Pulp Injection Molding Explanatory Material
Introduction

With the motto of “leaving an irreplaceable global environment to future generations”, the Daiho Group has been committed to activities based on the concept of eco-friendly manufacturing by acquiring ISO14001 for all its domestic and overseas offices, etc. In addition to research on energy saving and resource saving, the Daiho Group is also carrying out research on Pulp Injection Molding (PIM) which uses pulp and starch as raw materials. This pamphlet introduces the technology, by providing details of the processes involved, etc.

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Background

1995  Started research on PIM

1998  Acquired first patent on PIM

2000  Acquired trademark for PIM, improved existing method, and started mass production

2002  Started special production plant

2005  Started joint research with Yokoi Laboratory of University of Tokyo and Nissei Plastic to enhance productivity

2006  Set up PIM consortium in University of Tokyo Production Technologies Research Foundation

2007  Enhanced productivity by more than 60%

2008  Started Phase 2 consortium of runnerless molding

Present
Introduction of Products

- File binding accessories
- CD case
- Speaker cone
- Reel case
- Ampule case
- Lap cutter
- Chopsticks
- Plate
- Paper core cover
- Cup and cup lid
- Container/planter
Disk Storage Cases (10 sheets)

Digital Camera Packaging Cases
Outline of PIM Process

Material manufacture process

60wt% Pulp

40wt% Starch (+PVA)

kneading

Water

Heat

PIM Material

Injection molding process

PIM Material

Injection Machine

Water

Molded products
Injection Molding Process

(1) Reciprocating and metering process

PIM material (Pulp, Starch, PVA, Water)

(2) Injection process

Heating mold (150-180°C)

(3) Heating and drying process

Opening and closing of mold
# PIM Injection Molding Machine

110T PIM Machine
Made by Nissei Plastic Industrial

## Machine Specifications (110T)

<table>
<thead>
<tr>
<th>Specification item</th>
<th>9E</th>
<th>12E (Standard)</th>
<th>18E</th>
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<tbody>
<tr>
<td>Screw diameter (mm)</td>
<td>AA A B</td>
<td>AA A B A B A B</td>
<td>A B A B</td>
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<tr>
<td>Injection capacity (cm³)</td>
<td>26 28 32</td>
<td>28 32 36</td>
<td>32 36 40</td>
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<tr>
<td>Plasticization capacity [PS] (kg/h)</td>
<td>19 28 40</td>
<td>20 40 54</td>
<td>40 54 75</td>
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<tr>
<td>Max. injection pressure (MPa [kgf/cm²])</td>
<td>[2700] [2480] [1900] [2700] [2280] [1800]</td>
<td>[2700] [2220] [1800]</td>
<td>[2700] [2220] [1800]</td>
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<tr>
<td>Injection rate (cm³/s)</td>
<td>Standard</td>
<td>High velocity</td>
<td>High load</td>
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<td></td>
<td>159 185 241</td>
<td>166 217 275</td>
<td>161 204 251</td>
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<tr>
<td></td>
<td>201 255 314</td>
<td>201 255 314</td>
<td>201 255 314</td>
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<tr>
<td>Injection velocity (mm/s)</td>
<td>Standard</td>
<td>High velocity</td>
<td>High load</td>
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<tr>
<td></td>
<td>300</td>
<td>270</td>
<td>200</td>
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<tr>
<td></td>
<td>250</td>
<td>250</td>
<td>250</td>
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<tr>
<td>Screw velocity (rpm)</td>
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<td>0 ~ 300</td>
<td>0 ~ 300</td>
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<tr>
<td>Hopper capacity [Optional] [L]</td>
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<tr>
<td>Clamping force [kN [tf)]</td>
<td>1080 [110]</td>
<td>1080 [110]</td>
<td>1080 [110]</td>
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<tr>
<td>Clamping stroke (mm)</td>
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<td>350</td>
<td>350</td>
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<tr>
<td>Mold thickness [min. - max.] (mm)</td>
<td>220 ~ 410</td>
<td>220 ~ 410</td>
<td>220 ~ 410</td>
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<tr>
<td>Max. daylight opening (mm)</td>
<td>760</td>
<td>760</td>
<td>760</td>
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<tr>
<td>Tie bar clearance [H x V] (mm)</td>
<td>460 x 460</td>
<td>460 x 460</td>
<td>460 x 460</td>
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<tr>
<td>Die plate dimensions [H x V] (mm)</td>
<td>647 x 647</td>
<td>647 x 647</td>
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<tr>
<td>Min. mold dimensions [H x V] (mm)</td>
<td>325 x 325</td>
<td>325 x 325</td>
<td>325 x 325</td>
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<tr>
<td>Locating ring diameter (mm)</td>
<td>100</td>
<td>100</td>
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<td>Ejector stroke (mm)</td>
<td>85</td>
<td>85</td>
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<tr>
<td>Heater band capacity (kW)</td>
<td>7.22 8.36 9.26 7.98 9.13 8.88 10.57</td>
<td>8.88 10.57</td>
<td>8.88 10.57</td>
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<tr>
<td>Machine dimensions [L x W x H] (m)</td>
<td>4.45 x 1.19 x 1.80 4.49 x 1.19 x 1.80 4.53 x 1.19 x 1.80 4.48 x 1.19 x 1.80 4.57 x 1.19 x 1.80 4.48 x 1.19 x 1.80 4.57 x 1.19 x 1.80</td>
<td>4.48 x 1.19 x 1.80 4.57 x 1.19 x 1.80 4.57 x 1.19 x 1.80 4.57 x 1.19 x 1.80</td>
<td>4.48 x 1.19 x 1.80 4.57 x 1.19 x 1.80 4.57 x 1.19 x 1.80 4.57 x 1.19 x 1.80</td>
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<tr>
<td>Floor dimensions [L x W] (m)</td>
<td>4.12 x 0.78 4.12 x 0.78 4.12 x 0.78</td>
<td>4.12 x 0.78 4.12 x 0.78 4.12 x 0.78</td>
<td>4.12 x 0.78 4.12 x 0.78 4.12 x 0.78</td>
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<tr>
<td>Machine weight (t)</td>
<td>4.8</td>
<td>4.8</td>
<td>5</td>
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Evaluation of Properties

・Advantages/disadvantages of PIM products
・Records of biodegradation experiments
・Comparison of mechanical characteristics
・Environment impact factors of PIM
・LCA comparison of PIM materials
・LCA comparison of packaging container
・Results of hygiene analysis and combustion measurement
・Heat-resistance tests
・Water suction characteristics
Advantages/Disadvantages of PIM Molded Products

**Advantages**
- No adherence of dusts
- Can be disposed with general waste (can be recycled as paper)
- No toxic substances produced when burnt
- Light specific weight (about 0.85)
- Biodegradable performance (degradation in soil in about six months)
- High heat-resistance About 200°C
- No change even in -20°C environment
- Dimensional accuracy is same as general resin
- Products can be recycled as raw materials

**Disadvantages**
- Weak in high temperature high humidity (moisture absorption deformation ±0.5%)
- Welded portions lack strength
- Risks of animal and insect damage

Biodegradation Experiment Data
Addition of water twice/day for three months (8:00 and 17:00 daily)

Comparison of Mechanical

Pulp material (Purge valve)

After one week

After two weeks

After one month

After three months

Pulp material (Recycled material)

After one week

After two weeks

After one month

After three months
# Characteristics

<table>
<thead>
<tr>
<th></th>
<th>PIM material</th>
<th>General resin</th>
<th>Polylactate</th>
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<tbody>
<tr>
<td></td>
<td>Virgin</td>
<td>Used</td>
<td>PS</td>
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<tr>
<td>Specific weight</td>
<td>0.85</td>
<td>0.78</td>
<td>1.05</td>
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<tr>
<td>Tensile Strength (MPa)</td>
<td>29</td>
<td>19</td>
<td>28</td>
</tr>
<tr>
<td>Elongation (%)</td>
<td>8.5</td>
<td>4.8</td>
<td>40</td>
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<tr>
<td>Bending strength (MPa)</td>
<td>24.5</td>
<td>35</td>
<td>47</td>
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<tr>
<td>Bending elasticity (MPa)</td>
<td>2,900</td>
<td>3,600</td>
<td>2,500</td>
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<tr>
<td>Impact Strength (kg·J/m²)</td>
<td>11.5</td>
<td>5.6</td>
<td>6</td>
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</tbody>
</table>

Average fiber length : N-P25 > S-P25 > L-P25
Environment Impact Factors of PIM

Recycling/Disposal Stage
- No toxic substances
- Easy to degrade
- High recycling rate
- High reuse rate

Using Stage
- Recycled pulp used
- Easy to use shape and material

Materials Used
- Little raw material used
- No toxic substances used
- Recycled parts/resources used

Manufacturing Stage
- Little energy used
- No toxic substances used
- No wastes produced

Distribution Stage
- Buffer effects
- Contributes to rationalization of transportation
- Minimizes/simplifies packaging material
LCA Comparison of PIM Materials

Amount of CO₂ generated
(During manufacturing process from raw materials to pellets)

- The figures for polylactate are that when the Nature Works 140000t plant is fully operating.
- Material data of pulp etc. was calculated by totaling the data disclosed by the Japan Paper Association using the raw material mixing rates, and adding the value calculated based on the data disclosed by the Environmental Agency to the energy used for manufacturing PIM material (Kneading, extrusion, pelletization).

Data prepared by Daiho Industrial Co., Ltd.
LCA Comparison of Packaging Container

In the case of digital camera manufacturer O;
210, 563 tons-CO2 in 2006

As 70% of digital cameras are shipped by air, the distribution sector’s percentage for CO2 emissions is high.
Results of Hygiene Analysis and Combustion Measurement Analysis

Analysis Results of Hygiene Tests (heavy metals, others)

<table>
<thead>
<tr>
<th>Analysis test items</th>
<th>Results</th>
<th>Detection limit</th>
<th>Note</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead</td>
<td>Undetected</td>
<td>5 ppm</td>
<td></td>
<td>Atomic absorption photometry</td>
</tr>
<tr>
<td>Cadmium</td>
<td>Undetected</td>
<td>0.5 ppm</td>
<td></td>
<td>Atomic absorption photometry</td>
</tr>
<tr>
<td>PCB</td>
<td>Undetected</td>
<td>0.1 ppm</td>
<td>1</td>
<td>Gas chromatograph</td>
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<tr>
<td>Elution tests</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Heavy metals (as Pb) (Solvent: 4V/V% acetic acid)</td>
<td>Undetected</td>
<td>1µg/ml</td>
<td></td>
<td>Sodium sulfide colorimetric sensor</td>
</tr>
<tr>
<td>Phenols (as phenol) (Solvent: water)</td>
<td>Undetected</td>
<td>0.5µg/ml</td>
<td></td>
<td>4-aminoantipyrine absorption photometry</td>
</tr>
<tr>
<td>Formaldehydro (Solvent: water)</td>
<td>Undetected</td>
<td>0.5µg/ml</td>
<td></td>
<td>Aminoantipyrine absorption photometry</td>
</tr>
</tbody>
</table>

Florescent substances

Note 1: Elution conditions: 2ml of solvent was used per surface area of 1 cm², and immersed elution was carried for 30 minutes at 60°C.

Note 2: Test methods for devices or container packaging using fluorescent substances conform to 1971 Environment Corrosion Article 244, 2004 Corrosion Safety Regulations No. 0107001 and Corrosion Safety Supervision Article No. 0107001.

Source; Japan Food Research Laboratories

Results of Combustion Measurement Analysis

- Test samples
  PIM(N-P25)
- Test items and methods
  Combustion test conforms to FMVSS302
  Test sample: 300mm×100mm×1mm
  Test room conditions: 24°C, 59%RH
  Number of tests: n=5
- Test results
  Combustion speed: 39mm/min

Source; DIA Analytical Service Center Co., Ltd.
Heat-Resistance Tests

Date of measurement: 07/07/26
Heating conditions:
Temperatures 150°C, 200°C, 250°C, 300°C
Heating time: 60min
Sample size: 3cm×5cm, cut out from normal sheet of thickness 1mm

Changes in weight

<table>
<thead>
<tr>
<th></th>
<th>Before processing</th>
<th>150°C</th>
<th>200°C</th>
<th>250°C</th>
<th>300°C</th>
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<tbody>
<tr>
<td>Weight decrease</td>
<td>0.0%</td>
<td>3.6%</td>
<td>5.9%</td>
<td>31.3%</td>
<td>65.5%</td>
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<tr>
<td>rate</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

No change in color or weight when heated at 120°C.
Water Absorption Characteristics

Contact angle (°)

Elapsed time (s)

Contact angle

- PIM
- Copy paper
- Paper with increased water repellency
Examples of PIM Technology

- Thin-wall molding
- Undercut
- Insert molding
- Multi-rib structure/hinge shape
- Microshape
- Foaming agent for PIM extrusion molding
- Printing sample
- Addition of other cellulose materials
Thin-Wall Molding

Cup lid

Thickness (0.3mm)

Undercut

Ampoule case

Cross-section of enlargement

Undercut
Insert Molding

Water absorption paper insert

Picture insert

Microshape

Lap cutting edge
Multi-Rib Structure

Hinge Shape
Foaming Agent for PIM Extrusion Molding

**ABS resin only**

**PIM + ABS resin**

Specific weight can be decreased by nearly 30% max. Advantages such as no need for annealing after molding.
Printing Samples

Pad printing

Offset printing

Silk screen printing

Silk screen printing
Addition of Other Cellulose Materials

- Paper tube
- Wood chip
- Newspaper
- Wood powder
<table>
<thead>
<tr>
<th>Paper No.</th>
<th>Title</th>
<th>Page No.</th>
<th>Journal carried in</th>
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<tr>
<td>1</td>
<td>Study on Pulp Injection Molding I – Measure of Flow Characteristics Using Bar-flow Mold</td>
<td>P139-142</td>
<td>JSPP’05 Sympo.Papers</td>
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<td>2</td>
<td>Study on Pulp Injection Molding II – Evaluation of Molded Product Characteristics</td>
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<td>3</td>
<td>Study on Pulp Injection Molding III – Review of High-cycle Molding</td>
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<td>JSPP’05 Sympo.Papers</td>
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<td>4</td>
<td>Study on Pulp Injection Molding IV – Flow Characteristics and High-cycle Molding of Large Molded Products</td>
<td>P149-152</td>
<td>JSSP’06 Tech.Papers</td>
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<td>6</td>
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<td>Study on Pulp Injection Molding VII – Evaluation of Internal Voids of Molded Products and Correlation with Molding Conditions</td>
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<td>Visualization Analysis of Material Flow inside Simple Rib Cavity in Pulp Injection Molding</td>
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<td>Visualization Analysis of Material Flow around Weld-line Area in Pulp Injection Molded Products</td>
<td>P185-186</td>
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