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ALTERNATIVE FUEL FROM PYROLYSIS OF RICE HUSK

Habib Ahmed Shafique Ullah[1], **Bodius Salam**[2,*], **M Nurul Islam**[3] and **M Shahidul Islam**[4]

[1,4]Dry Dock Limited, Chittagong, Bangladesh
[2]Department of Mechanical Engineering, Chittagong University of Engineering & Technology
Chittagong, Bangladesh
[3]Department of Mechanical Engineering, Rahshahi University of Engineering & Technology
Rajshahi, Bangladesh

[1]drydock.bd@gmail.com, [2,*]bsalam@cuet.ac.bd, [3]mnislam60@yahoo.com, [4]shahidul02@gmail.com

Abstract- *Pyrolysis of rice husk in a 53 mm diameter and 800 mm high fixed bed pyrolysis reactor with natural gas as the carrier gas was investigated. Experiments were carried out with reactor temperature between 430-580°C to see the effect of reactor temperature on yields. Particle size of rice husk was 0.5-7 mm. The maximum liquid yield of 40 % (wt.) was obtained at the temperature 480-500°C with 35% (wt.) char and 25% (wt.) gas at 480°C. The oil obtained from 480-500°C temperature was analyzed by Fourier Transform Infra-red (FTIR) spectroscopy and gas chromatography/mass spectrometry (GC/MS) techniques The physical properties of the oil were also determined. The oil was highly oxygenated containing a high fraction of phenol-based compound.*

Keywords: Pyrolysis, Rice husk, Fixed bed.

1. INTRODUCTION

Williams and Besler [1] pyrolysed rice husks in a thermogravimetric analyzer in a nitrogen atmosphere and found thermal decomposition of the rice husk started at around 250°C and major loss of weight completed by approximately 450°C. Raveendran *et al*. [2] reported the results of studies on the effect of mineral matter present in rice husk on the pyrolysis characteristics, product distribution and product properties. Mansary and Ghaly [3] investigated the degradation of rice husks at heating rates 10-50°C/min in nitrogen atmosphere using thermogravimetric analysis between ambient temperature and 700°C. Rao and Sharma [4] proposed a method to predict pyrolysis rates of rice husk and other biomass materials from the species compositions in terms of cellulose, hemicellulose and lignin constituents and their individual kinetic parameters. Rice husk was converted into value-added materials and energy by a fluidized bed pyrolysis process by Islam *et al*. [5]. Sharma and Rao [6] studied the pyrolysis kinetics of rice husk in nitrogen and carbon dioxide under non-isothermal conditions at heating rates between 5-100°C/min and under isothermal conditions at temperatures between 250-500°C. Islam and Ani [7] carried out techno-economic analysis of the pyrolysis process for converting rice husk waste to pyrolysis oil and solid char. Williams and Nugranad [8] pyrolysed rice husks in a fluidized bed reactor in relation to temperature at 400°C-600°C. They analysed the pyrolysis oils to determine their yield and composition in relation to process condition. Rice husk was pyrolysed by Ji-lu [9] between 420°C and 520°C in a fluidized bed and chemical composition, heating value, stability, miscibility, and corrosion characteristics of bio-oil were determined. Fast pyrolosis of rice husks were carried out by Tsai *et al.* [10] in a fixed bed reactor using pyrolysis temperature 400-800°C and heating rate 100-500°C/min. Lu *et al.* [11] produced bio-oil in fluidized-bed pyrolysis reactor and analyzed the bio-oil for its chemical and physical properties. Natarajan and Ganapathy [12] conducted fixed bed pyrolysis experiments of rice husk to determine the effect of pyrolysis temperature, heating rate, particle size and reactor length on the product yields.

In this work, the fixed bed pyrolysis of rice husk was investigated to see the effect of reactor temperature on pyrolysis yields. The optimum operating condition was obtained to maximize the liquid yield. The pyrolysis oil obtained at optimum condition was analyzed for physical and chemical properties and compared with conventional fossil fuel.

2. MATERIALS AND METHODS

2.1 Biomass

The rice husk sample investigated was collected from a rice mill located at Pahartaly Bazar, Raozan, Chittagong. Collected samples were first sun dried and separated from physical impurities. The samples were then screened and sieved to size about 0.5 – 7 mm. The rice husk samples were dried in an oven at 115°C and were stored in airtight polythene bags. Table 1 shows the proximate and ultimate analysis of rice husks.

Table 1: Properties of rice husks [8]

Proximate analysis (wt.%)	Volatiles	59.5
	Moisture	7.9
	Ash	17.1
Ultimate analysis (wt.%)	Carbon	44.6
	Hydrogen	5.6
	Oxygen	49.3
Component analysis (wt.%)	Cellulose	34.4
	Hemicellulose	29.3
	Lignin	19.2
	Ash	17.1

2.2 Experimental Set Up

The pyrolysis equipment used was a fixed bed pyrolysis reactor (FBPR). Figure 1 shows the schematic diagram of the set up. Details of the set up were given in [13]. All the components were constructed using 316 stainless steel. The reactor was a vertical tube having 53 mm inside diameter, 60 mm outside diameter and 800 mm in height. The preheater was of 200 mm in height and same diameter as reactor. Two gas distribution perforated plates of 50 mm diameter and 5 mm thick were fitted at the bottom of the reactor tube. The plates were welded together that prevented solids from raining through the orifices when the gas flow was stopped. One plate had 54 numbers of inline holes and the other plate contained 52 numbers of staggered holes. A sand bed was on gas distribution plates having static height of 50 mm. The bed material had sizes ranging from 3.5 to 4 mm. The hopper and screw feeder was placed 125 mm above from the bottom of the reactor.

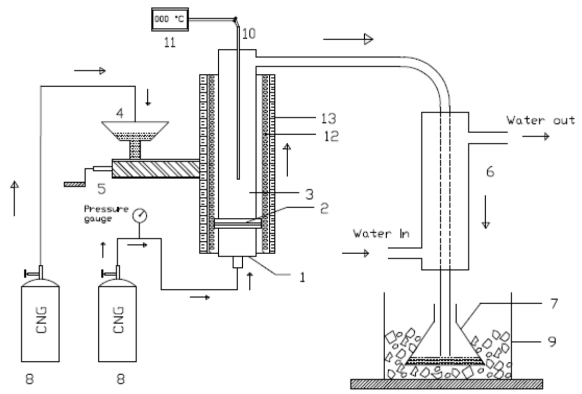

Fig.1: Set up of alternative fuel from pyrolysis of rice husk

1. Preheater, 2. Gas distributor, 3. Reactor, 4. Hopper, 5. Feed screw, 6. Condenser, 7. Liquid collector, 8. CNG cylinders, 9. Ice box, 10. Thermocouple, 11. Temperature monitor, 12. Electric heaters, 13. Insulation.

2.3 Experimental Technique

The pyrolysis of the rice husk was conducted in the FBPR. The rice husk was stored in an airtight plastic container prior to pyrolysis. The reactor was heated externally by electric heaters. The feeding system was manual. The feed rate was 200 grams per hour. The carrier gas was natural gas. About 100 grams of rice husk was placed in the hopper. The electric supply was controlled and monitored by the voltage regulators. The temperature in the reactor bed was measured by means of a K type thermocouple. After a few minutes the temperature was raised to about 400°C. The natural gas at 1.5 L/min was introduced into the pre-heater. Through the distributor plate, the gas was entered into the reactor chamber. When the bed temperature reached up to a proper temperature of about 500°C, the rice husk was dropped into the reactor from the sealed hopper. The residence time was 1.2 minutes. The vapors and gases left the reactor and entered into the water-cooled condenser. The pyrolysis vapors were cooled when they were passing through the condenser. Thus the liquid product, pyrolysis oil was collected in the ice-cooled collector. The char was collected after completing the runs. The bio-oil was analyzed for their properties as fuels. The physical properties were analyzed. The chemical composition of the bio-oil was investigated using chromatographic and spectroscopic techniques (FTIR and GC-MS).

3. RESULTS AND DISCUSSIONS

3.1 Product Yields

Figure 2 shows the effects of reactor temperature on different pyrolysis yields. Gaseous yields were calculated from the mass balance. A total 4 sets of experiments were conducted to see the effects of temperature on different yields. Curve shows the yields from the run where maximum liquid was obtained. It was

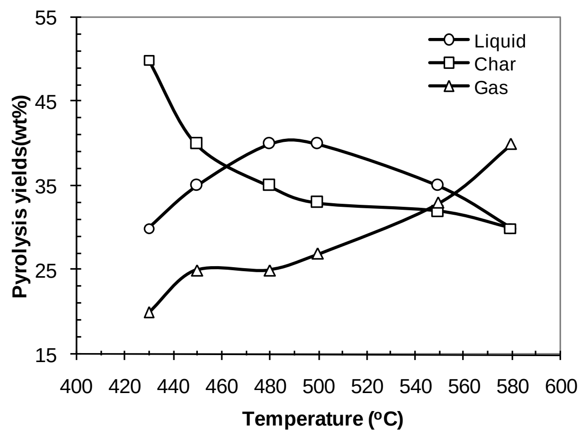

Fig.2: Effect of reactor temperature on pyrolysis yields

observed that with the increase of temperature gaseous yields always increased. At 430°C gaseous yield was found to be 20% and increased to 40% at 580°C. The char yields decreased from 50% to 30% with the increase of temperature from 430°C to 580°C. The liquid yield was found to be increased from 30% to 40% with the increase of temperature from 430°C to 480 – 500°C and decreased afterwards.

3.2 FTIR Analysis of Pyrolysis Oil

The functional groups of the pyrolysis oil obtained at optimum pyrolysis conditions were analyzed by Fourier

Transform Infrared (FTIR) spectroscopy to identify the basic compositional groups are shown, Fig. 3 and Table 2. The FTIR instrument of model JASCO FT/IR-6300 was used to produce the ir-spectra of the pyrolysis oil at Bangladesh Atomic Energy Center, Dhaka. The sample was water freed by using the solution of sodium sulphate (Na_2SO_4). A thin uniform layer of the liquid was placed between two salt sells and exposed to infrared beam, which provided the absorption spectrum in percentage incident intensity, along the wave numbers 4000 to 350 cm^{-1}.

The absorbance peaks of O-H stretching vibration between 3650 and 3100 cm^{-1} indicated the presence of water impurities and other polymeric O-H in the liquids [14]. The absorbance peaks of C-H vibrations between 3000 and 2800 cm^{-1}, between 1150 and 1000 cm^{-1} [14] and C-H stretching and bending vibrations between 1465 and 1380 cm^{-1} [10] indicated the presence of alkane groups in pyrolysis oil. The presence of alkenes was indicated by the absorbance peak between 1680 and 1575 cm^{-1} [14]. The absorbance peaks between 915 and 650 cm^{-1} indicated the presence of single, polycyclic and substituted aromatic groups [11].

Table 2: The FTIR functional groups and the indicated compounds of pyrolysis oil [10, 11, 14]

Frequency Range (cm^{-1})	Group	Class of compound
3650-3100	O-H stretching	Polymeric O-H, water impurities [14]
3000-2800	C-H stretching	Alkanes [14]
1680-1575	C≡C stretching	Alkenes [14]
1465-1380	C-H bending and stretching	Alkanes [10]
1150-1000	C-H bending	Alkanes [14]
915-650	C-H in plane benching	Aromatic compounds [11]

3.3 Physical and Fuel Properties

The physical and fuel properties of the pyrolysis oil were determined by standard test procedures. The tests were carried out in the institute of Fuel Research and Development, BCSIR, Dhaka. The properties found are mentioned in Table 3. The physical and physical properties determined were density, heating value, water content, p^H value, ash content, pour point, flash point, viscosity and corrosion. Density of pyrolysis oil was found to be higher than that of diesel and the presence of quite high amount of water in the oil could be responsible for this. Lu et al. [11] also reported high amount of water content in their pyrolysis oil. The heating value obtained was found to be close to that of diesel. The p^H value obtained was quite low and presence of carboxylic acids might be the responsible for low p^H value of pyrolysis oil. The pyrolysis oil showed significant amount of ash content. This ash could bring negative effects to the combustion of pyrolysis oil [11]. The viscosity of pyrolysis oil was found to be higher than diesel. For proper combustion the oil might have to be preheated for better atomization.

Table 3: Physical properties of pyrolysis oil

Name of test		Results	Diesel [15]
Density, kg/m^3		859	827.1
Heating value, MJ/kg		42.29	45.18
Water content, %		27	--
pH value		4.2	--
Ash content, %		0.1971	0.01
Pour point, ^oC		-2	--
Flash point, ^oC		62	53
Viscosity, cSt		5.11 @40^oC	2.61 @20^oC
		1.73 @100^oC	
Corrosion	Steel	Mild	--
	Aluminum	Mild	--
	Copper	Mild	--

3.4 GC/MS Analysis of Pyrolysis Oil

GC-MS analysis was conducted with the pyrolysis oil in order to get an idea of the nature and type of compounds presence in the pyrolysis oils. It was carried out in Bangladesh Atomic Energy Center, Dhaka. The instruments of model: VARIAN, CP-3800 and model: VARIAN, saturm 2200 were used for the analysis. The sample was water freed by sodium sulphate solution. It was found that the pyrolysis oil was a very complex mixture of organic compounds and contained a lot of aromatics and oxygenated compounds such as carboxylic acids, phenols, ketones etc. These also included acids, alcohols, aldehydes, esters, sugars, furans, guaiacols and multifunctional compounds. Lu *et al*. [11] also reported similar compounds. Some volatile compounds of low concentrations could not be perfectly identified due to the complex peaks displayed on the chromatogram. It might be solved by fractionation of the pyrolysis oil into several parts and then analysis of each part.

4. CONCLUSIONS

In this study pyrolysis of rice husk in a 53 mm diameter and 800 mm high FBPR with natural gas as the carrier gas was investigated. Experiments were carried out with reactor temperature between 430-580^oC. The maximum liquid yield of 40 % (wt.) was obtained at the temperature of 480-500^oC. The FTIR analysis showed that pyrolysis oil was highly dominant with oxygenated species. The physical properties analysis showed that the oil was acidic in nature with heating value close to diesel. The corrosivity of the oil was very mild towards copper, aluminum and stainless steel. The oil was highly oxygenated containing a high fraction of phenol-based compound.

5. REFERENCES

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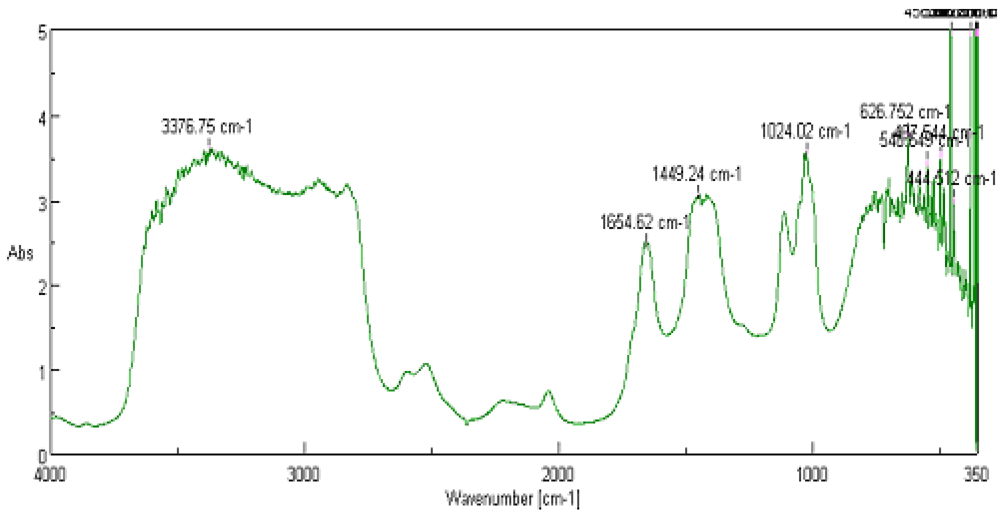

Fig.3: Infra-red spectrometry of pyrolysis oil