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Conventional Fuel Generated from Polypropylene (PP) Waste Plastic like Kerosene/Jet/ Aviation Grade with Activated Carbon

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ABSTRACT: *The thermal degradation and fractional distillation process applied with polypropylene (PP) of waste plastic using stainless steel reactor without using any kind of catalyst. The polymer has been selected for the experiment 100% by weight and 1% activated carbon was used. The experimental temperature was used for thermal degradation liquefaction process at 100-400 ºC and fractional distillation for third fraction fuel or aviation/kerosene/jet category fuel collection temperature was 180-210 ºC and overall experiment run time was 6-6.30 hours. The obtained products density is 0.75 g/ml and production yield percentage are third fraction liquid fuel or aviation/kerosene/jet category fuel yield is 30.40%, other fraction fuel percentage was 62.60% light gas 3% and black carbon residue 4%. Various techniques (Gas Chromatography and Mass Spectrometer, FT-IR and DSC) were used for produced third fraction fuel or aviation/kerosene/jet category fractional fuel analysis purpose. GC/MS result is showing that hydrocarbon compound ranges in this fuel are C_8-C_{19} and light gas are present hydrocarbon range C_1-C_4. Third fractional fuel or kerosene / jet / aviation category fuel analysis results is showing different carbon range and produced third fractional fuel present short chain to long chain hydrocarbon like alkane and alkene group. Produce fuel can be use for internal combustion engine or electricity generation or feed stock refinery process.*

Keywords: *PP, waste plastic, kerosene, fuel, activated carbon, GC/MS, polypropylene*

I. INTRODUCTION

Solving the problem of waste materials such as used plastics, waste tires, and waste oils is undoubtedly a major challenge being faced in all the countries of the world to maintain the sustainable and environmentally compatible economic growth. One of the major problems caused in the recycling of waste plastics is the in homogenecity of the polymers in the waste. Actually, different types of polymers (polyethylene (PE), polypropylene (PP), polystyrene (PS), polyethylene terephthalate (PET), polyvinyl chloride (PVC), acrylonitrile–butadiene– styrene (ABS) and etc.) can be present in waste plastic mixture. Especially, co-processing of co-mingled waste plastics with waste motor oils through a tertiary recycling technique [1–4] can achieve the purpose of waste recycling into commercially viable chemicals or fuel oils. The growing amount of plastic waste is generating more and more environmental problems worldwide. The present rate of economic growth is unimaginable without saving of fossil energy like crude oil, natural gas or coal. Suitable waste management is another important aspect of sustainable development. Plastic wastes represent a considerable part of municipal wastes; furthermore huge amounts of plastic waste arise as a by-product or faulty product in industry and agriculture. According to estimates, plastic wastes represent 15-25% of municipal waste. The amount of plastic materials was 25 Mt in Europe and it will reach 35 Mt by 2010 [5, 6].

Nowadays there are three ways to utilize plastic waste: landfilling, incineration with or without energy recovery and recycling. The largest amount of plastic wastes is disposed of by landfilling (65-70%), and incineration (20-25%), Recycling is only about 10%. At the present time, it is thought that efficient co-processing processes which are feasible in technical and economical aspects should be developed. In parallel with this, an overall national network system [7–10] such as waste plastics collection, pretreatment and regulatory considerations should be provided for successful recycling of waste materials. Korea produces 2.6 million tonnes per annum of thermoplastic wastes of which less than 10% is recycled for the material recovery (primary recycling). In addition, almost 120 million gallons of waste motor oils are generated each year posing severe environmental problems as a result of its metal compounds and high sulfur content (ca. 4000– 6000 ppm wt.) resulting from such additives as dispersants (Co-petroleum sulfonate), oxidation inhibitors (organic sulfur compounds, aminophenol), corrosion inhibitors (organic amines) and extreme pressure additives and from existing sulfur naturally in lube base stock. In this study, co-processing of waste plastics (HDPE, LDPE, PS, PP, PET and ABS) with waste oil by statistical rotatable pentagonal design experiments in a micro-reactor system (40 ml capacity) were explored to extract the optimum pyrolysis conditions for conversion of each plastic/ waste oil blend into oils [11].

II. MATERIALS & METHOD

PP waste plastic was collected from local city coffee shop and local restaurant. Coffee cup PP waste plastic color was transparent, food container and food container cover was white and black color. PP plastic comes with food particle and left over coffee because we collected PP waste plastic from store. After collection PP waste plastic wash with water and none foaming detergent by using electrical plastic washing machine. After finished wash PP waste plastic make it dry with using same machine at 22 ºC temperature. During washing PP waste plastic also generating some waste water that waste water we did not discharge into drainage system because our main goal is waste plastic problem solve from land fill not to create another waste problem. Produced waste water treatment for reuse of waster again waste plastic washing purpose.

This type process is one kind of cyclic process not to generate waste water. Waste water was treated by using chemical and chemical is not harm fuel for human body because we are using only Sodium Hydroxide and Potash Alum. PP waste plastic after dried cut into small pieces manually by using scissor then transfer into grinder machine of grinding and size about 2-3mm. Small pieces grounded PP waste plastic transfer into steel reactor chamber for liquefaction process. Experimental process setup was shown into figure 1. PP waste plastic to kerosene/aviation/jet category fuel production process diagram describe fig.1 and describe figure 1 all number such as 1 = polypropylene waste plastic, 2= Steel reactor, 3 = Fractional distillation column, 4= 1st fraction temperature , 5= 2nd fraction temperature, 6=3rd fraction temperature, 7= 4th fraction temperature, 8= 5th fraction temperature, 9= light gas cleaning system, 10= 1st fraction fuel collection tank, 11=2nd fraction fuel collection tank, 12=3rd fraction fuel collection tank, 13=4th fraction fuel collection tank, 14 = 5th fraction fuel collection tank , 15 = small pump, 16 = Teflon bag for light gas storage. Fuel production process diagram was shown number 12 is aviation/ kerosene/jet fuel collection system. PP waste plastic to fuel production process grounded waste plastic put into reactor chamber and covered by reactor cover and screw tighten properly because we do not want to escape any gas during fuel production period. Condensation with fractional distillation column setup top of reactor with grading temperature wise with electrical coil and temperature was monitor by using watlow company provided watlow meter. For experimental purpose feed was use only 500 gm by weight and activated carbon was use only1% by weight. In this experiment PP waste plastic to liquefaction temperature used 100 to 400 ºC and collection aviation /kerosene/jet category fuel fractional temperature was 180-210 ºC. Collection device end part was collected light gas cleaning device and this device was fill up with alkali solution for removing light gas contamination and water portion which was generated from production. In this experiment did not apply vacuum system and did not apply any kind of catalyst. After finished all set up experimental procedure we start reactor electrical power for heated up PP waste plastic. PP waste plastic start to melt due to heat applies then turns into liquid slurry, liquid slurry turns into gas vapor this gas vapor pass through fractional column based on boiling point temperature at the end collected 3rd fractional or aviation/kerosene/jet grade fuel. In this experiment main goal was aviation/kerosene/jet category fuel collection. Activated carbon help to reduce fuel dye level because when heated up PP waste plastic with activated carbon, activated carbon absorbed plastic additives color and produce fuel made cleaner. PP waste plastic to 3rd fractional fuel or aviation/ kerosene/jet category fuel production period also generate some light gas its call natural gas and this gas hydrocarbon range C_1-C_4. These gases pass through alkali chamber and remove contamination transfer Teflon bag by using small pump for future use. Collected 3rd fractional fuel purified by RCI purification device and removed fuel sediment. Total experiment run time was 6-6.30 hours and input electricity was 6.12 kWh. From this experiment in mass balance calculation indicate that 3rd fractional fuel or aviation/kerosene/jet category fuel conversion 152 gm from 500 gm of initial feed. Light gas converted feed sample 15 gm, solid black residue leftover 20 gm from total feed and rest of other grade fuel generated 313 gm sample during in this experiment. In percentage ratio third fraction liquid fuel or aviation/kerosene/jet category fuel yield percentage is 30.40%, other fraction fuel percentage was 62.60% light gas 3% and black carbon residue 4%.

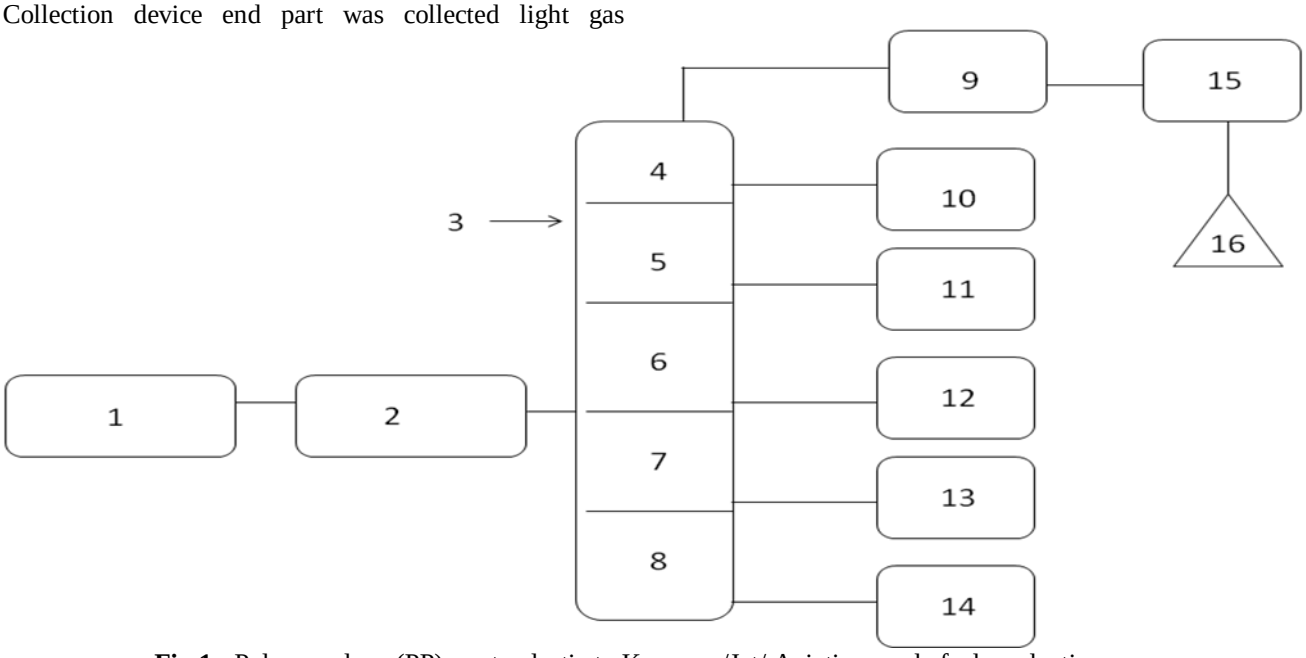

Fig.1: Polypropylene (PP) waste plastic to Kerosene/Jet/ Aviation grade fuel production process

III. RESULTS & DISCUSSION

From GC-MS analysis of PP waste plastic to 3rd fractional fuel or kerosene/jet/aviation (fig. 2 and table 1**)** in accordance with the various retention times 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_8 to C_{15} among them and 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 4.59 and trace mass 41, compound is 1-Heptene, 4-methyl- (C_8H_{16}), retention time 4.74 and trace mass 71, compound is Heptane, 4-methyl- (C_8H_{18}), retention time 5.05 and trace mass 56, compound is 1-Heptene, 2-methyl- (C_8H_{16}), retention time 5.22 and trace mass 95,compound is 2,4-Hexadiene, 2,5-dimethyl-, (C_8H_{14}), retention time 5.93 and trace mass 111,compound is Cyclohexane, 1,3,5-trimethyl-, (1α,3α,5α)-(C_9H_{18}), retention time 6.02 and trace

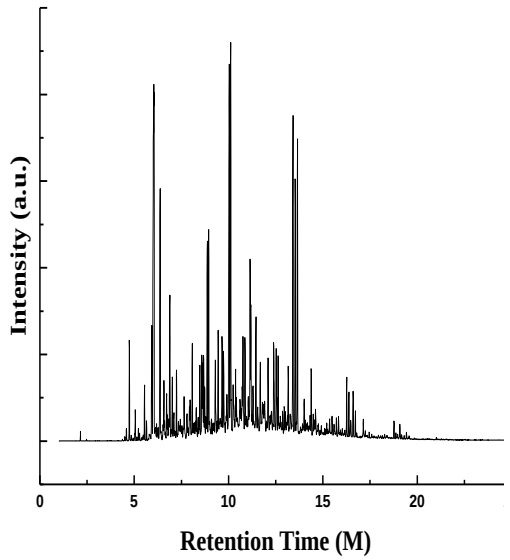

Fig. 2: GC/MS chromatogram of PP waste plastic to kerosene/aviation/ jet category fuel

mass 57, compound is 2,4-Dimethyl-1-heptene (C_9H_{18}), retention time 6.38 and trace mass 42, compound is Cyclohexane, 1,2,4-trimethyl-, (1α,2β,4β)-(C_9H_{18}), retention time 6.58 and trace mass 109, compound is Cyclohexane, 1,2,4-trimethyl-, (1α,2β,4β)- (C_9H_{16}), retention time 6.89 and trace mass 69, compound is 3-Octene, 2,2-dimethyl- ($C_{10}H_{20}$), retention time 7.02 and trace mass 43, compound is Hexane,2,4-Dimethyl-(C_8H_{18}), retention time 7.10 and trace mass 83, compound is 1,6-Octadiene, 5,7-dimethyl-, (R)-($C_{10}H_{18}$), retention time 7.64 and trace mass 43, compound is 2-Undecanethiol, 2-methyl- ($C_{12}H_{26}O$), retention time 7.34 and trace mass 95, compound is Cyclohexene, 3-methyl-6-(1-methylethyl)-($C_{10}H_{18}$), retention time 7.44 and trace mass 41,compound is compound is 1-Dodecyne ($C_{12}H_{22}$),retention time 7.96 and trace mass 41,compound is cis-3-Decene ($C_{10}H_{20}$), retention time 8.29 and trace mass 41, compound is trans-7-Methyl-3-octene ($C_{10}H_{18}$), retention time 8.48 and trace mass 56, compound is 2-Methyl-1-Nonene ($C_{10}H_{22}$), retention time 8.59 and trace mass 41, compound is 3-Unddecene,(Z),($C_{11}H_{22}$), retention time 8.95 and trace mass 42 compound is Octane, 2,6-dimethyl- ($C_{10}H_{22}$), retention time 9.45 and trace mass 56,compound name is 3-Undecene, (Z)- ($C_{11}H_{22}$), retention time 10.87 and trace mass 43, compound is 2-Undecanethiol, 2-methyl- ($C_{12}H_{26}S$), retention time 11.68 and trace mass 69, compound is Cyclohexane, 1,1,4,4-tetramethyl- ($C_{10}H_{22}$), retention time 12.39 and trace mass 43, compound is Decane, 2,3,5,8-tetramethyl- ($C_{14}H_{30}$), retention time 13.65 and trace mass 55, compound is E-14-Hexadecenal ($C_{16}H_{30}O$), retention time 14.38 and trace mass 55, compound is E-2-Octadecadecen-1-ol ($C_{18}H_{36}O$), retention time 15.48 and trace mass 43, compound is Decane, 2,3,5,8-tetramethyl- ($C_{14}H_{30}$) , retention time 16.27 and trace mass 43, compound is 2-Hexyl-1-octanol ($C_{14}H_{30}O$), retention time 17.14 and trace mass 55, compound is E-2-Octadecadecen-1-ol ($C_{18}H_{36}O$). Ultimately also at retention time 18.77 and trace mass 43, compound is 1-Heptadecene ($C_{17}H_{34}$) and ultimately retention time 19.57 and trace mass 69, compound is 11-Dodecen-1-ol, 2,4,6-trimethyl-, (R,R,R)- ($C_{15}H_{30}O$) respectively.

From FT-IR analysis of PP waste plastic to 3rd fractional fuel or jet/kerosene/aviation fuel (fig. 3 and table 2) 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 wave number 2927.06 cm^{-1} and 2727.53 cm^{-1} functional group is C-CH_3, wave number 1781.50 cm^{-1} and 1648.95 cm^{-1} functional group is Non-Conjugated, wave number 1470.16 cm^{-1} functional group is CH_3, wave number 993.43 cm^{-1} functional group is –CH=CH_2, wave number 964.95 cm^{-1}, functional group is –CH=CH-(trans) and ultimately wave number 887.95 cm^{-1} functional group is C=CH_2 respectively. Energy values are calculated, using formula is E=hυ, Where h=Planks Constant, h =$6.626x10^{-34}$ J, υ= Frequency in Hertz (sec^{-1}), Where υ=c/λ, c=Speed of light, where, c=$3x10^{10}$ m/s, W=1/λ, where λ is wave length and W is wave number in cm^{-1}. Therefore the equation E=hυ, can substitute by the following equation, E=hcW. According to their wave number such as for 2927.06 (cm^{-1}) calculated energy, E=$5.81x10^{-20}$ J, wave number 2727.53 (cm^{-1}) calculated energy, E=$5.41x10^{-20}$ J. Similarly, wave number 1781.50 (cm^{-1}) energy, E =$3.53x10^{-20}$ J, wave number 1648.95(cm^{-1}) calculated energy, E=$3.27x10^{-20}$ J, wave number 1470.16 (cm^{-1}) calculated energy, E = $2.92x10^{-20}$ J, wave number 993.43 (cm^{-1}), calculated energy, E=$1.97x10^{-20}$ J, wave number 964.95 (cm^{-1}) calculated energy ,E=$1.91x10^{-20}$ J and eventually wave number 894.22 (cm^{-1}) calculated energy ,E =$1.78x10^{-20}$ J respectively.

Table1: GC/MS chromatogram of PP waste plastic to 3rd fractional or kerosene/jet/aviation fuel compound list

Peak Number	Retention Time (M)	Trace Mass (m/z)	Compound Name	Compound Formula	Molecular Weight	Probability %
1	4.59	41	1-Heptene, 4-methyl-	C_8H_{16}	112	30.7
2	4.74	71	Heptane, 4-methyl-	C_8H_{18}	114	54.6
3	5.05	56	1-Heptene, 2-methyl-	C_8H_{16}	112	48.4
4	5.22	95	2,4-Hexadiene, 2,5-dimethyl-	C_8H_{14}	110	13.9
5	5.55	69	Cyclopentane, 1,1,3,4-tetramethyl-, cis-	C_9H_{18}	126	15.8
6	5.65	43	Hexane, 3-ethyl-	C_8H_{18}	114	19.4
7	5.93	111	Cyclohexane, 1,3,5-trimethyl-, (1α,3α,5α)-	C_9H_{18}	126	31.1
8	6.02	57	2,4-Dimethyl-1-heptene	C_9H_{18}	126	17.7
9	6.03	56	Cyclohexane, 1,1,2-trimethyl-	C_9H_{18}	126	7.04
10	6.38	42	Cyclohexane, 1,2,4-trimethyl-, (1α,2β,4β)-	C_9H_{18}	126	19.4
11	6.58	109	Cyclohexene, 3,3,5-trimethyl-	C_9H_{16}	124	41.5
12	6.76	56	trans-7-Methyl-3-octene	C_9H_{18}	126	33.4
13	6.89	69	3-Octene, 2,2-dimethyl-	$C_{10}H_{20}$	140	6.58
14	7.02	43	Hexane, 2,4-dimethyl-	C_8H_{18}	114	9.82
15	7.10	83	1,6-Octadiene, 5,7-dimethyl-, (R)-	$C_{10}H_{18}$	138	13.8
16	7.24	67	1,6-Octadiene, 2,6-dimethyl-, (Z)-	$C_{10}H_{18}$	138	9.53
17	7.34	95	Cyclohexene, 3-methyl-6-(1-methylethyl)-	$C_{10}H_{18}$	138	16.0
18	7.44	41	1-Dodecyne	$C_{12}H_{22}$	166	7.63
19	7.64	43	2-Undecanethiol, 2-methyl-	$C_{12}H_{26}S$	202	6.50
20	7.80	41	1-Octene, 2,6-dimethyl-	$C_{10}H_{20}$	140	9.54
21	7.92	41	1-Octyn-3-ol, 4-ethyl-	$C_{10}H_{18}O$	154	9.35
22	7.96	41	cis-3-Decene	$C_{10}H_{20}$	140	16.1
23	8.08	43	Octane, 2,3-dimethyl-	$C_{10}H_{22}$	142	17.7
24	8.29	41	Dihydromyrcene	$C_{10}H_{18}$	138	12.5
25	8.48	56	2-Methyl-1-nonene	$C_{10}H_{20}$	140	22.8
26	8.59	41	3-Undecene, (Z)-	$C_{11}H_{22}$	154	6.97
27	8.87	43	Decane, 4-methyl-	$C_{11}H_{24}$	156	13.8
28	8.95	42	Octane, 2,6-dimethyl-	$C_{10}H_{22}$	142	10.2
29	9.29	41	2-Nonenal, (E)-	$C_9H_{16}O$	140	6.03
30	9.45	56	3-Undecene, (Z)-	$C_{11}H_{22}$	154	7.76
31	10.04	69	1-Methyl-2-(4-methylpentyl) cyclopentane	$C_{12}H_{24}$	168	2.96
32	10.12	69	1-Dodecene	$C_{12}H_{24}$	168	4.61
33	10.38	43	Undecane	$C_{11}H_{24}$	156	23.5
34	10.61	41	E-2-Octadecadecen-1-ol	$C_{18}H_{36}O$	268	3.55
35	10.72	69	1-Isopropyl-1,4,5-trimethylcyclohexane	$C_{12}H_{24}$	168	30.3
36	10.76	43	1-Dodecanol, 3,7,11-trimethyl-	$C_{15}H_{32}O$	228	4.19
37	10.87	43	2-Undecanethiol, 2-methyl-	$C_{12}H_{26}S$	202	6.55
38	11.04	41	3-Dodecene, (E)-	$C_{12}H_{24}$	168	7.31
39	11.14	69	7-Octadecyne, 2-methyl-	$C_{19}H_{36}$	264	4.52
40	11.18	55	3-Tridecene	$C_{13}H_{24}$	180	4.24

41	11.30	43	2,3-Dimethyldecane	$C_{12}H_{26}$	170	11.3
42	11.45	69	1-Isopropyl-1,4,5-trimethylcyclohexane	$C_{12}H_{24}$	168	22.9
43	11.68	69	Cyclohexane, 1,1,4,4-tetramethyl-	$C_{10}H_{20}$	140	10.9
44	12.09	69	1-Isopropyl-1,4,5-trimethylcyclohexane	$C_{12}H_{24}$	168	20.8
45	12.39	43	Decane, 2,3,5,8-tetramethyl-	$C_{14}H_{30}$	198	7.56
46	13.16	43	3-Tetradecene, (E)-	$C_{14}H_{28}$	196	4.21
47	13.53	69	9-Eicosene, (E)-	$C_{20}H_{40}$	280	3.82
48	13.65	55	E-14-Hexadecenal	$C_{16}H_{30}O$	238	3.61
49	14.01	43	1-Dodecanol, 3,7,11-trimethyl-	$C_{15}H_{32}O$	228	3.29
50	14.38	55	E-2-Octadecadecen-1-ol	$C_{18}H_{36}O$	268	4.61
51	15.20	69	2-Piperidinone, N-[4-bromo-n-butyl]-	$C_9H_{16}BrNO$	233	7.25
52	15.48	43	Decane, 2,3,5,8-tetramethyl-	$C_{14}H_{30}$	198	11.0
53	16.17	83	1-Nonadecanol	$C_{19}H_{40}O$	284	2.89
54	16.27	43	2-Hexyl-1-octanol	$C_{14}H_{30}O$	214	3.57
55	17.14	55	E-2-Octadecadecen-1-ol	$C_{18}H_{36}O$	268	4.68
56	18.77	43	1-Heptadecene	$C_{17}H_{34}$	238	3.92
57	19.57	69	11-Dodecen-1-ol, 2,4,6-trimethyl-, (R,R,R)-	$C_{15}H_{30}O$	226	5.52

Table 2: FT-IR spectrum's PP waste plastic to 3rd fractional or jet/kerosene/aviation fuel functional group name

Number of Wave	Wave Number (cm^{-1})	Functional Group Name	Number of Wave	Wave Number (cm^{-1})	Functional Group Name
1	2927.06	C-CH_3	5	1470.16	CH_3
2	2727.53	C-CH_3	6	993.43	-CH=CH_2
3	1781.50	Non-Conjugated	7	964.95	-CH=CH-(trans)
4	1648.95	Non-Conjugated	8	894.22	C=CH_2

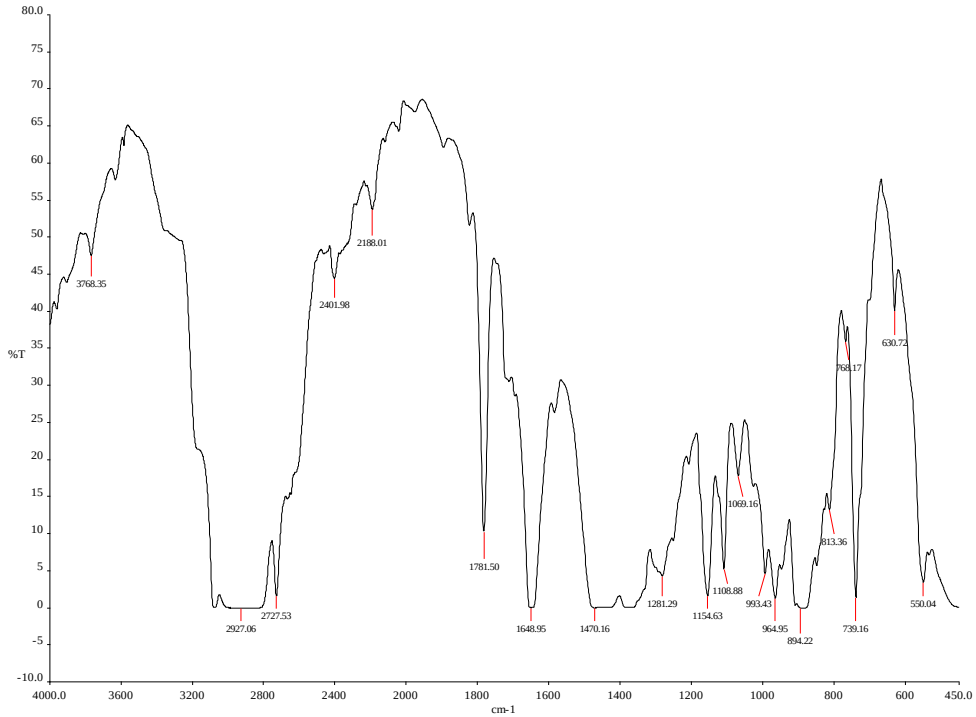

Fig. 3: FT-IR spectrum of PP waste plastic to 3rd fractional fuel or jet/kerosene/aviation fuel

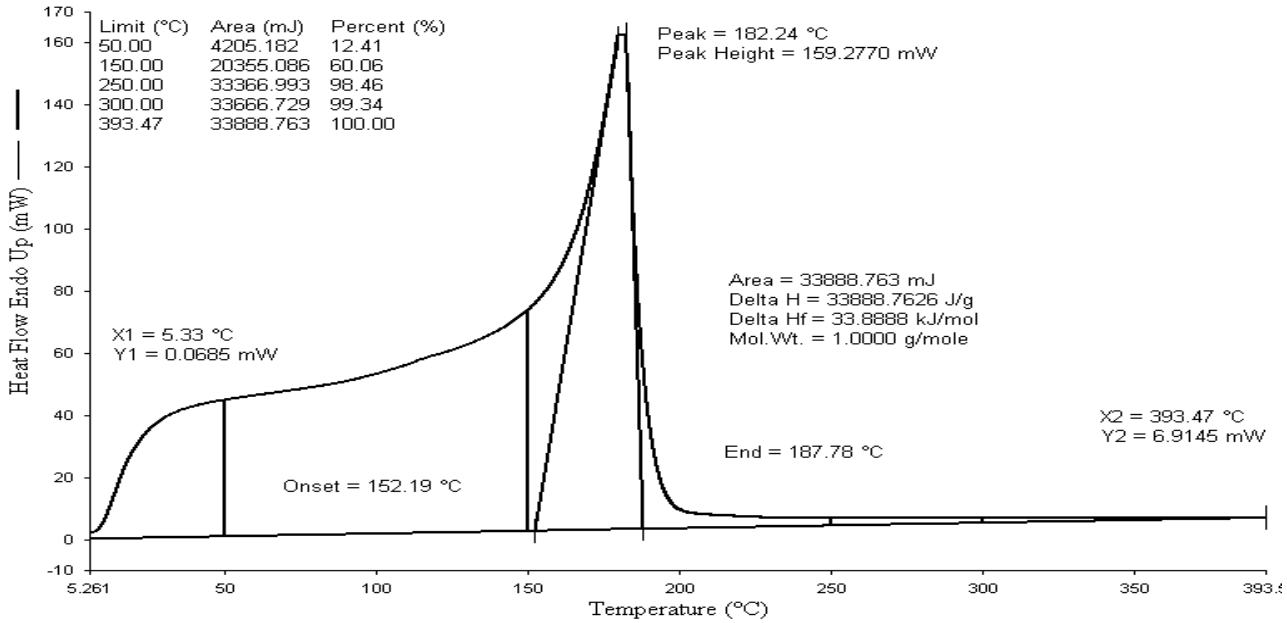

Fig.4: DSC graph of PP waste plastic to 3rd fractional or jet/kerosene/aviation fuel

Third (3rd) fractional fuel or kerosene/aviation/jet category fuel (seen fig. 4) collected from PP waste plastic by using fractional distillation column process at temperature range was 180-210 ºC. This fuel category is similar to jet/kerosene/aviation fuel. This fuel looks like heaver fuel and 3rd fractional fuel was analysis by using DSC for boiling point and enthalpy value measuring. After analyzed fraction fuel by DSC, we noticed that fuel graph showed fuel boil start 5.33 ºC and 0.0685 mW, fuel graph onset temperature 152.19 ºC and fuel boiling point peak temperature is 182.24 ºC, peak height 159.2770 mW. 3rd fraction fuel or kerosene/aviation/ jet fuel heat enthalpy value delta H is 33888.7626 J/g and graph area 33888.763 mJ. Analysis fuel graph showing end temperature is 187.78 ºC. Fuel boiling percentage shown at 50ºC temperature was 12.41%, 150 ºC temperature was 60.06% and finally 100 % fuel boil finished at temperature was 393.47 ºC.

IV. CONCLUSION

PP waste plastic to 3rd fractional or kerosene/aviation/ jet category fuel production purposed was use 2 type temperatures profile one for liquefaction temperature and another one was fractional distillation temperature. PP waste plastic produced fuel percentage is 30.40% and in this experiment collected also other grade fuels. Produced fuel density is 0.75 g/ml. Different types of equipment were used for analysis 3rd fractional or aviation/kerosene/jet category fuel such as GC/MS, FTIR and DSC. GC-MS (Gas Chromatography and Mass Spectrometer) analysis result is indicates that in aviation/kerosene/jet category fuel contains extensive number of carbon chain compounds that s are derived out by numerous retention time and trace masses of distinct compound. FT-IR analysis derived out available hydrocarbon functional groups are in the aviation/kerosene/jet category fuel and determined that the wide number of hydrocarbon functional group including alkane, alkene and alkyne (Saturated and unsaturated hydrocarbon) compounds are also present in the fuel. Differential Scanning Calorimeter (DSC) giving the onset temperature of the fuel which represents the boiling point of the aviation/kerosene/jet category fuel. Fuel analysis of GC/MS results indicate that produce fuel hydrocarbon range C_8 to C_{19}. Produced fuel could be use as feed stock refinery for further modification or commercial use. By using this technology could be solve PP waste plastic problem and also reduce the land fill problem that is the cause of infertility of agriculture land.

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