Analysis of Pyrolysis Processes of Waste Tyre Potential

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***Abstract*- Pyrolysis of Waste Tyre has been examined in this work to assess the possibility of using derived products as potential clean energy sources. The scope of research work covers thermal analysis of waste tyre as raw materials, studying effects of slow pyrolysis conditions on product yields and properties. Products derived from pyrolysis can be used in various forms of energy sources or as valuable feed-stocks for further product synthesis. Tyre pyrolysis oil is chemically very complex containing aliphatic, aromatic, heteroatom and polar fractions. The fuel characteristics of the tyre oil shows that it is similar to a gas oil or light fuel oil and has been successfully combusted in test furnaces and engines.**

Index Terms- Waste Tyre, Pyrolysis, thermal analysis, Thermochemical conversion, Bio Oil.

I. INTRODUCTION

Fossil fuels are unsustainable sources of energy. Oil, gas and coals were originally formed from plants and animals through geological compression and heat more than a large number of years and its extraction involves energy and resource intensive drilling and mining. These sources are considered to be out of a sustainable natural cycle and when these are spent, they are not replenished and the final chemical products of its combustion add to the global warming phenomenon. Renewable and sustainable energy sources such as wind, tidal, geothermal and solar energy, on the other hand, do not add to global warming. Biomass, an effectively stored form of solar energy through plant photosynthesis, is therefore considered as renewable and sustainable because of the natural molecular bond making and cycle of energy storage also, breaking cycle of energy stockpiling and ignition included. Notwithstanding, its impediments incorporate low energy and mass densities, high dampness content and wasteful inventory network coordinations (as it is a tremendously circulated and diffused asset).

Mechanical thermochemical forms permit the creation of oils, gases and coals from sustainable sources without holding up a great many years and its application ranges from minutes to hours for the expected transformation to happen.

In this way, because of the poorer characteristics of biomass for energy purposes, it is basic that biomass is overhauled through appropriate change techniques into a higher quality fuel or item. Transformation innovations for biomass can be separated into two streams, the "Bio-chemical course" which exploits nature through miniaturized scale living beings or catalysts to debase biomass and the "Thermochemical course" which utilizes heat and at times weight.

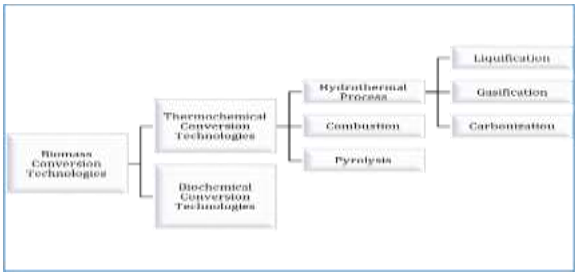


Figure 1.1 Biomass Conversion Technologies.

Waste Tires

It is evaluated that 1,500,000,000 tires are created worldwide every year which will in the long run wind up as waste tires (ETRMA, 2011). Regarding tonnages, waste tires speak to a critical extent of the aggregate solid waste stream. For instance, around 3.3 million tons of waste tires were created every year inside Europe (EU-27) in 2010 and an expected reserve of 5.7 million tons of waste tires all through Europe (ETRMA, 2011). The administration of waste tires in the European Union has been controlled under the End of Life Vehicle Directive which stipulates the different gathering of tires from vehicle dismantlers and empowers the reusing of tires (EC, 2000). Likewise, the EU Waste Landfill Directive has restricted the landfilling of tires (EC 1999).

II-LITERATURE REVIEW

Various researchers have been study Pyrolysis process for various biomass and other wastes components some of them are described in this chapter.

"*Potential of pyrolysis processes in the waste management sector",* D. Czajczynska, L. Anguilano , H. Ghazal, R. Krzyzyn ska , A.J. Reynolds , N. Spencer , H. Jouhar, 2017, Thermal Science and Engineering Progress 3 (2017) 171–197

The fundamentals of pyrolysis, its most recent advancements, the diverse states of the procedure and its residues are of extraordinary significance in assessing the materialness of the pyrolysis procedure inside the waste administration division and in squander treatment. Specifically the sorts of residue and their further utilize or treatment is of outrageous enthusiasm as they could turn into the wellspring of optional raw materials or be utilized for energy age in squander treatments. The fundamental zone of focal point of this paper is the examination of the connection between the pyrolysis conditions, the compound and mineralogical sythesis of their items and the advantages of pyrolysis in the waste administration area. All the more particularly the broadside concealments the quick, transitional and moderate pyrolysis of natural waste and blends of inorganic and natural waste from family units. The impact of impetuses amid quick pyrolysis on the item yield and piece isn't being considered in this survey. This paper is considered as the base paper for the study.

"Modeling and pilot plant runs of slow biomass pyrolysis in a rotary kiln", 2017, Matthaus U. Babler, Aekjuthon Phounglamcheik, Marko Amovic, Rolf Ljunggren, Klas Engvall

Pyrolysis of biomass in a rotary kiln discovers application both as a middle of the road venture in multistage gasification and also a procedure all alone for the generation of biochar. In this work, a numerical model for pyrolysis of lignocellulosic biomass in a rotatory kiln is created. The model depends on an arrangement of protection conditions for mass and vitality, joined with autonomous sub models for the pyrolysis response, warm transferand granular stream inside the furnace. The pyrolysis response is depicted by a two-advance component where biomass rots into gas, roast, and tar that in this manner experience assist responses; the heat exchange display represents conduction, convection and radiation inside the furnace; and the granular stream show is portrayed by the outstanding Saeman demonstrate. The model is diverged from trial information gained from a pilot scale turning oven pyrolyzer. In outright 9 pilot plant preliminaries at different maintain stream rate and unmistakable warmth supply were kept running For moderate heat supplies we discovered great assention between the model and the analyses while deviations were seen at high heat supply. Utilizing the model to recreate different activity conditions uncovers a solid interchange between heat exchange and granular stream which both are controlled by the oven pivot speed. Likewise, the model shows the significance of heat misfortunes and establishes the framework for scale up computations and process advancement.

"CFD Aided Design of Integrated Spray Pyrolysis Furnace for Liquid Ore Exploitation", 2017, Wei Du, Ze Sun, Guimin Lu and Jianguo Yu

Conventional splash pyrolysis of liquid mineral incorporates the two procedures of shower drying and calcination. A novel splash .pyrolysis heater was intended to coordinate the two strategies into one unit undertaking and separate solid particles from the heater gas meanwhile. Computational liquid elements was utilized to help the outline and research the stream design, which had the normal for co-hub whirling stratified stream. The mass stream rate dissemination of the sight-seeing was figured under various limit conditions and basic sizes to upgrade the structure and stream field of the heater. An infusion display was worked to mimic the empty cone splash. The temperature and species circulation of the constant stage, and the partition proficiency and living arrangement time of the scattered particles were acquired. Reproduction results demonstrated that the vanishing and pyrolysis process were isolated in the upper and lower parts of the heater chamber with constant stream. The partition effectiveness and mean home time of the molecule item was in excess of 95 % and 6 seconds, individually. Favored movement conditions and structure parameters are proposed for expansive use of shower pyrolysis of different fluid metals.

III-RESEARCH METHODOLOGY

3.1. Process Model Simulator

In recent times, numerous processes modeling software set have become obtainable to progress computational model of gasification process and to achieve simulation and validation lessons. Usually, investigators and authorities use Aspen Plus, Computational Fluid Dynamics (CFD, composed of GAMBIT and FLUENT), ChemCAD and MatLab software sets to advance and enhance their gasification models.

While the CFD is influential software, the programs have extraordinary computational necessities. Instead, Aspen Plus is one of the classy processes modeling computer software sets which is aware to numerous users and has confirmed its capability for gasification model expansion and reproduction. Because of its tremendous capacity and correct outcomes in process demonstrating, Aspen Plus was utilized as a part of this investigation to create and mimic a settled bed gasification process for different feed stocks (MSWs, wood squanders, green squanders and espresso bean husks).

The reproductions of the biomass gasification method depended on the mass-energy adjust and concoction equilibrium for the entire movement. Aspen Plus is stranded on “blocks” linked to unit progressions in addition to chemical reactors, through which most modern tasks can be reenacted. It incorporates various databases containing physical, chemical and thermodynamic information for an extensive diversity of chemical compounds, in addition to a collection of thermodynamic models compulsory for the precise simulation of any assumed chemical system [12].

Aspen Plus

ASPEN is an acronym of Advanced System for Process ENgineering. It depends on a stream sheet reproduction. Notice that Aspen was supplanted by Aspen Plus® in most recent adaptations. A stream sheet reenactment is a PC programming that is utilized to quantitatively demonstrate a chemical preparing plant, which, notwithstanding the central power source unit, likewise incorporates pre and post-treatment steps. where every symbol remains for a unit activity, chemical process, input/yield material stream, input/yield vitality stream, or info/yield electric/pneumatic flag. As far as Aspen Plus stream sheet documentation, there will be a square symbol and stream symbol. The notable stream sheet test system, for example, Aspen Plus, enables us to foresee the conduct of a procedure utilizing fundamental building connections. As instructed in process demonstrating and reproduction course that we depict a given physical (i.e., genuine) process by an arrangement of straightly autonomous arithmetical/differential conditions with the end goal that the quantity of composed conditions will be equivalent to the quantity of factors (or obscure amounts) and the physical procedure all things considered is said to be indicated or depicted by a proportionate numerical depict. By and large, composing such conditions originates from

- balance conditions of broad thermodynamic properties, for example, mass, mole, and vitality;
- thermodynamic connections for responding and non-responding medium, for example, stage and chemical harmony;
- rate relationships for energy, warmth, and mass exchange;
- reaction stoichiometry and active information;
- physical imperatives forced on the procedure.

With Aspen Plus process test system, we can configuration better plants and increment benefit in existing plants. Aspen Plus stream sheet recreation is valuable all through the whole lifecycle of a procedure, beginning from an unpleasant R&D idea/thought and zooming to a refined anticipated thought with an alternate level of points of interest, including reasonable building, fundamental designing, nitty gritty building, lastly plant activities and patches up.

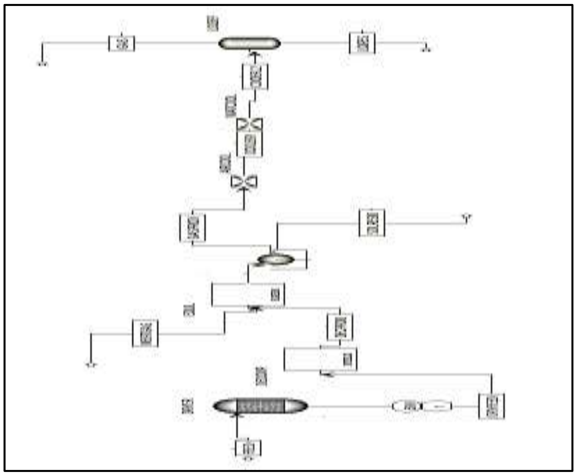


Figure 3.1 Aspen Plus Flow Diagram for the Process

In this work, the reenactment of the unfaltering state, consistent pyrolysis of a lignocellulosic biomass feedstock has been endeavored by means of Aspen Plus. Exactly, the portrayal of pyrolysis pursues a harmony based, non-stoichiometric methodology, that is, no specific response is determined. Aside from pyrolysis, various rudimentary advances are recognized and spoken to as model squares for disentangled process reenactment.

The stream sheet of the model created with Aspen Plus® is spoken to in Fig. 3.1.

The procedure is inferred in various areas. First of pyrolysis/response and the second of partition/recuperation.

The real response segment, in which drying, essential and auxiliary pyrolysis of feedstock occur, is demonstrated by the initial three hinders, that is, the DRYER, the DECOMP and the EQUIL in Fig. 3.1. All things considered, they are only three reactor hinders from the reactor library of Aspen Plus.

The principal square called DRYER is a "RStoic square", takes as information the wet biomass, named FEED, and reproduces the drying stage. This square necessitates the measure of expelled water (per unit mass of aggregate feed, barring inerts) must be indicated. The second square, called DECOMP, is a "RYield square" and takes as info the dried biomass, named DRYFEED. This square necessitates the yields of the items (per unit mass of aggregate feed, barring any idle segments) must be indicated. DECOMP predicts the deterioration, at settled temperature and weight, of the feedstock into reference parts that are: C (settled carbon), fiery remains, H2O, H2, Cl2, S, O2 and N2.

For every one of the squares, i.e., DRYER and DECOMP, an outer, client provided FORTRAN subroutine completes the mass equalization figurings and supplies the correct qualities as sources of info.

The third square, which finishes the pyrolysis area, is a "RGibbs square" named EQUIL. This square takes in information the disintegrated biomass and the inactive gas feed, named individually DECPROD and INERTGAS. The RGibbs square uses Gibbs free vitality minimization with stage part to figure thermodynamic harmony and it doesn't require response stoichiometry. The criteria for thermodynamic balance attest that an isothermal and isobaric chemical framework is at balance when the Gibbs free vitality is limited. The minimization is gotten by tackling a nonlinear compelled issue utilizing a punishment work strategy. Inside this recreation the EQUIL square takes as information the reference parts originating from the DECOMP square and the latent gas and, by limiting the Gibbs free vitality, it figures the synchronous stage and chemical harmony at settled temperature and weight; as yield, there are the species that have been indicated in the EQUIL obstruct as "conceivable items"

The Peng-Robinson condition of state with Boston-Mathias changes was selected as the property strategy utilized for the model. The Peng-Robinson condition are broadly utilized in industry (Sadus, 1994). The benefits of these condition is that it is anything but difficult to utilize and that they regularly precisely speak to the connection between temperature, weight, and stage arrangements in paired and multicomponent frameworks. This condition just require the basic properties and acentric factor for the extensive limitations. Slight PC properties are required and those prompt conventional stage harmony relationship. However, the accomplishment of these changes is restricted to the estimate of stage balance weight. The expected soaked fluid volumes are not improved and they are constantly higher than the deliberate information

$$p = \frac{RT}{V-b} - \frac{a(T)}{V(V+b)+b(V-b)} \quad \ldots\ldots\ldots.. \quad (3.1)$$

Peng and Robinson defined a (T) as

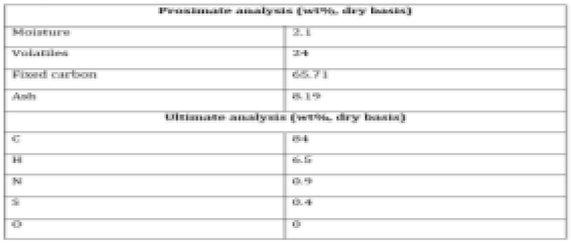
$$a(T) = 0.45724\,\frac{R^2T_C^2}{P_c}\left\{1 + k\left[1 - \left(\frac{T}{T_C}\right)^{0.5}\right]\right\}^2 \quad \ldots\ldots\ldots.. \quad (3.2)$$

Where k = $0.37464+1.5422\omega - 0.26922\omega^2$.. (3.3)

$$b = 0.077880\,\frac{RT_C}{P_C} \quad \ldots\ldots\ldots.. \quad (3.4)$$

The ultimate and proximate analysis for tyre are given in Table 3.1

Table 3.1 Fuel proximate, ultimate and heating value analyses for Tyre



Proximate analysis (wt%, dry basis)	
Moisture	2.1
Volatiles	24
Fixed carbon	65.71
Ash	8.19
Ultimate analysis (wt%, dry basis)	
C	84
H	6.5
N	0.9
S	0.4
O	0

The proximate and ultimate analysis which is considered for the study is given in table 3.1.

3.2 Pyrolysis products

3.2.1 Char

Char is a permeable carbon structure that remaining parts after the hydrogen and oxygen portions have left the fuel. Char is frequently characterized as the strong buildup after pyrolysis. Usually contaminated with different segments: mineral divisions and after inadequate pyrolysis, huge parts of hydrogen and oxygen, that can in any case be available in char.

Char is accepted to add to the arrangement of polycyclic sweet-smelling hydrocarbon (PAHs) amid biomass pyrolysis, especially at low temperature. Char can be utilized as a fuel in type of briquettes or as a char-oil, charwater slurry; on the other hand char can be moved up to actuated carbon and utilized in cleansing procedures.

3.2.2 Pyrolysis liquid

The liquid product from biomass pyrolysis is known as bio-oil. Bio-oil isn't a result of thermodynamic balance amid pyrolysis in any case, it is created with short home occasions and fast cooling or extinguishing from the pyrolysis temperature. This condensate isn't at thermodynamic harmony at capacity temperatures. Thus the bio-oil chemical arrangement tends to change toward thermodynamic balance amid capacity.

3.2.3 Gas

The third fundamental item from pyrolysis is gas. The gas chiefly comprises of H_2, CO_2, CO and CH_4 together with hints of C_2 species. CO_2 and CO are specially delivered at low temperature, while H_2 is created at high temperature

IV-RESULTS & ANALYSIS

Biomass pyrolysis has been known as one of the most promising process for energy recovery along with the production of valuable products. Nevertheless, the pyrolysis process requires several operational units and reliable process technologies to achieve the desired pyrolysis conditions. This could cause complication of process construction and operation.

In this work, the reenactment of pyrolysis of waste tire was performed in a fixed-bed tubular reactor.

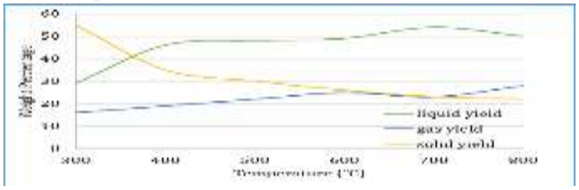


Figure 4.1 Effect of pyrolysis temperature on product yields; (a) liquid, (b) char (Solid) and (c) gas derived from pyrolysis of waste tyre

Table 4.1 Effect of pyrolysis temperature on product yields;

Temperature (C)	300	400	500	600	700	800
Liquid yield (Wt %)	29	46	48	49	54	50
Gas yield (Wt %)	16	19	22	25	23	28
Solid yield (Wt %)	55	35	30	26	23	22

Figure 4.1 demonstrates the impact of pyrolysis temperature on the item yields of waste tire. Pyrolysis of waste tire gave greatest yields of fluid at 700°C The most extreme fluid yield of waste tire pyrolysis were in the scope of 29-50 wt%.

The impact of weight augment on the yield of strong, fluid and gas items are appeared in figure 4.2. It is evident from the assume that strong (Char) items diminishes as for weight increments while there is stunning changes in fluid and gas yields appeared.

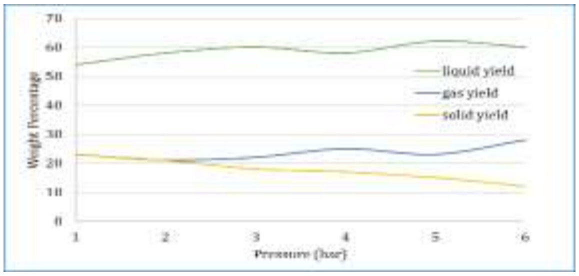


Figure 4.2 Effect of pyrolysis pressure on product yields; (a) liquid, (b) char (Solid) and (c) gas derived from pyrolysis of waste tyre

Table 4.2 Effect of pyrolysis pressure on product yields

Pressure (bar)	1	2	3	4	5	6
liquid yield	54	58	60	58	62	60
gas yield	23	21	22	25	23	28
solid yield	23	21	18	17	15	12

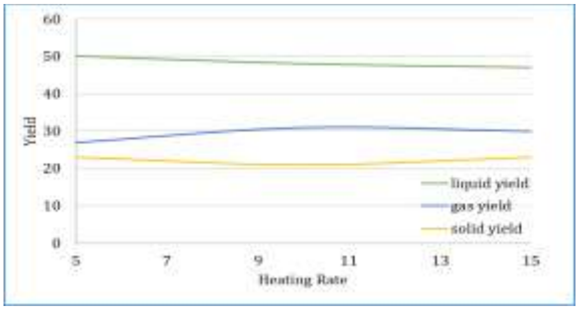


Figure 4.3 Effect of Heating Rate on product yields; (a) liquid, (b) char (Solid) and (c) gas derived from pyrolysis of waste tyre

Table 4.3 Effect of Heating Rate on product yields;

Heating Rate	5	10	15
liquid yield	50	48	47
gas yield	27	31	30
solid yield	23	21	23

Figure 4.4 shows the trend of the pyrolysis gas composition with temperature of five H_2, CO, CO_2, CH_4 and H_2O leading species.

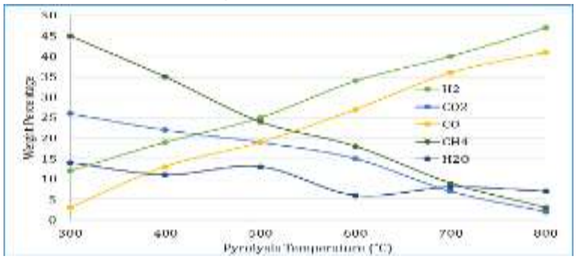


Figure 4.4 Weight percentage of H_2, CO, CO_2, CH_4 and H_2O in the gas product as functions of pyrolysis temperature.

Particle measure is another factor that can impact the warming rate and the item yields of pyrolysis. Bigger particles require more opportunity to warm by intra-molecule conduction. Lower warming rates amid pyrolysis are known to build the char yield, and accordingly discharge less vapors.

Table 4.4 Weight percentage of H2, CO, CO2, CH4 and H2O in the gas product as functions of pyrolysis temperature

Temperature	H_2	CO_2	CO	CH_4	H_2O
300	12	26	3	45	14
400	19	22	13	35	11
500	25	19	19	24	13
600	34	15	27	18	6
700	40	7	36	9	8
800	47	2	41	3	7

It is obvious from the figure 4.5 that the gas and solid yields increases with the increment in particle size while liquid yields decreases with the same.

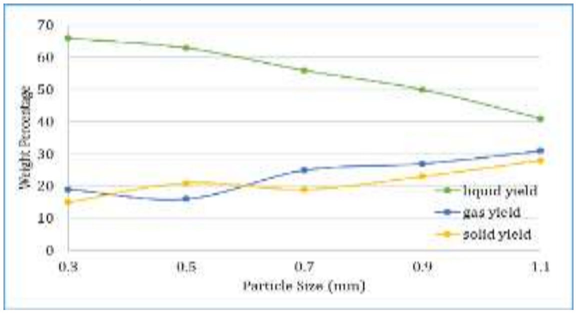


Figure 4.5 Effect of particle size in product yield

Table 4.5 Effect of particle size in product yield

Particle Size (mm)	0.3	0.5	0.7	0.9	1.1
liquid yield	66	63	56	50	41
gas yield	19	16	25	27	31
solid yield	15	21	19	23	28

V-CONCLUSIONS

A computer simulation model of the slow pyrolysis process is established using Aspen Plus software tool. The goal of the research work was to develop a model of sluggish pyrolysis procedure for waste tyre, and utilize it to inspect the effect of the key operating parameters on process performance. The following conclusions has been obtained:

- Pyrolysis of waste tyre gave maximum yields of liquid at 700°C there was a quick reduction of char yield from 300 to 500°C, surveyed by a sluggish decrease at higher temperatures and approaching a constant value at 800°C. This coincided with the increased generation of liquid and gas products which was pronounced up to 500°C
- Solid (Char) products decreases with respect to pressure increases while there is curvy changes in liquid and gas yields shown. Maximum yields in fluid and gas goods shown in high pressure ranging from 5 to 6 bar respectively.

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