Liquefaction of Waste Plastic by a New Type Reactor (KUROKI PROCESS-6)

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The authors have developed a new visbreaker type reactor (KUROKI PROCESS-6) in order to reduce the effect of temperature gradient in the molten polymer, to carry out the thermal decomposition in continuous operation. In this paper, the results of polystyrene thermal decomposition in a continuous operation (100 kg/h, 3-4 ton) using this reactor is described. As a result, a new type reactor is able to prevent the formation of carbon. The yield of oily products and carbon residue were on the average 93 wt% and less than 3 wt%, respectively.

Introduction

Waste plastics liquefaction plants have been constructed and examined for the purpose of recycling the enormous quantity of waste plastics into resources and energy [1].

This is due to the enormous problems remaining regarding the plant capacity and the property of produced oil from conventional equipment. For example, attempts were made to carry out the decomposition reaction at a high temperature so as to improve the performance, but it not only accelerated the production of carbon or coke which gave a critical interference to the operations, but also caused deterioration of the oil property [2].

Most of the waste plastic liquefaction apparatus has a stirred tank type reactors [3]. The product cost using such a reactor is two or three times of commercial A-grade heavy oil [1][4]. As this process is relatively expensive compared to other recycling method, and it is why this not in practical use. The main problem that prevents the continuous operation of reactor is the carbon deposition on the heating surface (inside wall of the reactor) and the effusion pipe lines.

Thus the authors have developed a new visbreaker type reactor (KUROKI PROCESS-6) in order to reduce the effect of temperature gradient in the molten polymer.

Materials and Methods

Sample

Waste polystyrene foam tray (briefly "waste PS") was used as a sample.

Reactor and Procedure

The reactor used for the experiment is a visbreaker type and capable of processing 100kg of waste PS per hours. It consists of a screw-system melter for the sample melting and put into the reactor vessel a drum screw. The flow sheet is shown in Figure 1.

The structure of this visbreaker type reactor is markedly different from the conventional tank type reactor. The tank type reactor discharges decomposition vapor only using self-pressure from the melting polymer (tank contents) in the reactor pot, while this reactor has structure that eliminates vapor (volatile product) forcibly from polymer liquid phase. Furthermore, extracts high-viscosity liquid phase component as visbreaking oil and circulate and redecompose it in the same reactor. The extracted component is high-viscosity liquid phase component precipitated in the bottom of the reactor.

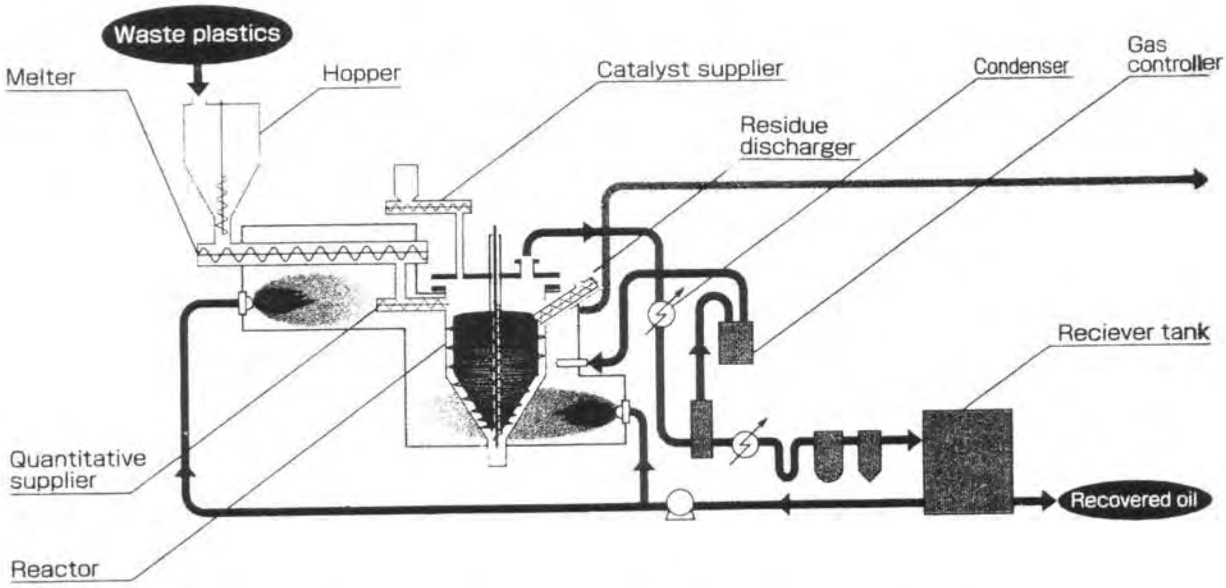

Figure 1 Flow sheet of the new visbreaker type reactor (KUROKI PROCESS-6)

Waste plastics (waste PS only for thermal decomposition) are fed from the hopper into the melter at a constant rate.

The polymers are also thermally decomposed partially in the melter and sent into the reactor using screws. The decomposition temperature in the reactor is 350-500℃. Polymeric component in the bottom of the reactor is pumped up with the screw-pump set in the center of drum screw and sent back to the top of the reactor as visbreaking oil.

Decomposed product is discharged from the upper side of the visbreaker.

Results and Discussions

Table 1 shows the results of continuous operation for 37 hours (feed rate 100kg/h) at 430 ℃ of waste PS foam tray which melted with pre-heating. The feed rates were 120kg/h through from 30 minutes (early stage) to 10 hours, and an average 100kg/h after 10 hours. The recovery ratio of oily products was 80-90 wt% (average 85wt%) for the first 10h, however, a small quantity of the unreacted polymer was found in the residue recovered. The lower yield has resulted from a high feed rate which was too high for the decomposition temperature of 430℃. A high rate of yield was recovered when the feed rate was decrease to 100 kg/h after the 13 hours of reaction time.

At the constant feed rate of 100kg/h, the recovery ratio was 90-98 wt% (average 93 wt%) after 20 hours. Other product was were 2-3 wt% carbon residue (including for pitch and tark (SiO_2) and the balance gaseous products (CH_4, CO_2) and water.

Table 1　Data on thermal decomposition of waste polystyrene foam tray

Reaction time (h)	1	2	4	9	13	21	25	29	33	37
Sample feed rate (kg/h)	90	120	119	125	108	100	100	100	60	70
Yield of oily product (wt%)	60	90	83	80	86	85	93	100	100	90
Components (wt%)										
Benzene	2	2	2	2	2	2	2	2	3	2
Ethylbenzene	2	2	2	2	3	2	2	2	2	3
Styrene	65	67	66	64	59	64	65	65	65	63
α-Methylstyrene	2	3	3	3	4	3	2	3	3	3
2,4-Diphenyl-1-butene	10	10	10	10	10	10	10	10	10	9
2,4,6-Triphenyl-1-hexene	5	6	7	7	7	7	8	7	2	7
Isomeric dimer and trimer	14	11	11	12	15	13	11	12	17	13

Reaction temp. = 430℃

The yield of each constituent indicated a constant rate, but both yields of isomeric dimer (2,4-diphenyl-1-butene) and trimer (2,4,6-triphenyl-1-hexene) constituents increased after 13 and 33 hours of reaction but the cause is unknown. However, since the increase of isomeric dimer correspond to decreasing trimer yield, it is suggested that a redecomposition of the trimer fraction took place in the molten polymer matrix. Table a shows the properties of oily products.

The present reactor developed satisfies the above requirements of reactor operation. In this experiment, is was possible to obtain a high yield oily products with a small amount of carbon deposits, and also to carry out the decomposition at a high temperature while removing the residues.

Conclusions

As a result, a new type reactor is able to prevent the formation of carbon deposit and to control the effect of temperature gradient in the reactant. The yield of oily products and carbon residue were on the average 93 wt% and less than 3 wt%, respectively.

References

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