Research Paper

Polypropylene Waste Plastic into Light Fractional Gasoline Grade Fuel for Vehicle by using Two Step Thermal Processes

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Abstract: Plastics are an integral part of our modern life and are used in almost all daily activities. Since plastics are synthesized from non-renewable sources and are generally not biodegradable, waste plastics are the cause of many of the serious environmental problems the world faces today. However, waste plastics can become a source of enormous energy with the correct treatment. According to a recent study performed by the Environmental Protection Agency (EPA) approximately 48 million tons of waste plastic are generated in the USA alone, to be specific PETE-1 (10%), HDPE-2 (19%), PVC-3 (6%), LDPE-4 (23%), PP-5 (14%), PS-6 (9%) and Other-7 (19%). Statistics show that approximately 10% of this plastic is recycled, 25% is incinerated and the remaining 65% is dumped in landfills. Established technology can convert waste plastics into a renewable source of hydrocarbon fuel. This technology plans to acquire waste plastics from City / Local Municipalities and Recycling Facilities. For plastic fuel production purposes the plastics can be collected as commingled or separated into different categories. Another source of large amounts of waste plastic is floating on our oceans and seriously damaging the ecosystem and the environment. Recent studies show that approximately 100 million tons of waste plastic are floating on the Pacific Ocean, creating an island that stretches over an area twice the size of Texas. These waste plastics can be collected using collection vessels. The waste can then be converted into hydrocarbon fuel either in the collection vessel itself or in off-shore facilities, using established technology.

Introduction

In recent years, as a result of changes in people's consumption patterns, large amounts of waste plastic are available in municipal solid waste (MSW). With an annual increase rate of 48%, in 1996, 12.6% of the annual generation of MSW was comprised of waste plastic in Beijing, 1 reaching the level of developed countries; for example, in Western Europe, 6-10% of MSW was composed of plastic (9.3 million tons in 1992).2 In 2000, the production of plastic in the world had reached 150 million tons. According to the formula that the yield of waste plastic is about 70% of the plastic product in the corresponding period, the yield of waste plastic is 105 million tons.3 In our country, 70% of the MSW is disposed of as landfill.1 because land filling not only wastes the resources but also engrosses land with pollution with macromolecules of plastic that are not biodegradable, it is important to find an efficient strategy to treat them.

Our present study of thermal degradation is concerned with polypropylene (PP) as a representative of plastic waste. PP is a hydrocarbon polymer made from petrochemicals; it has a large amount of volatile matter (>99 wt %) with high heating value and low ash content (<0.1 wt %); these factors may favor a better product yield from thermal degradation. Thermal and first of all catalytic cracking process of waste polymers are economically and environmentally accepted methods of their utilization. The products of such processes are liquid mixtures of hydrocarbons boiling in the temperature range ~35-360 ºC, gaseous hydrocarbons as well as solid residue, similar to wax and coke. Different type of catalysts, acid silica-alumina or zeolite (HY, HZSM-5, mordenite) containing ones as well as alkaline compounds such as ZnO, CaO and K_2O can be applied, (Uemichi et al, 1998; Zhibao 1996), but in the course of the process all these materials deactivate very quickly. Through the years excellent results have been obtained from liquefaction of individual polymers (Polyethylene (PE), Polypropylene (PP), Polystyrene (PS) etc.) and relatively clean mixed plastics using solid acid catalysts and metal-promoted solid acid catalysts. For example, Venkatesh et al. (1996) and Shabtai et al. (1997) have obtained high yields of liquids that consist predominantly of isoalkanes in the gasoline boiling range from HDPE, PP, and PS at relatively low temperature (300-375 ºC) using similar metal catalysts mentioned above. Some other research paper was cited for this manuscript such as thermal process (Prakash et al, 1998; Tange and Drohmann, 2005), Catalytic process (Jerzy and Mieczyslaw 2001; Nishino et al, 2008) and Pyrolysis process (Umberto and Maria, 2000; Pinto et al, 1999) applied for waste plastic to fuel production process.

Usually batch experiments are carried out at laboratory scale (1-500 g) using one or two types of polymers, which are clean and not waste polymers. On the other hand, the effects of the cracking temperature on the properties of products are well demonstrated in the literature not only in batch processes but also in continuous or semi-continuous cracking. Experiments have conducted with PE, PP and PS in a continuous flow stirred tank reactor in many different studies. It was found that the degradation by continuous flow operation is a suitable technique for converting waste polymers into liquid hydrocarbon. The volatile products could be used as feedstock components, e.g. in refineries. Their further utilization for petrochemical purposes has not yet been solved. One possibility is a fuel-like application or mixing in fuels as a blending component. Before blending the high olefin content is to be saturated with hydrogen, or hydroisomerized. These steps result in a high quality synthetic diesel fuel, with high cetane number, and theoretically free from sulphur, nitrogen and metals. In practice these fractions generally have a very low heteroatom content, even if the raw material was pure and not waste, because most polymers contain, e.g. sulphur containing anti-flame or antioxidant additives, etc.

Materials and Method
Materials and Preparation

PP waste plastic collected from Stamford city local restaurant and PP waste plastic was food container and container cover. PP waste plastic color was transparent and white color. Waste plastic was collected with food particle. After collected waste plastic manually wash into sink with liquid soap and water. During waste plastic washing period also generated waste water. This waste kept into separate container for waste water treatment by using acidic and alkali method. Wash out PP waste plastic cut into small pieces size 3-4 inch manually by using scissor. PP waste hard plastic grinding with grinder machine and grounded PP waste plastic size was 3.4 mm then transfer into reactor chamber for liquefaction process.

Material Pre-analysis

PP hard waste plastic was pre-analysis by using GC/MS Clarus 500 series with CDS pyroprobe 5000 series. Pyroprobe used for hard sample volatile and sent to GC column through mass detection and chromatogram displayed compound structure with different retention time. Pyroprobe temperature used 1200 ºC for volatile sample for GC. Elemental analyzer 2400 series used for carbon, hydrogen and nitrogen percentage determination by used ASTM method (5291.a) and results was shown from transparent polypropylene carbon was 79.93%, hydrogen 14.17% and nitrogen was <0.30 %. FT-IR Spectrum 100 series was use raw material functional group and wave band number energy determination and at

the end TGA pyrias-1 was use for raw material onset temperature and how much percentage sample was volatile by using temperature and in convenient time.

Experimental Process

For the 1st step, thermal degradation process has been conducted in a small scale with individual PP waste plastics in laboratory under Labconco fume hood without catalyst and vacuum system. For small-scale laboratory process the weight of input waste plastics weight 600 gm (see figure 1). The process of converting the individual waste plastic to alternative hydrocarbon fuel energy begins with heating the solid plastic without the presence of cracking catalyst under atmosphere to form liquid slurry and temperature range used for thermal degradation process from 120-420 ºC, condensing the vapor with standard condensing column to form liquid hydrocarbon fuel termed into PP plastic fuel. The produced fuel density is 0.74 gm/ml. In equivalent to obtaining the liquid hydrocarbon fuel we also received light gaseous hydrocarbon compounds (C_1-C_4) which resembles natural gas individual plastic to fuel production average yield 92%, light gas 5 % and solid residue 3%. Individual PP waste plastic experiment took time 5-6 hours and also input electricity for every individual experiment 13- 15 kWh for 1 gallon production. Produced fuel purified by RCI fuel purification system to remove all water and other sediments. Light gas was transfer through gas cleaning device to remove gas emission.
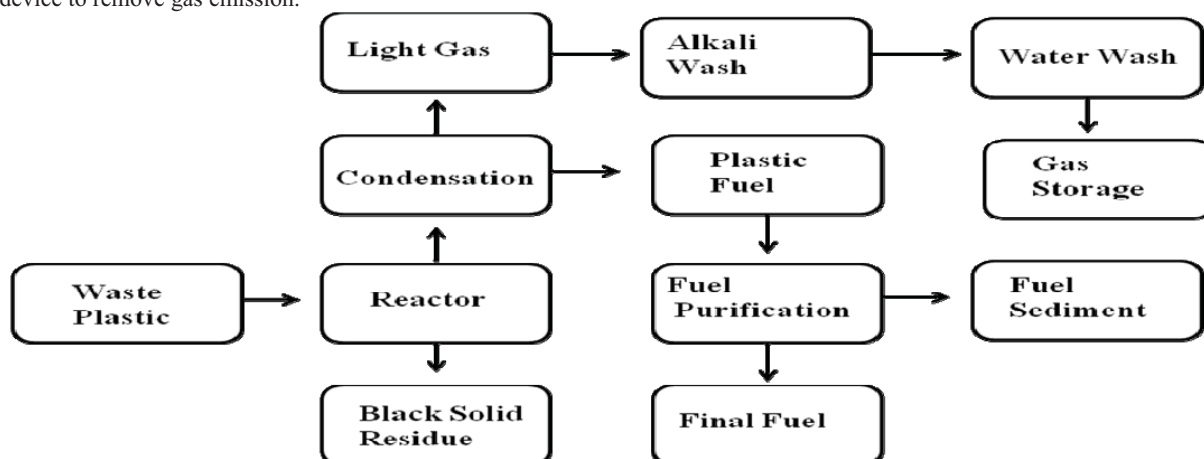

Figure 1: 1st step process for fuels production of PP waste plastics

For fractional distillation process (2nd step process) PP plastic fuel put into reactor for further distillate the fuel with different temperature profile for fractional column produced 5 (five) category fuels (see figure 2). For 1st fraction fuel temperature setup to be collected at 40-60 ºC, 2nd fraction fuel temperature setup at 110-120 ºC, 3rd fraction fuel temperature setup at 180-200 ºC, 4th fraction fuel temperature setup at 260-280 ºC and 5th fraction fuel temperature setup at 320-360 ºC. 1st fractional fuel density is 0.72 gm/ml, 2nd fractional fuel density is 0.78gm/ml, 3rd fractional fuel density is 0.80 gm/ml, 4th fractional fuel density is 0.82 gm/ml and 5th fractional fuel density is 0.84 gm/ml. During 2nd fractional distillation period a type of light gas is also produced and is clean with alkali wash and after wash the cleaned light gas is stored in a gas cylinder for future use and analysis. By using this process 12% light fraction liquid hydrocarbon fuel was collected and light gas was 3% and rest of 85 % different grade fuel collected with different temperature range.
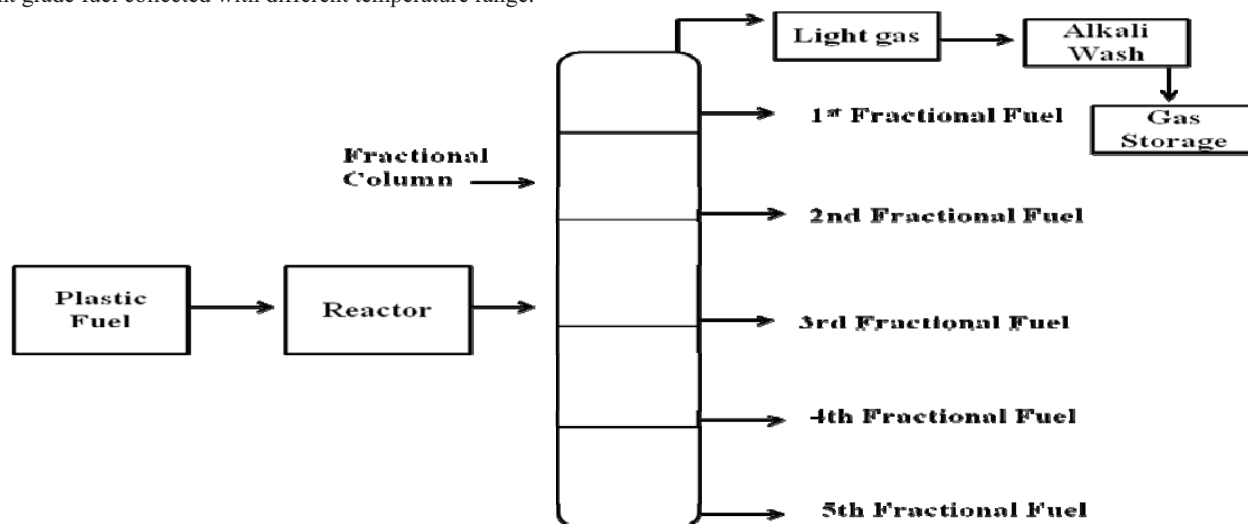

Figure 2: 2nd step process PP waste plastic fuel to 1st fractional fuel production

Result and Discussion
Analysis Technique

Perkin Elmer Differential Scanning Calorimeter (DSC) was used for liquid fuel boiling point and fuel enthalpy value indication. Program temperature range was 0-400 ºC and temperature increased rate was 10 ºC/min. Carrier gas was use nitrogen at 20 ml/ min. Perkin Elmer Elite–5MS Capillary Column Length is 30 meter, 0.25 mm ID, 0.5 um df, Maximum Program Temperature 350°C, Minimum Bleed at 330 °C. GC Program set up for sample analysis. Initial temperature 40 °C, in temperature 325 °C, temperature ramping 10 °C per minute, final temperature hold for 15 minute. Total sample run time is 44.50 minute. Sample inject volume is 0.5 μL, helium used as a career gas, Split Flow=101.0 ml/minute and mass program set up type MS scan, Ion Mode EI+, Data format - Centroid, Start Mass 35.00, End Mass 528.00,Scan Time (Sec) 0.25, Start Time (min) 1.00, End Time (min) 44.50. For Perkin Elmer GCMS analysis purposes a National Institute of standard testing (NIST-2002) mass spectral libraries software is used as library compound and in the analysis only those compounds are detected by their trace mass and retention time. Perkin Elmer FT-IR (Spectrum 100) used for raw sample per analysis and liquid sample analysis. Raw waste plastic sample analyzed by diamond crystal plate KRS 5 check there functional group and band energy value. Liquid fuel sample was analyzed by NaCl cell 0.025 mm thickness. Both samples analysis by same parameter used such as scan number was 32, resolution 4 and range 4000-450 cm^{-1}. Perkin

Elmer EA-2400 analyzer was used for raw waste plastics carbon; hydrogen and nitrogen percentages determine and follow ASTM method ASTM D5291.a. Carrier gas was used helium, oxygen and nitrogen. Perkin Elmer Thermogavimetric (TGA Pyris-1) was used for raw waste plastics onset temperature measuring. Temperature range used starting 50 to 800 ºC and temperature ramping range used for onset temperature 10 ºC/min. Helium gas used as a carrier at 20 psi.

Residue Analysis

Solid black residue metal contained analysis was performed by ICP –AES ASTM D1976 showed result below table 1 and table 2 showed residue carbon, hydrogen and nitrogen percentage. PP waste plastics to black solid residue were analyzed by ICP (Induced Couple Plasma) and numerous metal contents are found in the analysis noticed that some metal content are very high compare to less contents metal in the residue. High content metal elements are Aluminium 4,570 ppm (ppm=Perts per million), Boron 2,701 ppm, Calcium 16,740 ppm, Chromium 2,696 ppm, Copper 1,687 ppm, Iron 395,600 ppm, Magnesium 4,001 ppm, Manganese 1,375 ppm, Sodium 58,290 ppm, Tin 37,520 ppm, Titanium 2,674 ppm, Zinc 5,598 ppm. On the other hand less content metal elements are following Silver <1.0 ppm, Arsenic <1.0 ppm, Barium 14.2 ppm, Beryllium <1.0 ppm, Cadmium 9.1 ppm, Potassium <1.0 ppm, Lithium 8.7 ppm, Nickel 379.6 ppm, Lead 19.2 ppm, Antimony <1.0 ppm,Selenium 132.3 ppm, Silicon 28.2 ppm and eventually Vanadium <1.0 ppm as well. PP Waste plastics are fallen in the open nature for long run as well as contaminated with different metal / Non-metal and other materials of soil and air components as well as in the residue analysis various elements content are appeared. Elemental Analyzer (EA 2400) analysis of PP Waste plastics to Black solid residue Carbon and Hydrogen and other contents are mentioned that is Carbon 45.77% , Hydrogen 1.14% and Nitrogen 1.30% etc. In waste PP residue analyses noticed less organic and inorganic element content are constituents of residue. Because the origin PP waste plastic are fallen in the open nature for long run as well as contaminated with different metal and other materials of soil and air components. Also during the manufacture of waste plastics added some additives to gave the plastic shape and make it durable. Despite all of these factors are involved as well when expedited thermal degradation most of the portion of carbon and hydrogen contents are converted to liquid fuel because of condensation and at certain temperature its remains at liquid state as fuel. Rest of carbon and hydrogen contents are remain as a residue at the terminate phase of the experiment with other additives and metal/ non-metal components.

Table 1: PP waste plastic to black solid residue ICP trace metal analysis result

ASTM Test Method	Metal Name	Results (ppm)	ASTM Test Method	Metal Name	Results (ppm)
ASTM D1976			ASTM D1976		
	Silver	<1.0		Magnesium	4,001
	Aluminum	4,570		Manganese	1,375
	Arsenic	<1.0		Sodium	58,290
	Boron	2,701		Nickel	379.6
	Barium	14.2		Lead	19.2
	Beryllium	<1.0		Antimony	<1.0
	Calcium	16,740		Selenium	132.3
	Cadmium	9.1		Silicon	28.2
	Chromium	269.6		Tin	37,520
	Copper	1,687		Titanium	2,674
	Iron	395,600		Vanadium	<1.0
	Potassium	<1.0		Zinc	5,598
	Lithium	8.7			

Table 2: Black solid residue EA 2400 analysis result

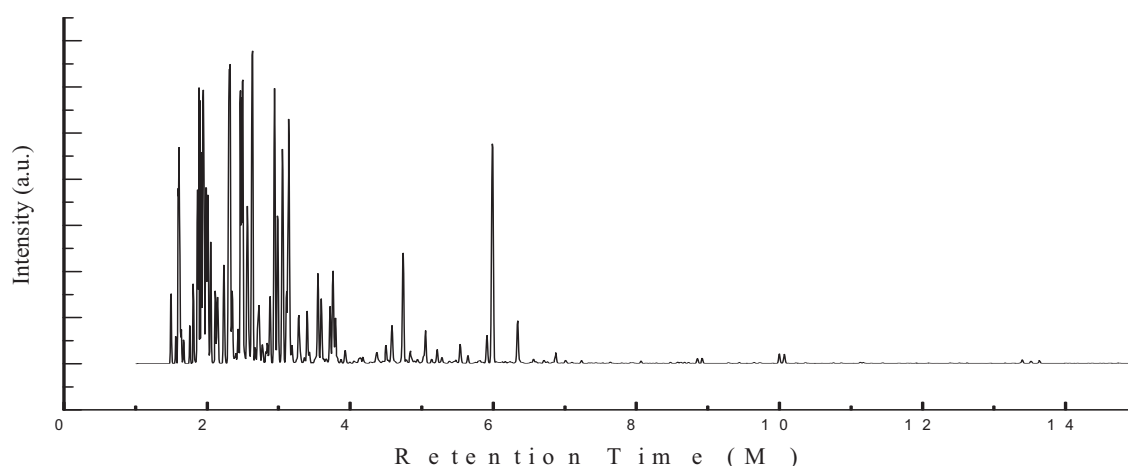| ASTM Test Method	Carbon %	Hydrogen %	Nitrogen %
ASTM D5291.a	45.77	1.14	1.30

Figure 3: GC/MS Chromatogram of PP fuel to 1st fractional fuel

Produced Fuel Analysis

Gas Chromatography and –Mass Spectrometer analysis of PP plastic fuel to1st fractional fuel (figure 3 and table 3) in accordance with the various retention time and trace masses different types of hydrocarbon compounds are appeared in the analysis result index. Many compounds are emerged on the analysis carbon range C_3 to C_{10} among them few of compounds are discussed. Based on the retention time and trace mass following hydrocarbon compounds as follows such as at the initial phase of the analysis at retention time 1.50 min and trace mass 39, compound is Cyclopropane (C_3H_6), retention time 1.56 and trace mass 43, compound is Isobutane (C_4H_{10}), retention time 1.59 and trace mass 39, compound is 1-Propene,2-methyl- (C_4H_8), retention time 1.61 and trace mass 41,compound is 2-Butene,(E), (C_4H_8), retention time 1.75 and

trace mass 55, compound is 1-Butene, 3-methyl- (C_5H_{10}), retention time 2.56 and trace mass 41, compound is Hexane (C_6H_{14}), retention time 2.64 and trace mass 68,compound is 4-Heptenal, (Z)- ($C_7H_{12}O$), retention time 2.72 and trace mass 67,compound name is 2,4-Hexadiene, (Z,Z)- (C_6H_{10}), retention time 2.94 and trace mass 67,compound name is trans-1,4-Hexadiene (C_6H_{10}), retention time 3.55 and trace mass 41, compound is Cyclopentane,1,2-dimethyl-,cis-(C_7H_{14}), retention time 4.59 and trace mass 43, compound is –Heptene-4-methyl-(C_8H_{16}), retention time 5.54 and trace mass 83, compound is Cyclopentane,1,1,3,4-tetramethyl-,cis-(C_9H_{18}), retention time 5.91 and trace mass 69, compound is Cyclohexane, 1,3,5-trimethyl-, (1α,3α,5α)- (C_9H_{18}), retention time 6.57 and trace mass 109 compound is Cyclohexene,3,3,5-trimethyl-(C_9H_{16}), retention time 7.24 and trace mass 55, compound is 3-Octyne,2-methyl-(C_9H_{16}) , retention time 8.86 and trace mass 43, compound is Octane, 3,5-dimethyl-($C_{10}H_{22}$), retention time 8.92 and trace mass 43, compound is Octane, 3,5-dimethyl- ($C_{10}H_{22}$). Ultimately also at retention time 10.1 and trace mass 43, compound is 3-Tridecene, (E)--($C_{13}H_{26}$) and retention time 10.07 and trace mass 43,compound is Cyclooctane, 1,4-dimethyl-, cis- ($C_{10}H_{20}$) etc.

Table 3: GC/MS Chromatogram of PP fuel to 1st fractional fuel compound list with different retention time

Peak Number	Retention Time (M)	Trace Mass (m/z)	Compound Name	Compound Formula	Molecular Weight	Probability %	NIST Number
1	1.50	39	Cyclopropane	C_3H_6	42	63.4	18854
2	1.56	43	Isobutane	C_4H_{10}	58	71.9	61289
3	1.59	39	1-Propene, 2-methyl-	C_4H_8	56	19.0	18910
4	1.61	41	2-Butene, (E)-	C_4H_8	56	15.4	105
5	1.75	55	1-Butene, 3-methyl-	C_5H_{10}	70	20.5	160477
6	1.81	41	Butane, 2-methyl-	C_5H_{12}	72	77.7	291251
7	1.87	55	2-Pentene, (E)-	C_5H_{10}	70	35.2	291780
8	1.89	40	2-Buten-1-ol, (E)-	C_4H_8O	72	24.7	53333
9	1.95	39	1,3-Pentadiene	C_5H_8	68	9.55	291890
10	2.01	53	2-Pentene, (E)-	C_5H_{10}	70	38.4	291780
11	2.05	53	1,3-Pentadiene	C_5H_8	68	18.4	291890
12	2.24	41	1-Pentene, 4-methyl-	C_6H_{12}	84	17.8	227589
13	2.32	43	Pentane, 2-cyclopropyl-	C_8H_{16}	112	19.2	113439
14	2.35	67	1,4-Pentadiene, 2-methyl-	C_6H_{10}	82	10.2	114465
15	2.43	41	Pentane, 3-methyl-	C_6H_{14}	86	58.6	565
16	2.47	84	3-Octyn-1-ol	$C_8H_{14}O$	126	9.25	113251
17	2.56	41	Hexane	C_6H_{14}	86	72.8	291337
18	2.64	68	4-Heptenal, (Z)-	$C_7H_{12}O$	112	5.45	57733
19	2.72	67	2,4-Hexadiene, (Z,Z)-	C_6H_{10}	82	11.3	113646
20	2.88	56	Cyclopentane, methyl-	C_6H_{12}	84	40.1	114428
21	2.94	67	trans-1,4-Hexadiene	C_6H_{10}	82	10.1	227590
22	3.05	39	1-Pentene, 2,4-dimethyl-	C_7H_{14}	98	12.6	114435
23	3.14	79	Butyraldehyde, 4-(methylenecyclopropyl)-	$C_8H_{12}O$	124	12.1	156865
24	3.28	41	1-Hexyne, 5-methyl-	C_7H_{12}	96	28.2	113089
25	3.40	43	Hexane, 3-methyl-	C_7H_{16}	100	68.7	113081
26	3.55	41	Cyclopentane, 1,2-dimethyl-, cis-	C_7H_{14}	98	13.7	113132
27	3.72	43	Heptane	C_7H_{16}	100	67.0	61276
28	3.76	81	1,3-Pentadiene, 2,4-dimethyl-	C_7H_{12}	96	19.4	114450
29	4.59	43	1-Heptene, 4-methyl-	C_8H_{16}	112	22.6	113433
30	4.74	43	Heptane, 4-methyl-	C_8H_{18}	114	61.3	113916
31	5.05	56	1-Heptene, 2-methyl-	C_8H_{16}	112	57.8	113675
32	5.22	95	5,5-Dimethyl-1,3-hexadiene	C_8H_{14}	110	15.2	113453
33	5.54	83	Cyclopentane, 1,1,3,4-tetramethyl-, cis-	C_9H_{18}	126	14.5	27589
34	5.91	69	Cyclohexane, 1,3,5-trimethyl-, (1α,3α,5α)-	C_9H_{18}	126	43.6	2479
35	5.99	43	2,4-Dimethyl-1-heptene	C_9H_{18}	126	39.5	113516
36	6.43	69	Cyclohexane, 1,3,5-trimethyl-, (1α,3α,5β)-	C_9H_{18}	126	42.2	2480
37	6.56	109	Cyclohexene, 3,3,5-trimethyl-	C_9H_{16}	124	37.9	114765
38	6.88	43	Ethanone, 1-(1,2,2,3-tetramethylcyclopentyl)-, (1R-cis)-	$C_{11}H_{20}O$	168	6.62	186082
39	7.24	82	1,6-Octadiene, 2,5-dimethyl-, (E)-	$C_{10}H_{18}$	138	4.75	62075
40	8.85	43	Octane, 3,3-dimethyl-	$C_{10}H_{22}$	142	9.28	61706
41	8.92	43	Octane, 3,5-dimethyl-	$C_{10}H_{22}$	142	8.65	114062
42	10.00	43	3-Tridecene, (E)-	$C_{13}H_{26}$	182	3.16	142616
43	10.07	43	Cyclooctane, 1,4-dimethyl-, cis-	$C_{10}H_{20}$	140	4.07	61409

FT-IR (Spectrum 100) analysis of PP waste plastic fuel to 1st fractional fuel (figure 4 and table 4) according to their wave number and spectrum band following types of functional groups are appeared in the analysis. In the spectrum field we noticed that higher wave number are emerged in the initial phase and middle index of the spectrum and in higher wave number small and bulky both functional groups are available and in low wave number double bond and single bond functional groups are available such as methane group, cis and trans alkene etc. Hereafter wave number 3633.98 cm^{-1} functional group is Free OH, wave number 3365.34 cm^{-1}, functional group is Intermolecular H bonds (broad), wave number 2926.33 cm^{-1},2731.26 cm^{-1} and 2667.03 cm^{-1} functional group is C-CH$_3$, wave number 1900.39 cm^{-1}, 1871.50 cm^{-1} and 1717.92 cm^{-1} functional group is Non-Conjugated, wave number 1654.77 cm^{-1} functional group is Conjugated, wave number 1465.85 cm^{-1} functional group is CH$_3$, wave number 992.15 cm^{-1} functional group is –CH=CH$_2$, wave number 964.36 cm^{-1},functional group is –CH=CH-(trans), wave number 888.95 cm^{-1} functional group is C=CH$_2$ and ultimately wave number 732.82 cm^{-1} functional group is –CH=CH-(cis) as well.

Table 4: PP fuel to 1st Fractional Fuel Functional Group Name

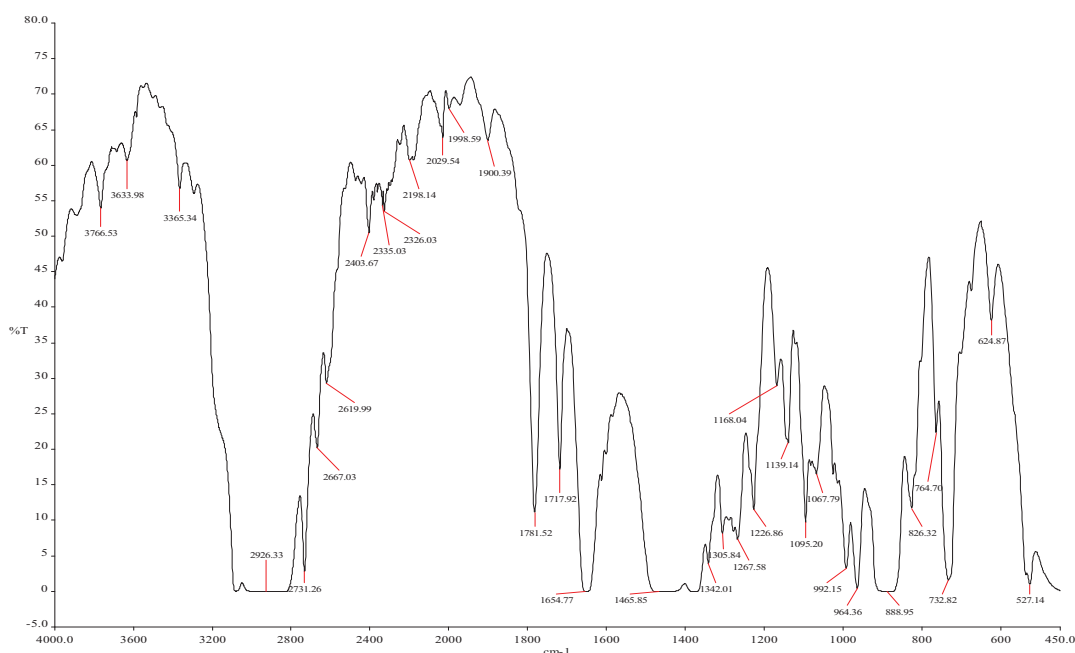| Number of Wave	Wave Number (cm^{-1})	Functional Group	Number of Wave	Wave Number (cm^{-1})	Functional Group
1	3365.34	Free NH	9	1342.01	
2	2926.33	C-CH$_3$	10	1305.84	
3	2731.26	C-CH$_3$	11	1267.58	
4	2667.03	C-CH$_3$	12	1226.86	
5	2619.99		13	992.15	-CH=CH$_2$
6	1718.52	Non-Conjugated	14	964.36	-CH=CH-(trans)
7	1654.77	Non-Conjugated	15	888.95	C=CH$_2$
8	1465.85	CH$_3$	16	732.82	-CH=CH-(cis)

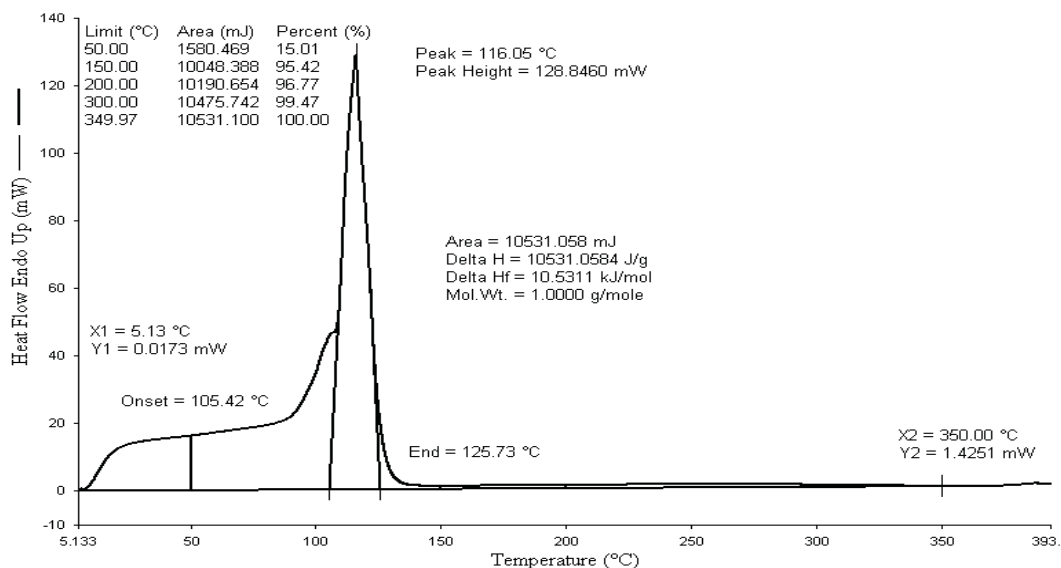**Figure 4:** FT-IR Spectrum of PP plastic fuel to 1st fractional fuel

Figure 5: DSC graph of PP fuel to 1st fractional fuel

Polypropylene waste plastic to 1st fractional fuel was analysis by using of DSC equipment. By using DSC produce fuel boiling (figure 5) point can determine. Analysis purpose 50 µL fuels was use for DSC and carrier gas used Nitrogen at 20 ml/min. analysis graph showed sample start to boil at 5.13 ºC that time mW was 0.0173. Onset temperature showed from analysis graph 105.42 ºC, peak 116.05 ºC and peak height

128.8460 mW. Peak height indicates fuel heat flow Endo up need to generate fuel final peak boiling point. Peak end showed 125.73 ºC and Peak area 10531.058 mJ. Enthalpy value showed from fuel graph 10531.0584 J/g and full graph temperature showed at 350 ºC heat flow Endo up showed 1.4251 mW. This fraction fuel has light hydrocarbon range for this reason graph showed peak intensity high almost 130%.

Some ASTM test was performed of this fuel such as distillation (ASTM D86), MTBE (ASTM D5599_EPA), ETBE (ASTM D5599_EPA), DIPE (ASTM D5599_EPA), TAME (ASTM D5599_EPA), t-butanol (ASTM D5599_EPA), methanol (ASTM D5599_EPA), API gravity at 60 ºF (ASTM D4052), dry vapor pressure (ASTM D5191_EPA), Appearance (ASTM D4176), sulfur (ASTM D5453), Benzene (ASTM D3606), Presence of water (ASTM D4176), methanol (ASTM D5599_EPA), research octane number (ASTM D2699), motor octane number (ASTM D2700), average octane number (ASTM D4814), metal ICP, cloud point (ASTM D2500), freezing point (ASTM D5972), temperature (ASTM D2624), electric conductivity (ASTM D2624), calculated cetane index (ASTM D4737), cold filter plugging point (IP 309), gross heat combustion (ASTM D240).

Conclusion

PP waste plastic fuel to first fraction fuel collected during the production process consists of very light groups of hydrocarbons. Those carbon ranges from $C_3 – C_{10}$. The carbon range represents the viscosity of the fuel and gives us a view about how affective the fuel can be. The PP light fraction given these characteristics is a strong competitor of the gasoline grade fuel. This fuel is very bright in appearance, it density is measured at 0.72 gm/ml. The fuel derived from the PP waste plastics is considered to be a cleaned product since an analytical test of the fuel indicates it has low sulfur and other harmful contents. Some ASTM methods such as, D5599, D5453 and others standard tests has been also done for the fuel. Since the PP fuel in low in density it is a very light able and flammable fuel. A practical burn test was conducted for the PP fuel to compare against similar commercial gasoline fuel. The PP fuel had a slightly higher burning time than the gasoline fuel because it contained a higher carbon chain of $C_3 – C_{10}$ compared to gasoline carbon chain of $C_3 – C_9$.

Acknowledgement

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