Expeditious Refining of Tyre Pyrolysis Oil to Alternative Fuel: A Review

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***Abstract*— Waste tyre disposal and management to avoid its impact on nature is the most challenging and trending issue in the world. On the other hand, the world is taking initiative and spending millions of currency units to explore the alternative option for gasoline to overcome the fossil fuel crisis. Millions of tyres get wasted each year and it also affects the environment badly. Pyrolysis is a method followed to degradation of waste tyres into a liquid, where the tyre pyrolysed oil (TPO) can be taken out. Further refining and modification of TPO in terms of removing moisture, desulphurization with chemical treatment requires maintaining the standard values of properties of TPO. Distillation of processed TPO with vacuum and fractional setup has been compared at the standard operating conditions and the collected condensed alternative fuel has been compared with the conventional diesel. This paper reviews the inexpensive, expeditious method and a better way of converting tyre waste to form of useful energy.**

Keywords*— Desulphurization, Alternative fuel, Tyre pyrolysis oil, Distillation.*

I. INTRODUCTION

With the digitalization and modernization in the society, demand to the rubber industry has also raised. Recycling of waste created from typical and complex scrap tyres has become necessary now. Currently, India is one of the biggest tyre producer countries. Nearly 2.5 to 3 lakh tyres are collected as scrap in India per day, along with that India also imports tyre waste from other countries which further reduced to oil. And it can be used for the various industrial furnaces as a fuel source. The current situation of India indicates that more than 1.3 billion tyre units produced in India, which stood third in all over the world. More than 65 million scrap tyres are being collected in a year, and the number is going increasing year by year [1].

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In a work by A.S.M Rezaun Nabi et.al [2] around the globe, the fossil fuel crisis is a leading problem which creating disturbances in the natural sources. The need and requests for fossil fuels concerning fuel are going to increases massively. Rising prices of gasoline fuels and oils put a requirement to have an initiative in front of the world for alternative fuel. Crores of currency units are being invested to have an option for current energy sources. Overuse and rapid depletion of energy sources comprise various matters along with fuels such as kerosene, petrol, diesel. etc Such conditions lead to needing alternative fuel which can reduce the heavy load from an earth's natural resources by serving the crude to the world. Along with that, scraps and waste created from automobiles also giving problems for disposal of waste. To degrade and reduce its structure has become more and more complex. Disposal of the waste tyre has become the major uncontrolled, undesirable problem in the world.

In a research work done by Jaswinder Singh [1], tyre waste production is a major issue and had been noticed mostly in high population and highly automized, industrialized countries. If the waste tyres are not handled properly, it will give rise to new problems of pollution because of its non-biodegradable nature and long-lasting rubber strength and property. So, the globe is taking an interest to transform scrap tyre into a useful energy source. The volatile fraction content of tyres and the fixed carbon fraction content makes them an exceptional and remarkable solid and can be used as a fuel source.

In a research work done by Muhammad Imran Ahmad et.al [3], due to the rapid increase in the economy of the world, the use of tyre has been increased, so the collection of scrap tyre also has been increased. Typical structure and strength of tyre cant be decomposed without thermal treatment. Standard properties of TPO such as calorific value (heating value), pour point, flash and fire point also indicates it has potential, that it can be used as an alternative resource. Proper handling and reducing sulphur content in the TPO itself is a must and necessary to avoid environmental pollution problems.

Scrap tyre is a monstrous, unreliable and hazardous matter which impacts the environment. If tyre waste cannot be managed properly, it will adversely affect human health, wildlife and the environment too. Viral diseases can be raise when scrap tyre comes in contact with water. As the tyres are not biodegradable, it also acquires open space. And fire in such cases may lead to emission of hazardous pollution gasses [4]. Waste tyre fire affects not only quality and fertility

of the soil, but natural air and water resources too. It ruins life cycle when it undesirably enters into a living thing, plant, animals and in human [5].

Therefore to manage and overcome scrap tyre rubber waste and to reduce its harmful impacts on the environment has become a consequential issue now. On the other side, to reduce consumption of fuels, reuse of fuels, and reduction of a load of non-renewable sources is also a challenging issue nowadays facing by the world. It can be tackled by the waste tyre degradation and decomposition into pyro-oils and further refining.

II. Composition Of Tyre

The tyre is full of carbon where tyre comprises of Carbon, fabric materials, sulfur and other components also like nitrogen, hydrogen, oxygen.etc. Automobile tyres or passenger car tyres have been made with a mixture of two different rubbers. Mainly it comprises of natural and manmade rubber. The total tyre composition has plentiful organic matter [1]. Which contains C-H bonding components (alkanes, olefins, aromatics.etc.) and others also like sulphur and nitro groups [2]. In the tyre oil, 19.8 % to 59.2% aliphatic and 34.7% to 75.6% aromatics had been observed [6].

The composition of tyre material, composition analysis of tyre rubber and composition of tyre pyrolysis oil (TPO) each have different content. It can be given as follows,

Table-I: Composition of tyre material

Rubber (wt%)	Carbon black (wt%)	Fillers (wt%)	Accelerators (wt%)	Reference
60 - 65	25 - 35	3	-	[7]

Table-II: Proximate analysis of scrap tyre rubber

Volatile (wt%)	Fixed Carbon (wt%)	Moisture (wt%)	Ash (wt%)	Steel (wt%)	Reference
58 - 94	22 - 31	0.4 -1.72	2.4 -15	9.6	[1]

Table-III: Composition of TPO

Carbon (wt%)	Hydrogen (wt%)	Nitrogen (wt%)	Sulfur (wt%)	Oxygen (wt %)	Ash (wt%)	Reference
85.54	11.28	0.42	0.84	1.92	-	[6]
86.51	10.10	1.20	0.80	1.39	-	[8]
80	7	0.4	1.5	3	8	[9]
82	8	0.4	1.3	2.4	5.9	[10]
74-86	6-8	0.3-1	1.4-2	1-15	-	[3]

The percentage fraction obtained in the composition of a passenger car tyre is compared with the heavy-duty vehicle tyre. Heavy-duty tyres have a higher composition of hydrocarbons comparatively.

Table-IV: Composition of Truck TPO

Carbon (wt%)	Hydrogen (wt%)	Nitrogen (wt%)	Sulfur (wt%)	Oxygen (wt %)	Ash	Reference
86.47	11.73	<1	0.83	-	<1	[8]

After pyrolysis of scrap tyres, fabrics content and the metal rings content (Steel) from a tyre had been taken out [6]. It can be also converted to black coloured powder which can replace as a fuel in furnaces for the cement industry. The sludge remaining after the distillation and the refining process of TPO can be also used for industrial furnace applications. Therefore by reducing tyre waste into pyrolysis oil gives that whole tyre can be converted into the useful energy source.

III. METHODOLOGY

A. Pyrolysis

The scrap tyre is reduced into tyre pyrolytic oil by the thermal degradation of scrap tyre solids. Pyrolysis is the method in which the solid component can be thermally decomposed and reduced at specific temperature and pressure. Where finally its get converted into its liquid form. It is an irreversible conversion due to application oh heat where the organic content is decomposed into useful energy. Pyrolysis can be done above 450-500 ℃ [1].

B. TPO Desulphurization Processing

In a research work conducted by A.S.M. Rezaun Nabi et. al. [2] given that the various modifications required in TPO to get converted into useful fuel energy. The first step was to heat the TPO to get removed the fraction of moisture from the oil to make it emulsion free oil. Therefore moisture content gets removed by heating oil at 100℃. After that, Desulphurization is also important to have fuel with fewer emission standards. To control environment pollution and to maintain engine specific emission standards it is most important to desulphurise the oil. For Desulphurization, TPO had been taken for Sulphuric acid treatment where the 8% (Weight) H_2SO_4 had been added to TPO. Then it supposed to stirring continuously at 50 ℃ for 4 hours and left for the settling process for 40 hours. Two layers formed in the solution where the separated upper layer had been taken for the further bentonite and calcium oxide treatment. Activated Bentonite (100 gm) and Calcium oxide (50 gm) powder had been mixed with per litre of the separated upper layer. Again mixture required to stir at 70 ℃ for 4 hours continuously and put for settling process for 24 hours. Finally, the mixture had been filtered and then it had been taken for the vacuum distillation process.

In a research work conducted by Makhan Mia et.al [6] given the method of desulphurization of TPO based on the hydrogen peroxide and the formic acid method. In this method, fractionated oil had taken for further chemical treatment where it mixed with the mixture of hydrogen peroxide (H_2O_2) and Formic acid (HCOOH) 100 and 10ml respectively. For treating, formic acid had been taken half of the known volume of hydrogen peroxide and stirred at 1000 rpm for 2 hours with 30-50 ° C temperature. After that N, N-dimethylformamide (100 ml) had been mixed and stirred at 1000 rpm at room temperature for 2 hours. After the settling process, the desulphurized oil obtained. Finally activated Bentonite powder used for the decolourization of the mixture.

C. Distillation process

In a research work conducted by A.S.M. Rezaun Nabi et. al. [2] given that different method for de-moisturization and desulphurization of the TPO. After that Vacuum distillation setup had been used for separation of heavier and lighter fractions chemically processed tyre oil. Vacuum distillate had been carried out at the 70 to 90 ℃ in the vacuum chamber. Vacuum chamber differentiates 70 to 80% distillate of TPO by using the principle of lowering of vapour pressure by decreasing pressure or by creating a vacuum. Finally, vapours generated vacuum setup gets condensed and final output of processed TPO distillate collected.

In a research work conducted by Makhan Mia et.al [6] studies that refining of TPO by fractional distillation method before the chemical treatment. The fractional distillation is a way, which was used to differentiate the more volatile fraction of oil from the crude TPO. The fractional distillation had been carried out in between 40 to 270 ℃ which gives various fractions of oil. Fractional distillation is the separation technique which is a more systematic, structural and efficient method than the other distillation methods. Fractional distillation is used because its working is quite similar just like the numbers of simple distillation set up in arranged in series. Fractional distillation had been done by heating TPO in a cylindrical vessel and supposed to heated electrically, then the vapours formed are condensed in the condenser by continuous water supply. Finally, the light liquid had been separated and the non-condensable vapours are taken out from setup, and the TPO distillate had been collected.

IV. COMPARISON OF RESULTS

After the vacuum and fractional distillation process, different results had been observed, which are as follows,

Table-V: Composition of Final Product Output

Distillation Methods	**Crude TPO (ml)**	**Sludge**	**Oil Obtained (%)**	**After Distillation (ml)**	**TPO Obtained (%)**	**Reference**
Vacuum (70-90 ℃)	1000	330	67	228	22.80	[2]
Fractional (120-180 ℃)	1000	330	67	289	28.90	[6]

From above data collected it had been cleared that nearly 67% of oil can be obtained from TPO after sludge removal and the total percentage of pyro oil obtained finally is 22.8% in vacuum distillation and 28.90 % in fractional distillation respectively.

Table-VI: Composition of Final Product Output.

Property	Conventional Diesel	Distillate (vacuum)	Distillate (fractional)	References
Density (Kg/m^3)	872.3	845.6	848.69	[6], [2]
Viscosity (CP) (40 °C)	4	1.51	1.4	
Calorific Value (MJ/Kg)	45.85	42.37	42.37	
Flash Point	46	34	45.7	
Pour Point	-30 to -40	-2	-6	

The above results for the standard properties of fuel had been measured and compared with the conventional diesel. The results obtained from the vacuum and fractional distillation having very less difference in them.

CONCLUSION

Desulphurization of TPO by using sulphuric acid (H_2SO_4) and Bentonite-Calcium oxide (CaO) treatment is a time-consuming and, complicated & sluggish process. Whereas, oxidative method desulphurization that is desulphurization with hydrogen peroxide (H_2O_2) and Formic acid (HCOOH) treating method is cost-effective, reasonable and expeditious process comparatively.

Alternative Fuel from crude TPO after the proper treatment can be obtained by using both methods vacuum and fractional distillation setup. The properties measured of collected oil are quite indistinguishable in both of the techniques. The fractional distillation gives more efficient output than vacuum distillation as the final collected oil is 6% more than the vacuum setup. But, vacuum distillation setup requires less temperature to boil TPO, therefore itis more economical than the fractional distillation. The best results for fractional distillation can be obtained only at distillation temperature range 120 to 180 °C.

FUTURE SCOPE

In future, it can help to reduce the consumption of diesel fuel. Therefore, the load of exploration and mining of natural resources can be reduced.The alternative fuel is extracted from the scrap oil. So, rubber waste can be managed in a better way. The overall process is based on the waste-to-energy principle. Therefore it also supports green chemistry.

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