ALUMINIUM RECYCLING INDEX

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Recycling Driving Changes in Aluminium Alloy Development

- Previous approach to alloy development
  - Driven solely by desired performance
  - Limited considerations of end-of-product-life
  - Less considerations for cost, carbon footprint and availability of alloying elements
- Beginning to recognize impact of recycling
  - How will product be recovered for recycling ?
  - How will composition impact cost & recyclability?
  - What will be it's carbon footprint?

Driving Forces for Recycling Aluminium

- **Recycling aluminium alloys impacts energy needs and carbon footprint**
  - **Requires only 5% of energy compared to primary**
    - **~2.8 kWh/kg Al vs. ~45 kWh/kg Al**
  - **Produces only 5% of CO_2 compared to primary**
    - **~0.6 kg/kg Al vs. 12 kg/kg Al**
  - **Alloying elements (Mg, Mn, Cu ,Zn, Si)**
    - **Require more unit energy and produce more unit CO_2**

Urban Aluminium Mine – A Major Stored Energy Bank

- Tremendous amounts of aluminium in
  - Automotive vehicles reaching end of use at >20 MM/year
  - Buildings being demolished, thousands each year
  - Aircraft, stored in "graveyards; being decommissioned annually

- These all represent our "Urban Aluminium Mine"
  - Literally an on-the-ground source of aluminium , cheapest "bauxite"
  - Important source for alloying elements
  - Invested and recoverable energy bank for newer aluminium alloys
  - Avoids new carbon dioxide emissions

New Paradigm for Evaluation of Existing and Designing of New Alloys

- For both existing and new alloys --- Recycle to same product
- For existing alloys:
  - Recognize relative value when recycled
    - How big are energy source and carbon footprint?
  - Consider how best to group alloys for remelting to maximize value of remelt composition?
- For designing new alloys
  - Consider how useful composition will be when remelted
    - Avoid adding elements that become contaminants
  - Consider possibility of direct production from recycle remelts
    - Avoid tight impurity limits unless required for performance
    - Consider compositions likely to come from automotive, B&C, packaging or aircraft recycling (new class of “elements”)

A Tool for Assessing Recycle Value The Aluminium Recycle Index (ARI)

- **Definition:**
  - **ARI is a measure of the relative ease, value, and desirability of recycling & remelting alloys in end-of-life products**
    - **Includes potential for recycling back to the same product or to another high-value product with minimal primary additions**
  - **ARI is a measure of the energy content and carbon footprint**

KEY FACTORS

1. Elemental Composition
2. Al Recovery (other/same & wrought / cast)
3. Recovery of Elements (any / same product)
4. Production Processing Parameters
5. End- of-Life Dismantling & Recyclability
6. Energy / Carbon Dioxide (Al & Elements)
7. Remelting Energy Efficiency & Recovery

Aluminium Recycle Index (ARI)

Calculated Using Factors # 1 & 2
Elemental Composition & Aluminium recovery

- **Most of the energy effectively stored in an alloy is contained in the aluminium content**
  - **Relatively little of the total energy in alloying elements**

- **Calculate ARI as the nominal aluminium content**
  - **Sum nominal alloying content (sum of mid-ranges)**
  - **Sum impurities (sum of 50% of max limits)**
  - **Combine sums and subtract from 100**
  - **Equals nominal aluminium content -- ARI**

ARI for Wrought Commercial Alloys

Alloy	Nominal Alloying Content %	Nominal Impurity Content %	Sum Element Content %	Nominal Aluminum Content ARI, %	Notes re ARI
1100	- -	- -	- -	99.0	
1350	- -	- -	- -	99.5	
2011	5.5	0.8	6.3	93.7	Pb, Bi
2024	6.5	0.9	7.4	92.7	
2195	6.0	0.4	6.5	93.6	Li
3003	1.4	0.8	2.1	97.9	
3004	2.2	0.9	3.1	97.0	
3105	1.1	1.3	2.4	97.7	
4145	14.0	0.8	14.8	85.2	Hi Si
5052	2.8	0.7	3.5	96.6	
5086	4.6	0.7	5.3	94.7	
5182	4.9	0.7	5.5	94.5	
5456	6.0	0.7	6.7	93.3	
6061	2.1	0.7	2.8	97.2	
6063	1.1	0.5	1.6	98.4	
6101	1.2	0.4	1.6	98.4	
6201	1.4	0.4	1.8	98.2	
7050	10.8	0.3	11.1	88.9	Hi Cu, Zn
7075	9.9	0.8	10.7	89.3	Hi Cu, Zn
7129	7.7	0.4	8.1	91.9	Hi Zn
7475	9.7	0.3	10.0	90.0	Hi Cu, Zn

ARI for Cast Commercial Alloys

ALLOY	NOMINAL ALLOYING CONTENT %	NOMINAL IMPURITY COUNT %	SUM ELEMENT COUNT %	NOMINAL ALUMINUM CONTENT, ARI, % [4]
201.0	6.3	0.2	13.8	86.3
242.0	7.5	1.5	13.1	86.9
295.0	5.6	1.0	15.1	84.9
319.0	9.5	1.9	20.6	79.4
354.0	11.1	0.4	17.9	82.2
355.0	6.8	1.0	14.1	86.0
356.0	7.3	1.0	14.7	85.4
A356.0	7.4	0.5	17.4	82.7
360.0	10.0	2.2	22.0	78.0
380.0	12.0	3.5	34.1	65.9
390.0	22.1	2.0	27.3	72.7
443.0	5.2	1.7	11.0	89.0
512.0	5.8	1.4	15.9	84.2
520.0	10.1	0.7	17.8	82.3
710.0	7.7	0.6	15.3	84.7
772.0	7.6	0.3	15.8	84.2
850.0	8.2	1.1	22.0	78.1
853.0	13.8	0.9	13.8	86.3

Aluminium Recycle Index

Descriptor	Wrought Alloys	Casting Alloys
Optimum	97-100	95-100
Excellent	96-97	90-95
Good	95-96	87-93
Fair	93-95	84-86
Difficult	90-93	80-83
Unlikely	<90	<80

Implications of Aluminium Recycling Index

- **High ARI (> 95) for wought cast (>87) alloys:**
  - Relative high purity, few contaminants
  - Relatively low alloying levels, greater likelihood of compatibility
  - For casting alloys only, moderate Si and few other alloying elements

- **Medium ARI (93-95) for wrought cast (83-87) alloys:**
  - Moderately high in alloying content, moderate impurity and insoluble constituents
  - Used in applications where pre-shred segregation prior to remelt seems practical (automotive wheels and bumpers).
  - For casting alloys only, high levels of Si with few other alloying elements

- **Low ARI (< 93) for wrought cast (< 83) alloys:**
  - Relatively high content in one or more elements, or
  - Undesirable elements for most remelts (e.g., Ag, Be, ,Pb, Li)
  - For casting alloys, alloys with very high Si plus high Cu, Sn, or Zn.
  - Even lowest rated alloys ARI worth recycling

Summary and Future Work

Aluminium Recycling Index and its Usefulness

- Defined as nominal aluminium content in alloys considering alloying elements and impurities (Key Factors # 1 & 2)
- Provides measure of energy invested , carbon dioxide emitted and remelting efficiency in end-of-life aluminium products
- Illustrates relative importance of recycling all end-of-life products, vehicles, buildings, aircrafts
- Useful in alloy design recognizing recycling and remelting
- Future work planned to include Key Factors # 3 to # 7