Overview of Recycling Technology in Textile Industry in Japan and the World

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1. Administration country measures on the textile product recycling promotion in Japan.
2. The amount of the textile waste and the amount of the recycling of it in Japan.
3. The development of the textile recycling technology in Japan.

There are four methods for textile recycling. The first is mechanical recycling, and the second is chemical recycling and the third is thermal recovery. The last is other method such as the usage in blast furnace instead of the coke. The recycling method of the post consumer textile waste is mainly the mechanical recycling. A part of synthetic fiber manufacturer carries out the chemical recycling. But the amount of it is very small.

3.1 Some examples of the mechanical recycling of the synthetic fiber.

Re- melting

1) The reuse of the Nylon66 air bag edge materials.

(Toyobo)

<table>
<thead>
<tr>
<th>Non coating Nylon Fabric</th>
<th>Air Bag Fabric</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cutting chips</td>
<td>Used Air Bag</td>
</tr>
<tr>
<td>Engine Cover</td>
<td>Molding Good</td>
</tr>
<tr>
<td>Electron Rice Cooker</td>
<td>Ecocrerief</td>
</tr>
</tbody>
</table>

A film for preventing the fusion is also melted in a under way
Add special chemicals for increasing strength and modulus of it.

Slide 1 shows a example of the mechanical recycling. It is re-melting of the nylon 66 air bag edge materials. Cutting chips of non-coating nylon air bags are collected and re-melted with special chemicals in order to increase its strength and modulus. The recycled resin can be used for molding goods such as engine cover for automobile and so on.
3. Acrylic fiber 100% Re-dissolving by the solvent
Toray Industries
Collecting acrylic fiber chips which comes out of spinning mills, etc., TORAY INDUSTRIES dissolves it, it carries out the recycling which regenerates in the fiber.

This technology was established by applying coloring prevention technique originally developed.

The eco-mark is given on the products using this regenerated acrylic fiber.


Slide 2 shows the mechanical recycling of acrylic fiber. Acrylic fiber chips collected from spinning mills, etc. is dissolved in the fiber plant. Then it regenerates in the acrylic fiber. This technology was established by applying coloring prevention technique originally developed by Toray. The eco-mark is given on the products using this regenerated acrylic fiber.

3.2 Chemical recycling of the synthetic fiber.
1) Nylon

Slide 3 is the nylon 6 chemical recycling. This slide shows the recycling flow of American BASF carpet recycling. Collected carpet is peeled to face yarn and bucking fabric and resin. The face yarn of nylon 6 is de-polymerized using the phosphoric acid for catalyst and it is steamed then it changes in lactam. The lactam is distilled and becomes the pure lactam. This lactam is used for the raw material of the nylon 6.
Some examples of Nylon 6 chemical recycling

Toray Uniform Chemical Recycling

Toray Fine Chemicals Co., Ltd

Toray Industries Inc.

Nylon 6 Uniform

Apparel maker

Apparel maker

Apparel maker

Consumer

Consumer

Consumer

Nylon 6 Fabric, Nylon 6 Button, Nylon 6 Zipper etc.

Recycling Label

Ecological Life and Culture Organization: administration, management

Slide 4

Slide 4 is the chemical recycling of the nylon 6 uniform of TORAY. Almost all of the component of the uniform such as face fabric and lining cloth, button and zipper are made of nylon 6. The recycling label has been attached to the uniform. The uniform is collected then the de-polymerization is done by the same method as the BASF process in the plant of TORAY Fine Chemicals. This system is managed by Ecological Life and Culture Organization.

Slide 5 shows the methods of nylon 66 chemical recycling. There are some methods to de-polymerize nylon 66 to hexamethylene diamine and adipic acid. But in this process separation and purification must be carried out, so it becomes the cost increase. And also adipic acid is cheap. So ammolysis is effective. This process is to recover only the hexamethylene-diamine from nylon 66 and nylon 6. Adipamide from Nylon 66 and aminocaproamide from nylon 6 are changed to hexamethylene diamine. But this process has not been industrialized still now.
2) Polyester

Slide 6 shows the chemical recycling of polyester of the Teijin process. PET bottle and PET fiber can be de-polymerized by the ethylene glycol, and it changes in BHET. Then ester interchange is down by the methanol and re-crystallization is down, then the crude DMT is obtained. This DMT can be used for the raw material of the polyester fiber. In this process the technology which removed different polymer and dyestuff, additives and finishing agent such as the pigment has been developed by Teijin. The production scale of the recovery polyester fiber to DMT is approx. 10,000 tons per year. The technology which removed different polymer and dyestuff, additives and finishing agent such as the pigment was developed.

The production scale for the recovery PET bottle: The Autumn, 2003 -- about 60,000 tons (approx. 3 billion bottles of 500ml PET Bottle) is correspondent. The production scale for the recovery polyester fiber: The July, 2002 -- approx. 10,000 tons is correspondent.

Slide 7 shows the direct process. The recycled PET flakes are de-polymerized by the ethylene glycol in sodium carbonate. Then crude terephtharic acid can be obtained. Then purification is down by the active carbon. And it is neutralized by the sulfuric acid.

Test Plant 100 tons / y. In the case of 8000 tons Plant, the running cost will be same as virgin PTA cost. The investment cost is 1.8 Billion Yen. 

Aug.29, 2003
Then pure PTA can be obtained. This process has tried only test plant.

Slide 8 shows the AIES process. This process can be used only for PET bottle recycling. AIES Co., Ltd. developed the process of purification of the crude BHET. This purification of the crude BHET is down by adsorption and ion exchange process. And also distillation by a thin film is down. PET Rebirth introduced this technology and constructed the commercial plant. The production capacity of the plant is 22,300 tons per year. The operation of this plant was started in August 2004.

3.3  The development of the Carpet recycling technology.
Slide 9 shows the recycling of the industrial carpets waste. Suminoe made a recycling plant of the cutting chips of the automobile carpets. This is a pilot plant. The capacity of the plant is 170 tons per year.
2) Carpet recycling In Europe

A: Carpet Recycling Europe GmbH
Collection and Sorting are carried out.
The operation was started in 2002.
Capacity: 100,000 tons/y.
(Running Cost is 30 EURO/t)

B: Polyamide 2000 (Germany)
The operation was started in 2001.
The period of the operation is from 2001 to 2003.
Under pause at present.
Capacity: 120,000 tons/y
Nylon 6 --- De-polymerization (Caprolactam)
Nylon 66 --- Resin for the molding
Others --- Cement kiln and so on, PP → Plywood

And the last slide shows the carpet recycling in Europe. The Carpet Recycling Europe was established in 1998. The company carries out the business which collects and sorts. The carpet, Polyamide 2000 in Germany is in charge of the recycling of the carpets. Operation of the company was started in 2001. Sorted Nylon 6 carpets are recycled by de-polymerization to the Caproactam. Sorted Nylon 66 carpets are recycled by re-melting to resin. Other carpets go to cement kiln except Polypropylene carpets. Polypropylene Carpets are recycled to plywood. But the company stopped his operation at present.

One of the major challenges facing Japan in the 21st century is to create a new recycling-oriented society.
Overview of Recycling Technology in Textile Industry in Japan and the World

Yoshikazu Yamasaki
Japan Chemical Fibers Association
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   3.1 The mechanical recycling technology.
   3.2 The chemical recycling technology.
   3.3 The thermal recovery.
4. The development of the Carpet recycling technology.
1. Administration country measures on the textile products recycling promotion in Japan.

- Basic Law for Establishing the Creation of a Recycling-Based Society
- Waste management Law
- Law for Promotion of Effective Utilization of Resources
- Regulations in accordance with the characteristics of specific products
  - Containers and Packaging
  - End-of-life Vehicle
  - Food
  - Home appliance
  - Construction Material
  - (Not included Textile Products)

Ensure material recycling in society,
Reduce consumption of natural resources
Reduce environmental burdens.
Green Purchasing Law

The national government shall take the initiative in promoting procurement of recycled products.

The law specifies the types of environmentally friendly products on which priority should be placed in procurement and judgment criteria with respect to 199 articles. Examples of Textile Goods

<table>
<thead>
<tr>
<th>Items of Textile goods</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Uniform and Working Wear</strong></td>
<td>Use of resin recycled from PET Bottles.</td>
</tr>
<tr>
<td><strong>Interior Goods</strong></td>
<td>Curtains, Carpets, etc.</td>
</tr>
<tr>
<td><strong>Meeting Tents, etc.</strong></td>
<td></td>
</tr>
</tbody>
</table>
2. The amount of the textile waste and the amount of the recycling of it in Japan.

The consumption of the textile products. (1999)
Total of Textile Products 2,317
   ( Clothing 1,171 )

The disposal amount of the textile products.
Total amount 2,076
   ( Clothing 1,069 )

The amount utilized again by recycling
Total amount 247
   Recycling of Post Consumer Waste 167
      ( Second hand clothing 72 )
      ( Shoddy 40 )
      ( Wiping cloth 55 )
   Recycling of Industrial Waist 80

• The unit: 1000 tons.

Recycling rate: 11.4%
### 3. The development of the textile recycling technology in Japan.

<table>
<thead>
<tr>
<th>Kind of Technology</th>
<th>Outline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical recycling</td>
<td>Wiping cloth, Shoddy (Non-woven fabric to automobile and Geo-textile). Synthetic fiber 100% [→] Re-melting [→] Molding materials.</td>
</tr>
<tr>
<td>Chemical recycling</td>
<td>Nylon 6, Nylon 66 and PET De-polymerized to the raw materials.</td>
</tr>
<tr>
<td>Thermal Recovery</td>
<td>Incineration with Heat recovery Cement kiln as raw material and fuel. RDF (Refuse Derived Fuel)</td>
</tr>
<tr>
<td>Others</td>
<td>Blast furnace (Instead of the coke). Heat decomposing to the oil</td>
</tr>
</tbody>
</table>

The recycling methods of post consumer textile waste is mainly the Mechanical recycling. Some synthetic fiber manufacturer carries out the chemical recycling of uniform and industrial waste. But the amount of it is very small.
3.1 Mechanical recycling

A : Re-carded Fiber (Shoddy)

Garnet machine

Used clothing.

Cutter
Re-carded → Spinning

Fear naught machine → Carding machine → Sliver machine

This process can be used mainly to the woolen waste.

The manufacturing of middle count spun yarn from the recycling cotton (Used Jeans goods).

(50% recycling cotton / 50% virgin cotton: 16 – 20 S)

(Be suppressed that the fiber is cut off by the card process. The damage of the fiber is decreased.)

Fiscal 2000, KURABO INDUSTRIES
B : Re-melting or Re-dissolving

1) Synthetic fiber 100% \(\rightarrow\) Re-melting \(\rightarrow\) Molding materials.

2) PET bottle flakes \(\rightarrow\) Re-melting \(\rightarrow\) PET fiber

3) Acrylic fiber 100% \(\rightarrow\) Re-dissolving by the solvent \(\rightarrow\) Acrylic fiber
1) The reuse of the Nylon66 air bag edge materials.

(Toyobo)

Air Bag

Used Air Bag

Molding Good

“Ecocrerief” Polymer Alloy Technique

Electron Rice Cooker

A film for preventing the fusion is also melted in a under way

Add special chemicals for increasing strength and modulus of it.
2) PET Bottle Flakes to PET Fiber

Sorting | Grind | Washing | Separation
---|---|---|---
Y shape PET fiber using Recycled PET | | | Mitsubishi Rayon Co., Ltd.

Flakes
PET Fiber | A PET Sheet
3. Acrylic fiber 100%  Re-dissolving by the solvent

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3.2 Chemical recycling

A: Nylon 6

Bucking Fabric

Thermal Recovery

Cutting

Peeling

Carpet

BASF Nylon 6

Carpet face yarn

De-polymerization

Phosphoric acid

steam

Pure Lactam

Distillation

oxidation concentration

Recycling flow of BASF Nylon 6 Carpet

Crude Caprolactam
Some examples of Nylon 6 chemical recycling

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Chemical Recycling

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Nylon 6 Fabric, Nylon 6 Button, Nylon 6 Zipper etc.

Ecological Life and Culture Organization

: administration,

: management,
This business is not carried out at present, because TEIJIN withdrew from the nylon business.
*Separation and purification must be carried out, so this process becomes the cost increase.
*And also Adipic acid is cheap.

These methods can be applied to the fiber in which nylon 6 was mixed with nylon 66.
The technology which removed different polymer and dyestuff, additives and finishing agent such as the pigment was developed.

The production scale for the recovery PET bottle: The Autumn, 2003 -- about 60,000 tons (approx. 3 billion bottles of 500ml PET Bottle) is correspondent.

The production scale for the recovery polyester fiber. The July, 2002 --- approx. 10,000 tons is correspondent.
2. Direct Process
Tsukishima Kikai Co., Ltd. Process

PET Bottle → Recycled PET Flakes

Sodium Carbonate → Heating → Ethylene glycol

Crude Terephtharic Acid + Ethylene glycol → dissolve in the water

PTA → Sulfuric Acid → neutralized

Purification → Terephtharic Acid Solution → Active Carbon

Test Plant 100 tons / y.
In the case of 8000 tons Plant, the running cost will be same as virgin PTA cost. The investment cost is 1.8 Billion Yen.

Aug. 29, 2003
On producing the PET Bottles using reproduced BHET, the approval of FDA in U.S.A. was acquired.

PET Rebirth Co., Ltd.

Plant:
Operation: April 2004
Production Capacity: 22,300 tons / y
(PET Bottle: 27,500 tons / y)
3.3 Thermal Recovery

A : RDF (Refuse Derived Fuel)

Grinder  Dryer  Recovery of Metal  Sorting  Grinder  Add lime  RDF

JIS TR Z 0011-2002  “Refuse Derived Fuel”
Improved Fluidized Bed Boiler which can utilize RDF

HAMADA Boiler Co., Ltd
B: Utilized for the raw material and fuel of the Cement kiln

TOKUYAMA Production Capacity is 25,000 - 30,000 tons / y
C : Utilized for the raw materials instead of the coke in the blast furnace

Pretreatment of the plastic chip.

Plastics

Tuyere

Blast furnace gas

Blast furnace

127
The pretreatment in case of the polyvinyl chloride chip.
4. The development of the Carpet Recycling Technology

As the disposal amount of the carpet is abounding, so the request of the recycling of it has been heightens.

In Europe and U.S.A, the challenge which promote the recycling of the post consumer carpets has been begun.

However, in Japan the disposal waste of post consumer carpets is still landfill or incineration.

But the recycling of the cutting chips in the factory has been started.
1) Carpet recycling in Japan
Recycling of the Industrial Waste

1) Recycling of the cutting chips in the carpet factory.
Suminoe Co., Ltd.

This business received the country support in fiscal 2000.
(215 million yen)
The line of the carpet for the automobile.
(Recycled products can be used for the carpet backing Materials again)
Capacity 170 tons/y (2002)
(Pilot Plant)
Bucking for the carpet for the automobile

Cutter

Carpet Chips

Bucking Chips

Mill

Carpet Chips Hopper

Resin Chips Hopper

Stabilizer

Melt mixing Extruder

Pellet
2) Carpet recycling in Europe

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Raman spectroscopy
Thank you very much for your kind attention

Move away from being a society characterized mass production, mass consumption and massive waste disposal

Building a new recycling-oriented society