ISSN: 0974-5823 Vol. 7 No. 4 April, 2022

International Journal of Mechanical Engineering

Production of bio oil and bio char through the pyrolysis route

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ABSTRACT:

Energy frameworks are perceived as a promising answer for the energy lack and ecological contamination emergencies. To fulfill the expanding need for energy, different potential frameworks have been researched for the creation of alternate energy sources are investigated rigorously. The current study explains the pyrolysis process for the generation of bio oil and bio char from the pyrolysis process. The study investigates the effect of the pyrolysis process parameters on the bio oil yield and the bio char yield. Observations made by the study reveal that these process parameters significantly affect the bio char yield as well as the bio oil yields. Bio oil yield increased with the rise in the heating time and heating temperature. The reason may the higher temperature or heating rate suits the chemical reactions which remove off the volatiles preset in the material. Thus the gaseous component increases which on cooling become liquid product. The bio char yield is found to reduce with the rise in either of the heating time or heating temperature in the current study.

Keywords: Energy storage, Pyrolysis, Thermal treatment,

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1. Introduction

Orgy is being requested and devoured around the world. Meanwhile, the broad depletion of petroleum derivatives has made mankind face genuine energy emergency and ecological disturbances in ongoing many years. Specifically, the radical emanations of ozone harming substance and other burning poisons have caused non-unimportant outcomes, for example, a dangerous atmospheric deviation and air contamination, undermining the future improvement of human culture. As per the Worldwide Energy Specialist measurements, the all out CO2 emanations from fuel ignition expanded to 32.3 billion metric tons in 2013, a number expected to increment as the non-OECD (Association for Monetary Co-activity and Advancement) non-industrial nations are expected to burn-through more energy in the forthcoming many years. In the present circumstance, investigating substitute energy assets and practical energy frameworks has turned into an exceptionally pressing mission confronting all nations as of now [1].

In light of these expressed difficulties, numerous endeavors have been dedicated to new energy framework innovative work, and different elective advancements have been proposed and researched. Hydrogen energy frameworks began to draw in perceptible consideration during the energy emergency of the 1970s and have gone through colossal improvement from that point forward Hydrogen is viewed as an extremely encouraging energy transporter on account of its high level inborn properties, like its high energy thickness of 14,300 J/(kgK) [2], long haul feasibility, harmless to the ecosystem burning items, and broad assets . Despite the fact that hydrogen is the most bountiful component on the planet, it for the most part exists in water and hydrocarbons, where it is bound to oxygen and carbon and henceforth not normally prepared to utilize subsequently; various cycles have been created and used to deliver unadulterated hydrogen from different assets. Among these accessible hydrogen creation measures, the steam transforming response (SRR) of petroleum gas followed by the water gas shift response (WGSR) is perceived as the most prudent cycle and is answerable for more than 90% of the complete hydrogen creation as of now . Meanwhile, other promising advances, including water parting and biomass preparing, are quickly creating a result of their capability to change over spotless and sustainable power assets to hydrogen. The utilization of biomass preparing for hydrogen creation is direly required, not just on account of the enormous stockpile of sustainable assets yet additionally as a result of the capacity to save the climate by using unloaded mining and agrarian squanders. To accomplish an effective clean hydrogen energy society, delivering hydrogen from a carbon obliged technology, like biomass, is just the initial segment of the entire hydrogen energy framework. The division and decontamination, the capacity and conveyance and the proficient usage of the hydrogen gas delivered are additionally vital stages in understanding the advantages of utilizing the hydrogen energy produced from manageable assets [3]. Among these means, the division and decontamination establish a basic interaction in the hydrogen energy framework from both the specialized and monetary points of view. Presently, different gas detachment advancements are promptly accessible for isolating hydrogen from the blended gases delivered, and film division technology enjoys shown unmistakable benefits of low energy utilization, harmless to the ecosystem properties and the alluring capability of filling in as a multifunctional layer reactor [4].

Thinking about hydrogen's extraordinary potential as a perfect energy transporter, the hydrogen energy framework was proposed and perceived as a long-lasting answer for the oil based fuel consumption and ecological emergency. In a hydrogen energy framework, the energies delivered from various essential energy sources (sunlight based, wind, biomass, and so on) are at first moved to a hydrogen transporter through an assortment of responses (gasification, water parting and improving, and so on) The energy transporter hydrogen is then shipped, put away lastly used by the terminal clients, as displayed in. In this framework, hydrogen fills in as the mediator to move energy between the energy asset and the energy use clients Right now, the hydrogen energy situation isn't just standing out according to the examination viewpoint, yet additionally a few state run administrations have made enormous speculations to fabricate the foundation for understanding a hydrogen energy-driven society. One astounding occasion is that the public authority of Iceland has defined the objective of turning into a total hydrogen-economy country in the extended time of 2030 by utilizing their geothermal energy through hydrogen energy frameworks [5].

Furthermore, the advancement of hydrogen-fueled vehicles is empowered by numerous areas, like Japan and China. Notwithstanding, there are four significant specialized provokes that should be looked before a proficient hydrogen energy framework can be acknowledged, including hydrogen creation and decontamination through a carbon-compelled measure, hydrogen conveyance and dissemination through wide-running and very much oversaw foundation, hydrogen stockpiling in solid and safe plants and hydrogen use through a productive interaction.

Gasification is a two-venture measure in which a strong fuel (biomass or coal) is thermochemically changed over to a low-or medium-energy-content gas. Flammable gas contains 35 MJ/m^3. Air-blown biomass gasification brings about roughly 5 MJ/m^3; oxygen-blown in 15 MJ/m^3. In the principal response, pyrolysis, the separated and unstable parts of the fuel is disintegrated at temperatures as low as 600 °C. Remembered for the unpredictable fumes are hydrocarbon gases, hydrogen, carbon monoxide, carbon dioxide, tar, and water fume. Since biomass powers will in general have more unstable parts (70-86 % on a dry premise) than coal (30%) 6,7], pyrolysis assumes a bigger part in biomass gasification than in coal gasification. Gas stage warm breaking of the volatiles happens, lessening the degrees of tar. Burn (fixed carbon) and debris are the pyrolysis results that are not disintegrated. In the subsequent advance, the burn is gasified through responses with oxygen, steam, and hydrogen. A portion of the unburned scorch might be combusted to deliver the hotness required for the endothermic pyrolysis responses.

Gasification combined with water-gas shift is the most broadly polished cycle course for biomass to hydrogen. Warm, steam and fractional oxidation gasification innovations are a work in progress all throughout the planet. Feed stocks incorporate both devoted harvests and rural and backwoods item buildups of hardwood, softwood and herbaceous species.

Warm gasification is basically high seriousness pyrolysis in spite of the fact that steam is by and large present. An illustration of this is the Sylvagas (BCL/FERCO) low-pressure, in a roundabout way warmed circling liquid bed [8].

$$Biomass + Energy \rightarrow CO + H_2 + \ CH_4 + \cdots$$

Other relevant gasifier types are bubbling fluid beds being tested by Enerkem, and the highpressure high-temperature slurry-fed entrained flow Texaco gasifier.

All of these gasifier examples will need to include significant gas conditioning, including the removal of tars and inorganic i impurities and the conversion of CO to H2 by the water-gas shift reaction

$$CO + H_2O \rightarrow CO_2 + H_2$$

Significant attention has been given to the conversion of wet feedstocks by high-pressure aqueous systems. This includes the supercritical-gasification-in-water approach by Antal and coworkers as well as the supercritical partial oxidation approach by General Atomics.

Pyrolysis to hydrogen and carbon is being investigated as a practical technology for carbon sequestration albeit most work is applied to flammable gas pyrolysis. Biomass or biomassderived intermediates could be handled along these lines. Organic transformation through anaerobic assimilation is presently being rehearsed by laborers all throughout the planet bringing about methane that can be handled to hydrogen by regular steam improving cycles [9].

1.2 Storable Intermediates

Pyrolysis creates a fluid item called bio-oil, which is the premise of a few cycles for the advancement of fills, synthetic substances and materials. The response is endothermic:

$$Biomass + Energy \rightarrow Bio - oil + Char + Gas$$

The oil can be framed in 66 wt.% yields. Chornet and collaborators have fostered the idea of utilizing the lingering parts of the oil for hydrogen after co-items have been delivered. Synergist steam improving of Bio-oil at 750-850°C over a nickel-based impetus is a two-venture measure that incorporates the shift response:

$$Bio - oil + H_2O \ \rightarrow CO + H_2$$

$$CO + H_2O \ \rightarrow CO_2 + H_2$$

The overall stoichiometry gives a maximum yield of 1 7.2 g H/1 00 g bio-oil (1 1 .2% based on wood).

$$CH_{1.9}O_{0.7} + 26H_2O \ \rightarrow CO_2 + 2.21H_2$$

Local organizations of pyrolysis plants could be establ ished to give oil to a focal steam improving office. The interaction is viable with other natural waste streams, for example, aqu ous-steam fractionation measures utilized for ethanol creation and trap oil.

Methanol and ethanol can likewise be delivered from biomass by an assortment of innovations and utilized for on-board transforming for transportation. Methane from anaerobic assimilation could be changed alongside gaseous petrol. Methane could be pyrolyzed to hydrogen and carbon if markets for carbon dark were accessible. Frameworks investigation has shown that biomass gasification I shift change is financially troublesome contrasted with gaseous petrol steam improving aside from exceptionally minimal expense biomass and expected natural motivations. The pyrolysis with significant co-item approach yields hydrogen in the value scope of \$6 - \$8/GJ, which is promising for close to term applications 10].

2. Experimental work

The experiments were conducted to develop the energy rich products from the waste materials and convert these into electrodes and check their performance.

Biomass derived char was synthesized using the pyrolysis of the biomass waste. The selected biomass was fed to a muffle furnace and then the chamber was filled with nitrogen gas. The nitrogen gas flow rate was controlled and from outside and it was determined with the help of a nitrogen flow meter. Once the whole reactor chamber was filled with the nitrogen gas, the heater was switched ON, and the heater was programmed to reach a t a definite temperature at a fixed heating rate. Once everything was set, biomass started to heat. The heating of the biomass was carried out at various temperature, and time combinations. The Table 1 shows the various combinations of time and temperature which were used to synthesize the char.

Run No.	Time of heating (min)	Temperature (^{0}C)
1	10	650
2	20	650
3	30	650
4	40	650
5	50	650
6	60	650
7	10	700
8	20	700
9	30	700
10	40	700
11	50	700
12	60	700
13	10	750
14	20	750
15	30	750
16	40	750
17	50	750
18	60	750
19	10	800
20	20	800
21	30	800
22	40	800
23	50	800
24	60	800
25	10	850
26	20	850
27	30	850
28	40	850
29	50	850
30	60	850
31	10	900
32	20	900
33	30	900
34	40	900
35	50	900
36	60	900

3. Results and discussions

3.1. Effect of temperature on pyrolysis product yield

It is well known fact that the pyrolysis products yield depends upon the pyrolysis parameters. The experiments performed very clearly confirmed this. It is seen clearly that with the rise in the temperature, the product yield is changing significantly. The yield of each product depends upon the temperature. As the temperature increases, the bio oil yield starts increasing and the char yield goes down. The reason for this behavior may be understood from the fact that as the temperature increases up, the reaction within the materials increases and the thermal cracking of various types of bonds present in the biomass starts. The thermal cracking of these bonds leas to the breaking of bonds and thus the volatile material p[resent in the biomass starts to convert themselves into the gaseous form. These gasses liberates from the materials and these starts to get away from the materials. The gas then comes out and is collected into the condenser. Clearly as the temperature will increase more and more volatiles will be released from within the biomass material and thus the bio oil yield will be enhanced.

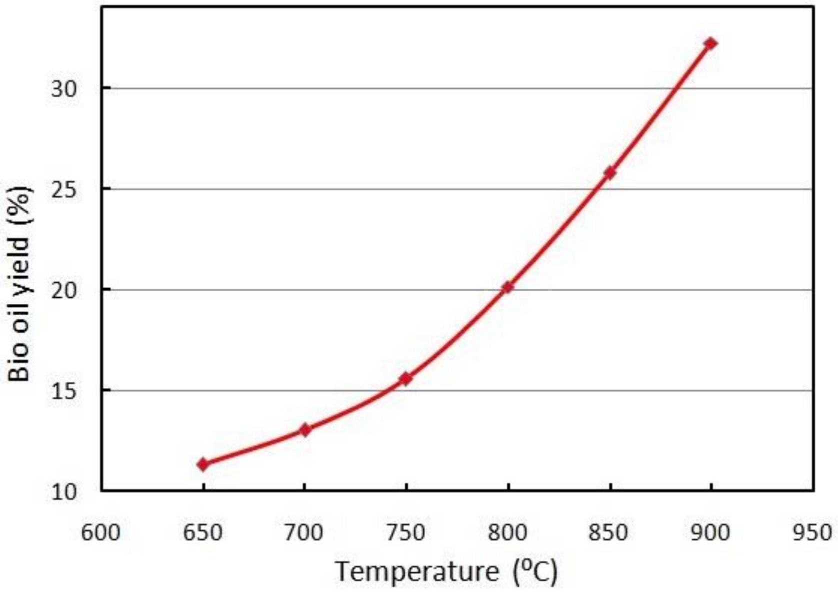

Fig. 1: Bio oil yield as a function of temperature

However, when the bio oil yield will go up, clearly it will occur at the cost of the char yield. As more and more volatiles will come out of the char clearly it will reduce the char yield. The similar observations can be made from the results obtained from the experiments. A graph plotted between bio oil yields vs. the temperature is shown in Fig. 1. It shows that the rise in the temperature has increased the bio oil yield significantly. The reason of such a behavior is already explained. Similarly, the char yield vs. temperature is shown in Fig. 2. The Fig. 2 shows the expected behavior, where it is seen that as the temperature rise, the char yield goes down. The reason being that the rise in temperature may lead to the evaporation of volatiles and thus the bio char yield lowers.

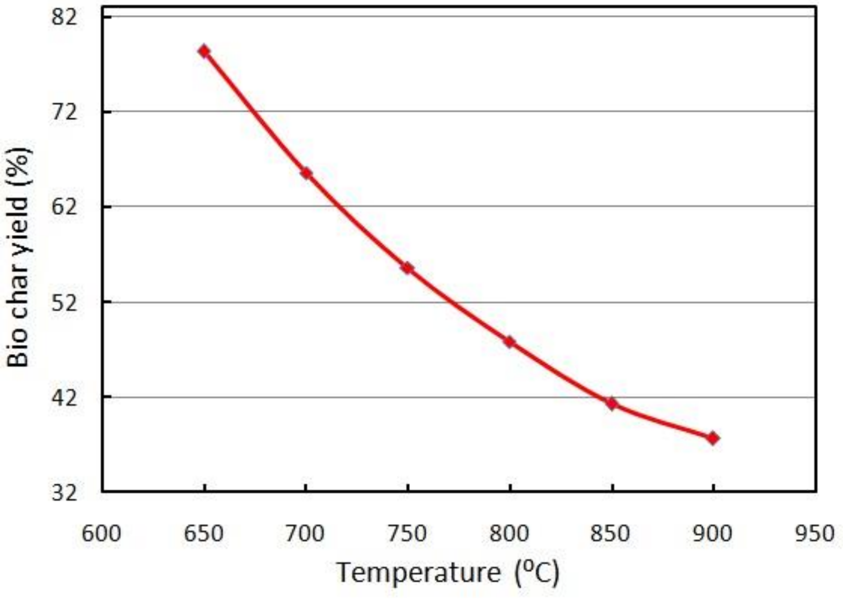

Fig. 2: Bio char yield as a function of temperature

3.2. **Effect of reaction time on pyrolysis product yield**

The effect of the heating time on the bio oil yield was also investigated in the present study. The results obtained from the experiments are shown in the graphical form in Fig. 3. This Fig. 3 shows the variation of the bio oil yield as a function of the heating time. It is evident from the fig. 3 that the rise in the heating time enhances the bio oil yield. The enhanced bio oil yield with rise in temperature is seen because longer heating time provides more time for the chemical reaction to take place and as the results of these chemical reactions, the volatile material present in the biomass converts itself into the gas and slowly it comes out. The more the heating time the more will be the reaction time which further will liberate more volatiles which eventually will produce more gasses. These gasses will finally be condensed to get the bio oil. The study showed that the bio oil yield increased from 3.12 % to 27.23 % on increasing the heating time from 10 min to 60 min. This is almost 89.5 times rise in the bio oil yield which is significantly high. Thus it is seen that the heating time affects the bio oil production up to a large extent.

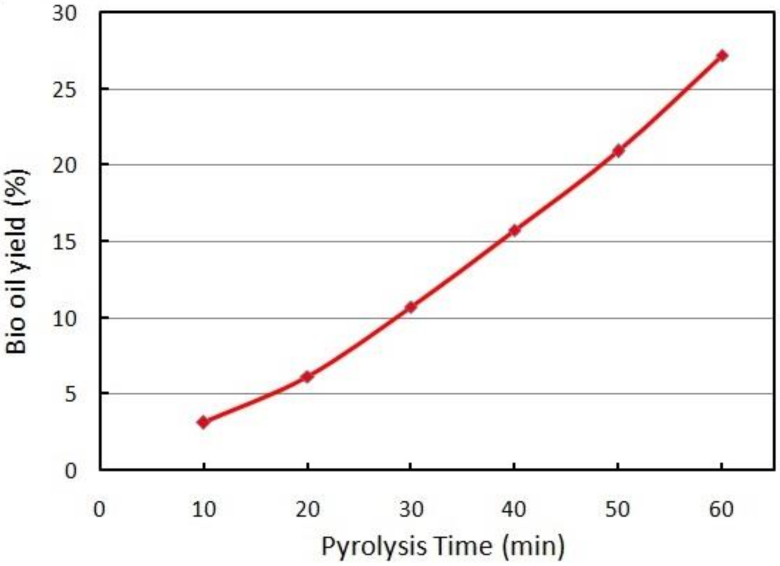

Fig. 3: Bio oil yield as a function of pyrolysis time

Fig. 4 is a representation of the bio char yield as a function of the heating time. The bio char yield in the present experiment is seen to be lowered significantly with the rise in the heating time. It is observed that with the rise in the heating time from 10 min to 60 min, the bio char yield is reduced from 86.62 % to 66.55 %. This is a reduction of almost 25 % in the bio char yield. This lowering in the bio char yield is seen as the more heating time provides sufficient time for the material under investigation to perform the chemical reactions. The resultant of these chemical reactions is the evaporation of the volatiles resent in the material. Thus the increment in the heating time reduces the bio char yield.

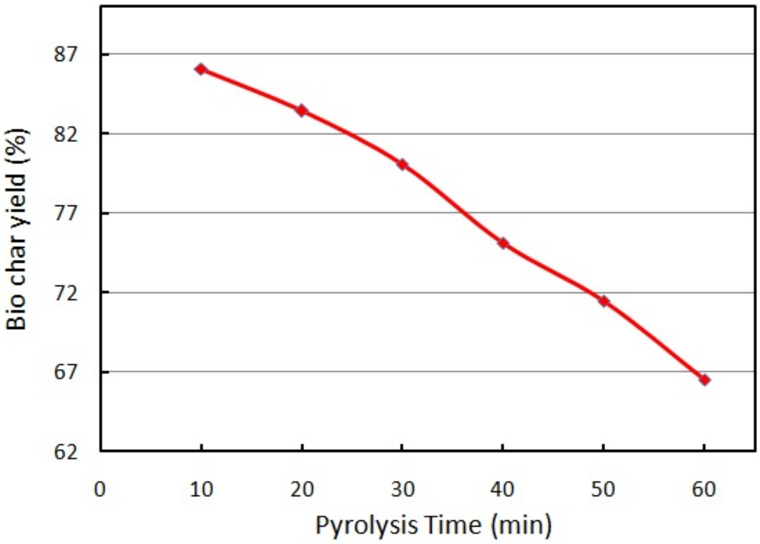

Fig. 4: Bio char yield as a function of pyrolysis time

4. Conclusions

The study discussed the impact of the pyrolysis process parameters on the bio oil yield and the bio char yield. Two different process parameters viz. heating temperature and heating time were chosen for this study. The study found that both of these parameters significantly affect the pyrolysis product yields. However, the effect of these process parameters is different for the different pyrolysis products. Whereas, bio oil production enhances on increasing the heating time or the heating temperature, the bio char yield lowers with the rise in either of the pyrolysis process parameter. The increase in the bio oil yield may be attributed to the better chemical reaction at longer heating time and heating temperatures. Improved chemical reactions may lead to the evaporation of the volatile present in the material. These volatiles can further be condensed and the bio oil can be extracted. Thus higher temperature or heating time produces more gasses and more bio oil is extracted. On the other hand with the longer heating rate or higher heating temperatures, the char yield lowers as the volatiles escapes away from the soild material reducing the bio char yield.

Referances

[1] Abedi, J., Yeboah, Y.D., Realff, M., McGee, D. , Howard, J., and Bota, K.B. , (2001) An Integrated Approach to Hydrogen Production from Agricultural Residue for use in Urban Transportation, Proceedings of the 2001 U.S. DOE Hydrogen Program Review (NRELICP 570-30535).

[2] Bakhshi, N. N.; Dalai, A. K. , and Srinivas, S. T; (1 999). Conversion of Various Biomass-derived Chars to Hydrogen/High Btu Gas by Gasification with Steam. Proceedings of the 4th Biomass Conference of the Americas, Oakland, CA, August 29-September 2, 1999:pp. 985- 990.

[3] Chaudhari, S. T.;. Bej, S. K. ; Bakhshi, N. N.; Dalai, A. K (2001) Steam Gasification of BiomassDerived Char for the Production of Carbon Monoxide-Rich Synthesis Gas. Energy and Fuels 15 pp. 736-7 42

[4] Demirbas, A.; Caglar, A. (1 998). Catalytic Steam Reforming of Biomass and Heavy Oil Residues to Hydrogen. Energy Edu. Sci. Technol.1:pp. 45-52.

[5] Ferdous, D. ; Dalai, A.K. ; Bej, S.K.; Thring, R.W. ; Bakhshi, N.N. (2001). Production of H2 and Medium BTU Gas via Pyrolysis of Lignin's in a Fixed-Bed Reactor. Fuel Processing Technology 70(1): pp. 9-26.

[6] Gallin-Ast. (1 999). Method and Apparatus for Production of Hydrogen, Particularly High-Purity Hydrogen, During Gasification of Biomass. Offenlegungsschrift, Hannelore Germany, Patent No. DE-197-34-259191 :pp. 2-6.

[7] Hauserman, W. B. (1 994b). High-Yield Hydrogen Production by Catalytic Gasification of Coal or Biomass. Int. J. Hydrogen Energy, 1 9, (5):pp. 41 3-41 9.

[8] Kubiak, H.; Papamichalis, A. , and van Heek, K. H. (1 996). Production of Hydrogen by Al lothermal Gasification of Biomass. Hydrogen Energy Progress XI, Proceedings of the 1 1th World Hydrogen Energy Conference; Vol. 1 :pp. 621-629.

[9] McKinley, K.R.; Browne, S.H.; Neill, D.R; Seki, A. , and Takahashi, P.K. (1 990). Hydrogen Fuel from Renewable Resources. Energy Sources; 1 2: pp. 1 05-1 1 0.

[10] Pasternak, A. D. ; Richardson, J. H.; Rogers, R. S.; Thorsness, C. B. , and Wallman, H. (1 994). MSW to Hydrogen. Proceedings of the 1994 U.S. DOE Hydrogen Program Review, Livermore, CA, April 1 8-21 1 994 (NREL/CP-470-6431):pp. 433-450.