STUDY OF AN OIL RECOVERY SYSTEM FOR WASTE PLASTIC

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Abstract: Recently disposal in landfill sites has become a serious environmental problem because of the increasing volume of waste deposal. A variety of large capacity processes for waste plastic have been proposed from an environmental perspective. In this study, thermal decomposition of waste plastics including polyethylene (PE), polypropylene (PP), polystyrene (PS) was made using a designed batch plant that is an external heat type thermal decomposition batch type furnace capable of processing 500kg of waste plastic a day. The oil product yield of three kinds of waste plastics by thermal decomposition was compared and the trend of the recovery rate was analysed.

Key Words: liquefaction; polyethylene (PE); polypropylene (PP); polystyrene (PS); thermal decomposition; fuel

1. Introduction

Plastic has become something which is essential to our lives and 15,000,000 tons is produced annually in Japan. The quantity of waste plastic is 10,000,000 tons annually, which accounts for 67% of general waste. Therefore, recycling technology for plastic waste is required. Decomposition of waste plastic into fuel oil is one of the treatment methods that have been proposed for waste plastic recycling as an energy source. In this study, PE, PP, PS and their mixtures were thermally decomposed using a designed batch plant. After the reaction, the resulting oil recovery rates for various conditions were examined.

2. Experiments

2.1 Materials

The samples employed were PE, PP, PS and their mixtures. PE and PP were pure plastic pellets and PS was ingot. The mixed plastic was actual waste plastic from food packaging and industrial waste such as films, packs, etc.

2.2 Apparatus

The process of oil recovery from waste plastic is shown in Fig. 1. This small-sized waste plastic liquefaction plant is manufactured by MAEDA Seisakusho Co., Ltd., and designed to treat PE, PP, PS and mixtures of these substances. It is an external heat type batch type furnace which has two tubular reactors of diameter 70cm and length 200cm and capable of processing 500kg of waste plastic a day. It is quite easy to run and once the reaction is started, it is possible to run it almost automatically through to completion. The sample is heated and decomposed in this device, separating into liquid product, the residue and gas.

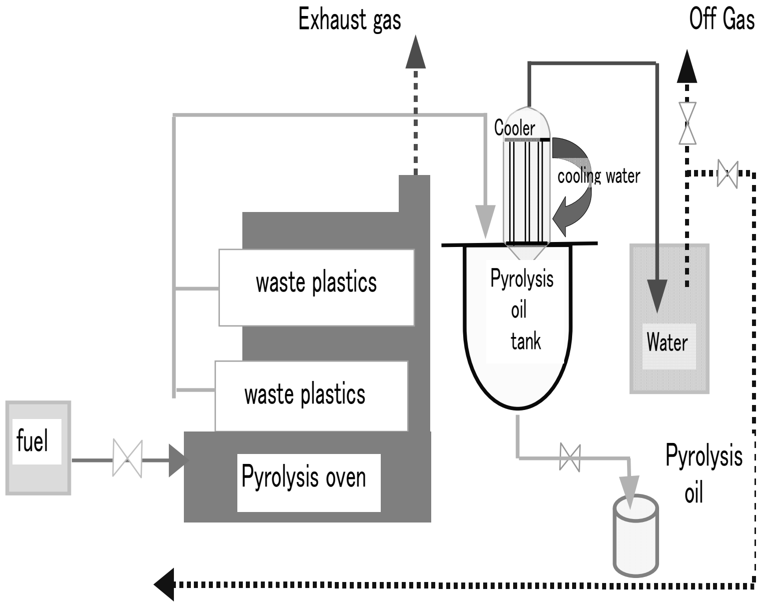

Fig. 1 The small-sized waste plastic liquefaction plant

2.3 Experimental Method

The quantity of samples was 250~500kg, and the temperature set was 500~590℃, the reaction time was 6 to 10 hours and the product yield was measured. Two sample lots consisting of the same amounts of material were put in the two batch type reactors under a standard pressure N_2 atmosphere. After nitrogen substitution, nitrogen was stopped and operation was started. The plant was to be stopped when the quantity of the produced gas decreased. The recovery rate of oil and a residual substance was measured after cooling, and the rate of gas recovery was calculated in total.

3. Results and Discussion

The thermal decomposition product yield of PE, PP, PS and their mixtures are shown in Tab.1.M-1,M-2 and M-3 show the single material experiment using PP, PS, PE. M-4, M-5 and M-6 shows the results from of two plastic mixtures and M-7, M-8, M-9 and M-10 shows the results from three plastic mixtures.

Tab. 1 The sample constitution and product distribution

Run NO	Set Temp (℃)	Sample Quantity (Kg)	PE	PP	PS (%)	Gas	Oil	Residue
M-1	500	200	0	100	0	7.5	93	0.1
M-2	560	300	0	0	100	5	94	1
M-3	545	257	100	0	0	37	63	0
M-4	570	99.7	0	62	37	20	77	3.4
M-5	570	158.5	80	20	0	24	82	3.2
M-6	590	140	43	0	57	15	77	8
M-7	570	202	16	53	31	20	74	6
M-8	560	234	26	37	37	18	77	5
M-9	420	200	50	25	25	9.5	90.5	0.1

Fig.2 shows a graph of product yield of the three single material separately. In case of PP and PS after thermal decomposition, more than 90% was collected as the liquid product, but in case of PE thermal decomposition, liquid yield was 63% and the gas product was abundant.

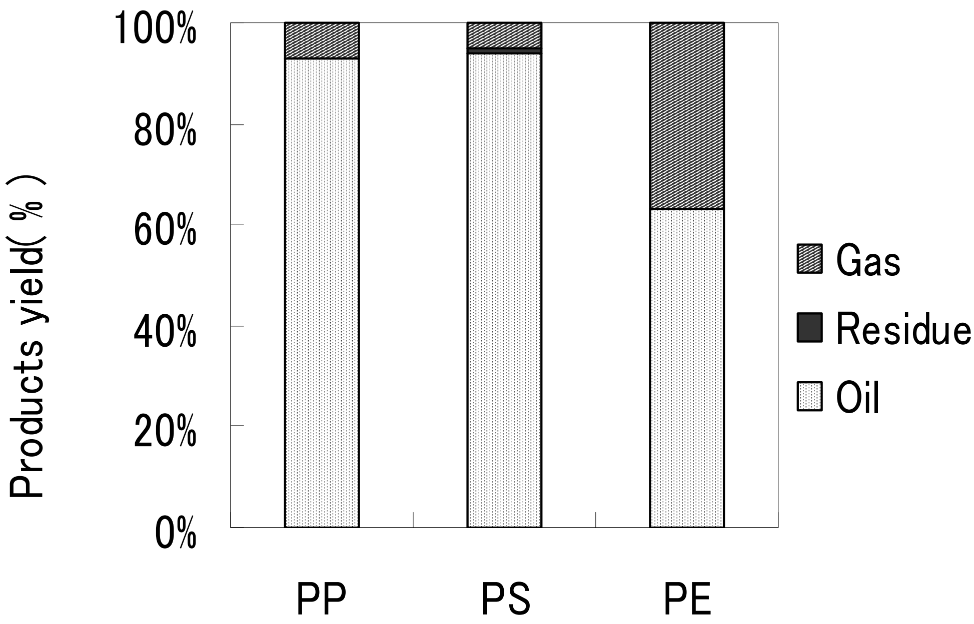

Fig.2 The effect of 3P single unit for products yield

Supposing that the additive rule applies, the recovery rate of produce yield of mixture of 2 and 3 plastics was calculated and was compared with the values actually observed. (Fig.3 and Fig.4)

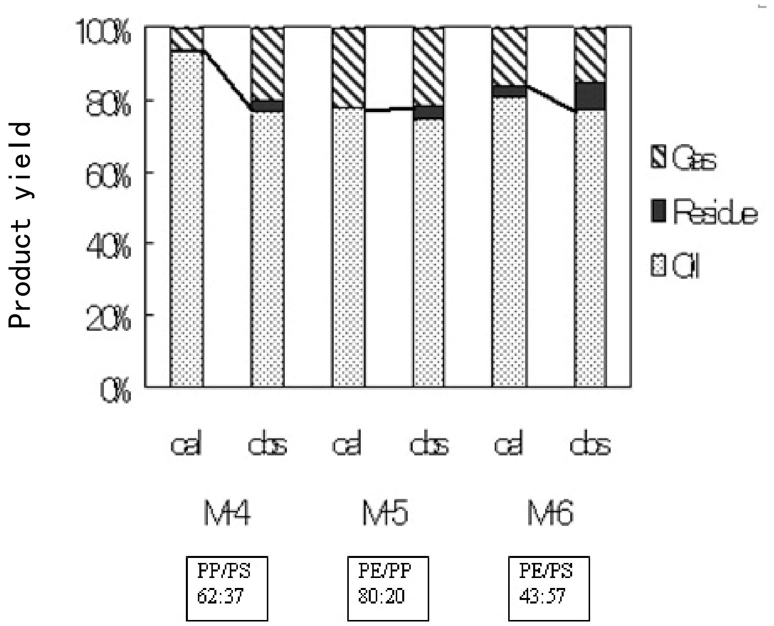

Fig.3 The effect of two plastic mixtures on product yield

In case of the mixtures of PE and PP (M-5), PE and PS (M-6) , when calculated values are compared to the observed value, the additive rule relatively applies, although the residue increased and the liquid product decreased a little.

However, in case of the mixture of PP and PS (M-4), the observed value is below the calculated value.

There is the similar trend in the experiment of mixtures of three plastics. However, in M-7 and M-8, the residue increased but the gas is half the calculated value and the liquid decreased. When M-9 is compared with the calculated value, the liquid has increased.

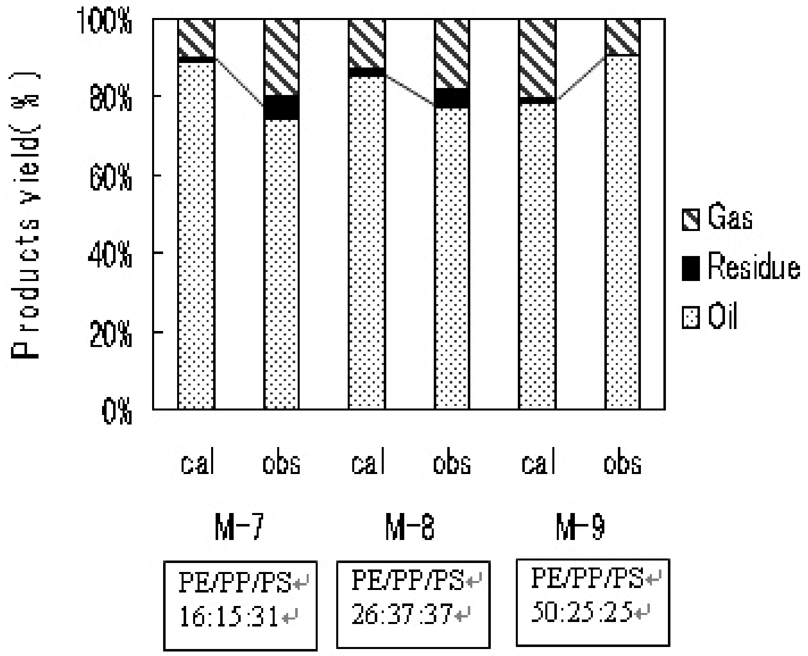

Fig.4 The effect of three plastic mixtures on product yield

In the case of mixed plastics, there is no strong correlation in particular in mixing rate and a liquid yield. As the whole, a liquid yield is lower than a calculated value, and the observed value has much residue. It is possible that the yield of the pure plastics used for the calculated value is too high as a reason. Especially the liquid yield of PP and PS is over 90%. It is necessary to verify the difference between the reaction conditions at this time, and the reaction conditions of other experiments. Moreover, in the case of M9, the liquid yield of the observed value is higher than a calculated value. Only in the case of M9, the liquid yield of the observed value is higher than a calculated value.Let it be a future subject to carry out comparison examination of the reaction conditions of M9 with the reaction conditions of other experiments. The reaction conditions of each experiment will be verified from now on, and it will search for the reaction conditions for the improvement in a liquid yield.

Tab. 2 Analysis of Produced Oil

	PS	PE-PS mixed	PE-PP mixed	PE-PP-PS mixec	Heavy oil
Flash point(℃)	32/32	9.0	4.5/4.5	-7.0	>40
Density(g/cm3)	1.0	0.9	0.8	0.9	0.70～0.95
Ash(%)	0.0	0.0	0.0	0.0	
Element analysis(%)					
C	90.8	88.6	85.7	88.3	82.0～87.0
H	9.0	10.1	13.4	11.8	11.7～14.7
N	0.2	0.9	0.9	0.0	0～1.0
S	8.0	0.0	-	0.0	0.1～3.0
O	0.1	0.6	0.5	0.0	0～0.1

Tab. 2 shows the analysis of the produced oil. Because it resembles the features of heavy oil, liquid product derives from waste plastics can be used for power generation or as a fuel for boilers.

4. Conclusion

PE, PP and PS were decomposed in an external heat type batch type furnace of 500kg/day of practical scale and the recovery rate of product oil was compared for both the single unit and the mixtures. The tendency of formation oil recovery factor of two plastic mixtures and three plastic mixtures was analysed on the basis of the result of actual scrap material processing data.

(1) The small-sized waste plastic liquefaction plant which is used for this research is able to process each single material and to process the mixtures.

(2) In the observation, formation oil yield in case of the single material with PP and PS is 90%, but PE is low at of 60% output generation, while gas formation ratio is high.

(3) In the case of mixed plastics, there is no strong correlation between the mixing rates and the liquid yield. As a whole, the actual liquid yield is lower than the calculated value, and

greater residue was observed. It is possible that the yield of the pure plastics (PP and PS) used for the calculated value was too high.

(4) Only M-9 showed a liquid yield that is higher than the calculated value.

(5) In this research, the relationship between the mixing rates of plastics and the product yield was observed. In the future, in addition to this, the temperature conditions in the reactor will be verified.

(6) Thermal decomposition formation oil yield of the mixtures averaged approximately 75%. According to the analysis of the formation oil, it was verified that it is usable as an alternate fuel.

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