MAKING ALUMINUM SCRAP RECYCLING WORTH WHILE

AMAP COLLOQUIUM, APRIL 12TH 2018
CONTENT OF TODAY’S PRESENTATION

• Introduction of TOMRA Sorting, the Recycling division and TOMRA Systems
• Introduction to Sensor Based Sorting and the available sensors
• Overview of applications and installations of sensor based sorting in the Aluminum Recycling Industry
• Application Examples from different Industries
• Sorting of Production Scrap by alloy group
• Summary
TOMRA SORTING AND TOMRA SYSTEMS

IDEAS INTO ACTION
*Based on founding years of BEST Sorting, CommodasUltrasort, ODENBERG and TITECH

110* YEARS COMBINED INDUSTRY & SORTING EXPERIENCE

PIioneer In sensor-based sorting

Offering cutting-edge technology for industries where automated sorting and processing are key for value creation.

10,500 INSTALLED UNITS

*Based on founding years of BEST Sorting, CommodasUltrasort, ODENBERG and TITECH
FOOD
Potatoes, vegetables, nuts, dried fruit, seeds & grains, fruit, fresh cut, seafood, meat, gummies, tobacco

Steam peelers for potatoes, vegetables and fruits, process analytics for fat & moisture analysis

MINING
Industrial minerals, gems, precious metals, ferrous metals, non-ferrous metals, fuels

RECYCLING
Municipal solid waste, packaging, commercial & industrial waste, automobile shredder, electronic scrap
REVENUE DEVELOPMENT AND KEY MILESTONES

MEUR

- Total revenue growth (organic plus inorganic) CAGR of ~32% per year from 2004-2015
- Average annual organic growth for the same period was ~21%
- Technology base and segment/application knowledge expanded both through acquisitions and in-house ventures

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- TITECH acquired
- Qvision established
- CommoDas acquired
- Ultrasort acquired
- ODENBERG acquired
- BEST SORTING acquired

~ 261m EUR

14m EUR
INCREASE REVENUES
Enhance purity
Increase recovery rate
Consistent quality of output streams
New and innovative business fields

REDUCE COSTS
Reduce labor requirements
Lower operational and service costs
Low space requirements
Easily adaptable

OTHER BENEFITS
Significantly fewer landfills
More efficient use of primary resources
Less environmental pollution
PRODUCT-SPECIFIC EQUIPMENT DESIGN OFTEN INCLUDING MULTIPLE TECHNOLOGIES TO MAXIMIZE SORTING EFFICIENCY

High-tech sensors to identify objects

Precise ejection by air jets or mechanical fingers

Feeding of unsorted material

High-speed processing of information (material, shape, size, color, defect, damage and location of objects)
80 patents owned

Development of own sensors

Own software and data processing tools

Partnership with leading R&D institutions (SINTEF, CTR, Fraunhofer ILT; Universities like RWTH and Brussels)

20% of all employees work in in-house R&D

8% of revenue reinvested in R&D

KEY FACTS AND FIGURES R&D
GLOBAL PRESENCE

AN EXTENSIVE AGENT & DISTRIBUTOR NETWORK COVERING DIFFERENT SEGMENTS AND MORE THAN 80 COUNTRIES

TOMRA Sorting subsidiary
HIGH STANDARD PRODUCTION & WORKSHOPS

Quality, Environmental and Health & Safety management systems according to ISO 9001, ISO 14001 and OHSAS 18001

- BRATISLAVA, SLOVAKIA
- DENVER, US
- EINDHOVEN, THE NETHERLANDS
- KOBLENZ, GERMANY
- LEUVEN, BELGIUM

1300 AVERAGE NUMBER OF PRODUCED SYSTEMS PER YEAR
OUR TEST CENTERS: SORTING EXCELLENCE

Test your own product or material in our test centers worldwide.

- FOOD TEST CENTER in Leuven, Belgium
- The complete sensor portfolio can be tested.
- MINING TEST CENTER in Hamburg, Germany
- Experienced application engineers develop tailored solutions for individual needs.
- RECYCLING TEST CENTER in Koblenz, Germany
Publicly listed on Oslo Stock Exchange (OSEBX: TOM)

2600
EMPLOYEES
GLOBALLY

650
MILLION EUR
REVENUES 2015
ALUMINUM SORTING APPLICATIONS
THERE ARE MANY DIFFERENT ALUMINUM SCRAP SOURCES THAT HAVE QUITE DIFFERENT LEVEL OF COMPLEXITY

Increasing content of impurities in original input

- Alu from ELV shredder
- Alu from bottom ash
- UBC
- Alu-Profiles
- Alu-sheets
- What's your input?
Different applications of TOMRA Sorting units in the Aluminum Industry

- **Zorba Sorting:**
  - Removing of Heavy metals form Zorba – clean, mixed aluminum material
  - Removal of alloyed aluminum materials - reduction in e.g. Zn content
  - Separation of wrought aluminum from cast aluminum

- **Taint Tabor Sorting**
  - Removal of free Heavy metals from Taint Tabor
  - Removal of 2.xxx and 7.xxx alloys – reduction in Cu and Zn content

- **Production alloy sorting**
  - Sorting of 5.xxx and 6.xxx production stamping alloys
  - Different alloy sorting 1-7xxx groups for clean scrap

Over 40 TOMRA Sorting units in aluminum segments in operation today.
How it works:

- Input stream is fed on a high speed conveyor belt (mono layer)
- Materials on conveyor belt are exposed to X-RAYs and penetrated.
- A sensor system (2 line sensor = DUOLINE) identifies the atomic density, shape, conductivity and other properties and the exact position of each object.
- Air jets eject the impurities into a bunker belt
- The rest fraction (cleaned aluminum) falls into another bunker
XTRACT XRT CAN SEPARATE MATERIALS BASED ON ATOMIC DENSITY

APPLICATION EXAMPLE: ALUMINUM SCRAP PROCESSING, RECOVERY/REMOVAL OF ALUMINUM, ALLOYS AND MIXED HEAVIES
ZORBA SORTING APPLICATIONS

WASTE INTO VALUE
Frame conditions

- Generation of ELV Zorba by ‘traditional’ treatment and separation technology.
- ELV Zorba as input material into the density sorting unit
- ELV Zorba to be screened in different grain sizes – small, medium, large
- In example, grain sizes are 10-30 mm, 30-70 mm, 70-110 mm
- Ejection of free heavy metals such as Copper, Brass, Zinc
- Additionally, ejection of high alloyed cast aluminum (e.g. > 2-3% Zn content)
- Aluminum purity by hand sorting (manual counting) is approx. 97-99%
PURITIES OF FINISHED ALUMINUM PRODUCTS IN THE DIFFERENT GRAIN SIZES
WITH SENSOR BASED SORTING IT IS POSSIBLE TO REGAIN A WROUGHT ALUMINUM FRACTION FROM ZORBA

- Aluminum fraction from previous ZORBA sorting can be split further into ‘cast’ and ‘wrought’ fraction
- Grain sizes separation upfront necessary
- Main content of wrought is in larger grain sizes
- Classification of material by X-Ray Transmission technology
- Separation by atomic density mainly
- Eventually, need for second sorting step.

Aluminum cast + alloy + polymer

Aluminum wrought product
TAINT TABOR & EXTRUSION SORTING APPLICATIONS
Trend of upgrade various Aluminum scrap materials, for example sheet rich Taint Tabor scrap

Focus for recycler/metal producer is to substitute “virgin” or top qualities by upgrade of “lower” qualities.

Therefore, reduction of downcycling and at same time saving in material costs.

Sorting task is the reduction of free heavy’s and high alloy Aluminum such as 2.xxx and 7.xxx

REMOVAL OF CU/ZN AL ALLOYS TO ENSURE HIGH QUALITY RECYCLING OF TAINT TABOR
CONTENT OF DIFFERENT METALS IN ALUMINUM SHEET PRODUCT PRODUCED BY XTRACT

Heavy Metal content in Al product

- Cu
- Zn
- Si
- Fe
- Ni
- Mg
- Pb
- Ti
INCINERATOR BOTTOM ASH SORTING APPLICATIONS
Frame conditions and findings:

- Traditional bottom ash treatment yields Aluminum rich Eddy Current Product
- Sorting of ECS product – removal of heavy metals by XTRACT
- Grain sizes to be sorted 4-8 mm, 8-12 mm, 12-25 mm & 25-50 mm
- Precious metals are concentrated in grain size <25/30mm
- Aluminum from ashes is a quite nice wrought Alu product
MELT RESULT OF FRACTION SORTED BY SENSOR BASED SORTING SHOWS HIGH ALUMINUM PURITY

XRF Analysis light fraction sample

- Al: 97.79%
- Others: 1.54%
- Cu: 0.43%
- Ni: 0.03%
- Fe: 0.70%
- Pb: 0.05%
- Zn: 0.33%
PRODUCTION SCRAP SORTING APPLICATIONS
• Aluminum usage in cars increasing; from 115 kg (250 lbs.) in 2000 to 235 kg (520 lbs.) in 2025*
• Worldwide (light) vehicle production is 90,000,000 units/year
• Globally, 34% of the vehicle fleet will be electrified by 2025* which will lead to lower consumption of aluminum cast alloys
• CO₂ emission regulations are tightening up, examples
  - EU 28 2015: 130 g/km, 2021: 95 g/km
  - US 2016: 36.2 mpg, 2025: 54.5 mpg (150 g/km; 100 g/km)
  - China 2015: 6.9 l/100 km, 2020: 5.0 l/100 km (160 g/km; 116 g/km)
• Major contributors for CO₂ decrease are**
  - Powertrain Efficiencies – e.g. 5-8% CO₂ reduction by cylinder deactivation = 8 g CO₂/km reduction
  - Aerodynamics and energy management – e.g. 1% CO₂ reduction by 2% drag reduction
  - Ligthweighting – e.g. 50 kg weight reduction = 5 g CO₂/km reduction

CONCLUSION: More aluminum usage by lightweighting BUT less aluminum usage by casting engine blocks!

*Ducker Study, 2015
**IHS Markit – 2017 Fall Automotive Conference; Frankfurt
USAGE OF ALUMINUM CAST AND ALUMINUM SHEET MATERIAL IN THE CAR INDUSTRY

Source: 2015, Ducker Worldwide
Aluminum bonds tightly with other elements
- Only limited possibilities to remove alloying elements metallurgical
- Influencing composition of molten (secondary) aluminum is blending/dilution with primary aluminum.

Wrought alloys and cast alloys differ significantly in composition:
- Cast alloys – main alloying elements Si, Zn and others; significant amount
- Wrought alloy – main alloying elements Mg, Si; viewer percentages
- Due to high alloy amounts in cast; fractions that are ‘contaminated’ by cast alloys can not be used for the production of new wrought materials

Wrought alloys sub-devide into 8 different groups; group definition by alloying element

**Conclusions:**

- wrought and cast alloys need to be recycled separately
- downcycling if fractions are mixed
- Today, only material kept separate is recycled into wrought
PRICE DEVELOPMENT ALUMINUM SCRAP

Price Development Aluminum - Mill Scrap Grade 2017 - 2018

- Non-ferrous scrap and secondary metals - Aluminium - Aluminium scrap MLC mill grade del US
- Non-ferrous scrap and secondary metals - Aluminium - Aluminium scrap 5052 clips mill grade del US
- Non-ferrous scrap and secondary metals - Aluminium - Aluminium scrap 6061 new bare mill grade del US

MONTH/YEAR

AVERAGE PRICES IN US DOLLAR / T
LIBS DETECTION PRINCIPLE

![Diagram of LIBS detection principle](image)

- Q-switched Nd:YAG Laser
- Fiber optic routing
- Plasma
- Dispersion of emitted light (spectrograph)
- Collection of emitted light
- Measurement of dispersed light (CCD camera)

**ALL ELEMENTS EMIT LIGHT!!**

![Graphs of Alloy F and Alloy E](image)

- Intensity vs. Wavelength
- Comparing spectra of Alloy F and Alloy E
HOW DOES TOMRA’S LIBS SYSTEM WORK?

Singulation
- Particles can be fed randomly to conveyor belt
- Conveyor belt runs at 3 m/s

3D/Surface Detection
- 3D analysis (scanning)
- Computer identifies right position for laser

Cleaning/Analyzing
- Same laser targets particle for both steps
- Laser is focused by dynamic mirror system

Ejection
- Ejection of particles into two fractions
- Ejection by means of air jets

Feeding of unsorted material
3D-Object recognition
Scanning/LIBS analysis
Separation chamber
TOMRA SORTING LIBS TESTSYSTEM IN KOBLEN TEST CENTER
EXAMPLE 1: SORTING OF 6XXX FROM 5XXX

<table>
<thead>
<tr>
<th>Input</th>
<th>kg</th>
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<tbody>
<tr>
<td>Total</td>
<td>6,31525</td>
<td>100%</td>
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</tbody>
</table>

**Composition (calculated)**

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<table>
<thead>
<tr>
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<tbody>
<tr>
<td>5xxx</td>
<td>4,6625</td>
<td>73,8%</td>
</tr>
<tr>
<td>6xxx</td>
<td>1,65275</td>
<td>26,2%</td>
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**Sum**

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<td>100%</td>
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<th>Material</th>
<th>kg</th>
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<tr>
<td>EJECT</td>
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<tr>
<td>Step</td>
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**Material kg**

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<tr>
<th>Material</th>
<th>kg</th>
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<td>Total</td>
<td>1,72725</td>
<td>27%</td>
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**Composition**

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<td>5xxx</td>
<td>0,14025</td>
<td>8,1%</td>
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<tr>
<td>6xxx</td>
<td>1,587</td>
<td>91,9%</td>
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**Sum**

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<tr>
<td>Sum</td>
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<td>100,0%</td>
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**Accept Material kg**

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<tr>
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**Material kg**

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<tr>
<th>Material</th>
<th>kg</th>
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<tbody>
<tr>
<td>Total</td>
<td>4,588</td>
<td>73%</td>
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</tbody>
</table>

**Composition**

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<td>5xxx</td>
<td>4,52225</td>
<td>98,6%</td>
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<td>6xxx</td>
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**Sum**

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<tbody>
<tr>
<td>Sum</td>
<td>4,588</td>
<td>100,0%</td>
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**Recovery 5xxx: 97,0%**
**Recovery 6xxx: 95,8%**
SENSOR BASED SORTING CAN SUPPORT AND ENABLE HIGH QUALITY RECYCLING OF DIFFERENT ALUMINUM SCRAP SOURCES

Summary

• Different scrap sources can today be separated in higher quality fractions that can be recycled in a high quality application
• Down-cycling of valuable aluminium alloys can be reduced by sensor based sorting
• Usage of virgin material resources can be reduced by sorting the scrap materials with sophisticated sorting technologies
• Risk of aluminum scrap usage for recyclers can be reduced
• Viewer need of blending and melt corrections
• In future, sorting of production scrap as well as old scrap into alloy group or eventually separate alloys will be possible
WASTE INTO VALUE

www.tomra.com/recycling