A Process of Municipal Waste Plastic Thermal Degradation into Fuel Oil

E. Sugiyama*[1], H. Muta[2] and H. Ibe[1]
[1]Environmental Control Systems Engineering Department, Government and Public Corporation Systems Division, Toshiba corporation
1-1, Shibaura 1-Chome, Minato-ku, Tokyo, Japan
[2]Plant & System Department, Isogo Nuclear Engineering Center, Toshiba corporation
8, Shinsugita-cho, Isogo-ku, Yokohama, Japan
E-mail: eiichi.sugiyama@toshiba.co.jp FAX: +81-3-5444-9411

We have developed system for oil reclamation with municipal waste plastic material. With a small scaled model plant, we have collect data for organizing a commercial plant since 1997. Recently, we have established the process of the system. It can dechlorine polyvinyl chloride and produce oil from waste plastics.

Based on data collected , a new plant scaled up is under design and construction. It will be available for commercial operation at April in 2000. It will be able to treat approximately 40 tons of waste plastics a day.

In the beginning of process design, the process has been studied through risk analysis. The analysis consists of HAZOP(Hazard and Operability studies).The result of HAZOP has been applied to the process design and planning of the operation.

Introduction

It is a fact known that thermoplastic can be recovered to oil by thermal cracking. So thermal degradation has been regarded as one of the measures.[1]
However, municipal waste plastics has a much variety of resins. Figure 1 shows breakdown of total plastic waste by resin varieties. [2] Firstly,it is necessary to decrease the chlorine contents of mixed plastics that suffers structures and product oil. Thermal degradation of the PVC produces gaseous hydrochloric acid (HCl) at 270 to 360 ℃ and makes possible of the dechlorination of PVC. We have investigated such technology and process with operating the small scaled plant installed in our factory since 1997, and established a process of municipal waste plastic thermal degradation into fuel oil.

The design and construction of the plants which use the process(Toshiba Oil Reclamation System) is in progress.

Process outline

The objective of Toshiba Oil Reclamation System is as follows.

1) Oil, residue, and HCl produced by the degradation of mixed waste plastics is available to industrial use.
2) The process includes the dechlorination process of PVC.
3) Energy and thermal balance of the process perform in a high efficiency.
4) Safety measures are taken in every part of the process based on hazard analysis.
5) Product oil is collectable in safe and simple measures.
6) Residue derived from the degradation process is collectable in safe.

Figure 2 represents the flow sheet of the process. Figure 3 shows typical material balance of the process.

Process description

The total system contains seven processes. It consists of pelletizing, dechlorination, degradation, oil refining, HCl treatment, exhaust gas treatment, and wastewater treatment (as Figure 4).

1) Pelletizing process .

This process includes a shredder by disintegrating rotors, a dryer and a pelletizer.

Shredded and dried waste plastics is pelletized to $\phi 6 \times 10$mm of pellets whose bulk density is approximately 0.4.

Pelletized waste plastics is stored in a silo and fed to the next process by a conveyor .

2) Dechlorination process

This process is equipped with a hopper, a reservoir, an extruder, and a buffer vessel . The hopper and the reservoir are filled with pellets ,and initial oxygen gas in this process is purged with N2 in advance. And pellets are supplied continuously to the extruder. Inner temperature of the extruder is controlled to be approximately 350℃ with electrical heaters and cooling fans.

Chlorine contained in PVC becomes gaseous HCl at the extruder and the vessel.

Melted plastics is dechlorinated as much as possible there to be gaseous product and slurry product. The gaseous product that has hydrocarbon is burned at HCl treatment process. The slurry product is carried into a thermal reactor in the degradation process.

3) Degradation process

This process is equipped with a thermal reactor, a recirculator, a pipechained conveyor, a hopper ,etc. Melted plastic is supplied to the thermal reactor that has many ceramic balls inside. Agitation of the balls prevent inner surface of the reactor from coking.

Dechlorinated plastics is heated up to approximately 450 ℃ and changed to gaseous products and residue.

Fine particles of residue are discharged from the thermal reactor and carried to the hopper with the spiral conveyor.

Gaseous product is supplied to the oil refining process.

4) Oil refining process

This process is equipped with a cracked gas ejector, a cracked oil storage drum, an feed/fractionator bottom heat exchanger, distillate coolers, fractionator, a furnace, a feed gas scrubber, an off gas scrubber, an oil tank, etc.

Oil gas derived from the reactor is cooled with the ejector and supplied to the cracked oil storage drum where Terephthalic acd and dregs are deposited and cracked oil are stored. A part of the stored oil in the drum is cooled for the cooling source of the ejector . The other of the oil is heated up and sent with a pump to the fractionator and cracked to yield a few kinds of fuel oils.

Gaseous product from the drum is carried to the feed gas scrubber.

Acidic gas derived from the top of the fractionator is send to the offgas scrubber where it is neutralized and treated. Treated gas is carried with a vacuum pump to the exhaust gas treatment process.

5) HCl treatment process

This process is equipped with a incinerator and scrubbers.

Gaseous product derived from the extruder and the vessel in the dechlorination process is fed to the incinerator that burns completely organic matter in itself.

Quenching water absorbs gaseous HCl and circulated until the purity of HCl is in design.

Residual HCl and acid gas is absorbed at the scrubbers in this process.

6) Exhaust gas treatment process

This process is equipped with a burner, a boiler, fans, a condenser, a water softener unit, a chimney, etc.Exhaust gas from the other processes is disposed to the air through a burner and a chimney in this process.

7) Wastewater treatment process

Wastewater of each process is carried to this process and disposed to a sewerline after proper treatments.

Discussion

This process handles flammable products, and fire and explosion at the plant must be preventive events in safety point of view.We have carried out hazard and operability analysis (HAZOP) at the earliest stages in the scaledup facility and performed quantitative risk analysis (QRA).

Many important fire and explosion scenarios were drawn and unimpornant scenarios were screened out. The criteria of the screening was both of occurrence probability and magnitude of the effect of each scenarios.

In the QRA we assumed the yardstick of the acceptable occurrence rate was $\sim 10^{-4}$/year and that of the acceptable magnitude was besed on fire loads calculated with amounts of flammable materials at each portion.

Important scenarios were studied as design condition in detail. And the process has been improved and optimized with the result of the assessment.

The primary safety measures are as follows

a) pelletizing process

・The conveyor can be stopped automatically and can be isolated with air-operated valve installed at the process boundary.

b) Dechlorination process

・Nitrogen is used to exclude oxygen, which protects materials from oxidative degradation ,and reduces the chance of fire and explosion.

・Thermocouples and electrical heaters are properly mounted and wired in the piping so that it's temperature might be controlled closely.

c) Degradation process

・The facility in this process, along with a part of dechlorination one, is segregated from areas of the other processes by protective screening walls against fire and explosion. And it is equipped with firefighting foam system.

・Important process parameters which includes temperature,pressure and oxygen concentration density of the critical parts of the process are monitored in the control room.

d) Oil refining process

・Material which has possibility to be blocked in the fracionator is removed at the cracked oil storage drum.

e) HCl treatment process

・Gaseous product will be shut by an isolating valve while enough water is kept in the feedwater tank.

f) miscellaneous

・Nitrogen gas receiver tanks and a backup supply system are installed to provide capacity needed for emergency.

Conclusion

We have established a process of municipal waste plastic degradation into fuel oil. One of the Toshiba Oil Reclamation System using this process is under construction. It is scheduled to be in commercial operation in the fiscal 2000, designed for a capacity of 14,800 tons per year of plastic mixtures including PVC resin. Figure 5 shows outline of the plant.

References

1.Fine Chemical,Vol.23 No.4 ,1994

2. PlasticWaste Management Institute ,PWMI Newsletter, No.18,1999.7.

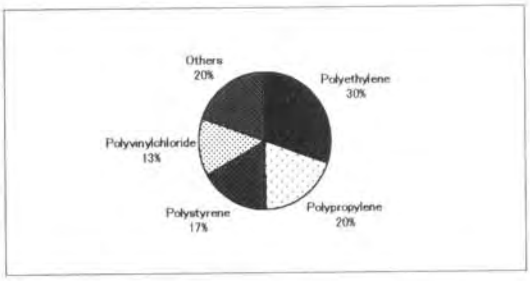

Fig.1 Total plastic waste
By resin varieties [2]

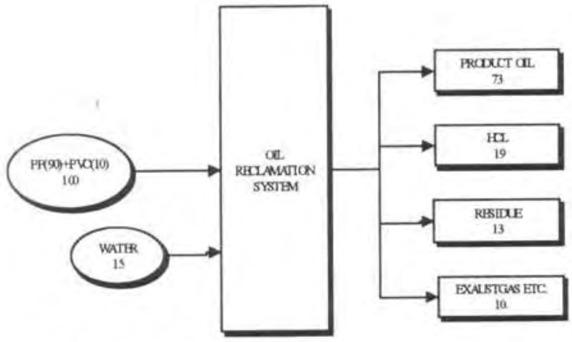

Fig.2 Example of Material balance of
Oil reclamation system

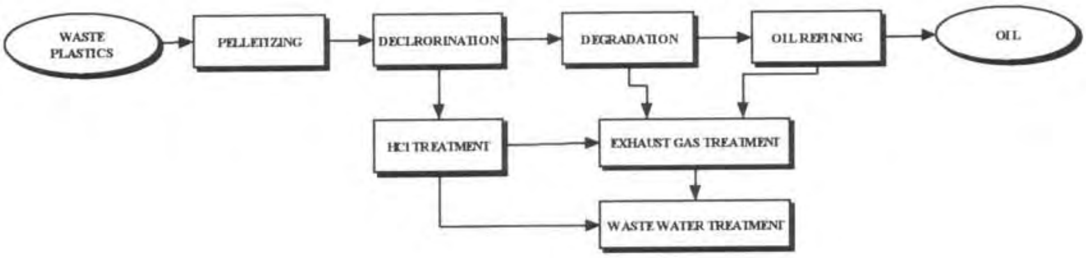

Fig.3 Process flow chart

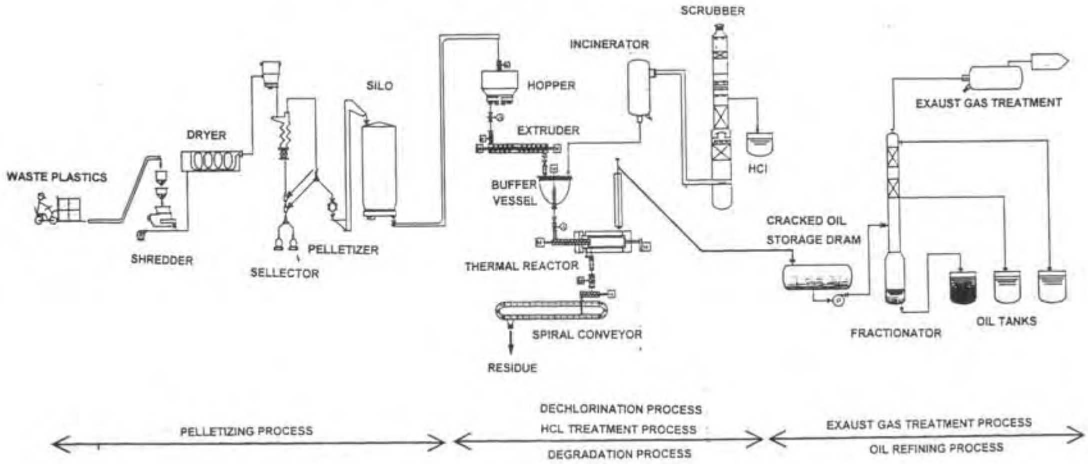

Fig.4 Outline of typical process flow diagram

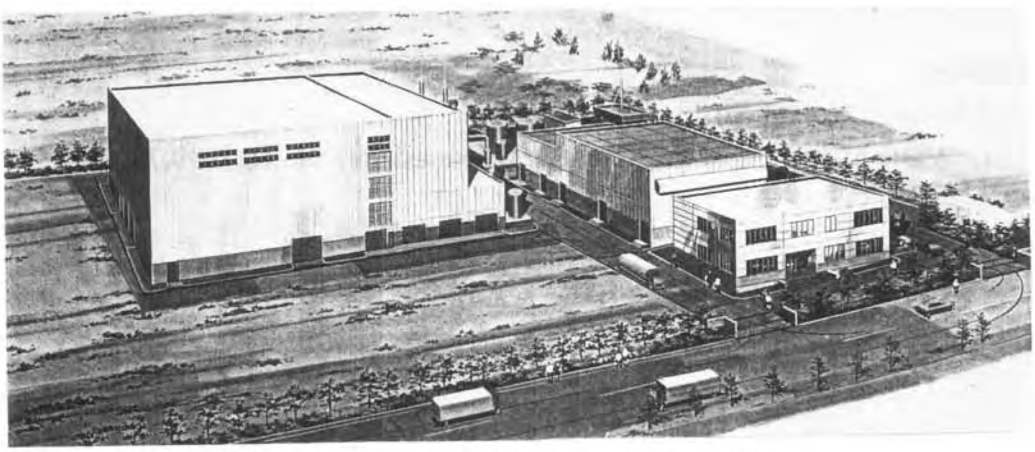

Fig.5 Bird's-eye view of a typical plant