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Motor Vehicle Tyre and Low Density Polyethylene into Refinery Feed

Moinuddin Sarker, Mohammad Mamunor Rashid

Department of Research and Development, Natural State Research Inc, 37 Brown House Road (2nd Floor), Stamford, CT-06902, USA

Abstract- Vehicle used tyre and low density polyethylene mixture to fuel production process was performing into laboratory batch process. Catalyst was use as a ferric oxide and percentage was 3%. For experiment purposed waste mixture was 75 g, motor vehicle tyre was 25 g and low density polyethylene was 50 g by weight. Temperature range was 270 - 440 ºC and reactor was use Pyrex glass reactor. Product fuel density is 0.76 g/ml and liquid fuel conversion rate was 61.73%, light gas was 7.07%, and left over residue was 31.2%. Fuel was analysis using GC/MS and GC/MS Chromatogram showed hydrocarbon range C_3 to C_{28} including aliphatic, aromatic, halogenated, nitrogen content, oxygen content and alcoholic content. Fuel can use for internal combustion engines and refinery feed.

Index Terms- tyre, waste plastic, LDPE, refinery feed, hydrocarbon, oil

I. Introduction

In 1993, the total production of plastics in the United States was 19.3 million tons [1]. A predominant part of such materials is ultimately disposed as waste. Further, about 280 million automotive tires were discarded in the United States in 1990 [2]. As a result, the effective disposal of waste polymers is now recognized as a major environmental problem. Plastics and rubbers are undesirable components for landfilling, since they are not presently biodegradable. Their destruction by incineration poses air pollution problems due to the release of airborne particles and carbon dioxide into the atmosphere. An alternative would be true recycling, i.e., conversion into monomers that can be reused. For example, DuPont has commercialized a depolymerization process for polyethylene terephthalate (PET) to reclaim ethylene glycol and terephthalic acid for reuse in the production of new PET. However, waste streams usually consist of polymer mixtures; furthermore, even pure polymers do not depolymerize thermally to corresponding monomers with sufficient selectivity. On the other hand, waste plastics and rubbers can be regarded as a potentially cheap and abundant source for transportation fuels and useful chemicals. Thermodegradation of polymers has been investigated extensively since World War II, [3-7] but relatively few studies on the catalytic conversion of polymers have been carried out, especially for production of liquid fuels [8].

In recent years, because of the growth of urban waste, there has been increasing attention paid to the coutilization of coal and waste materials [9-11]. The intention of this is to reduce the high cost of the coal hydrogenation process [12] and at the same time to profitably employ some waste materials by taking advantage of their components, [13] in addition to reducing environmental damage [14]. This attention has mainly been focused on plastics [15, 16] and rubber [17]. Discarded automotive tires, with 60-70% of their composition originating from petroleum, have shown to be a very attractive material [18]. Different types of reactors have been used for tire pyrolysis, such as autoclaves [19] and fixed bed reactors,[20-24] and for a larger scale operation, bubbling fluidized bed reactors,[23-28] moving beds under vacuum, in one and two steps,[29-31] ablative beds, [32] and rotary ovens [33-35]Key factors for process viability are high throughput and products with suitable properties for their subsequent valorization toward value added compounds such as high-quality carbon black, active carbon, or chemical compounds, such as benzene, toluene, xylene, limonene, and so on [36]. This good performance of the conical spouted bed has been proven in catalytic polymerizations, [37, 38] in the thermal and catalytic pyrolysis of biomass, [39, 40] and in plastic wastes [41- 43]. It has also been proven to be suitable for the kinetic study of tire pyrolysis thanks to bed isothermicity and gas flow versatility, given that operation with a short gas residence time allows for minimizing secondary reactions of tire devolatilization products. [44] In a recent paper, a study was carried out on the effect of operating conditions on the yields and composition of tire pyrolysis products [45].

II. Materials and Method Description

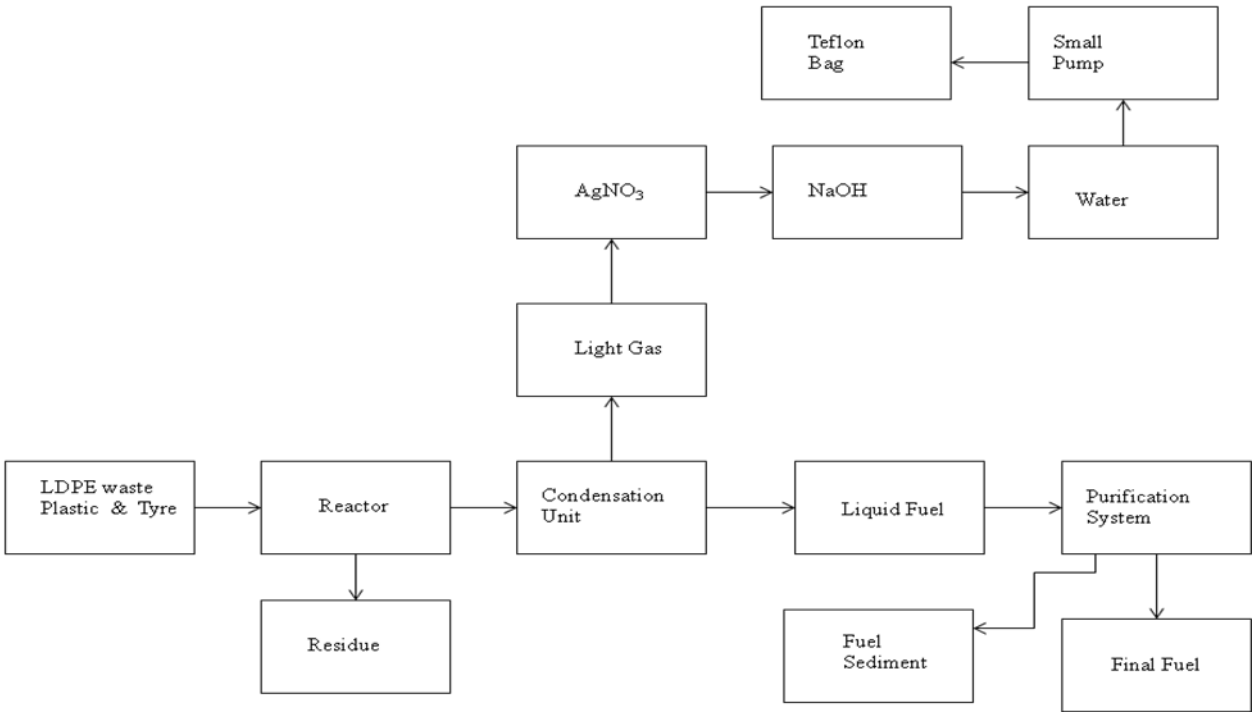

Figure 1: Motor Vehicle Tyre and Low Density Polyethylene into oil Production Process

Motor vehicle used tyre and low density polyethylene was collected from local city motor vehicle collision center and home depo store. Both waste materials were dirty and it was clean with water and liquid soap using laboratory sink. Then waste materials were cut into small pieces for reactor setup and liquefaction process. For experimental process purpose catalyst was provided from VWR Company. Ferric Oxide catalyst was powder format. 3% catalyst was use for the experiment and motor vehicle used tire 25 g, low density polyethylene was used 50 g by weight. Total raw materials were use 75 g. Small scale conversion process was performing under laboratory fume hood to prevent gas leakage into environment. Catalyst helps to accelerate the reaction performance. Whole process diagram showed figure 1 and necessary accessories and equipment was glass reactor with heating device and temperature controller, condensation unit, fuel collection container, fuel purification small device with filter system, fuel sediment container, final fuel collection container, light gas cleaning liquid solution silver nitrate (0.25N), sodium hydroxide solution (0.5N), water container, small pump, Teflon bag and residue collection container. Waste materials was transfer into glass reactor chamber then placed into heating chamber for liquefaction temperature range was 270 - 440 ºC. Temperature was controlled by controller device because sometimes temperatures need to increase and sometimes temperatures need to decreased. When LDPE waste plastic, motor vehicle mixture heated up with ferric oxide catalyst it's create huge amount of vapor. Produce vapor can pass through condensation unit at the end collected liquid fuel. But in this case all vapors cannot turn into liquid oil because during heat materials breaking down C_1 to higher compounds. C_1 to C_4 compounds are lighter compounds and their boiling point negative due to negative boiling point they cannot convert into liquid in normal temperature. C_1 to C_4 coming out as light gas and this type of gas can generate from start to experiment finished time. Light gas cleaning purpose silver nitrate solution was use because plastic has halogenated additives and it forms chlorinated compounds. Silver nitrate solution and chlorine can produce silver chloride salt. Same a sodium hydroxide solution can produce sodium chloride salt. The gas was passes through clean water to remove alkali. Liquid oil was cleaned with micron filter and removed sediment keep into separate container as container as final clean fuel. Fuel sediment keep into separate container and its can reuse with initial materials. Collected fuel density is 0.76 g/ml and conversion rate was 61.73%. In mass balance calculation showed 75 g raw materials to liquid fuel was 46.30 g, residue was 23.4 g, and light gas was 5.3 g. Total experiment run time was 4.50 hours. Input electricity was required 0.65 KWh. Catalyst recoveries under investigation.

III. Results and Discussions

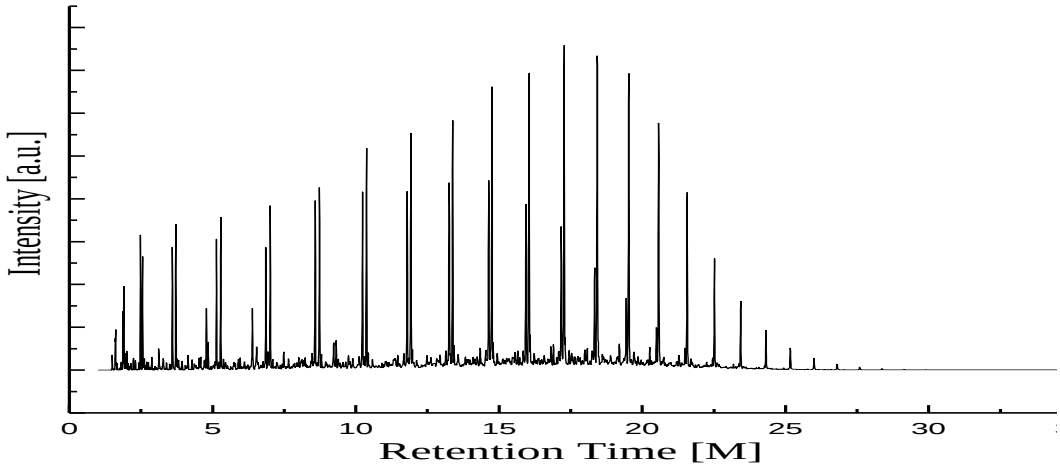

Figure 2: GC/MS Chromatogram of Motor Vehicle Tyre and Low Density Polyethylene into oil

Table 1: GC/MS Chromatogram compound list of Motor Vehicle Tyre and Low Density Polyethylene into oil

Number of Peak	Retention Time (min.)	Trace Mass (m/z)	Compound Name	Compound Formula	Molecular Weight	Probability %	NIST Library Number
1	1.49	41	Cyclopropane	C3H6	42	29.2	18854
2	1.56	43	Isobutane	C4H10	58	68.1	121
3	1.60	41	2-Butene, (E)-	C4H8	56	26.7	105
4	1.61	43	Butane	C4H10	58	73.2	18940
5	1.67	41	2-Butene, (E)-	C4H8	56	26.1	105
6	1.81	43	Butane, 2-methyl-	C5H12	72	79.1	61287
7	1.87	42	Cyclopropane, ethyl-	C5H10	70	21.3	114410
8	1.90	43	Pentane	C5H12	72	78.9	114462
9	1.94	55	2-Pentene, (E)-	C5H10	70	15.2	231217
10	2.05	67	1,3-Pentadiene, (Z)-	C5H8	68	19.2	160480
11	2.12	67	1,4-Pentadiene	C5H8	68	17.9	114494
12	2.42	57	Pentane, 3-methyl-	C6H14	86	44.6	565
13	2.48	56	1-Hexene	C6H12	84	32.0	227613
14	2.56	57	Hexane	C6H14	86	82.4	61280
15	2.62	55	3-Hexene, (Z)-	C6H12	84	22.3	114381
16	2.88	56	Cyclopentane, methyl-	C6H12	84	65.9	114428
17	2.94	67	3-Hexyne	C6H10	82	30.6	19282
18	2.98	79	1,3-Cyclopentadiene, 5-methyl-	C6H8	80	10.9	419
19	3.12	67	Cyclopentene, 1-methyl-	C6H10	82	20.0	107747
20	3.28	41	1-Pentanol, 2-ethyl-	C7H16O	116	21.0	114889
21	3.39	43	Hexane, 3-methyl-	C7H16	100	66.7	113081
22	3.50	67	Cyclohexene	C6H10	82	32.4	114431
23	3.60	56	1-Heptene	C7H14	98	41.9	107734
24	3.72	43	Heptane	C7H16	100	77.0	61276
25	3.76	81	3-Hexene, 2-methyl-, (E)-	C7H14	98	8.80	114086
26	3.81	55	2-Heptene	C7H14	98	22.5	113119
27	4.15	83	Cyclohexane, methyl-	C7H14	98	72.2	118503
28	4.29	69	Cyclopentane, ethyl-	C7H14	98	29.8	231044
29	4.37	79	Cyclopropane, trimethylmethylene-	C7H12	96	9.33	63085
30	4.59	67	1-Ethylcyclopentene	C7H12	96	42.2	114407

31	4.71	43	Butane, 1-chloro-3-methyl-	C5H11Cl	106	8.89	227754
32	4.78	91	Toluene	C7H8	92	45.9	291301
33	4.84	81	Cyclopropane, trimethylmethylene-	C7H12	96	9.00	63085
34	4.95	67	3,4-Heptadiene	C7H12	96	14.1	54096
35	5.13	55	1-Octene	C8H16	112	29.5	1604
36	5.29	43	Octane	C8H18	114	50.0	229407
37	5.37	55	3-Octene, (Z)-	C8H16	112	13.1	113895
38	5.75	95	1-Methyl-2-methylenecyclohexane	C8H14	110	9.95	113437
39	5.90	81	1,4-Heptadiene, 3-methyl-	C8H14	110	5.41	1484
40	5.96	83	Cyclohexane, ethyl-	C8H16	112	66.3	113476
41	6.39	91	Ethylbenzene	C8H10	106	62.6	114918
42	6.54	91	Cyclohexanol, 1-ethynyl-, carbamate	C9H13NO2	167	13.8	313023
43	6.77	70	4-Nonene	C9H18	126	9.28	113904
44	6.86	56	1-Nonene	C9H18	126	13.1	107756
45	6.92	104	Bicyclo[4.2.0]octa-1,3,5-triene	C8H8	104	35.2	154588
46	7.02	43	Nonane	C9H20	128	34.0	2665
47	7.36	67	Cycloheptene, 1,2-dimethyl-	C9H16	124	5.53	2342
48	7.48	105	Benzene, (1-methylethyl)-	C9H12	120	48.5	228742
49	7.65	55	Cyclohexane, propyl-	C9H18	126	12.1	249350
50	7.75	95	1,2-Dipentylcyclopropene	C13H24	180	5.98	90651
51	7.86	67	Cyclopentene, 1-butyl-	C9H16	124	29.1	113491
52	7.94	57	1-Tridecyne	C13H24	180	7.77	232732
53	8.01	91	Benzene, propyl-	C9H12	120	63.5	113930
54	8.48	70	trans-4-Decene	C10H20	140	5.73	162825
55	8.59	55	1-Decene	C10H20	140	17.3	107686
56	8.73	57	Decane	C10H22	142	40.0	291484
57	8.81	55	cis-3-Decene	C10H20	140	15.7	113558
58	9.23	119	Benzene, 1-methyl-3-(1-methylethyl)-	C10H14	134	21.8	149866
59	9.31	68	Limonene	C10H16	136	24.6	57640
60	9.39	55	Cyclodecane	C10H20	140	11.0	237923
61	9.65	105	1-Decen-4-yne, 2-nitro-	C10H15NO2	181	10.1	186798
62	9.75	91	Bicyclo[3.1.0]hex-3-en-2-ol, 2-methyl-5-(1-methylethyl)-, (1α,2α,5α)-	C10H16O	152	11.3	250249
63	9.89	57	Decane, 3-methyl-	C11H24	156	25.0	113894
64	10.12	70	Bicyclo[3.1.1]heptan-3-ol, 6,6-dimethyl-2-methylene-, [1S-(1α,3α,5α)]-	C10H16O	152	4.99	151861
65	10.24	41	1-Undecene	C11H22	154	7.31	232523
66	10.30	55	5-Undecene, (E)-	C11H22	154	5.27	114227
67	10.38	57	Undecane	C11H24	156	33.5	114185
68	10.43	55	5-Undecene, (E)-	C11H22	154	12.3	114227
69	10.58	55	2,4-Pentadien-1-ol, 3-pentyl-, (2Z)-	C10H18O	154	8.45	142197
70	11.68	70	2-Undecene, 3-methyl-, (E)-	C12H24	168	4.47	61840
71	11.79	55	1-Dodecene	C12H24	168	13.9	107688
72	11.92	57	Dodecane	C12H26	170	36.3	107687
73	11.98	55	3-Dodecene, (E)-	C12H24	168	11.8	70642
74	13.15	70	5-Tridecene, (E)-	C13H26	182	5.49	142619
75	13.26	55	1-Tridecene	C13H26	182	14.4	107768
76	13.38	57	Tridecane	C13H28	184	49.1	114282
77	14.54	70	7-Tetradecene	C14H28	196	6.33	70643
78	14.64	55	1-Tetradecene	C14H28	196	5.31	69725
79	14.76	57	Tetradecane	C14H30	198	43.4	113925

80	14.80	55	3-Tetradecene, (E)-	C14H28	196	7.71	139981
81	15.84	70	Z-10-Pentadecen-1-ol	C15H30O	226	6.46	245485
82	15.94	55	1-Pentadecene	C15H30	210	12.8	69726
83	15.94	55	1-Pentadecene	C15H30	210	12.8	69726
84	16.05	57	Pentadecane	C15H32	212	39.6	107761
85	16.08	55	E-2-Hexadecacen-1-ol	C16H32O	240	6.72	131101
86	17.17	55	1-Hexadecene	C16H32	224	9.93	69727
87	17.27	57	Hexadecane	C16H34	226	39.9	114191
88	17.45	55	1-Dodecanol, 3,7,11-trimethyl-	C15H32O	228	4.69	22776
89	18.08	55	Hexadecane, 3-methyl-	C17H36	240	16.2	68902
90	18.34	55	E-14-Hexadecenal	C16H30O	238	6.65	130980
91	18.43	57	Heptadecane	C17H36	240	38.9	107308
92	19.44	55	E-15-Heptadecenal	C17H32O	252	5.39	130979
93	19.53	57	Octadecane	C18H38	254	17.0	57273
94	19.70	57	1-Hexadecanol, 2-methyl-	C17H36O	256	7.02	36540
95	20.26	57	Heptadecane, 9-octyl-	C25H52	352	7.06	15951
96	20.49	55	9-Nonadecene	C19H38	266	10.1	113627
97	20.57	57	Nonadecane	C19H40	268	31.3	114098
98	21.28	57	Nonadecane, 2,3-dimethyl-	C21H44	296	13.1	68922
99	21.49	55	1-Eicosene	C20H40	280	6.74	13488
100	21.57	57	Eicosane	C20H42	282	30.6	290513
101	21.70	57	1-Docosanol	C22H46O	326	5.64	23377
102	22.46	55	10-Heneicosene (c,t)	C21H42	294	8.44	113073
103	22.52	57	Heneicosane	C21H44	296	28.5	107569
104	23.38	55	1-Docosene	C22H44	308	14.7	113878
105	23.44	57	Heneicosane	C21H44	296	11.6	107569
106	24.32	57	Heneicosane	C21H44	296	10.1	107569
107	25.17	57	Tetracosane	C24H50	338	17.8	248196
108	25.99	57	Heneicosane	C21H44	296	10.7	107569
109	26.80	57	Nonadecane	C19H40	268	19.9	114098
110	28.37	57	Octacosane	C28H58	394	4.33	149865

Vehicle tyre and low density polyethylene mixture to fuel was analysis using GC/MS and solvent was use carbon disulfide (C_2S). Perkin Elmer GC/MS model 5000 Clarus and capillary column was use. Helium was use as a carrier gas. Liquid sample Chromatogram was analysis using NIST library and compounds was traced based on chromatogram peak intensity, trace mass (m/z), and retention time (m). GC/MS Chromatogram and compounds table showed figure 2 and table 1. Waste LDPE plastic and motor vehicle tyre mixture into fuel hydrocarbon range is showed by GC/MS C_3 to C_{28}. GC/MS staring compounds showed Cyclopropane (C3H6) (t=1.49, m/z=41) compound probability percentage is 29.2 %, then rest of all compounds traced low carbon number to higher carbon number wise such as 2-methyl- Butane (C5H12) (t=1.81, m/z=43) compound probability percentage is 79.1 %, (Z)-1,3-Pentadiene (C5H8) (t=2.05, m/z=67) compound probability percentage is 19.2 %, Hexane (C6H14) (t=2.56, m/z=57) compound probability percentage is 82.4 %, methyl- Cyclopentane (C6H12) (t=2.88, m/z=56) compound probability percentage is 65.9 %, 1-methyl-Cyclopentene (C6H10) (t=3.12, m/z=67) compound probability percentage is 20.0 %, 3-methyl- Hexane (C7H16) (t=3.39, m/z=43) compound probability percentage is 66.7 %, 3- (E)-2-methyl-Hexene (C7H14) (t=3.76, m/z=81) compound probability percentage is 8.80 %, methyl-Cyclohexane (C7H14) (t=4.15, m/z=83) compound probability percentage is 72.2 %, 1-chloro-3-methyl- Butane (C5H11Cl) (t=4.71, m/z=43) compound probability percentage is 8.89 %, 1-Octene (C8H16) (t=5.13, m/z=55) compound probability percentage is 29.5%, 1-Methyl-2-methylenecyclohexane (C8H14) (t=5.75, m/z=95) compound probability percentage is 9.95 %, Ethylbenzene (C8H10) (t=6.39, m/z=91) compound probability percentage is 62.6 %, Nonane (C9H20) (t=7.02, m/z=43) compound probability percentage is 34.0 %, (1-methylethyl)- Benzene (C9H12) (t=7.48, m/z=105) compound probability percentage is 48.5 %, 1-butyl-Cyclopentene (C9H16) (t=7.86, m/z=67) compound probability percentage is 29.1%, propyl- Benzene (C9H12) (t=8.01, m/z=91) compound probability percentage is 63.5 %, 1-methyl-3-(1-methylethyl)-Benzene (C10H14) (t=9.23, m/z=119) compound probability percentage is 21.8 %, Limonene (C10H16) (t=9.31, m/z=68) compound probability percentage is 24.6 %, 3-methyl-Decane (C11H24) (t=9.89, m/z=57) compound probability percentage is 25.0 %, Undecane (C11H24) (t=10.38, m/z=57) compound probability percentage is 33.5%, (E)-3-methyl-2-Undecene (C12H24) (t=11.68, m/z=70) compound probability percentage is 4.47 %, (E)-3-Dodecene (C12H24) (t=11.98, m/z=55) compound probability percentage is 11.8 %, Tridecane (C13H28) (t=13.38, m/z=57) compound probability percentage is 49.1 %, Tetradecane (C14H30) (t=14.76, m/z=57) compound probability percentage is 43.4 %, Z-10-Pentadecen-1-ol (C15H30O) (t=15.84, m/z=70) compound probability percentage is 6.46%, Pentadecane (C15H32) (t=16.05, m/z=57) compound probability

percentage is 39.6%, Hexadecane (C16H34) (t=17.27, m/z=57) compound probability percentage is 39.9 %, Heptadecane (C17H36) (t=18.43, m/z=57) compound probability percentage is 38.9%, Octadecane (C17H36) (t=19.53, m/z=57) compound probability percentage is 17.0 %, Nonadecane (C19H40) (t=20.57, m/z=57) compound probability percentage is 31.3 %, Eicosane (C20H42) (t=21.57, m/z=57) compound probability percentage is 30.6 %, Heneicosane (t=22.52, m/z=57) compound probability percentage is 28.5%, Tetracosane (C24H50) (t=25.17, m/z=57) compound probability percentage is 17.8%, Octacosane (C28H58) (t=28.37, m/z=57) compound probability percentage is 4.33 %. Analysis fuel result showed that fuel has aliphatic compounds, aromatic compounds, halogen group, nitrogen content, oxygen content compounds and alcoholic group compounds. Halogen group compounds appeared from raw materials additives. Plastic and tyre has additives that additive some negligible percentage are appeared into liquid fuel and rest of all additives are comes out as solid black residue. Fuel additives or sediment can remove by using separation technique. Fuel aromatic group appeared from tyre materials because tyre has aromatic group and LDPE waste plastic has long chain hydrocarbon only aliphatic group. Fuel can use for internal combustion engines and refinery feed.

IV. Conclusion

Motor vehicle used tyre and low density polyethylene waste plastic mixture into liquid fuel using Ferric Oxide catalyst in presence of oxygen. Laboratory batch process experiment was conducted to recover liquid fuel and conversion percentage determination. Low percentage motor vehicle tyre and high percentage waste LDPE plastic mixture to fuel conversion rate was 61.73%. Residue percentage was high because tyre to liquid fuel conversion rates less because tyre has high percentage of additives that additives cannot convert into liquid oil. Fuel density is 0.76 g/ml, fuel color is yellow and liquid fuel is ignited. Product fuel has some aromatic group compounds such as Toluene (C_7H_8), Ethylbenzene (C_8H_{10}), (1-methylethyl)-Benzene (C_9H_{12}), propyl-Benzene (C_9H_{12}), 1-methyl-3-(1-methylethyl)-Benzene ($C_{10}H_{14}$), Limonene ($C_{10}H_{16}$). Light gas and solid black residue analysis under investigation and also catalyst recover from solid black residue under investigation. Fuel can use for refinery process for further modification and appropriate for combustion engines. By using this present technology can convert all LDPE waste plastic and motor vehicle to fuel and same time can save the environmental problem. For waste plastics and motor vehicle tyre are creating environmental problem this waste problem can solve convert into liquid fuel using this technology.

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AUTHORS

First Author – Moinuddin Sarker, Department of Research and Development, Natural State Research Inc, 37 Brown House Road (2nd Floor), Stamford, CT-06902, USA Phone: (203) 406 0675, Fax: (203) 406 9852, E-mail: msarker@naturalstateresearch.com

Second Author – Mohammad Mamunor Rashid, Department of Research and Development, Natural State Research Inc, 37 Brown House Road (2nd Floor), Stamford, CT-06902, USA Phone: (203) 406 0675, Fax: (203) 406 9852