Advanced Industrial Technologies for Aluminium Scrap Sorting

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2007 Global Al Flows in million tonnes

**MATERIAL FLOW**
- **Bauxite** 200.7
- **Alumina** 73.3
- **Primary Aluminium used** 37.8
- **Remelted Al >42 incl. old scrap** 10
- **Bauxite Residues** 84.5
- **Scrap collected** 10

**METAL FLOW**
- **Melt Scrap: traded 1.6 home?**
- **Casting Scrap: traded 1.6**
- **Fabricator Scrap 20.0**
- **Traded New Scrap 1.6**
- **Semi-fabricated and Finished Products (input) 73.9**
- **Fabricator Scrap 20.0**
- **Traded New Scrap 9.5**
- **Finished Products (output) 44.4**
- **Old Scrap** 10
- **Burned or landfilled 4.2**
- **Under Investig. 1.8**
- **Old Al scrap collected 62.5%**

**Source:** IAI
### Main markets for secondary Al and the most popular alloys for these markets

<table>
<thead>
<tr>
<th>Market</th>
<th>Secondary alloy</th>
<th>Compatible scrap sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al packaging</td>
<td>3X04 can body sheet</td>
<td>Old cans, can manufacturing scrap Non-can wrought manufacturing scrap Al- and Mg-based scrap mix from 2 g/cc float fraction of a dense-media sink-float plant</td>
</tr>
<tr>
<td>Building Al</td>
<td>3105 painted sheet</td>
<td>Old Al siding Al siding and extrusion construction scrap Mixed wrought manufacturing Al scrap with low copper content Old wrought scrap</td>
</tr>
<tr>
<td>Automotive Al</td>
<td>38X.X casting alloys</td>
<td>Some 38X alloys can accept a mixture of the most common old scrap varieties without dilution, providing the Mg concentration is controlled by chlorination</td>
</tr>
<tr>
<td></td>
<td>319.x casting</td>
<td>Tighter concentration limits on 319 increase the dilution requirement and limit the types of old scrap that can be added to a 319 alloy batch</td>
</tr>
<tr>
<td>Steel deoxidants</td>
<td>95% Al</td>
<td>This specification can be met by many mixtures of old wrought alloy scrap</td>
</tr>
</tbody>
</table>
Secondary alloy markets

- Secondary alloy market for the four main secondary alloys far exceeds the global old scrap supply. These alloys can be batched using the scrap categories already on the market.
- Prompt new scrap is typically recycled to a more impurity tolerant alloy within the same alloy family.
Dismantling gives parts for re-use!
Shredding

- Is cost-efficient
- Liberates mono-material particles
- Increases the bulk density
- Permits mechanized material handling and storage
Primary shredding plant

ELVs white goods mixed metal dealer scrap CDW MSW

5,000-15,000 HP hammer mill

oversize

Oversize 5, 30 mm screens

>5<30 mm >30<100 mm

Overbelt magnet

Eddy current rotor circuit

<5 mm fines (nonmetal)

Al + Mg concentrate NMMC nonmagnetic metal concentrate

Cyclone & baghouse

Nonmetal lead, wire stainless steel

Eddy current coil particle sorter circuit

Steel

Aluminium-21/Recycling , St.Petersburg, October 12-14, 2010.
Nonmagnetic metal concentrate (NMMC)

- NA supply ~1,000 kT of NF metal/year, growing quickly
- 20-95% metal
- 60-70% Al in metal (~600 kT/year)
- 30-50% wrought in Al (~200 kT/year)
Al mix from dense-media float fraction
Scrap sorting plant (current technology)

Dense metal mix (dense media sink)
Dense metal mix (dry sort)
Al + Mg (light media float)
Al Recycling System Needs and Opportunities

- There is a need to improve Al scrap collection through improved diversion from landfills and incinerators, and better separation from steel, non-metals and fines residues.
- There is a need to keep Mg scrap out of Al recycling system.
- There is no need for closed loop recycling (back to the same alloy).
- There is no recycling system need to further upgrade scrap to use it in other alloys.
- There is no system need to develop new secondary alloys, or use post-consumer scrap in prime alloys.
- There are financial opportunities in buying lower grade mixed scrap and upgrading it to your own alloy specifications.
## Status of metal scrap particle separation

<table>
<thead>
<tr>
<th>Desired separation</th>
<th>Separation method</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Metal - nonmetal</strong></td>
<td></td>
</tr>
<tr>
<td>Steel from nonmetal + nonmagnetic metal</td>
<td>Drum magnet, overbelt magnet</td>
</tr>
<tr>
<td>Nonmagnetic metal from nonmetal</td>
<td>Screen, air elutriator, eddy current rotor, <strong>eddy current coil sensor</strong></td>
</tr>
<tr>
<td>Metal from nonmetal fines (&lt;9 mm)</td>
<td>Jig, eddy current rotor</td>
</tr>
<tr>
<td>Nonmetal or other metal contaminants from Al</td>
<td>Magnetic headpulley, eddy current rotor, hand sort</td>
</tr>
<tr>
<td><strong>Al - other metal</strong></td>
<td></td>
</tr>
<tr>
<td>Light from dense NF metals</td>
<td>Sink- float (wet or dry), eddy current rotor, hand sort, <strong>colour sensor, XRT sensor</strong></td>
</tr>
<tr>
<td>Al from Mg</td>
<td></td>
</tr>
<tr>
<td><strong>Al-Al</strong></td>
<td></td>
</tr>
<tr>
<td>Al with attachments from liberated Al</td>
<td>Hand sort, <strong>XRT sensor</strong></td>
</tr>
<tr>
<td>Alloy grouping and Al by alloy</td>
<td><strong>LIBS sensor, XRF sensor</strong></td>
</tr>
<tr>
<td>Particle-by-particle target alloy batching</td>
<td><strong>LIBS sensor, XRF sensor</strong></td>
</tr>
<tr>
<td>Average particle stream elemental composition measurement</td>
<td><strong>LIBS sensor, XRF sensor, PGNAA sensor</strong></td>
</tr>
</tbody>
</table>
Chute type particle sorter

Small particle sorting
3-20 mm

1. Unsorted particle feed
2. Scanning and processing
3. Diversion

Aluminium-21/Recycling, St.Petersburg, October 12-14, 2010.
Belt type particle sorter

Larger particle sorting
20-200 mm

1. Unsorted particle feed
2. Scanning and processing
3. Diversion

Aluminium-21/Recycling, St.Petersburg, October 12-14, 2010.
Eddy-current coil sensor sorter

Find metal in residue
and/or
separate stainless steel
Combined color/NIR and ECC sensor sorter

Separate Cu, brass, Zn, stainless steel, nonmetal
or
Al, Mg and nonmetal
or
Insulated wire from non-metal
Dual energy x-ray transmission sensor sorter

Identify contaminants, attachments, separate:
light metals from dense metals
Al from Mg?
Al(Mg, Si) from Al(Cu,Zn)?
DE-XRT identification of Al and Mg

Aluminum with steel

Magnesium with steel

$Z_{\text{eff}}$ vs. compactness of particle

Compactness ($4\pi \text{Area}/(\text{circum}/4)$)

Calculated $Z_{\text{eff}}$

TU Delft

International Aluminium Recycling Workshop, Trondheim, Norway 14-15 June 2010
Elemental concentration sensor sorters

XRF sensor
Alloy sort based on analysis of dense elements

LIBS sensor
Alloy sort based on analysis of all elements, light and dense
TiTech LIBS sensor Al alloy sorter specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conveyor belt width</td>
<td>60 cm</td>
</tr>
<tr>
<td>Conveyor belt speed</td>
<td>3 m/s</td>
</tr>
<tr>
<td>Particle chemical analyses</td>
<td>40 /s</td>
</tr>
<tr>
<td>14 alloying elements analyzed</td>
<td>Al, Mg, Si, Cu, Zn, Mn, Fe, Cr, Sr, Ti, Zr, Ce, La, Nd</td>
</tr>
<tr>
<td>Particle size</td>
<td>&gt;1 &lt; 15 cm</td>
</tr>
<tr>
<td>Particle weight</td>
<td>&gt;1 &lt; 250 g</td>
</tr>
<tr>
<td>Throughput for 50 g particles</td>
<td>7.2 t/h</td>
</tr>
<tr>
<td>for 20 h/d, 5 d/w operation</td>
<td>36,000 t/y</td>
</tr>
<tr>
<td>Output streams</td>
<td>4</td>
</tr>
</tbody>
</table>
Alloy Sorter feed end
LIBS Sensor
Typical Al wrought scrap illuminated by laser line
Splitter Box
Blowbar, splitters and four output bins
Particle tracking and targeting reproducibility

3 m/s, 40 Hz
Individual Mn and Mg LIBS measurements on particles moving at 3 m/s
LIBS sensor virtual sort of Al sheet alloys and a Mg-based alloys

Parent metal identification based on single-laser-bursts on clean particles moving at 3 m/s

<table>
<thead>
<tr>
<th>Metal Sorted</th>
<th>Output bins</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Al 1095</td>
</tr>
<tr>
<td>Al 1095</td>
<td>96%</td>
</tr>
<tr>
<td>Al 7075</td>
<td>0%</td>
</tr>
<tr>
<td>Mg</td>
<td>0%</td>
</tr>
</tbody>
</table>

Recovery wt%
LIBS sensor signal for wrought Al alloys

Average spectral line count ratio (Al)

Aluminium sheet alloy

- Zn
- Mn
- Cu
- Si
- Fe
- Mg
Virtual sort results on wrought Al alloys based on single laser burst LIBS measurements on moving samples

<table>
<thead>
<tr>
<th>Alloy Sorted</th>
<th>8011</th>
<th>1070</th>
<th>1020</th>
<th>6205</th>
<th>6060</th>
<th>3105B</th>
</tr>
</thead>
<tbody>
<tr>
<td>8011</td>
<td>83%</td>
<td>10%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>1070</td>
<td>7%</td>
<td>83%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>1020</td>
<td>0%</td>
<td>3%</td>
<td>83%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>6205</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>83%</td>
<td>57%</td>
<td>0%</td>
</tr>
<tr>
<td>6060</td>
<td>0%</td>
<td>0%</td>
<td>3%</td>
<td>67%</td>
<td>83%</td>
<td>0%</td>
</tr>
<tr>
<td>3105B</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>87%</td>
</tr>
</tbody>
</table>

Output Bin Composition wt%:

<table>
<thead>
<tr>
<th>Bin</th>
<th>Al</th>
<th>Si</th>
<th>Fe</th>
<th>Cu</th>
<th>Mn</th>
<th>Mg</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td>8011</td>
<td>98.325</td>
<td>0.522</td>
<td>0.638</td>
<td>0.084</td>
<td>0.044</td>
<td>0.046</td>
<td>0.049</td>
</tr>
<tr>
<td>1070</td>
<td>99.545</td>
<td>0.108</td>
<td>0.168</td>
<td>0.021</td>
<td>0.011</td>
<td>0.016</td>
<td>0.020</td>
</tr>
<tr>
<td>1020</td>
<td>99.095</td>
<td>0.301</td>
<td>0.112</td>
<td>0.008</td>
<td>0.015</td>
<td>0.324</td>
<td>0.126</td>
</tr>
<tr>
<td>6205</td>
<td>98.289</td>
<td>0.615</td>
<td>0.224</td>
<td>0.084</td>
<td>0.077</td>
<td>0.502</td>
<td>0.053</td>
</tr>
<tr>
<td>6060</td>
<td>98.399</td>
<td>0.570</td>
<td>0.221</td>
<td>0.071</td>
<td>0.063</td>
<td>0.513</td>
<td>0.042</td>
</tr>
<tr>
<td>3105B</td>
<td>97.804</td>
<td>0.620</td>
<td>0.170</td>
<td>0.007</td>
<td>0.780</td>
<td>0.550</td>
<td>0.029</td>
</tr>
</tbody>
</table>
Competition:
Sorting table vs Sorting circuit
New recycling processes enabled by sensor-based sorters

- Stainless steel recovery from shredder non-metallic residue
- Dry sorting of shredded non-magnetic mixed metals
- Light metal alloy batching/sorting
Shredded metal concentrate dry sorting plant

NMMC = Nonmagnetic metal concentrate

1000-2000 HP hammer mill

Oversize 30 mm 9 mm fines screens

Overbelt magnet

Headpulley magnet

Eddy current rotor circuit

DE x-ray sensor particle sorter circuit

Al-alloy mix Mg-alloy mix Dense metal mix Wire

>3<9 mm 9<30 mm >30<100 mm

Eddy current coil particle sorter circuit

>3<9 mm metal mix >9<100 mm metal mix

NMMC from SDF

NMMC from SLF

3 mm screen Overbelt magnet Cyclone separator & baghouse

Nonmetal fines & dust

Steel

Dense metal mix Wire

Aluminium-21/Recycling, St. Petersburg, October 12-14, 2010.
Takeaway

• Dismantling enables remanufacturing and reuse

• Shredding liberates mono-material particles and enables material recycling

• Bulk material separations for separation of metal from non metal and metal shred by density are mature and low cost

• Sensor based industrial sorters are industrially proven robust

• Sensor based sorters are displacing manual sorting in EU and NA

• Sensor based sorters enable new scrap recycling processes

• LIBS elemental concentration sensor sorter is now industrially well proven and commercial model is under development.

• Sensor based sorters now need market pull from the recycling industry