Study on Scrap Tyres Pyrolysis

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Abstract- *This paper discusses the scrap tyres pyrolysis process. As we living in 21st century, the demand and the cost of the fuel are being increases due to increase in the number of vehicles worldwide as well as its great dependency in the area where it is very essential to complete any work. So, this has become a global issue for researchers to find out the alternative way to fulfill the future demand of the fuels. In most populated country like India the crises might be come in the future need. However, India has lots of sources of waste available from various sectors like biomass from agriculture and forests; industrial waste, plastic waste and scrap tyres etc. which can be used as great source of renewable energy production. There is an urgent need to utilize such wastes for producing alternate fuels by using proper technique and methodology. In India about a million tons of scrap tyres are available annually. Globally it is a major environmental concern to dispose the waste tyres. Alternative technology is being adopted by researchers to produce an alternate fuel by using such discarded waste. Chemical decomposition of organic substances called pyrolysis is considered as a useful technique for recycling of scrap tyres.*

Keywords- Pyrolysis, Alternative Fuels, Scrap Tyres. Plastic waste, Industrial waste.

I. INTRODUCTION

The increasing industrialization and motorization of the world led to a steep rise in demand of petroleum products[1] the prices of the fuels are increasing at a high rate so it has become necessary to develop the alternate renewable fuels. Use of renewable fuels not only save environment but also contribute to economy of the country. The pressure is increasing day by day due to rising fuels prices, diminishing global supplies of crude oil and legislation to control climate change which resulted in aggressive renewable fuel policies and a rapid growth in the emerging bio fuel industry[2] It has become a global environmental threat due to its disposal characteristics. Currently, global estimate of 13.5 million tonnes is generated annually[3]. In Bangladesh, total waste tyre generation of each year is about 90000 tons. One common way for disposal of these waste tyres is land filling. Tyres are bulky, and 75% of the space a tyre occupies is void, so the land filling of waste tyres has several difficulties .If the scrap tyres burn directly in brick fields or any other incineration plant then various harmful gases such as CO, CO_2, SOx, and NOx will be produced which cause environmental pollution[4] A number of studies related to tyre pyrolysis had been reported in the literature for its conversion into valuable compounds. Developed countries have been paying great attention to the effective utilization of discarded tyres to achieve the goals of protecting environment, recycling resources and preserving energy. Waste tyres have a high content of volatile matters as well as fixed carbon that makes them an interesting solid as a fuel for energy production or hydrogenation processes and in pyrolysis processes to obtain different fractions of solid, liquid and gaseous products [5]. The awareness about the environmental issue is increasing day by day that's why the pressure for environmental sustainability and implementation of the various strategies is mounting on organization to reduce environmental impact of their product and waste. India is the country in which there is lots of waste available every year from various sector like agriculture and industrial waste. Therefore, it has become necessary to think about the utilization of such wastes for producing alternate fuels through proper up gradation processes and technique. [2]

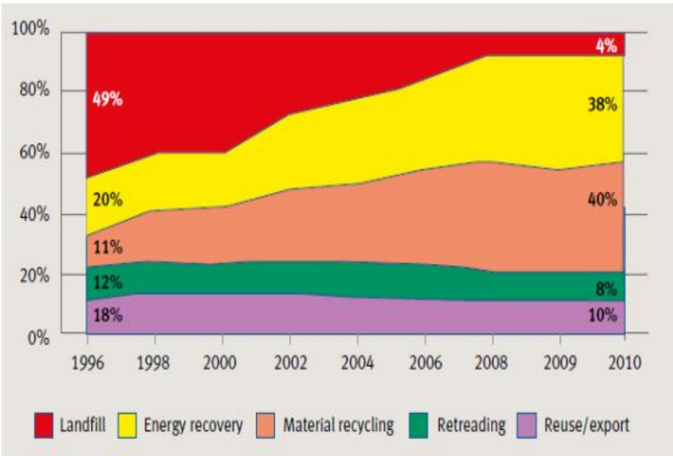

Figure 1. Summary of the evolution of waste tyre treatment[6]

1. Waste tyres:-

Waste tyres also referred to as used tyres can be defined as tyres that have expired as a result of exceeding their production life span or are no longer safe for usage due to defects, such as degradation of its physical composition/structure from use and cannot be retreaded. It is one of the most challenging hazardous solid wastes facing modern society, particularly in developing countries. It is estimated that the EU, Japan, and USA generate 6 × 106 tons of waste tyres annually. According to a report, 160,000 tons of waste tyres are generated in South Africa annually and up to 28 million used tyres are dumped unlawfully or burnt. This figure is projected to increase by 9.3 million yearly. The non - biodegradable nature of this polymer material makes its disposal difficult. Disposal by massive stockpiling and landfilling is one of the common ways of handling waste tyre, but this requires a large space as the volume of tyres cannot be compacted. These also poise the danger of the possibility of fire outbreak with the emission of harmful gases [7]

Difficulties with the Waste Tyres:-

Tyres are made of vulcanized rubbers (with styrene butadiene (SBR), natural rubber (NR) and polybutadiene (BR), carbon black, steel, textile cord and little amount of other additives. The dumping of waste tyres is one of the main environmental issues all over the world. The toughness and resistance of the over material to biological removal make their removal and reprocessing difficult. Greater than 3.4 x 106 tonnes of end-of-life tyres are generated yearly in European Union, 2.5 x 106 tonnes in North America and 1 x 106 tonnes in Japan. Though the measure of scrap tyres formed in India does not exactly exists but the growing trend of use of road moving force will certainly generate a problem of removal in very near future. In the year 2008 India had over 100 million vehicles recorded on its roads. This was an enlargement of about 100% in the last 9 years. [8]

II. LITERATURE REVIEW

In the desulfurization pyrolysis fuels obtained from waste. In this work, they used two affordable desulfurization techniques without hydrogen to reduce the sulfur content of these three pyrolysis fuels with moderate success that could make them useful as heating fuels. These desulfurization methods are based on the oxidation of the sulfur compounds present in these fuels with hydrogen peroxide to more polar sulfur compounds like sulfoxides and sulfones that can be later eliminated by methanol extraction or silica gel adsorption. The desulfurization rate was 64%.[4]

In the study the behavior and chemical analysis of tyre pyrolysis oil. In this work, it is reported that tyre oil is a complex mixture of organic compounds of 5–20 carbons with a higher proportion of aromatics. The percentage of aromatics, aliphatic, nitrogenated compounds, and benzothiazole were also determined in the tyre pyrolysis oil at various operating temperatures of the pyrolysis process. Aromatics were found to be about 34.7% to 75.6% when the operating temperature was varied between 300°C and 700°C, while aliphatic were about 19.8% to 59.2%.[4]

A study to optimize the fuel production from waste tyres by pyrolysis and resembling diesel fuel various desulfurization methods. To minimize high sulfur content in fuel some catalysts were used like CaO, Ca(OH)2 , and NaOH. In addition, effects of variables such as temperature, the catalyst ratio, and the N2 flow rate on yield were investigated. The sulfur content of the product was observed to be 34.25% lower with the utilization of 5% Ca (OH)2 in the reaction. In order to make the sulfur content of the product closer diesel fuel, the acetic acid H2O2, formic acid H2O and H2SO4 were used in different amounts. The properties of low sulfur tyre fuel are very close to diesel fuel but density is slightly higher than diesel. [4]

The pyrolysis of scrap tyres continuously in a conical spouted bed reactor and the results (yields, composition of the volatile fraction and carbon black properties) have been compared with thus obtained operating in batch mode. This continuous operation in the 425-600°C range gives way to a yield 1.8-6.8 wt. % gas, 44.5-55% liquid and 36-39% char. [9] The production hydrogen and other gases from the bench scale pyrolysis-gasification of scrap tyres. The experiment was carried using two stages system consisting of pyrolysis of the scrap tyres at 500°C followed by catalytic steam gasification in a second reactor at 800°C using Ni-Mg-Al (molar ration 1:1:1) as catalyst. [9]

The thermal behavior of pyrolysis proposing multi-stages pyrolysis is an approach to optimize waste tyre pyrolysis process by minimizing the pyrolysis energy requirement. They used a tyre particle with radius of 3 cm in a batch reactor that can provide a constant heating rate of 10°C/min and target pyrolysis temperature of 510°C in nitrogen atmosphere. [9]

In studied the pyrolysis of waste tyres in an internal heated fixed-bed fire-tubing heating reactor system under N2 atmosphere and investigated the effects of operating temperature, feed size and vapor residence time on the yields and compositions of product liquids. The highest pyrolytic oil product yield (51%) was obtained at a pyrolysis temperature of 475°C for size of 4 cm3 and vapor residence time of 5 sec, with yield solid char 40.5%wt and gas 8.5%wt. [9]

III. TYPES OF SCRAP TYRES RECYCLING

Waste tyres are recycled in different ways which are:

1) Retreading
2) Landfills
3) Incinerations
4) Pyrolysis of scrap tyres.

1. Retread is a manufacturing process designed to extend the lifespan of worn out tyres. The old tread is removed and a new tread is applied to the bare casing using specialized tools. This procedure is regularly carried out in airplane tyres as they are worn out very frequently and the necessity for them to be in good condition. On an average 4.5 gallons of oil is saved through this process compared to manufacture of a new tyre. In case of commercial vehicles, the savings can go upto 12.5 gallons of oil.
2. Land filling is the most common way of disposing waste tyres, accounting up to 53% of the total waste tyre generated. Presently about 50% of the waste automobile tyres are used for landfill in every country. A small percentage is used for engineering purposes at landfill sites. But it has a serious impact on land usage, fertility of land and is a potential hazard as it is prone to fires. Tyres are very difficult to extinguish when they catch fire. Citing this many countries have banned this form of disposal of waste tyres. Incineration and TDF are two wastes to energy technologies that are available for the treatment of waste tyres.
3. In incineration, energy recovery systems are used to recover the energy. TDF or tyre derived fuel the energy remains in a liquid form that can be used in combustors, IC engine etc.[2]
4. Pyrolysis process takes place without air or in anaerobic atmosphere typically at a temperature of 400-700°C. During this process, in the case of tyre pyrolysis, sulfide bonds occurring in the rubber become broken and next carbon chains are bursting and finally gaseous, liquid and solid products are formed, which then can be subjected to further processing. The main components are: methane gas (and other simple hydrocarbons), hydrogen, hydrogen sulfide and carbon monoxide (which constitute about 10%). Oil represents around 44%, and part of solids about 46%. The liquid phase consists of a mixture of aliphatic and aromatic hydrocarbons, such as benzene, toluene and others. The separation of these components from the liquid fraction can be achieved by distillation and refining. The solid fraction consists of char, remnants of steel, silica, ZnO, ZnS, and any residues of catalysts, which were used. Char can be used as a filler for rubber compounds, or may be subject to activation. The composition of the products formed, both qualitative and quantitative, is dependent on the pyrolysis process parameters such as temperature, the duration of the process, the conditions of pressure, inert gas and catalyst presence. [10]

Types of Pyrolysis –

Slow Pyrolysis

Slow pyrolysis has been used for thousands of years to enhance char production at low temperatures (550-950 °K) and low heating rates between 0.1-1 °K /s. In this process, the vapour residence time is too high and may range between 5 min to 30 min. The components during the process are in the vapor phase which continues to react with each other resulting in formation of solid char and other liquids. However, slow pyrolysis has some technological limitations which made it unlikely to be suitable for good quality bio-oil production. Cracking of the primary product in the slow pyrolysis process occurs due to high residence time and could adversely affect bio-oil yield and quality. Moreover, long residence time and low heat transfer demands extra energy input. [2]

Fast Pyrolysis

In the fast pyrolysis process, biomass is rapidly heated to a high temperature (850–1250 °K) in the absence of oxygen and residence time between 0.5–10 s . Typically on a weight basis, fast pyrolysis produces 60%–75% of oily products (oil and other liquids) with 15%–25% of solids (mainly biochar) and 10%–20% of gaseous phase depending on the feedstock used. The production of liquids is usually yielded from biomass in a low temperature, high heating rate and short resident time environment. The basic characteristics of the fast pyrolysis process are high heat transfer and heating rate, very short vapor residence time, rapid cooling of vapors and aerosol for high bio-oil yield and precision control of reaction temperature. Fast-pyrolysis technology is receiving incredible popularity in producing liquid fuels and a range of specialty and commodity chemicals. This liquid product can be easily and economically transported and stored, thereby decoupling the handling of solid biomass from utilization. It also has potential to supply a number of valuable chemicals that offer the attraction of much higher added value than fuels. Fast pyrolysis technology can have relatively low investment costs and high energy efficiencies compared to other processes, especially on a small scale.[2]

Flash Pyrolysis

The flash pyrolysis of biomass is a promising process for the production of solid, liquid and gaseous fuel from biomass which can achieve up to 75% of bio-oil yield. This process can be characterized by rapid devolatilization in an inert atmosphere, high heating rate of the particles, high reaction temperatures between 450 °C and 1000 °C and very short gas residence time around less than 1s. However this process has some technological limitations, for instance: poor thermal stability and corrosiveness of the oil, solids in the oil, Increase of the viscosity over time by catalytic action of char, alkali concentrated in the char dissolves in the oil and production of pyrolytic water.[2]

Table 1 Typical operating parameters and products for pyrolysis process[2]

Pyrolysis Process	**Solid Residence Time (s)**	**Heating Rate (°K/s)**	**Particle Size (mm)**	**Temp. (°K)**	**Product Yield (%)**		
					Oil	**char**	**gas**
Slow	450–550	0.1–1	5–50	550–950	30	35	35
Fast	0.5–10	10–200	<1	850–1250	50	20	30
Flash	<0.5	>1000	<0.2	1050–1300	75	12	13

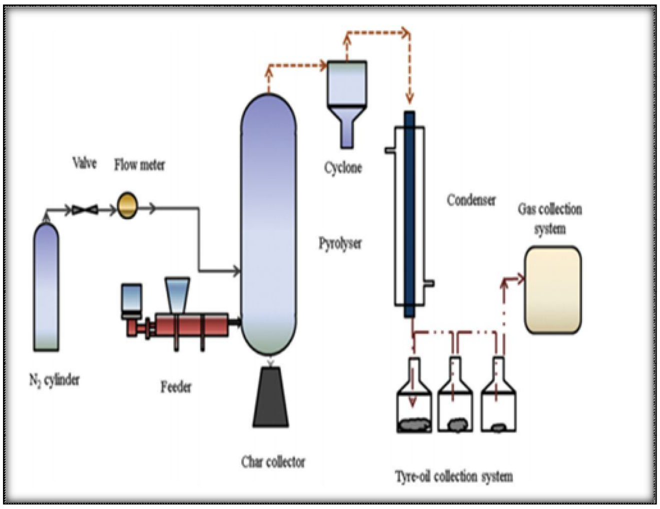

Figure 2. flow diagram of the pyrolysis process[12]

A. Fixed bed reactor:

Charcoal can be produced with a fixed bed reactor in which the biomass feedstock is partially gasified by air. The company Bio-Alternative SA operated a downdraft fixed bed gassier of 1 m diameter and 3 m height with a biomass throughput of 2000kg/h. Products of this process are gas, viscous tars and charcoal of which the yield is maximized. For fir and beech wood, charcoal yields of 300 weight percent on fed wood basis have been achieved. All products are used as energy carriers.

B. Fluid bed reactor

the well-known fluid bed reactor technology has Tar yields, produced by a medium scale (100kg/h) fluid bed reactor, are quite low due to cracking of the vapors in the large volumes of bed and freeboard. Fluid bed reactor technology offers good possibilities in gasifying biomass feed stocks with minimum tar formation. In that case, bed material should be selected on basis of optimum catalytic tar cracking behavior. If, however, tar is the product aimed at, a non-catalytic shallow fluid bed should be applied followed by immediate quenching of the gaseous products [14]

As the ingredient of tyres may be vary with varying in vehicle types. Some comparison has been identified between Car and Truck tyres are as follows.

Table 2. comparison of tyre ingredient breakdown for car and truck [13]

S.no.	**Material**	**Car Tyre (%)**	**Truck Tyre (%)**
1	Natural rubber	14	27
2	Synthetic rubber	27	14
3	Fillers (carbon black, silica)	26-28	26-28
4	plasticizers (oil and resin)	5-6	5-6
5	Chemical additives (sulfur, etc.)	5-6	5-6
6	Metal for reinforcement	16.5	25
7	Textile for reinforcement	5.5	-

IV. CONCLUSION

In this paper it is found that the waste tyres which are the great source of the renewable energy by using different mode of pyrolysis. These waste to energy options can address both environmental and energy challenges. It is feasible technology with small amount of investment, high availability of raw materials, short recovery period. The calorific value for tyre is 46199.12kj/kg which are approximately equal to diesel fuel that i.e. 45814.74 kJ/kg. Waste tyre pyrolysis produces gaseous products such as synthesis gas. This gas can be used for fuel, electricity, and chemicals.

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