Status of a New Waste Plastics Recycle Process for Power Generation

Tomoko Kaneko*, Ryoukichi Yamada, Shuntarou Koyama,
Masayoshi Kokubo (Hitachi, Ltd., Japan)
Tokunori Matsushima (Hitachi Engineering & Service Co., Ltd., Japan)
Akira Nishida (IPA, Japan)
E-mail:tkaneko@erl.hitachi.co.jp, Fax:+81-29-276-5783

Parametric test on Liquefaction of waste plastics was performed using a 200 kg/h pilot plant. The oil yield varied with pyrolysis temperature and reached 80 % in the range of 400-430℃. The cetane index of produced oil varied with a polystyrene content in feedstock and a operating condition of a reflux condenser. Under the combustion performance test using produced oil, a diesel engine ran smoothly and generated electricity with a high efficiency of 35 %. Exhaust emission characteristics met regulations for conventional diesel engines.

Introduction

Much attention has been paid to energy production from waste plastics. We have developed a diesel power production system using the oil recovered from waste plastics pyrolysis. In this development, we have focused on the quality of oil and whether it would be able to replace conventional fuel oil or not. The efficiency of power generation and the environmental performance are also of great importance. The 200 kg/h pilot plant tests have been programmed so as to improve and address those concerns. The present study shows the results of plastics pyrolysis and oil combustibility as a way to evaluate a new waste plastics recycle process.

Raw Materials and Methods

Polyethylene(PE), polypropylene(PP) and polystyrene(PS) were chosen as raw materials and were mixed depending on the test.

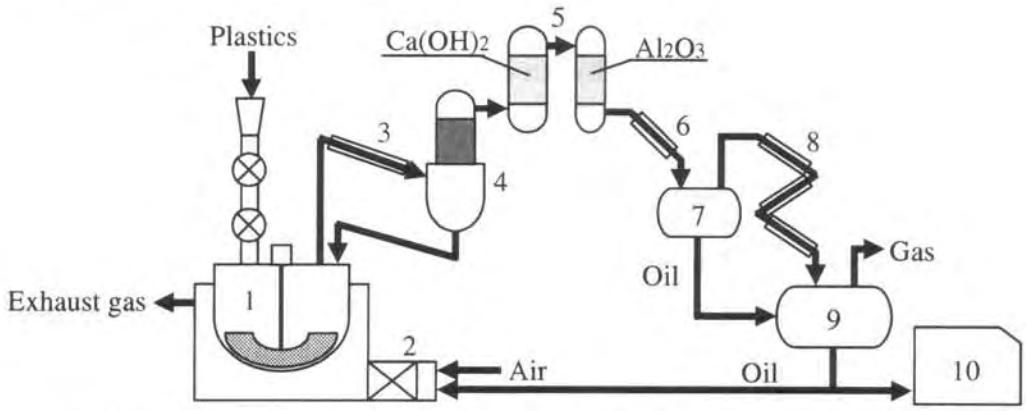

Fig.1 Schematic diagram of plastics pyrolysis and diesel power generation plant: (1)pyrolysis reactor, (2)catalytic combustor, (3)1st condenser, (4)reflux condenser, (5)de-chlorine reactor, (6)2nd condenser, (7)oil separator, (8)3rd condenser, (9)oil tank, (10)diesel power generator.

Fig.1 shows the schematic diagram of the waste plastics pyrolysis and diesel power generation system. The main features of this system are as follows;

1. Heavy components of the pyrolysis gas are separated in the reflux condenser and are refluxed into the pyrolysis reactor. This enables the produced oil to become lighter oil.
2. Both organic and inorganic chloride in the pyrolysis gas are removed by the $Ca(OH)_2$ and activated Al_2O_3 packed column.
3. The catalytic combustor heats the pyrolysis reactor uniformly and burns the produced oil cleanly.

Results and Discussions

Pyrolysis characteristics

Fig.2 shows the typical daily start and stop (DSS) operating characteristics of the pyrolysis process. At first, about 100 kg of plastics were charged as a initial provision in the pyrolysis reactor and then were heated by the catalytic combustor. When the pyrolysis temperature was near 400℃, additional material was fed continuously and the temperature was kept constant (a continuous feeding process). After the feedstock was introduced, the reactor was further heated in order to decompose the remains in the reactor (a drying process). When oil produce became constant, the combustion fuel was stopped. The time for continuous feed depends on the amount of feedstock that must be treated in a day. The following tests were carried out in the above procedure.

Oil, residue and gas yields are shown in Fig.3. More than 80 % of oil yield can be obtained below 430℃.

Fig.4 and 5 show the cetane index (CI) of produced oil. CI defines the ignitability, which is the most important property of diesel fuel. As the PS content of feedstock increase, CI of produced oil decrease. Compared to

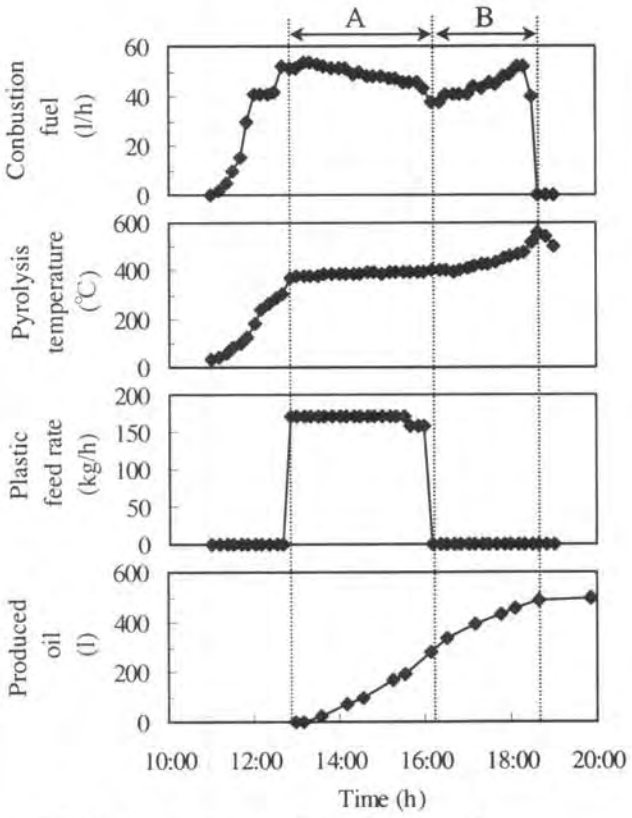

Fig.2 Operating conditions and results: A; continuous feeding process, B; drying process (material; PS 25 %, PE 35 %, PP 40 %).

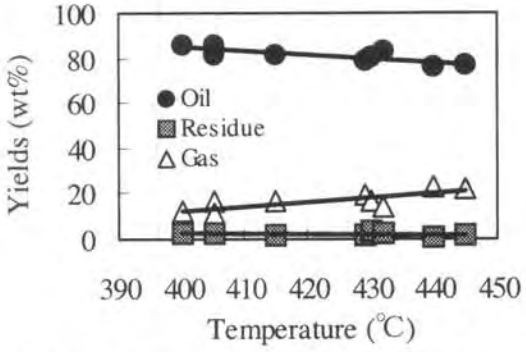

Fig.3 Oil, residue and gas yields as a function of pyrolysis temperature (materials; PS 10-25 %, PE 35-40 %, PP 40-45 %).

paraffinic oil, both aromatic and olefinic oil have low cetane index [1]. Since most pyrolytic products of PS are aromatics [2], oil recovered from the PS rich feedstock have low CI. Fig.5 shows the effect of reflux temperature on the CI of produced oil. A lower reflux temperature, decreased CI of produced oil. Under the lower temperature condition, the ratio of heavy fraction refluxed into pyrolysis reactor increase. Since the most refluxed fraction is decomposed to olefins, CI of produced oil becomes a lower value. CI of 27 or more is required to ignite the diesel engine smoothly [3]. Generally, oil produced from plastics that contain more than 25 % of PS is hardly applicable. However, it is possible to improve the CI by controlling the reflux temperature; that is quite useful to apply the waste plastics widely in this process.

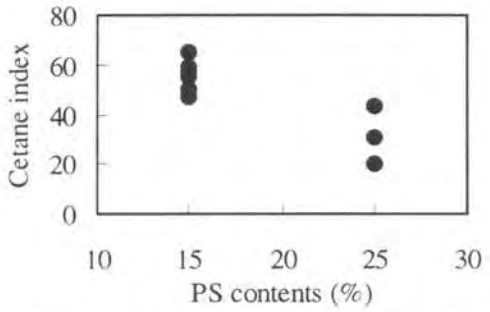

Fig.4 Relationship between PS contents of feedstock and cetane index of product oil (pyrolysis temp.; 400-445℃, reflux temp.; 200-282℃, PE content; 35-40 %, PP content; 40-45 %).

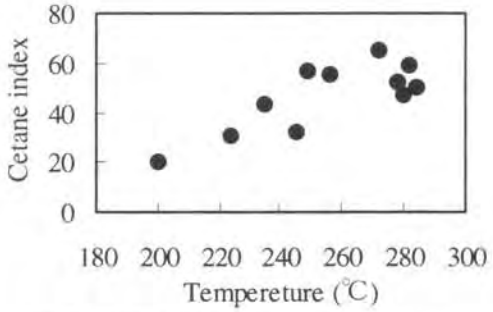

Fig.5 Effect of reflux temperature on cetane index of product oil (pyrolysis temp.; 400-445℃, PS content; 10-25 %, PE content; 35-40 %, PP content; 40-45 %).

Characteristics of long-term operation

Economical production of oil has led to increases for the rate of operation. The DSS operation as shown in Fig.2 requires a daily drying process, which loses time in the continuous feeding process. When a large amount of plastics is wasted daily, a DSS operation without the drying process is more economical. In such a case, the residue is accumulated day by day in the reactor bottom that seems to influence the controllability and pyrolysis performance of the reactor. Fig.6 shows the operating characteristics for an 11 day operation. This operation contains the initial charge process, 10 days DSS operation without the drying process and drying process on the final day. The plots in each day show the average value during the continuous feeding process. In this operation, feeding rate of plastics and pyrolysis temperature were conducted at 200 kg/h and 400℃, respectively. In order to keep the reflux temperature at 260℃, feeding rate and pyrolysis temperature were controlled. Gross oil yield determined by the next equation increased during the first 3 days and then slightly increased.

Gross oil yield = (Accumulated oil produced / Accumulated plastics feeded) × 100

The amount of residue was measured by its height before starting the daily operation. It also increased during the first 7 days and remained constant after that. Gross oil yield increased 6 % on the 11th day. This shows the importance of the drying process even for the long-

term operation. The oil yield of 80 % is the same level as the results by DSS operation. Through the 11 days operation, 6 tons of feedstock was treated. The accumulation of the residue will not affect both the difficulty of temperature control and the oil yield.

Performance of diesel engine

In our process, produced oil is provided to the diesel power generator directly. Electric power efficiency, which is calculated using a fuel consumption rate and a generated electric power, was achieved about 35 %. The properties of exhaust gas from the diesel engine cleared the regulatory standards. They are favorable even when compared with kerosene. The diesel engine has run without trouble for more than 1100 h so far. We will continue further test to establish the reliability.

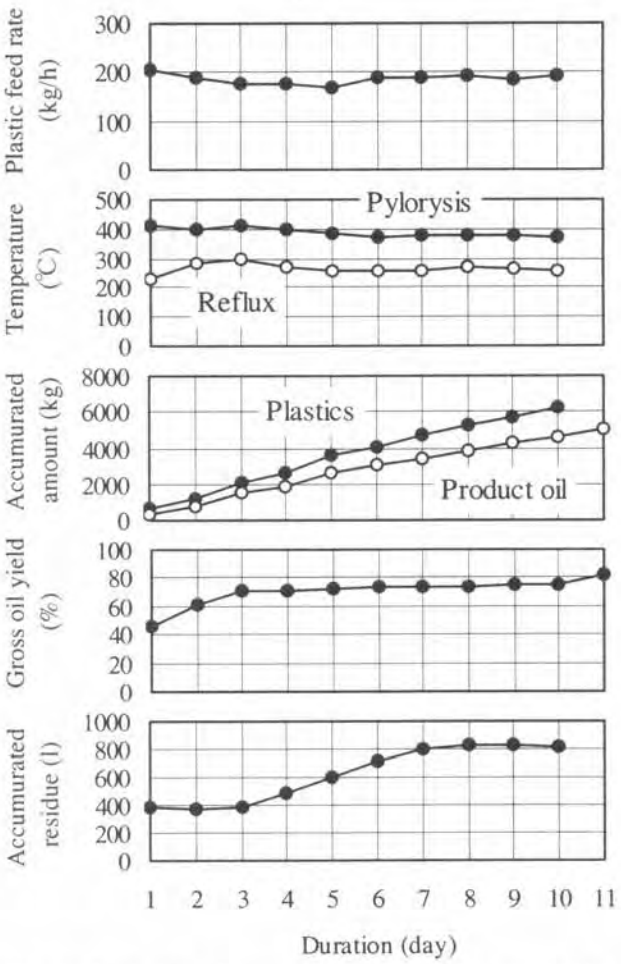

Fig.6 Operating characteristics for 11days operation (material; PS 25 %, PE 35 %, PP 40 %).

Conclusions

For the purpose of developing a diesel power generation system using the oil produced from waste plastics, we carried out pyrolysis tests using the pilot plant and obtained the following results.

(1) Oil yield reached 80 % when the pyrolysis reactor was operated in the range of 400-430℃.

(2) Cetane index of produced oil decreased with PS contents of feedstock and increased with reflux temperature.

(3) Electric power efficiency of diesel generator using produced oil was about 35 %. The properties of exhaust gas from the diesel engine cleared the regulation.

Acknowledgments

The pilot plant tests were performed under the sponsorship of Clean Japan Center. The authors express their gratitude to the members of organizations.

References

1. Tasaka, H.; Satou, T. *"Nainenkikan", p.46, Japan, 1995*
2. Inaba, A.; Inoue, H. *Kagaku kougaku ronbunsyu, 5, 243-249, 1979*
3. Kaneko, T. et al. *Trans. IEE of Japan, 118-C, 9, 1263 – 1269, 1998*