

“Purification of Tpo (Tyre Pyrolytic Oil) By Simple Distillation, Simple Distillation With Fe Catalyst, Simple Distillation With Water And Fe Catalyst”

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Abstract—At the global level, Energy crisis and proper waste disposal are the main problems that mankind is facing now a days. In the present study, purification of tyre pyrolysis oil (TPO) obtained by thermal pyrolysis of waste tyre and tube samples were carried out by three different techniques; a) simple distillation b) simple distillation with iron catalyst c) simple distillation by treatment of steam with iron catalyst. During purification TPO is distilled in a batch reactor made up of stainless steel within the temperature range of 80 °C to 100 °C. We got 25-30% purified oil(product) from all the these processes. And remaining is the light residue of oil which can be used as TPO. The oil obtained by all these processes was characterized by fourier transform infrared spectroscopy (FT-IR) and proximate and ultimate analysis. Characterization of these obtained oil shows that it is a mixture of gasoline and diesel. The composition of the oil showed the presence of aliphatic and aromatic compounds.

Keywords—waste tyre, TPO, FT-IR, simple distillation, iron catalyst, proximate and ultimate analysis.

I. INTRODUCTION

Now a day's most nations are facing two major problems, Environmental degradation and Energy crisis. This is due to the growing population, rapid industrialization and disposal of diverse solid wastes, which are generated on a regular basis. [1]. There is a predominant increase in tyre and tube wastes due to phenomenal increase in number of vehicles within India. The statistical data of production of tyre and tube can be known from the Indian rubber industry, at a glance 2011. In India, the production of tyre increased from 66032 metric tons to 97137 metric tons from 2005-06 to 2009. Similarly the production of tube increased from 53421 metric tons to 81448 metric tons from year 2005-06 to 2009. According to this data the production of tyre is forecasted to increase and this indicates that at the same time the annual disposal of waste tyre volume will increase at the same rate as new tyre is manufactured [2] fig (1, 2). The disposal of vehicle tyre and tube represents a major environmental issue throughout the world, especially in developing countries.

One of the common ways of disposal is land filling, but tyres do not degrade easily in soil as they are bulky, taking up valuable landfill space and prevent waste compaction [3]. Open dumping is another method of disposing the waste tyres, but it pollutes the soil, contaminates underground water, provides ideal breeding grounds for disease-carrying mosquitoes and other vermin [4]. Further incineration is also another method of disposing which involves combustion of waste tyres at highly controlled temperatures. Incineration of the tyre waste emits a lot of toxic compounds such as dioxin, mercury, Cadmium, nitrous oxide, hydrochloric acid, sulfuric acid, fluorides and particulates that can be inhaled and magnify or stay permanently in our lungs. They can cause a range of diseases like asthma and cancer. It is known that heavy metals like arsenic, lead, mercury, and organic chemicals such as polycyclic aromatics hydrocarbons, dioxins and radioactive materials are not destroyed by incineration [5]. Moreover, different

techniques are also used for tyre recycling such as retreading, reclaiming, incineration, grinding etc. so there is a necessity to find the alternative sources for which have significant drawbacks and limitations [6]. Recycling of these tyre wastes. One process which has received considerable recent attention is pyrolysis of the tyre to produce oil, gas, and char which has high potential for the other applications. Such as derived oil may be used directly as fuels or added to petroleum feed stocks and it may also be an important source for refined chemicals [7]. The derived gases are useful as fuel; solid char may be used either as smoke. Less fuel, carbon black or activated carbon. Much interest is laid in the production of hydrocarbon liquids from waste tyres since the production of liquid product can be a substitute of fossil fuel. Pyrolysis has several advantages which allow the proper utilization of the obtained product. Paul T. Williams has pyrolyzed the scrap tyre using a static batch reactor under N₂ atmosphere and obtained maximum 55% of liquid yield at 600°C [8].

Several studies on Thermal pyrolysis of waste tyre concluded that the pyrolytic oil of scarp tyre contains high concentrations of polycyclic aromatic hydrocarbons such as benzene, toluene and xylene etc. likewise, the oil has been shown to contain limonene, a valuable product used in industrial applications including formulation of industrial solvents, resins and adhesives, as a scatter agent for pigments [9, 10].

The present study focus on the purification of TPO obtained from thermal pyrolysis of waste tyre in a semi-batch reactor at a temperature range of 450°C to 700°C were carried out by three different techniques a) simple distillation b) simple distillation with iron catalyst c) simple distillation with steam and iron catalyst to get the purified oil. The obtained liquid was characterized for different physical and chemical analysis such as, FT-IR, proximate and ultimate analysis.

II. MATERIALS AND METHODS

The raw materials used for pyrolysis process was motor cycle waste tyre and tube. The waste tyres from nearby motorcycle repairing shops were collected and samples were cut into approximate size of 1cm. The steel thread was removed from tyre.

2.1 Designing

2.1.1 Lab scale reactor design for pyrolysis:

The pyrolysis reactor designed for the experiment is a cylindrical chamber of inner diameter 130mm and outer diameter 140mm and height 200mm. the diameter of outlet is 15mm and exhaust diameter is 25mm is used (Fig-3). The volume of the reactor is 2.5lit. The temperature is measured by digital thermometer and pressure gauge is provided to each reactor of 0-10kg/cm. 2 kW of power is supplied to the reactor for external heating (Fig-3). The temperature of the reactor is controlled manually. The process is carried out between 573K to 613K.

2.1.2 Lab scale reactor design for TPO oil purification

The two reactors designed for the purification experiment is a cylindrical chamber of inner diameter 175mm and outer diameter 180mm and height 320mm (Fig-4). The diameter of outlet is 15mm and drain diameter is 35mm is used. The volume of the reactors is 7lit (Fig-4). the temperature is measured by digital thermometer and pressure gauge is provided to each reactor of 0-10kg/cm² range (Fig-4). 1 kW of power is supplied to the reactor for external heating. The temperature of the reactor is controlled by a manual operator.

The process is carried out between 353K and 373K. The residence time of the feed stock in the reactor was 120 minutes.

2.1.3 Lab scale catalyst bed design for oil purification

The catalyst bed designed for purification is a cylindrical chamber of diameter 90mm and thickness is 5mm. height of the bed is 300mm having two inlets of diameters 15mm and one outlet of 15mm diameter (Fig-5). Packing arrangement is provided inside the bed. Designed reactor, catalyst bed is assembled as shown in (Fig-6).

2.2 Experimental procedure

2.2.1 Experimental Procedure for Processing Of TPO

1KG of waste tyre and tube sample was taken in the stainless steel reactor for each run and placed in an electricity heated reactor. Pyrolysis experiments were carried out in the reactor at various temperature ranges from 673K to 973K for tyre with a heating rate of 293K/min. The vapors from the reactor were condensed in a water cooled condenser and the non-condensable gas was vented to atmosphere. The condensed oil was collected from the outlet of the condenser in a measuring cylinder, and weighted. The remaining residue collected and weighted after cooling the reactor. The weight of non-condensable gases was measured by mass balance. The residence time of the pyrolysis process was 90 minutes. Purified oil Product obtained by this process is shown in (fig-10).

Three processes were used to purify the oil obtained analysis has been done the three samples for various properties and were compared.

2.2.2 Processing of TPO by Simple Distillation:

In simple distillation the product obtained from pyrolysis process is again passed through heat treatment. The TPO is taken into a reactor and it is heated up to its boiling point (80-85°C). then vapors generated in the reactor are send to the condenser for cooling and pure product is obtained at the bottom of condenser. The process is carried out between 80°C and 100°C. The residence time of the feed stock in the reactor was 120 minutes. As shown in (Figure-7). Purified oil product obtained by this process is shown in (fig-10)

2.2.3 Processing of TPO by Simple Distillation Using Iron Catalyst

In simple distillation using iron catalyst the product obtained from pyrolysis process is again passed through heat treatment with catalyst.

The TPO is taken into a reactor and it is heated up to its boiling point (353-358K). then vapor's generated in the reactor are send to the bed filled with iron fillings which act as a catalyst. The outlet of the bed is attached to the condenser for cooling and pure product is obtained at the bottom of condenser. The process is carried out between 80°C and 100°C. The residence time of the feed stock in the reactor was 120 minutes (Fig-8). Purified oil product obtained by this process is shown in (fig-10)

2.2.4 Processing of TPO by treatment of steam using iron catalyst:

In distillation along with water using iron catalyst the product obtained from pyrolysis process and water simultaneously is passed through heat treatment with catalyst. The TPO is taken into a reactor1 and water is taken into the reactor2, outlets of the both reactors are attached to the bed. TPO and water both are heated simultaneously. Then vapors' generated from both the reactor are sending to the bed filled with iron fillings which act as a catalyst. The outlet of the bed is attached to the condenser for cooling and pure product is obtained at the bottom of condenser. The process is carried out between 80°C and 100°C. The residence time of the feed stock in the reactor was 120 minutes. (Fig-9). Purified oil product obtained by this process is shown in (fig-10)

III. RESULTS AND DISCUSSION.

3.1 FTIR analysis of TPO and processed oil.

Fourier Transform Infrared (FTIR) Spectroscopy is one of the important techniques which base its functionality on the principle that almost all molecules absorb infrared light. Only the monatomic (He, Ne, Ar, etc) and homopolar diatomic (H₂, N₂, O₂, etc) molecules do not absorb infrared light. On interaction of an infrared light with oil, chemical bond will stretch, contract and absorb infrared radiation in a specific wave length range regardless structure of the rest of the molecules. Based on this principle functional group present in the pyrolytic oils were identified. The FTIR spectrum for TPO processed by simple distillation, simple distillation with iron catalyst and simple distillation by treatment with steam and iron catalyst is shown in Fig - 11, fig-12, fig-13 and results from the transmittance spectrums are presented in Table 1, table-2 and Table 3. The data shows that the present oils contain mainly aliphatic and aromatic compounds.

3.2 Proximate and Ultimate analysis of oil obtained

Proximate and ultimate analysis of oil obtained by all these three process. The proximate and ultimate analysis of tyre and tube char has been summarized in Table-4. Proximate analysis was used to determine the moisture, ash, volatile, and fixed carbon content and the ultimate analysis was used to determine the elemental composition in terms of carbon, hydrogen, sulfur, nitrogen, and oxygen.

IV. FIGURES AND TABLES



Figure-1. Production of tyre in India

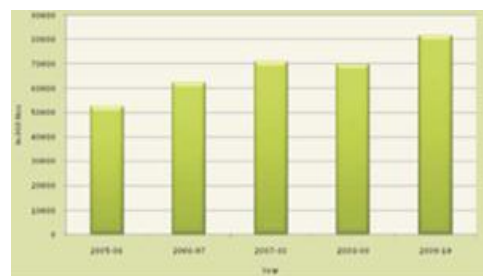


Figure-2 Production of tube in India



Figure-3 pyrolysis reactor



Figure-4 simple distillation reactor



Figure-5 catalyst bed



Figure-6 Reactor+catalyst bed assembly



Figure-7 TPO by simple distillation



Figure-8 simple distillation using iron catalyst



Figure-9 simple distillation
Using $H_2O + Fe$ catalyst



Figure-10 product from purification processes.

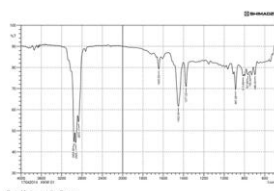


Figure-11 FT-IR spectra of tyre Pyrolytic processed by simple distillation

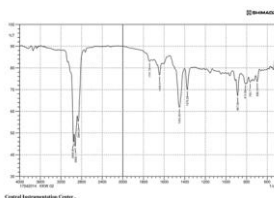


Figure-12 FT-IR spectra of tyre pyrolytic processed by iron catalyst bed

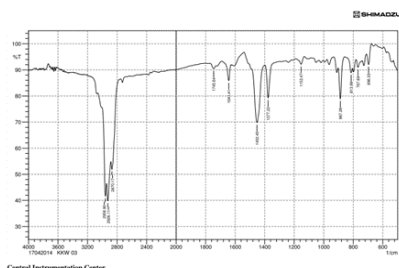


Figure-13 FT-IR spectra of tyre pyrolytic oil processed by steam

TABLE I
FT-IR functional groups of tube pyrolytic oil processed by simple distillation

Wavelength range(cm)	Functional group	Class of compounds
2958.90	C-H	Alkane
2962.11	C-H	Alkane
2870.11	C-H	Alkane
1645.33	N-H=C	Alkene
1452.45	C-H	Alkane
1377.22	C-H	Alkane
887.28	C-H	Alkene
813.99	C-H	Alkene
767.69	C-H	Aromatic substitution type
750.33	C-H	Aromatic substitution type
696.33	C-H	Aromatic substitution type

TABLE II
FT-IR FUNCTIONAL GROUPS OF TUBE PYROLYTIC OIL PROCESSED BY IRON BED

Wavelength range(cm)	Functional group	Class of compounds
2958.90	C-H	Alkane
2962.11	C-H	Alkane
2868.24	C-H	Alkane
1741.78	C=O	Ketone,aldehyde,ester
1643.41	N-H=C	Alkene
1452.45	C-H	Alkane
1375.29	C-H	Alkane
887.28	C-H	Alkene
813.99	C-H	Alkene
765.77	C-H	Aromatic substitution type
696.33	C-H	Aromatic substitution type

TABLE III
FT-IR FUNCTIONAL GROUPS OF TUBE PYROLYTIC OIL PROCESSED BY STEAM

Wavelength range(cm)	Functional group	Class of compounds
2958.90	C-H	Alkane
2926.11	C-H	Alkane
2870.17	C-H	Alkane, alkene aldehyde
1745.64	C=O	Cyclopentane
1643.41	N-H	Alkene
1452.45	C-H	Alkane
1377.22	C-H	Alkane
1153.47	S-H	Sulphone
887.28	C-H	Alkene
813.99	C-H	Alkene+phenyl ring
767.69	C-H	Aromatic substitution

TABLE IV
PROXIMATE AND ULTIMATE ANALYSIS OF TYRE OF TPO OBTAINED

Material	Simple distillation	oil+fe catalyst	Oil+h2o+fe catalyst
Viscosity cst	0.8828	1.0241	0.9348
Water content %	9 PPM	6 PPM	7 PPM
Flash point	38-40	32-34	34-46
Sulphur content%	0.49	1.49	0.083
Carbon content %	35.33	39.88	35.90
GCV(MJ/Kg)	9952.16	9784.49	9959.75

V. CONCLUSION

We got 25-30% purified oil (product) from processing obtained TPO by all these three different techniques (i.e a)simple distillation b)simple distillation iron catalyst c)simple distillation using steam and iron catalyst) at the residence time of 120 minutes and remaining is the light residue of oil which can be used as TPO. FTIR analysis shows that the chemical composition and the functional groups present in purified oil obtained were that of aromatics and aliphatic compounds. From proximate and ultimate analysis it is concluded that oil obtained from Simple Distillation Along With Water Using Iron Catalyst was found to be purest form which contains less amount of sulfur and higher flash point were in the range of diesel and gasoline. It seems the obtained purified oils were mixture of diesel and gasoline. By considering all these results, it can be concluded that the oil obtained can be used as alternative fuel after proper treatment .

Better experimental model can be made to improve the quality and quantity of products, Different catalysts or modification of the catalysts can be used to obtain more yields of the oil products, kinetic methods and models can be used for designing a suitable reactor to maximize the oil product. Optimization of the process to achieve an economical and eco-friendly method.

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REFERENCES

- [1] A. Liaqid, K. Naima Journal of Petroleum Technology and Alternative Fuels Vol. 4, pp. 30-43, March 2013
- [2] [online].Available:<http://all india rubber .net>
- [3] Islam MR, Haniu H, Beg Alam MR,. Liquid fuels and chemicals from pyrolysis of motorcycle tyre waste Product yields, compositions and related properties. Fuel 87,pp-3112–3122 ,2008
- [4] Ucar S, Karagoz S, Yanik J, Mehmet S, Yuksel M. Copyrolysis of scrap tyres with waste lubricant oil. Fuel Processing Technology, 87 pp. 53-58.
- [5] KessineeUnapumnuk. A thesis Report on A Study of the Pyrolysis of Tyre Derived Fuelsand an Analysis of Derived Chars and Oils.2006.
- [6] Jang J.W, Yoo T.S, Oh J.H, Iwasaki I. Discarded tyre recycling practices in the UnitedStates, Japan and Korea .Resource Conservation and Recycling, 22,pp 1–14,1998.
- [7] Rodriguez IM, Cabrero MA, Laresgoiti MF, Caballero B ,Torres A, Chomon MJ,Pyrolysis of scrap tyres. Fuel Processing Technology; 72:pp.9-22 ,2001
- [8] Williams PT, Taylor DT ,Besler S,The pyrolysis of scrap automotive tyres, the influence of temperature and heating rate on product composition. Fuel 69 pp. 1474–1482., 1990.
- [9] Williams PT ,Cunliffe AM, Composition of oils derived from the batch pyrolysis of tyres. Journal of Analytical and applied Pyrolysis 44:131-152,1998.
- [10] Pakdel H,Jean G, Aubin H,Coulombe S, Roy C ,Formation of dl-limonene in used tyre vacuum pyrolysis oils. Environment Science and Technology 9: pp-1646-1649, 1992.