan, 1982).

The briquettes made with pyrolytic oil or tree gum, however, have potential industrial application by direct combustion in lime kilns and steel furnaces, or by gasification to generate producer gas. The producer gas may be used directly in industrial kilns or as alternative fuel for stationary engines, for example, for water pumping and electricity generation. Preliminary gasification tests of briquettes made with pyrolytic oil and of ordinary charcoal have been done in a locally fabricated down-draught gasifier (Hagan, 1985). The composition of the producer gas from the two types of charcoal are shown in Table 5, in comparison with typical values for gas from charcoal as reported in the literature (Kjellstrom, 1980). Other results from the preliminary tests are summarised in Table 6.

The calorific value of the gas produced from the charcoal briquettes is comparable to that of the gas from ordinary charcoal. Both values were, however, lower than the typical value of 4.1 MJ/Nm^3 for charcoal reported by Kjellstrom (1980). This may be attributed to the low carbon monoxide and higher carbon dioxide contents of the gas in the preliminary tests. It may be possible to upgrade the calorific value of the gas by finding the optimum balance of air and fuels flow and the most suitable physical size of the briquettes.

The lower calorific value of the gas, certain gasifier design factors and the fuel quality may account for the rather low overall efficiency of the gasifier, compared with the typical gasifier efficiency of 70% reported by Kjellstrom (1980). However, there is some scope for improving the gasifier performance, for example, by modifications of the hearth and grate zones. The gasifier tests were only preliminary and further tests are required to demonstrate the real potential of charcoal briquettes for the generation of producer gas of satisfactory quality.

Project administration

A preliminary economic analysis by Hagan (1982) indicated that the pyrolytic conversion of sawdust and woodshavings could be profitable if the Demonstration Plant were efficiently managed to operate for a minimum of 300 days per year on 2 shifts (16 hours) each day, and the oil and charcoal sold at market prices. The payback period was projected to be about 3 years and the internal rate of return was 45%.

However, owing to the budget constraints and the administrative set-up of the research institute, it has not been possible to manage the Demonstration Plant to be self-sustaining. The plant is frequently shut down as a result of lack of funds for major plant modifications, for example of the feed dryer, for major plant repairs, and for the ready transport of plant feed and shift workers to the plant site. It has therefore not been possible to demonstrate the economic viability of the pyrolysis of sawdust, which could have enhanced the dissemination of the technology.

The administration of demonstration projects of this nature should involve potential commercial users, for example large private brick factories, or some other industrial interest group, for example, sawmills. These bodies could assist in the provision of funds and profitable management of the plant, whilst the research institute provides the technical skills for monitoring the plant performance and for necessary design modifications.

CONCLUSIONS

Considering the foregoing results and observations of the Pyrolytic Conversion Demonstration Project, the following conclusions are made:

i. The concept that the pyrolytic oil is the most important product of pyrolysis as an alternative industrial fuel may have to be revised, since its properties may not enhance ready competition with commercial petroleum fuel oils. More emphasis may have to be accorded to charcoal which may be briquetted with part of the pyrolytic oil. The briquettes may be gasified to generate producer gas for industrial kilns and furnaces, or used directly for the same purposes by direct combustion. Further gasifier experiments are needed to establish the gasification of the briquettes as an economical energy conversion process.

ii. It would seem more practical and economical to market the pyrolytic oil primarily as a wood preservative. It is therefore necessary to undertake laboratory analysis of the oil to identify its significant constituents, and also to explore other possible applications.

iii. Some aspects of the manual operation of the plant need to be reviewed to ensure higher product yields and quality, and uninterrupted production. In this regard, certain vital operations of the plant should be mechanised. These include the reactor charging and charge agitation. For better control of reactor temperatures, a modest automatic system for the control of air/feed ratio may be worthwhile.

iv. The pyrolytic conversion of sawdust could be profitable if the plant is managed on a commercial basis, with the products being sold at market prices and with funds readily available for plant repairs and supply of raw materials. In this effort, a sawmill or a wood preservative marketing company, who are potential users of the pyrolysis technology, may be requested to participate in the demonstration project.

Future work

The following activities are to be undertaken on the Pyrolytic Conversion Demonstration Project:

i. Serious effort to increase product yields through better process control and necessary plant modifications.

ii. Further studies on charcoal briquetting and gasificiation.

iii. Laboratory analysis of the pyrolytic oil to identify important constituents and other possible uses.

iv. Laboratory pyrolysis experiments on waste from different Ghanaian woods and other agricultural wastes.

v. Further development work on the powdered charcoal stove.

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TABLE 1: Availability of Forestry and Agricultural Wastes in Ghana

Waste material	Quantity generated tonnes/year	Major sources in Ghana (regions)
Reforestation waste	1,000,000	All nine regions
Coconut waste	686,000	Western Central
Rice straw and husks	517,700	Northern, Upper
Logging waste	403,000	Western, Ashanti, Brong-Ahafo
Sawdust	25,500	Western, Eastern, Ashanti, Brong-Ahafo
Oil palm waste	23,000	Western, Eastern

TABLE 2: Comparison of pyrolytic oil with heavy fuel oil

Property	Pyrolytic Oil	Heavy Fuel Oil
Calorific value (kJ/kg)	23,900	41,000
Flash point (°C)	104	66
Specific gravity	1.19	0.94

TABLE 3: Mean percentage weight loss of treated wood blocks exposed to termites and fungi

	% Weight loss of blocks		
Treatment	3 months exposure	6 months exposure	9 months exposure
Dense pyrolytic oil	7.7	9.8	16.8
Light pyrolytic oil	6.7	25.6	55.5
0.5% dieldrin solution	5.7	8.4	17.1
Untreated	20.6	61.9	89.8

TABLE 4: Properties of charcoal briquettes (with cassava starch as binder) compared with ordinary charcoal

Property	Charcoal briquettes	Ordinary charcoal
% pure carbon content	90	95
% volatile matter	1.0	0.7
% ash content	10.0	4.7
% moisture content	3.4	0.2
Compressive strength, mPa	2.3	3.7

TABLE 5: Composition of producer gas from charcoal briquettes and ordinary charcoal

	Gas composition from briquettes %	Gas composition from ordinary charcoal %	Typical gas composition from charcoal (from literature) %
CO_2	4.0	6.0	3.0
CO	17.8	16.6	28.7
H_2	1.6	3.8	3.8
CH_4	1.6	1.2	0.2

TABLE 6: Summary of gasifier test results

	Gasification of charcoal briquettes	Gasification of ordinary charcoal
Average feeding rate, kg/hr	10.4	8.4
Average gas discharge rate, Nm^3/min	0.23	0.23
Calorific value of gas, MJ/Nm^3	2.84	2.83
Rate of energy production, MJ/hr	39.2	39.2
Efficiency of gasifier, %	16	18

FIGURE 1: Flow diagram of pyrolysis system

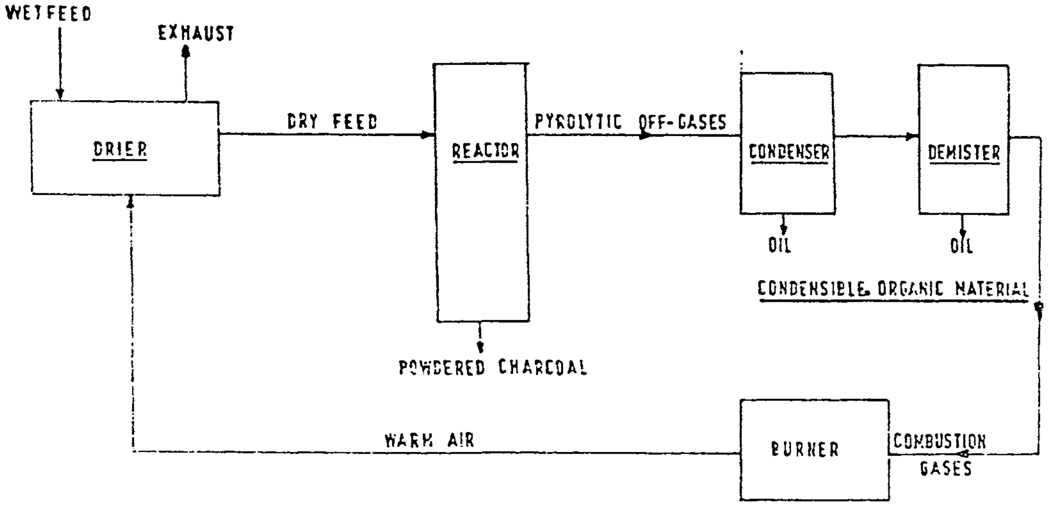

FIGURE 2: Sketch of powdered charcoal stove