Waste Treatment Using Induction-Heated Pyrolysis

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1. Introduction

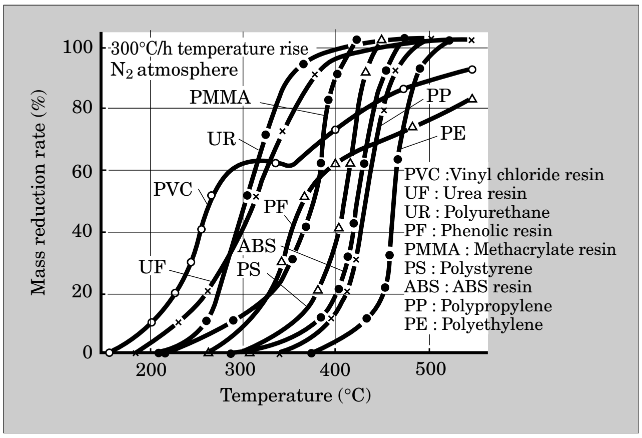
Japanese waste treatment policy has been developed with emphasis on incineration, aiming to reduce the quantity of waste at final landfill sites. Although incineration has been the major waste treatment method until now, the recent increase in quantity and diversification of types of waste are forcing a shift in policy from the exclusive promotion of waste incineration to policy that also promotes reduction of waste generation itself as well as reduction of waste quantity through reuse of the waste and its restoration as a resource.

Also, the negative environmental impact of emissions from incineration, including atmospheric and soil pollution, has become problematic and advanced technologies are required especially to limit the generation of dioxins.

At present, 50 million tons of general waste is generated annually (including about 4 million tons/year of waste plastics), of which about 75% is incinerated. Associated with this incineration are important issues that must be resolved.

As an alternative to incineration, pyrolysis technology was developed in the 1970s to limit the generation of dioxins. This is a technology for decomposing organic materials into gases, liquids and solids by heating them in an atmosphere where there is little or no oxygen content. Its practical use and popularization in the future is expected.

Fig.1 Pyrolysis temperatures and mass change of various types of plastics



Heat sources generally utilize combustion heat (as hot air, steam, exhaust gas etc.) of fossil fuels (oil, gas, coal etc.). Heating of the pyrolysis tank by electric resistance heaters is also utilized.

Fuji Electric has manufactured an induction-heated kiln type continuous pyrolysis demonstration apparatus, as an alternative to combustion type equipment, and performed experiments for treating waste plastics. An overview of this newly developed pyrolysis apparatus is presented below.

2. Pyrolysis of Plastics

2.1 Mechanism of pyrolysis

It is well known that plastics in general decompose into oil and gas when isolated from air (oxygen) and heated to 200 to 400°C. The progress of pyrolysis differs considerably depending upon the type of plastic and the pyrolysis temperature. An example is illustrated in Fig. 1. Polyvinyl chloride (PVC), for example, decomposes at 200 to 250°C primarily and at around 350°C secondarily, generating hydrogen chloride, hydrocarbons (gases and liquids) and solid (cinders). The decomposition is completed by most polymers at 250 to 450°C.

The combustion of organic compounds in the presence of air or oxygen generates carbon dioxide, steam and cinders (ashes) and, furthermore, combustion of plastics that contain chlorine such as PVC generates the problematic dioxins. Performing pyrolysis on these materials in an environment isolated from air (oxygen) causes dechlorination, breaking of C-C bonds and C-H bonds, or recombination with various ratios of generated gases, liquids and solids depending upon the different chemical structures and size of molecules and the pyrolysis temperature and speed. The resultant generated gases include carbon, hydrogen and hydrogen chloride and generated liquids include benzene and toluen, but no dioxins, which are compounds containing oxygen. The chemical structure of dioxins are shown in Fig. 2.

Fig.2 Chemical structure of dioxins

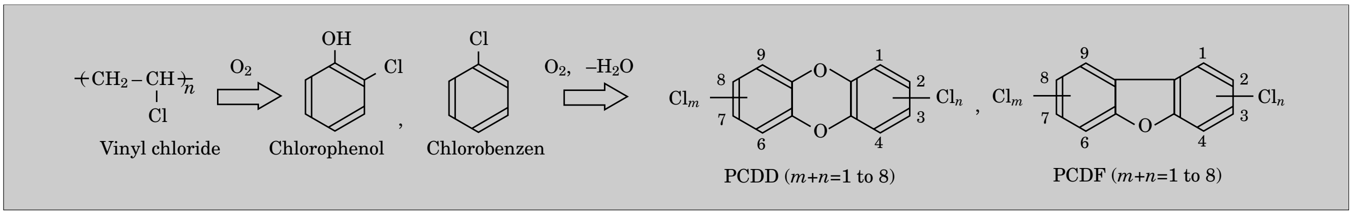


Fig.3 Pyrolysis process

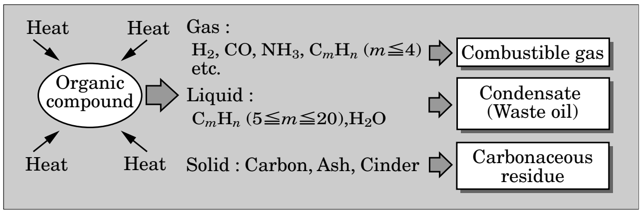
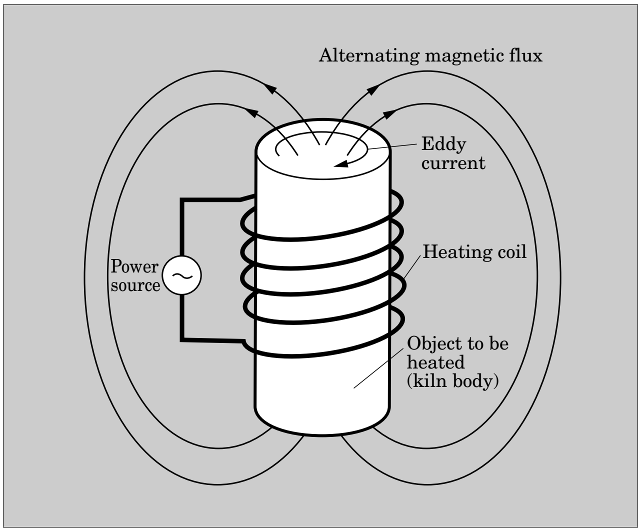


Fig.4 Principle of induction heating



The apparatus reported herein, a so-called dry distillation device, decomposes organic compounds by heating them in an environment isolated from gases such as oxygen, air, carbon dioxide and steam that contain oxygen, a factor which causes the generation of dioxins. "Dry distillation" is a process for decomposing organic compounds by heating them under no or lean oxygen conditions into the three flows of gas, liquid and solid respectively. The term "dry distillation" is used as a synonym for pyrolysis. Figure 3 shows the pyrolysis process.

2.2 Electric heating process for pyrolysis

Fuji Electric has been manufacturing electric heating systems for various types of heating processes. In the treatment of waste plastics, which has become a serious public concern, the problems are how to reduce waste volume while preventing the generation of dioxins, as well as how to progress toward the recovery of valuable materials and toward zero emission. Due to the present societal concerns, it is expected that practical application of pyrolysis technology to waste plastics will be realized. For wastes such as commercial waste having evident properties and consisting of a single type of waste, the treatment can be optimized by selecting a heating process suitable for the waste properties. But municipal waste involves different treatments for different types of waste, and this is why pyrolysis is needed. Electric heating is optimal for the required heating process, and induction heating is the most reasonable technology.

The principle of induction heating is shown in Fig. 4. When a metal body (kiln body) is inserted into a coil connected to an alternating power source, alternating magnetic flux flows through the kiln body. This flux induces electromagnetically an eddy current in the kiln body, which creates Joule heat, raising the temperature of kiln itself. This is induction heating. As the conditions of the enclosed atmosphere to be heated can be maintained at will, and temperature can be rapidly controlled, it is an excellent heating process for preventing dioxin generation.

3. Induction-Heated Kiln Type Continuous Pyrolysis Apparatus

3.1 Construction of apparatus and outline of system

The construction of the pyrolysis apparatus used for the demonstration test is shown in Fig. 5, the external view of the demonstration test apparatus in Fig. 6 and its specifications in Table 1. The demonstration test apparatus was manufactured for the purpose of treating waste plastics while suppressing the generation of dioxins. The plastics waste, which is collected in cities and towns, is fed into the input mouth and first compressed to a volume of about 1/15 through a screw feeder and then transferred to the kiln. The feeder is constructed such that the air from input mouth is automatically shut off and sealed by the compressed plastics waste. The kiln is constructed such that its interior is maintained at a very low oxygen condition by introducing N_2 gas into it and being insulating from the external atmosphere. As induction heating coils are installed at the periphery of the kiln body, the kiln body is heated by the induced heat directly, which heats up the input plastics waste. The temperature at certain points inside the kiln is measured by means of thermocouples, and feedback control is applied to maintain a predetermined temperature. The input plastics waste is heated up very

Fig.5 Construction of pyrolysis apparatus

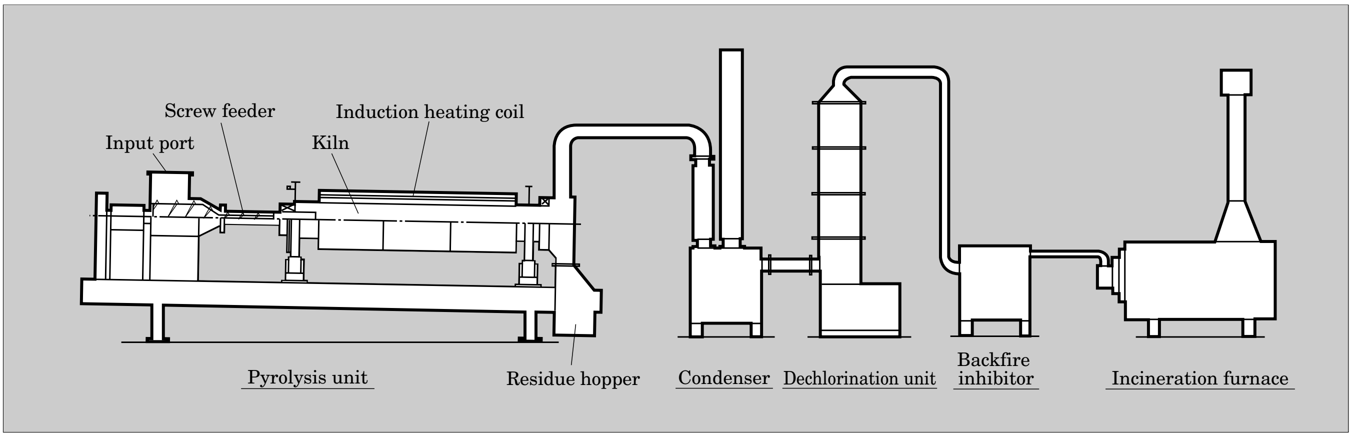


Fig.6 External view of demonstration test apparatus

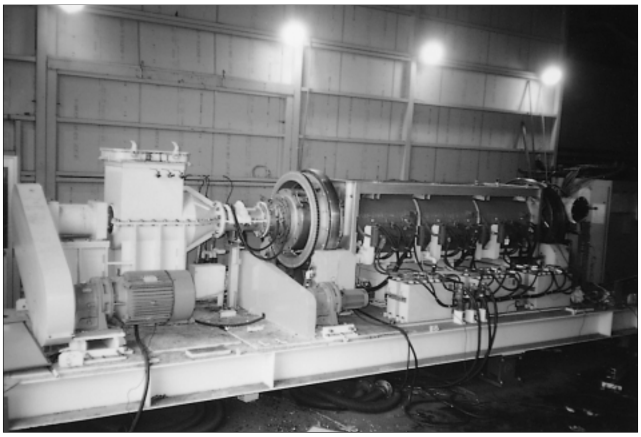


Table 1 Specifications of demonstration apparatus

Item	Specification
Waste plastics treatment capacity	100 kg/h
Kiln heating temperature	450 to 700°C
Pyrolysis temperature	500 ± 50°C
Heating method	Induction heating
Waste plastics input method	Screw feed mechanism
External dimensions of kiln	ø500×3,500 (mm) long
Atmosphere in kiln	Filled with N_2 gas
Dechlorination	Treated in later stage after heating in kiln
Heating power source capacity	100 kW

quickly in the closed space, kept at a high temperature of 500 ± 50°C, decomposed by pyrolysis in a very short time, and separated into carbonaceous residue and gas. The carbonaceous residue is fed to a hopper at the exit of the kiln. The gas is cooled in a condenser and separated into condensate and a combustible gas. The condensate is collected in a storage tank and the combustible gas is fed into a combustion furnace via a dechlorination unit and a backfire inhibitor.

3.2 Advantages of the apparatus

The apparatus has many advantages owing to the use of induction heating.

(1) Heating treatment method having a low possibility of dioxin generation

The generation of dioxins becomes prominent in an oxidizing atmosphere. As this method indirectly heats waste in a sealed inactive gas atmosphere without applying combustion flames directly to the waste to be treated, dioxin generation resulting from the existence of oxygen is extremely low in this treatment.

(2) Rapid heating and easy temperature control

The rapid heating property of induction heating makes rapid passing through the low temperature region (200 to 300°C) possible, where dioxins are apt to be generated. Furthermore, because induction heating has good temperature response characteristics, the apparatus is able to control temperature accurately and to keep the heated region at its required temperature.

(3) High energy efficiency

Induction heating has a heating efficiency of 85%, which is higher than that of other methods which use the kiln itself as the heat generating body. Furthermore, there is no decrease in efficiency caused by the adhesion of soot, as is seen in the combustion type.

(4) No restriction in the types of waste to be treated

Even in cases where scrap cans, dirt and sand are mixed into the plastics waste, treatment is possible without any problem; namely, any type of dust can be treated.

(5) Various operations are possible, ranging from continuous operation to batch operation

This apparatus is compatible with various operations ranging from continuous operation for 24 hours/day to batch operations, in which daily heating and cooling are repeated, and thus may be set up for a wide range of applications, from company use to personal use.

(6) Low equipment cost

There is no need to install a high temperature flue gas duct, as is required for large scale treatment

Table 2 An example of demonstration test results

Item	Measurement	After post-treatment
Waste plastics input quantity	300 kg	
Pyrolysis temperature	520°C	
Generated carbonaceous residue quantity	32.9 kg (10.9%)	
Carbonization degree of carbonaceous residue	96.0%	
Chlorine concentration in carbonaceous residue	62 g/kg	
Dioxin concentration in the residue	Not more than 0.016 ng-TEQ/kg	
Oleaginous condensate quantity	182.8 kg (60.9%)	
Oleaginous condensate property	Specific weight: 0.87 crude oil level	
Chlorine concentration in oleaginous condensate	218 mg/L	4.5 mg/L
Dioxin concentration in oleaginous condensate	Not more than 0.040 ng-TEQ/g	
Calorific value of oleaginous condensate	12,000 kcal/kg	
Combustible gas quantity	84.3 kg (28.2%)	
Dioxin concentration in exhaust gas from combustible gas combustion	Not more than 0.98 ng-TEQ/m^3N	

Fig.7 Test samples and test products

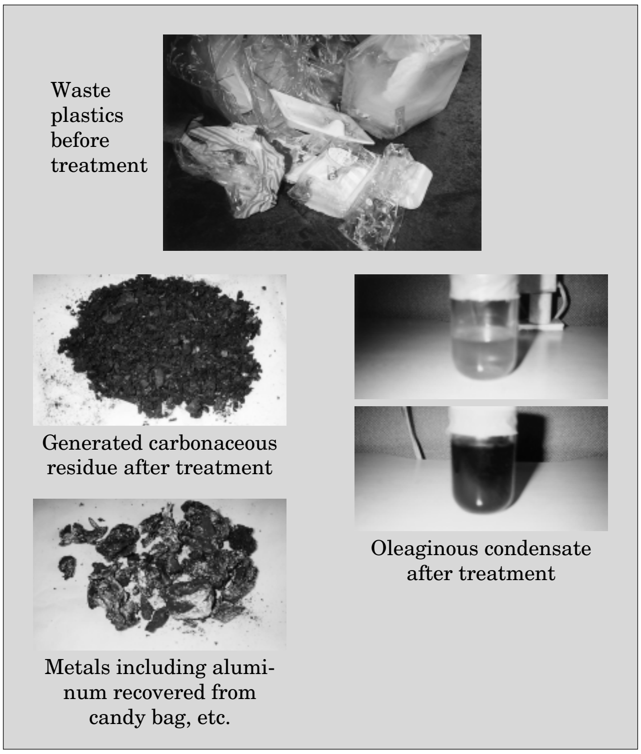
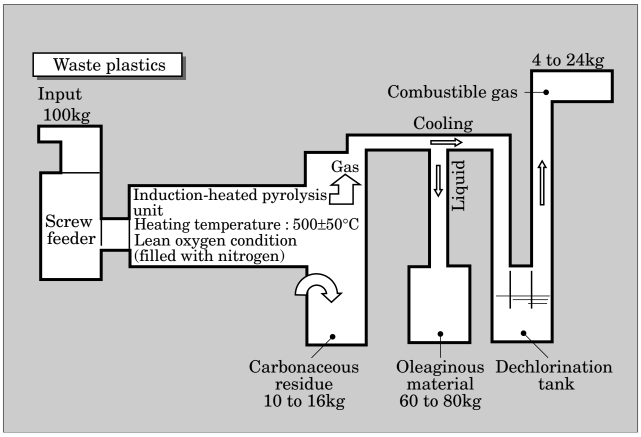


Fig.8 Concept and material flow of induction-heated pyrolysis apparatus



facilities, and there is also no increase of exhaust gas generated by burner. These simplify the post-treatment, resulting in lower total equipment costs.

3.3 Demonstration test results

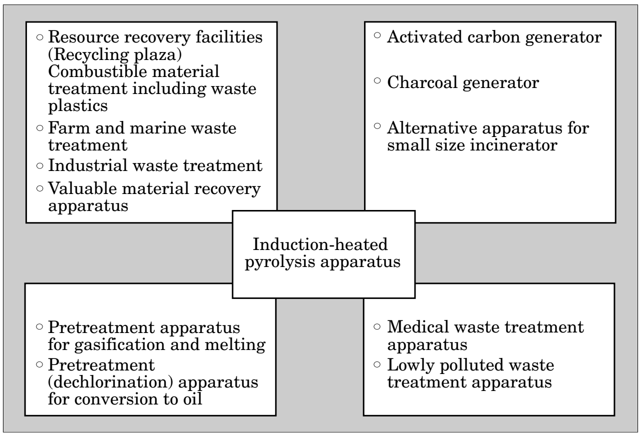
The demonstration tests using waste plastics provided by city A and city B are still ongoing, but the test results up through the present are reported as follows. An example of the test results is shown in Table 2, the test materials (input plastics) and test products are shown in Fig. 7, and the concept and material flow of the induction-heated pyrolysis apparatus are shown in Fig. 8.

The reduction in volume and weight of waste plastics for a pyrolysis temperature range of 500 ± 50°C resulted in carbonaceous mass being reduced to 1/10; a carbonization level of 96.0% was achieved and a dioxin level of lower than the specified value was secured. The generation rates of oleaginous condensate and combustible gas change remarkably depending upon the pyrolysis temperature; the generated quantity of combustible gas increases dramatically at temperatures above 550°C. The oleaginous condensate has a specific weight of 0.87, which is the level of crude oil, and has a calorific value of 12 kcal/g. The chlorine concentration is a little high, but can be reduced by post-treatment with alkaline water. It is very likely that the condensate will be used as recycled oil or fuel oil. The combustible gas is combusted secondarily; however, dioxins generated in exhaust gas are below the specified value. This is likely to be used as a fuel for small size boilers, etc. The residual metals, mainly aluminum, in the carbonaceous residue are interesting. Very thin film materials used for food packaging can be recovered as metal without oxidation.

4. Application Area of Induction-Heated Pyrolysis Apparatus

This pyrolysis apparatus, which suppresses the generation of dioxins, has a wide range of applications such as to waste treatment equipment and recycling equipment. With its temperature- and atmosphere-control characteristics, we are convinced that this pyrolysis apparatus will contribute to our environment-conscious society, which is struggling with many

Fig.9 Scope of application of dry distillation apparatus



problems in waste treatment. Such contributions will include its application as waste treatment apparatus and pre-treatment apparatus for recycling. The possible application range of the technology is shown in Fig. 9.

5. Conclusion

Tests using the induction-heated kiln type continuous pyrolysis demonstration apparatus have been almost completed and we believe that the initial targets of suppression of dioxins and weight and volume reduction of waste plastics have been achieved. On the basis of these results, we are going to design practical apparatuses, through which we hope to be able to contribute to the areas of waste treatment and recycling, which have become serious problems in our environmental-conscious society.