

Thermal Degradation of Plastic Wastes (PP, LDPE) Using Metal Particles, Metal Oxides and Metal Nano Particles as a Catalyst

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Abstract. Two different vacuum thermal degradation processes of plastic wastes materials: Poly Propylene (PP) and Low Density Poly Ethylene (LDPE) were conducted with homemade thermal degradation setup. The two processes were used 1-bulk metal particles, 2- metal oxides (Fe, Ni, Fe₂O₃, NiO) and 3-metal nano particles (Fe and Ni) as a catalysts supported on feldspar clay respectively. The experimental results for both processes shows the presence of different products like liquid, wax, gas, and carbon. Our characterization was focused on the liquid product. The produced liquid was characterized by Fourier transform infra-red (FTIR) and Gas chromatography (GC) The octane number, cetane number, flash point, fire point, aniline point and some physical properties were also measured. The results indicated that the process with metal nanoparticles catalyst produces liquid much better properties compared to the other materials results used metal particles catalyst.

Introduction.

The big amount of plastic waste and global demand are increase in polymer production, gives evidence to serious environmental risk, due to plastic does not full decay and remains in the municipal landfill for decade [1-2]. Also rates and quantities of municipal solid waste in some Arab countries are Egypt 81.300 million ton/Year, UAE 16.400 million ton/Year, Saudi Arabia 12.100 million ton/Year, Iraq 9.150 million ton/Year and Sudan 7.950 million ton/Year [3]. So a huge amount of energy could be obtained from this waste as hydrocarbons compounds. Therefore Many researchers improvement the possible transforming of waste to fuel and having prospective for industrial [4-5]. The expected benefit of using catalyst is to reduce degradation temperature, to promote degradation speed, and improve the final products Outputs. Catalytic decomposition of plastic wastes is produced by mixing melted plastic wastes with catalyst in fixed bed reactors [7]. Mixtures of polymer and catalyst grains have been heated in a reaction container [8,9,10]. The goal from research is aiming to reduce the environmental pollution and to improve the quality of liquid fuel production.

Experimental.

The nanomaterial were purchase from (MTI-corporation/USA) with size (Ni=50nm, Fe=80nm), the bulk material were purchase from (BDH company) with size (<53 μm) and the feldspar was purchase from (Itali, STIEL company, S.I.D.A.C) . The experimental setup for degradation of plastic waste consist of a batch reactor made of stainless steel ,height 11cm and diameter of 5.5cm in which the reaction takes place heated by oven supplied with a temperature controller. This reactor is contacted to three neck flask heated by heating mantle for waxes collection. The latter is contacted to Condenser and then to another three neck flask for final liquid product collection. The vacuum was created in the reactor to ensure the absence of oxygen during the reaction in the system. Polymer was charged into the reactor at the beginning and then the reactor was heated up to the required temperature. At the first 5 min; a linear temperature increase was observed and then increased with slow rate for remaining 10 minutes inter heating oven and 25 minutes inter reactor. The waste plastic from plastic shopping bags type low density polyethylene (LDPE), vegetable

boxes type polypropylene (PP) were used. The process uses thermal degradation to heat the waste plastic at a temperatures ranging from 370°C to 420°C with catalyst supported on the clay to form liquid slurry in the absence of atmospheric oxygen. In a laboratory scale, the weight of 50 grams for one type of input plastic as a single batch for the fuel production process was used. The waste plastics are collected, optionally sorted, cleaned of contamination and grinded into small pieces prior to the thermal liquefaction process. The final products of liquid were collected through the condenser in a collecting vessel are kept in a cooled container and the produced gases will be captured in kept plastic tire and the solid residue (waxes, coal) are kept in containers.

Results and discussion.

FTIR Analysis. Various experimental products of plastic wastes (PP, LDPE) are characterized by Fourier transform infrared (FTIR- model: Bruker-Aleha: Germany). Fig. 1-7, are shown the functional groups of the output liquid from plastic waste degradation alone and with catalyst supported on feldspar. The functional groups of, =C-H stretch for alkene, C-H stretch so for alkene, alkane, C=C stretch and C-H scissor for alkene, C-H methyl rock and =C-H bend for alkene are observed respectively.

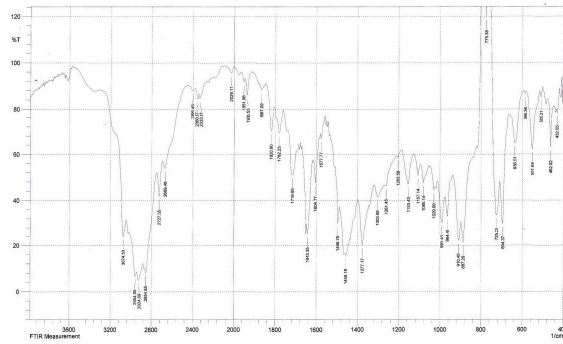


Fig. 1: FTIR for output liquid (feldspar only).

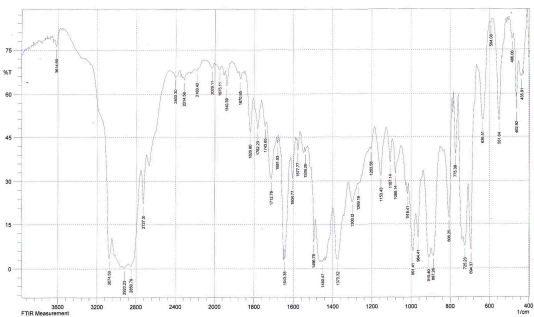


Fig. 2: FTIR for output liquid (feldspar+ Fe₂O₃).

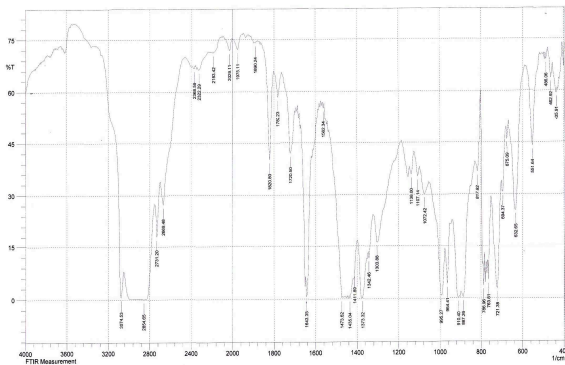


Fig. 3: FTIR for output liquid (feldspar+Fe metal).

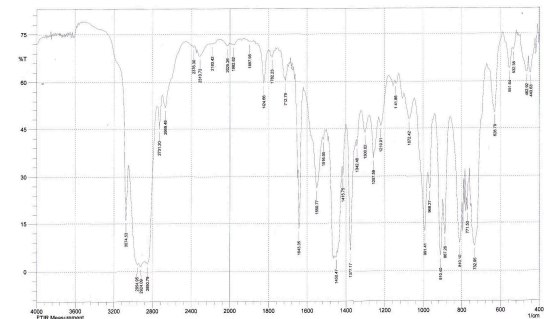


Fig. 4: FTIR for output liquid (feldspar+Fe nano).

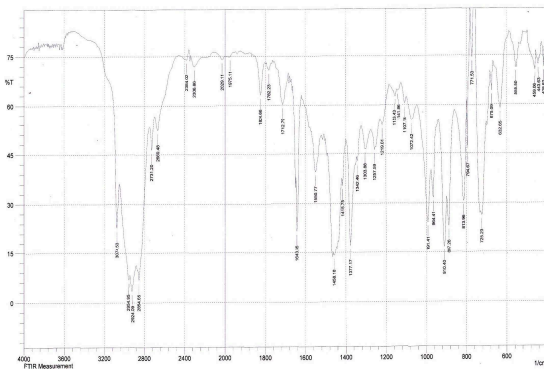


Fig. 5: FTIR for output liquid (feldspar +NiO).

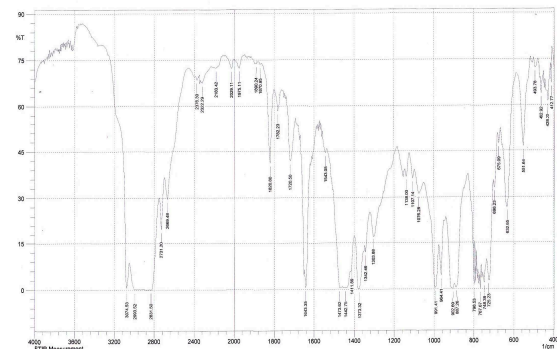
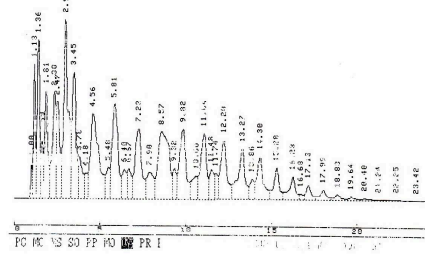
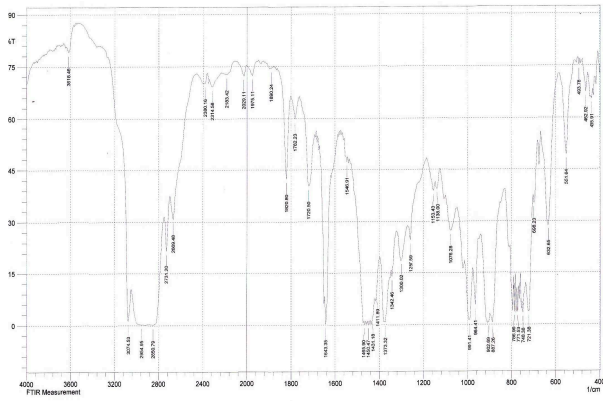


Fig. 6: FTIR for output liquid (feldspar + Ni metal).



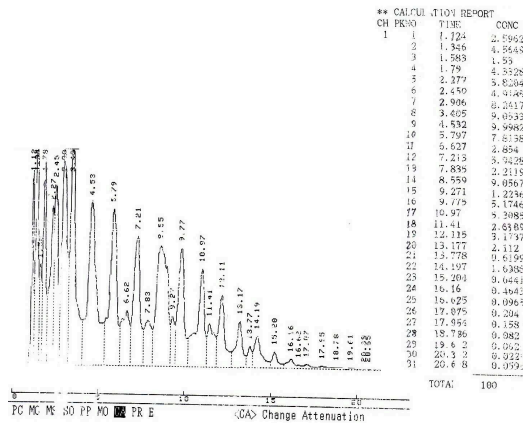
** CALCULATION REPORT **

CH PRNO	TIME	CONC
1	1.003	0.5265
2	1.139	2.6396
3	1.365	4.2431
4	1.607	1.2849
5	1.817	3.4096
6	2.303	4.6114
7	2.475	3.4549
8	2.938	8.575
9	3.452	5.7661
10	3.86	1.7651
11	4.19	0.8281
12	4.562	7.4411
13	5.481	1.2167
14	5.82	2.8899
15	6.407	1.3592
16	6.673	1.2851
17	7.231	4.8115
18	7.991	1.9682
19	8.572	7.7546
20	9.324	1.4951
21	9.826	4.7619
22	10.592	1.4653
23	11.047	4.365
24	11.487	1.4758
25	12.747	0.521
26	13.205	3.9111
27	13.278	3.6244
28	13.623	0.9785
29	14.309	2.9943
30	15.289	1.5225
31	16.233	0.8073
32	16.482	0.2487
33	17.119	0.8073
34	17.999	3.6868
35	18.535	0.433
36	19.644	0.2598
37	19.572	0.1811
38	21.219	0.0964
39	22.35	0.0451
40	23.428	3.6885

TOTAL 109

Fig. 7: FTIR for output liquid (feldspar +Ni nano). Fig. 8: GC for output liquid (feldspar only).

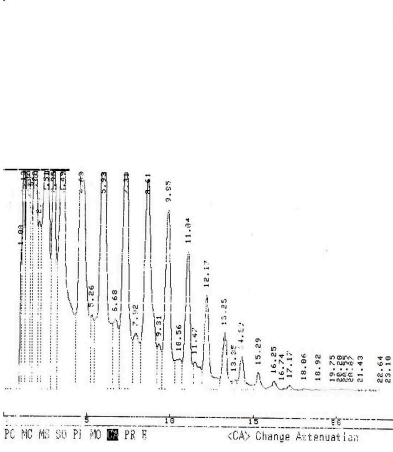
Gas chromatography (GC) Analysis .Gas chromatography (GC ,PACKARD model :43817) is used for the liquid products analysis .From studying Fig. 8-14, having many change in liquid mixture materials concentration and seeing that when plastic wastes degradation with feldspar compare by supported catalyst on feldspar ,having increasing in output liquids concentration specially with catalyst nano .that emphases by physical properties.



** CALCULATION REPORT

CH PRNO	TIME	CONC
1	1.124	2.5962
2	1.366	4.5643
3	1.583	4.553
4	1.79	4.5828
5	2.377	3.8284
6	2.450	4.8149
7	2.906	8.2617
8	3.405	9.0535
9	4.532	9.9862
10	5.797	7.8138
11	5.627	4.854
12	7.213	5.7628
13	7.835	2.2119
14	8.559	9.0567
15	9.271	10.2394
16	9.775	5.1746
17	10.97	3.3085
18	11.41	2.6389
19	12.135	3.1797
20	13.177	2.112
21	13.738	0.4399
22	14.197	1.0385
23	15.201	0.6441
24	16.16	0.4095
25	16.625	0.4643
26	17.075	0.204
27	17.956	0.158
28	18.786	0.8882
29	19.612	0.062
30	20.42	0.9222
31	20.42	0.0722

TOTAL: 100



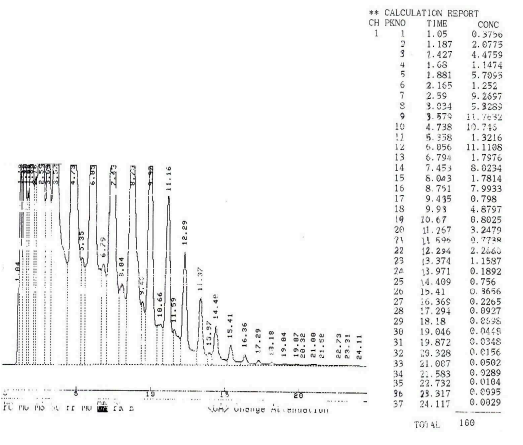
** CALCULATION REPORT

CH PRNO	TIME	CONC
1	1.607	0.8139
2	1.137	3.5207
3	1.371	2.3945
4	1.617	1.3353
5	1.82	6.5299
6	2.09	6.5299
7	2.519	2.2553
8	2.255	0.9785
9	3.452	11.12
10	4.633	9.6696
11	5.27	1.1536
12	5.534	10.0655
13	6.688	1.5647
14	7.32	7.261
15	7.928	1.7436
16	8.619	0.8139
17	9.319	1.57
18	9.99	0.8145
19	10.561	0.8145
20	11.043	3.1628
21	11.474	1.2108
22	12.178	2.3117
23	13.26	1.2108
24	13.853	0.433
25	14.235	0.8037
26	14.529	0.5796
27	14.823	0.8139
28	16.742	0.0383
29	17.177	0.8982
30	18.061	0.0786
31	18.926	0.6356
32	19.758	0.0305
33	20.208	0.0121
34	20.359	0.0167
35	20.87	0.0167
36	21.437	0.0527
37	22.942	0.0348
38	23.103	0.0523

TOTAL 100

Fig. 9: GC for output liquid (feldspar+Fe₂O₃).

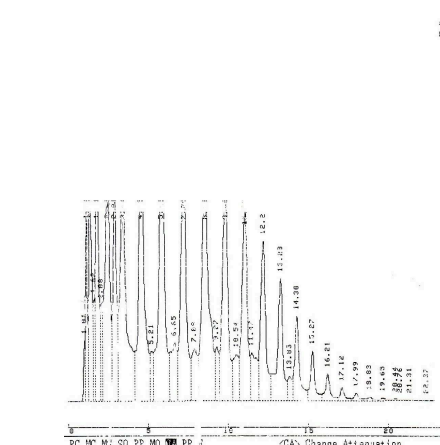
Fig. 10: GC for output liquid (feldspar+Fe metal).



** CALCULATION REPORT

CH PRNO	TIME	CONC
1	1.05	0.3736
2	1.187	2.0775
3	1.427	4.4759
4	1.66	1.1474
5	1.881	5.7095
6	2.165	1.252
7	2.35	5.2857
8	3.034	5.3288
9	3.573	11.0692
10	4.738	10.745
11	5.358	1.3216
12	6.056	11.1108
13	6.736	1.7976
14	7.454	8.0234
15	8.063	1.7814
16	8.751	7.9933
17	9.435	0.798
18	9.91	4.8797
19	10.47	0.8025
20	11.257	3.2479
21	11.636	0.7744
22	12.284	2.2464
23	13.374	1.1587
24	13.971	0.1892
25	14.409	0.755
26	15.41	0.3656
27	16.365	0.2288
28	17.294	0.0927
29	18.18	0.0325
30	19.046	0.0445
31	19.872	0.0348
32	20.328	0.0156
33	21.007	0.0302
34	21.583	0.0289
35	22.732	0.0104
36	23.317	0.0929
37	24.117	0.0029

TOTAL: 100

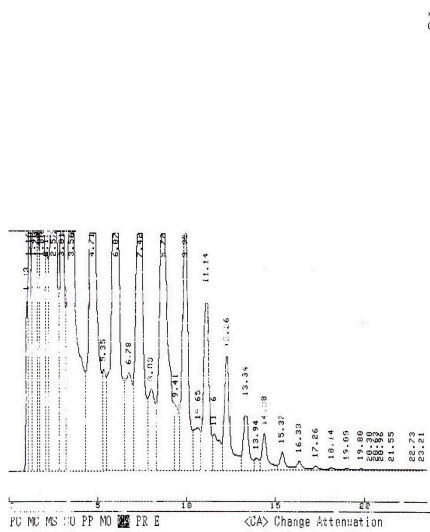


** CALCULATION REPORT

CH PRNO	TIME	CONC
1	1.912	0.4155
2	1.145	1.9193
3	1.377	4.0837
4	1.526	0.3135
5	1.813	4.5873
6	2.081	0.8316
7	2.392	0.9498
8	2.917	3.0968
9	3.443	8.4091
10	4.593	8.236
11	5.218	0.7923
12	5.531	8.3085
13	6.535	0.0878
14	7.261	7.2537
15	7.652	1.6818
16	8.32	5.7785
17	9.277	1.6213
18	9.86	0.6659
19	10.542	1.422
20	11.079	5.6577
21	11.475	0.0515
22	12.116	4.915
23	13.286	3.8624
24	13.949	0.0796
25	14.337	2.247
26	15.271	2.584
27	16.211	0.6438
28	17.12	0.7282
29	17.99	0.1465
30	18.834	0.91
31	19.65	0.0796
32	20.44	0.0302
33	20.76	0.0333
34	21.115	0.0302
35	22.571	0.916

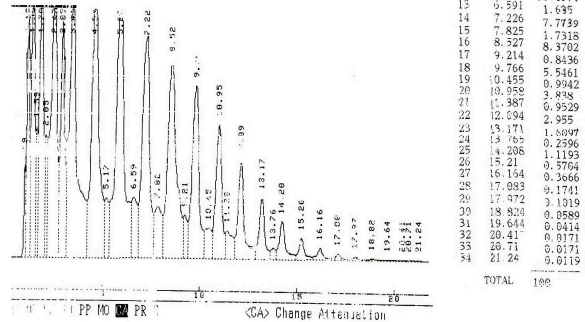
TOTAL 100

Fig. 11: GC for output liquid (feldspar + Fe nano). Fig. 12: GC for output liquid (feldspar+NiO).



GC CALCULATION REPORT

CH	PRNO	TIME	CONC
1	1	1.037	0.3146
2	1	1.169	3.4323
3	1	1.407	6.4273
4	1	1.659	1.9246
5	1	1.965	6.5696
6	1	2.138	1.5529
7	1	2.578	9.2423
8	1	3.015	5.084
9	1	3.565	10.8995
10	1	4.715	9.8164
11	1	5.351	1.1703
12	1	6.781	9.4867
13	1	6.781	2.2127
14	1	7.421	7.5381
15	1	8.03	1.6786
16	1	8.722	7.5349
17	1	9.414	0.7105
18	1	9.952	4.7401
19	1	10.654	0.8539
20	1	11.14	3.1245
21	1	11.508	0.8023
22	1	13.33	2.1592
23	1	13.345	1.0563
24	1	13.942	6.1757
25	1	14.95	0.5728
26	1	15.37	0.3112
27	1	16.39	0.1887
28	1	17.26	0.0822
29	1	18.147	0.0435
30	1	19.00	0.0346
31	1	19.8	0.0275
32	1	20.3	0.0144
33	1	20.33	0.0136
34	1	20.964	0.0194
35	1	21.554	0.0228
36	1	22.733	0.025
37	1	23.712	0.0692



GC CALCULATION REPORT

CH	PRNO	TIME	CONC
1	1	0.999	0.6971
2	1	1.173	2.7574
3	1	1.353	5.9898
4	1	1.594	1.1573
5	1	1.79	5.7464
6	1	2.053	1.441
7	1	2.47	8.2714
8	1	2.898	4.4528
9	1	3.414	10.12
10	1	4.599	9.5587
11	1	5.176	1.9572
12	1	5.829	10.4174
13	1	6.591	1.635
14	1	7.226	7.7739
15	1	7.825	1.7318
16	1	8.327	8.3792
17	1	9.214	0.8436
18	1	9.766	5.5461
19	1	10.455	0.9942
20	1	10.998	3.838
21	1	11.387	0.9529
22	1	12.094	2.955
23	1	13.171	1.8997
24	1	13.485	0.2596
25	1	14.288	1.1193
26	1	15.21	0.3764
27	1	16.164	9.1741
28	1	17.093	0.3666
29	1	17.472	3.1019
30	1	18.824	0.0589
31	1	19.641	0.0414
32	1	20.41	0.0171
33	1	20.71	0.0171
34	1	21.24	0.0119

Fig. 13: GC for output liquid (feldspar+Ni metal). Fig. 14: GC for output liquid (feldspar +Ni nano).

Physical characters. Table 1, shows many variables in quantities by using supported catalyst on feldspar, seeing reduce in residue material (carbon), gas production and experimental time, also increasing in output wax. In other side, output liquids are frequency between reduce and increasing but physical characterizes were best with using nano catalysts.

Table 2, is summarizing the physical characterization of the produced liquid. The reduced values of the distillation point, flash point, fire point, relative viscosity and aniline point is quite clear. While the octan number and cetane index is increased gradually. These experimental data improvements are due to the effect of catalyst nanomaterials through the reaction process.

Table 1: Quantities outputs of plastic wastes degradation.

Time Minute.	Gas g	Carbon g	Wax g	Liquid g	WASTE PLASTIC	Feldspar : catalyst
150	0.6	66.1	19.95	29.12	50g	Feldspar25g
90	0.89	34.47	46.12	35.02	50g	Feldspar20g+Fe ₂ O ₃ 5g
105	0.59	27.35	57.28	28.98	50g	Feldspar20g+Fe metal 5g
95	0.39	23.15	67.34	24.86	50g	Feldspar20g+Fe nano 1g
100	4.33	22.82	57.87	24.07	50g	Feldspar20g+NiO 5g
100	0.57	27.41	60.11	27.59	50g	Feldspar20g+Ni metal 5g
100	0.52	27.41	60.21	27.59	50g	Feldspar20g+Ni nano 1g

Table 2: Physical Characters of outputs liquids.

Cetane Index	Octan NO.			Aniline point	viscosity	Density	Fire point C°	Flash point C°	distillation point C°	Feldspar : catalyst
	Average	Motor	Research							
39.1	87.1	82.7	91.5	179	0.985	0.736	31.5	5	40-110	Feldspar25g
56.9	92.4	87.4	97.4	173	0.863	0.732	19.5	2	30-113	Feldspar20g+Fe ₂ O ₃ 5g
45.6	90.0	85.4	94.6	158	0.830	0.713	2	4.5 -	32-106	Feldspar20g+Fe m.5g
43.7	89.1	84.9	93.2	178	0.728	0.732	3.5 -	7 -	33-100	Feldspar20g+Fe nano1g
49.6	91.2	86.4	95.9	165	0.967	0.724	22	4.5	38-115	Feldspar20g+NiO5g
40.6	88.0	83.8	92.2	170	0.817	0.727	1	5.5 -	33-99	Feldspar20g+Ni m.5g
46.7	90.4	85.7	95.2	167	0.768	0.710	7.5	6 -	35-105	Feldspar20g+Ni nano1g

Conclusions.

In the present work, it was successfully produced liquid with novel specifications by using vacuum thermal degradation with nanocatalyst supported on feldspar in a comparison with metal and metal oxide catalysts. The results are clearly depends on the physical properties improvement that makes liquid product as good as an alternative fuel.

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