Aluminum Extrusion: Make Scrap Pay

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Make Scrap Pay

- Analyze and Maximize profits from aluminum scrap
- Built an OR model to determine most profitable method to manage scrap
- Determine the best option to deal with excess material
Aluminum Extrusion

- A process used to produce elongated components of variable lengths and uniform cross-sections.
Extrusion can be performed through two processes:

- **Indirect** - billet remains stationary and die is forced along its length
- **Direct** - hold the die stationary and forces the billet through die
Target Plant

- Metropolitan Metal Co. Ltd
- Based in Thailand
- Founded in 1979
- Uses a Direct extrusion process
- Offer three types of aluminum alloy: 6060, 6061 and 6063
Has three direct extrusion machines on site
Runs three shifts 20hrs/day 6days/week
Uses the same sized billets for machines 1 & 2
Uses a larger and more expensive billet for machine 3
Problem Definition

Two challenges face extrusion today extrusion plants:

- Downtime
- Scrap Management
Model Definition

- Using Multiple Objective analysis to maximize profit, which is generated from scrap

- Assumptions
Model Flow Diagram

Sell under Condition:
need profit
> 5% of first cost

$S^a$  

$S'$  

Xij produce on machine 1,2,3  

$G_j$  

$M_j$  

$W^b + D^b$  

$R^b$  

$S^f$  

80 Baht/Kg
Model Definition (Cont.)

\[ \begin{align*}
G_j &= \text{Good Product in month } j \\
S_j^f &= \text{Final Scrap in month } j \\
S_j^r &= \text{Scrap Required in month } j \\
S_j^a &= \text{Scrap Available in month } j \\
M_j &= \text{Demand in month } j \\
R_j^b &= \text{Returns from recycled product} \\
D_j^b &= \text{Defects from reprocess} \\
W_j^b &= \text{Waste from reprocess} \\
P &= \text{Profit} \\
P_j^u &= \text{Price per ton (1 ton = 1000 kg) = first cost } \times 1.05 \text{ (need > 0.5% of first cost)} \\
P^n &= \text{Production Output} \\
P^r &= \text{Hours operating} \\
C_{ij} &= \text{Capacity machine } i \text{ to month } j = 0.6(P^n / P^r) \times 24 \times 30 \\
A_{ij} &= \text{Cost of reprocessing machine } i \text{ to month } j \\
X_{ij} &= \text{Amount Produce from machine } i \text{ to month } j \\
Y_{ij} &= \begin{cases} 
1, & \text{if machine } i \text{ is selected in month } j \\
0, & \text{otherwise}
\end{cases}
\end{align*} \]
Multiple Objective Function

**MAX:** Profit = \( \sum_{j=1}^{12} G_j \cdot P_j^u + \sum_{j=1}^{12} S_j^f \cdot 2191.78 \)

**MIN:** Cost = \( \sum_{i=1}^{3} \sum_{j=1}^{12} X_{ij} \cdot A_{ij} \)

**MIN:** Final scrap = \( \sum_{j=1}^{12} S_j^f \)
Constraints:

\[
S^f_j = \sum_{i=1}^{3} W^b_i + \sum_{i=1}^{3} W^b - R^b \quad \text{Final Scrap constraint}
\]

\[
G_j = X_{ij} - \sum_{i=1}^{3} W^b_i - \sum_{i=1}^{3} W^b = S^r_j - \sum_{i=1}^{3} W^b_i - \sum_{i=1}^{3} W^b \quad \text{Good Product constraint}
\]

\[
\sum_{i=1}^{3} X_{ij} = S^r_j = S^a_j \quad \forall j \quad \text{Amount produce constraint}
\]

\[
X_{ij} \leq C_{ij} \ast Y_{ij} \quad \text{Capacity constraint}
\]

\[
X_{ij} \leq C_{ij} \quad \text{Minimum order constraint}
\]

\[
X_{ij} \geq 0.3 \ast Y_{ij} \quad \text{Minimum order constraint}
\]

\[
Y_{ij} = \text{binary} \quad \text{Binary}
\]
Goal Programming (GP)

**MIN:** the maximum of

\[
\frac{w_1 \left( \sum_{i=1}^{3} \sum_{j=1}^{12} X_{ij} \cdot A_{ij} - 1,922,730.48 \right)}{1,922,730.48}
\]

and

\[
\frac{w_2 \left( \sum_{j=1}^{12} S_j^f - 294.27 \right)}{294.27}
\]

**MIN:** \(Q\)
**Goal Programming (GP) (Cont.)**

**Constraints:**

\[ w_1 \left( \sum_{i=1}^{3} \sum_{j=1}^{12} X_{ij} * A_{ij} - 1,922,730.48 \right) / 1,922,730.48 \leq Q \]  
(goal 1 MINIMAX constraint)

\[ w_2 \left( \sum_{j=1}^{12} S_j^f - 294.27 \right) / 294.27 \leq Q \]  
(goal 2 MINIMAX constraint)
Lessons Learned

- Determine the problem to solve early.
- Let the model drive the data rather than the data drive the model.
- More granular data was required.
Future Research

- Energy and environmental impacts of recycling should be considered.
- Research how different companies value scrap for analysis.
- Further research required on the chemical breakdown of the material.
Conclusion

- Scrap can be reprocessed to fill a large percentage of orders at a fraction of the cost.

- Scrap is used first to fill orders and is sold directly as a second option.

- Results support assumed solution rather than an unanticipated approach.

- Model could be applied in other factories or in different fields with related variables.
Make Scrap Pay

Questions/Comments
Back up

Raw Material Cost (mach 1,2) = 108 Baht/Kg
Raw Material Cost = 110 Baht/Kg
Operation Cost = Gas+Electric+Labor
Capacity = 0.6\(P/\bar{P}\)

Machine 1,2,3

- **Good Product**
  - High Market
    - Expected Profit > 7-15% of first cost
    - Ending Product is Grade A
  - Low Medium Market
    - Expected Profit > 5% of first cost
    - Ending Product is grade B
      - Can sell only
      - Low Medium Market
        - Condition: need profit > 5% of first cost
        - Profit lower than High Market

- **Return+Waste**

- **Rework**
  - Some customers need coating, some do not
  - Ending Product is grade B
    - Can sell only
    - Low Medium Market
      - Condition: need profit > 5% of first cost
      - Profit lower than High Market