Overview and EE&C of Steel Industry in Japan

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1. Recent status of Energy Conservation in Mini Mill Industry in Japan

2. EE & C Activities in EAF

3. EE & C Activities in CC

4. Energy Conservation in Rolling Mill Process

5. Transition of Total Energy Intensity (Crude oil equivalent) - Example -
(1) Trend of Crude Steel Production, Operation Status in Japan

\[ EAF \text{ ratio} = \frac{(EAF \text{ steel})}{(All \text{ steel})} \]
(2) Energy Saving Technologies in Mini Mill Process

- Decrease of Input Power
- Decrease of Heat Loss
- Decrease of Holding Time
- Regenerative Burner
- Bag Filter
- VVVF
- DHCR (Direct Hot Charge Rolling)
- Furnace Operation
- Continuous Rolling
- Connecting of Billet
- Connecting of Bar

EAF

Scrap Preheater

Ladle & Tundish

Continuous Caster

Billet Heat insulator

Furnace

Rolling Mill

EAF Operation

Type 1
Type 2

Rod, Bar & Coil
(3) Energy Use in Mini Mill Factory
(Products: Steel Bars for Concrete Reinforcement)

![Pie chart showing energy use ratios in a mini mill factory.]

- **52%**: EAF (Power)
- **13%**: EAF (Chemical Reaction, O2, Oil, Others)
- **12%**: Auxiliaries of Steel Making Shop (Power)
- **9%**: Burner (Ladle+Tundish)
- **10%**: Burner (Re-heating Furnace)
- **4%**: Rolling Mill Shop (Power)
## (1) Transition of Technical Development (EAF-CC)

<table>
<thead>
<tr>
<th>Period</th>
<th>Introduction of new Technologies</th>
<th>Tap-Tap Time (min)</th>
<th>Power Consum. (kWh/t)</th>
<th>Oxygen m³N/t</th>
<th>Oil L/t</th>
</tr>
</thead>
<tbody>
<tr>
<td>~ 1976</td>
<td>Traditional operation method</td>
<td>176</td>
<td>560</td>
<td>10</td>
<td>--</td>
</tr>
<tr>
<td>1976~ 1978</td>
<td>LF installation Burners on wall Furnace water cooling</td>
<td>147</td>
<td>497</td>
<td>12</td>
<td>3.2</td>
</tr>
<tr>
<td>1979~ 1980</td>
<td>Wider water cool area High power factor operation Carbon injection</td>
<td>110</td>
<td>390</td>
<td>20</td>
<td>2.8</td>
</tr>
<tr>
<td>1981~ 1984</td>
<td>SPH installation Oxygen rich operation (PSA) New casting machine</td>
<td>95</td>
<td>345</td>
<td>28</td>
<td>2.3</td>
</tr>
<tr>
<td>1985~</td>
<td>EBT installation Installation of more wall burners</td>
<td>85</td>
<td>325</td>
<td>32</td>
<td>1.8</td>
</tr>
<tr>
<td>1988~ 2000</td>
<td>Bottom stirring DC furnace (More than 20 f’ces) Aluminum arm, Slag detector Powder casting or nozzle casting Large tundish, EMS Mist cooling</td>
<td>63</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hot metal operation Night time operation Utilization of waste materials</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2001~ 2006</td>
<td>Ecoarc (Shaft furnace and continuous operation)</td>
<td>200</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
(2) Trend in Operation Indices of EAF

**Power Unit Consumption of EAF (kWh/t-good steel)**

**Tap to Tap Time (min)**

- **Containing Special Steel**
- **Only Ordinary Steel**

Year:
- '71
- '75
- '80
- '85
- '90
- '95
- '99

Power Unit Consumption of EAF:
- 200
- 150
- 100
- 50
- 0
(3) Energy Conservation Activities in EAF Process

1) Energy conservation in EAF shop

(EAF: Electric Arc Furnace (AC, DC))

a) Increase of input energy
   - Enrichment of O$_2$

According to above countermeasure

- Increase of Oil (Burner), Carbon, Low cost alloys (Aluminum ash, Bundle made from Can, etc.)
b) Increase of efficiency in input energy

- Power
  
  *Common (DC, AC)*:
  
  - VVVF control of electrode lifting
  
  *Introduction of Inverter control system*

  - Foaming slag control in refining stage, etc.

  - **AC**: Al-arm, Reactor (in case of enough capacity of power station and high voltage operation), etc.

- Other

  *Post combustion (Shaft furnace), Supersonic lance, etc.*
c) Decrease of output energy

- *Increase of Heat size*
- *Decrease of Tap to Tap time and waiting time of the time after tapping (from tapping to the start of scrap charge)*
- *Decrease of heat loss by slag*
  - *Hot recycle of slag, Control of scrap’s dust, etc.*
- *Scrap preheating*
  - *Shaft furnace with decreasing technology of dioxin*

2) Others

- *Power saving in auxiliaries*
  - *VVVF control of dust collecting fan motor, etc.*
(4) Energy Balance-1

![Energy Balance Diagram]

- **Power** input: 380 kWh/t
- **C-combustion** input: 210 kWh/t
- **Metal oxidation** input: 100 kWh/t

- **Metal** output: 370 kWh/t
- **Slag** output: 37 kWh/t
- **Furnace loss** output: 100 kWh/t
- **Off gas** output: 140 kWh/t
(5)  Enriched Oxygen Operation (Example)

Melting Stage

Melt down and Refining Stage

Fe + 1/2 O₂ = FeO 1.15Mcal/kg-Fe
C + 1/2 O₂ = CO 2.2Mcal/kg-C
FeO + C = Fe + CO - 0.68Mcal/kg-Fe

Enriched Oxygen Operation (Example)

#1 Ch. #1 Me. #2 Me. #2 Ch. Refining and Heating Tap

Burner

Oxygen Carbon

5.3kA 700V 5.3kA 700V 675V

Time (min)

EBT Manipulator / Water Cooled Lance Coke Coke

O₂ O₂

Slag Foaming Detector
(6) Influence of Oxygen and Reheat on Power Consumption

![Diagram showing the relationship between power consumption and oxygen consumption. The diagram includes different symbols for power consumption with and without preheating, and with different types of furnaces. There are data points indicating the power consumption in kWh/t versus oxygen consumption in m³N/t. The graph shows a trend line indicating the influence of oxygen on power consumption.]
(7) Relation between Transformer Capacity and Tap to Tap Time of EAF
# (8) Scrap Preheater

## Several Types of Recent Scrap Preheater

<table>
<thead>
<tr>
<th>Consteel</th>
<th>Shaft Furnace</th>
<th>Twin Shell Furnace</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effect: 45kWh/t</td>
<td>Effect: 70kWh/t</td>
<td>Effect: 30kWh/t</td>
</tr>
<tr>
<td>(Reported value)</td>
<td>(Reported value)</td>
<td>(Reported value)</td>
</tr>
</tbody>
</table>
(9) Effect of VVVF  
(Example of Power saving calculation)

<table>
<thead>
<tr>
<th></th>
<th>Without VVVF</th>
<th>With VVVF</th>
</tr>
</thead>
</table>
| **Blower Motor of Direct Dust Collector (970kW)** | $970 \cdot 0.85 \ (\text{min}/60)$  
  $\Rightarrow 960 \text{kWh/ch.}$ | $970 \cdot 0.85 \ [1 \cdot 11/60$  
  $+ 0.85^3 \cdot 10/60$  
  $+ 0.75^3 \cdot 49/60]$  
  $\Rightarrow 520 \text{kWh/ch.}$ |
| **Power Consumption**          | $960/80 = 12 \text{kWh/t}$        | $520/80 = 6.5 \text{kWh/t}$        |
| **Difference**                 |                                   | $5.5 \text{kWh/t}$                 |

Operation rate: 100%  85%  75%
1 charge = 70 min: 11 + 10 + 49 min
(10) **Energy Control System**

**Standardized Operation and Reduction of Production Cost in EAF**

**Melting Control**
- Power control
- Melting profile calculation
- Raw/Submaterial feed control
- Additional scrap charging & meltdown determination

**Refining Control**
- Slag foaming guidance
- Thermal model calculation
- Metallurgical model calculation

**Data Management**
- Statistical data analysis
- Operation tracking and reporting (Electricity & fuel: daily & monthly report)

**Other Functions**
- Trend graph of kWh/t
- Correlation between kWh & oxygen
- Etc.
(1) Energy conservation in Ladle and CC
   - Regenerative burner for ladle & tundish
   - Matching of the productivity between EAF and CC (Continuous Casting)

(2) Energy conservation after CC
   - Billet heat insulating equipment
   - DHCR (Direct Hot Charge Rolling), etc.
   - Matching of the productivity between CC and Rolling Mill
(2) Regenerative Burner for Ladle
(Same System for CC Tundish)

**Effect:**

Fuel Reduction Ratio = 51%

[Condition]
- Ladle Capacity: 100 t
- Heating Period: 10 hours
(3) Billet heat insulating equipment

This equipment maintain the billet temperature in hot at waiting to the reheating furnace.

Steel Making Shop

Billet Yard

Heat insulating

Direct Hot Charge Rolling

Hot charge

Cold charge

Reheating Furnace

( Hot rolling Mill Shop)
## (1) Transition of Technical Development
(Rolling Mill)

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<th>Oil L/t</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995~</td>
<td>Regenerative burner</td>
<td></td>
<td>Oil reduction: 20~29%</td>
</tr>
<tr>
<td>2001~</td>
<td>DHCR (Direct Ht Charge rolling), and subsidiary furnace (Heat keeping furnace)</td>
<td></td>
<td>Oil reduction: 52%</td>
</tr>
<tr>
<td>2001~</td>
<td>Endless rolling</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2002~</td>
<td>Hot eddy current inspection</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
(2) Energy Conservation Measures in Rolling Mill Factory

(1) Matching of the productivity between CC and Mill
(2) DHCR (Direct Hot Charge Rolling), etc.
(3) Reheating furnace:
    Application of regenerative burner system
(4) Energy saving of fluid machinery:
    Pump, Fan, Air Compressor, etc.
(3) Application of Regenerative Burner

- Regular Industrial Furnace
  High temperature exhaust!

- High-performance Industrial Furnace (1)
  Metal type heat exchanger

- Recuperator (metal)
High-performance Industrial Furnace

Alignment of a pair of burners with a built-in ceramic storage heat exchanger, combustion and exhausting in turn, temperature preheated of combustion air.
**Merit of Regenerative Burner in Furnace**

- **Energy – saving**
  - Effect of high temperature combustion air over 1,000 °C (Reduction of fuel = - 20%)
- **Uniform heating**
  - Effect of the stirring of waste gas by cyclic combustion
- **Compact equipment**
  - Shortening of the furnace length by installing burners along the full length of the furnace
(4) Effect of Heat Pattern Change in Re-hearing Furnace

Temperature of re-hearing furnace

Temperature of heated material

<table>
<thead>
<tr>
<th>Heat pattern</th>
<th>Fuel usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>-</td>
<td>1.0</td>
</tr>
<tr>
<td>-</td>
<td>0.93</td>
</tr>
</tbody>
</table>
(5) Endless Bar Rolling System

- Loss reduction by eliminating of cutting off at both ends of bars
- Reduction of the idle time before feeding each new billet and the factors for rolling errors
- Drastic reduction in products of wrong dimension or insufficient length
- Reduction in energy cost $\leq 3\%$
Endless Bar Rolling - Welding

Flash Butt Welding

Crop shear

(Billet) or Bar

Flash butt Welding

Preset

Plane

(Billet) or Bar

ECCJ
(6) Energy Conservation System

• Accumulation and analysis of the energy consumption data
• Control and management of energy consumption & intensity
• Application of existing system examples
  Energy monitor and analysis system
  – Local devices
(1) Transition of Total Energy Intensity (Crude oil equivalent) - Example -

Electrical energy intensity (Crude oil equivalent L/t)

- Performance of energy conservation for 5 years = 10.5%
- Performance of energy conservation for 3 years = 8.1%
- Energy conservation effect by continuous rolling = 4.1% (FY2002)

Electricity / total = 85%
Electricity / total = 88%
Electricity / total = 93% (estimate)


(50t/heat EAF)
Thank You

The Energy Conservation Center, Japan