DRIVING INNOVATION WITH AUTOMOTIVE ALUMINUM

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DISCUSSION OUTLINE

- Why Automotive Aluminum?
- 50 Years of Growth
- Aluminum Materials
- Advances in Automotive Aluminum
- Corrosion
- Repair Industry Issues
THE ALUMINUM ADVANTAGE
ALUMINUM ADVANTAGES

What Automotive Customers Need...

- **Weight Reduction**
  (Multi-Material Vehicles)
- **Fuel Economy/CO2 (CAFE)**
- **Performance:**
  - Safety, 0-60, handling, ride, NVH, braking, etc.
  - Payload, towing capacity
- **Cost Effective**

- **Aluminum Products**
  - Body Sheet
  - Extrusions
  - Structural castings

- **Properties**
  - Strong
  - Tough
  - Energy absorbing
  - Corrosion resistant
  - Formable
ALUMINUM AUTO BODY SHEET AND EXTRUSIONS

- **1.0 lb. of aluminum replaces 1.7 lbs. of MS/HS/AHSS**
  - Body: -40% mass (BIW, Closures)
  - Curb mass: -12%
  - Jaguar, F-150, Aachen, FEV/EDAG …

- Secondary mass reductions
  - Up to 0.5 lbs.

- **10% vehicle mass reduction – “achievable”**
  - 6.5% FE improvement (+ 2.7 MPG)

- **Cost advantage over other fuel economy technologies**
  - Diesel, hybrid, electric, …

[Image of aluminum auto body sheet and extrusions]
THE VIRTUOUS CYCLE

Mass Reduction → Infinitely Recyclable → Lowest Lifecycle Emissions → Better Fuel Economy → Improved Safety → Enhanced Performance

Data Source: USGS Minerals Yearbook 2014
50 YEARS OF GROWTH
40 year growth trend continues

Highest growth = 2015
  - First high-volume automotive body and structures – F-150 pickup truck all-aluminum body
  - Sheet and extrusions – body, closures

Continued growth
  - Non-body applications: castings and extrusions
50 YEARS OF ALUMINUM GROWTH

Source: Ducker
50 Years of Aluminum Growth

Aluminum Component Share by Weight

- **Body & Closures**: 11%
- **Castings**: 73%
- **Engine**: 33%
- **Transmission & Driveline**: 19%
- **Blocks**: 12%
- **Heads**: 12%
- **Other Engine**: 9%
- **Wheels**: 16%
- **Suspension**: 2%
- **Steering**: 4%
- **Brakes**: 2%
- **Heat Transfer**: 10%
- **All other**: 2%
- **Bumpers**: 1%

Average 394 Lb. per Vehicle
6.9 Billion Pounds
AUTOMOTIVE MATERIAL MIX SHIFT - LIGHTER

2015
- Non Metallics: 23%
- Mild Steel: 17%
- HS Steel: 14%
- FR AHSS: 5%
- All Other Steel: 16%
- Iron: 8%
- Copper: 1%
- All Other Al: 8%
- Al Str Castings: 1%
- Aluminum: 10%

3700 lbs.

2025
- Non Metallics: 25%
- Mild Steel: 12%
- HSLA: 7%
- AHSS: 11%
- Other Metals: 3%
- Copper: 1%
- Cast Al: 8%
- AL Str Castings: 1%
- Other Steel: 16%
- Rolled Al: 4%
- Cast Al: 8%
- Aluminum: 13%

3427 lbs.
ALUMINUM BODY COMPONENTS

Body in White
Bumper Beams
Shock Towers
Door and other closure inners

Fenders
Deck
Door outer
Hood

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ALUMINUM-INTENSIVE VEHICLES TODAY

© Ford

© Audi

© Jaguar

© Jaguar

© Tesla

© Land Rover

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ALUMINUM DRIVES CREATION OF NEW SEGMENT: ULTRA-LUXURY SUV

Bentley Bentayga

Maserati Levante

Lamborghini Urus

Rolls Royce Cullinan
MULTI-MATERIAL VEHICLES: THE NEW NORMAL

© Cadillac

2016 Cadillac CT6

© Chevrolet

2016 Chevrolet Malibu

© BMW

2016 BMW 7-Series
ALUMINUM REPAIR - MARKET GROWTH

Aluminum Vehicle Repair
Annual Projection
2015 - 2025

Repair Incidences (MM s)

- AIV
- Closures
- Total

DRIVEALUMINUM.ORG
AUTOMOTIVE ALUMINUM MATERIALS
All aluminum materials are **NOT** the same
- Can not easily identify specific material in the field
- Repair practices varies by material

Automotive alloy selection
- Strength
- Ductility
- Corrosion resistance
- Cost (material, processing)
- Energy absorption
ALUMINUM AUTO BODY MATERIALS

- Different Automotive Aluminum Materials
  - Product form
    - sheet, extrusion, casting
  - Alloys
    - composition, mechanical properties, strengthening process
  - Tempers (strengthening)
    - mechanical properties, formability
    - Heat Treatable: Typically: body exterior, loaded structure
      - F, T4, T4PB, : High Formability
      - T6: Maximum Strength (+50% over T4 Typ.)
    - Non-heat treatable: Typically: under-body structure
      - HXX Work hardening
**Pretreatment – Sheet, Extrusions**

Function – alter natural oxide layer
- Chemically
- Physically

Purpose - enhance
- Adhesive bonding
- Paint adhesion
- Corrosion resistance

Types
- Anodize
- Alodine
- Alcoa 951

...
Exterior Body Sheet (class “A” surface)

Requirements
- Stiffness, Formability, Surface Quality, Dent Resistance, Corrosion Resistance

Product Attributes
- Alloys
  - 6005, 6009, 6010, 6013, 6016, 6022, 6111, 6451, (7XXX)
- Tempers
  - T4 or T4 PB Typ.
- Strength
  - T4: 185 – 250 MPa UTS (elongation 20-25 %)
- Gauge
  - 0.8 – 1.4 mm Typ.
- Forming
  - T4 temper
  - Some aged to T6 after forming
ALUMINUM AUTO BODY MATERIALS

- **Body Structure (non class “A” surface)**
  - Sheet, Extrusions, Castings
  - **Requirements**
    - Strength, stiffness, energy absorption
  - **Alloys**
    - Sheet – 5182, 5454, 5754, 7XXX, … (Cold worked in forming)
    - Extrusion - 6005, 6061, 6063, 6082, 7003, 7043, …. (T6 Typ.)
    - Casting – 380, 356, 357, ….. (T6 Typ.)
ADVANCES IN AUTOMOTIVE ALUMINUM
ADVANCED ALLOYS MEET AUTOMOTIVE NEEDS

- Continuous Product Improvement
  - High Strength
  - Energy Absorption
  - Advanced Formability
  - Value
  - Sustainability

Graphic: Alcoa R&D
“High Strength” Alloy/Temper Variants

Applications – body structure, bumper

**Sheet:**

- Variants: 6022, 6111, 6451, 7021
- UTS: 400 + MPa

**Extrusions:**

- Variants: 6082, 7003, 7046
- UTS: 400+ MPa
ALUMINUM ENERGY ABSORPTION

“Crush Grade” Alloy/Temper Variants

Excellent energy absorption

Applications – body structure, bumper, frame rails, crash cans

Sheet:

Variants: 6022, 5454, 5754

UTS: 300 + MPa

Extrusions:

Variants: 6005, 6061, 6082, 7046

UTS: 300 + MPa

Aluminum: Highest energy absorption automotive material, pound for pound
ENHANCED FORMABILITY ALUMINUM ALLOYS

“Formability” Alloy/Temper Variants

- Excellent: deep draw, hydroforming, hemming
- Applications – body structure, exterior panels, door inner
- Sheet (exterior):
  - Variants: 6111, 6022, 6XXX, ....
  - UTS: 250 – 365 MPa
- Sheet (structural)
  - Variants: 6022, 6111, 6XXX, 5182, 5454
  - UTS 250 – 575 MPa
- Extrusions:
  - Variants: 6061, 6082
  - UTS 300 – 350 MPa
Alcoa Micromill™ Technology:
- 30 percent greater strength
- 40 percent greater formability
- 6xxx alloy Class A surface quality
- 5xxx and 6xxx alloys components

Taking a 20 day traditional rolling process...

...to 20 minutes with the Micromill™

...and reducing the footprint to ~150 ft

- 130+ patents worldwide
- World’s most productive continuous caster
- 50% lower energy use
- Shifts alloys at the press of a button
- Offers product widths comparable to our other automotive mills
BREAKTHROUGH:
GM ALUMINUM WELDING

WELDING PROCESS MAY HELP IMPROVE FUEL ECONOMY

GM’s new resistance spot welding process, using a proprietary multi-ring domed electrode, will enable more use of lightweight aluminum, which can help boost fuel economy.
COST / EFFICIENCY IMPROVEMENT

Price Changes 1975:15
CPI  4.4
AL  2.0
Bread  5.0
Labor  4.9
Car  4.7
Elect.  4.5
Home  4.1
Gasoline  2.7

Aluminum Price 1975-2014
Market, CPI Adjusted (1975 = 1)
1975 Price CPI Indexed
Average MW Metal Price
ENVIRONMENTAL STEWARDSHIP

North American (U.S. Canada) Primary Aluminum Production:

**Primary Energy Demand - Primary Aluminum Production**
- 1991: 130,000 MJ/MT Al
- 1995: 140,000 MJ/MT Al
- 2005: 150,000 MJ/MT Al
- 2010: 200,000 MJ/MT Al

-26%

**Carbon Footprint - Primary Aluminum Production**
- 1991: 12,000 kg CO2e/MT Al
- 1995: 15,000 kg CO2e/MT Al
- 2005: 18,000 kg CO2e/MT Al
- 2010: 20,000 kg CO2e/MT Al

-45%
NAFTA PRIMARY ALUMINUM: LONG TERM TREND

CO2 Generation*
Coal – 20 lb./lb. Al
Hydro – 5 lb./lb. Al

* Includes: mining, refining, transportation
ALUMINUM AUTO BODY AND CORROSION
Auto Alloys - Corrosion Resistant

- Aluminum Automotive Alloys
  - Excellent Corrosion Resistance (5XXX, 6XXX)
    - Natural Oxide Film
  
  Cosmetic Corrosion – Certain conditions
    - Galvanic corrosion
    - Crevice corrosion
      - Filiform corrosion

- Preventive Measures
  - Known and practical
ALUMINUM – NATURAL CORROSION RESISTANCE

- **Natural Oxide Film (The Key Attribute)**
  - Forms instantaneously
  - increasing thickness over time
  - Transparent
  - Tenacious
  - Hard
  - Chemically stable in “normal” environments (pH 4.5-8.0)
  - exposed raw metal does not corrode engine, transmission, suspension

- **Corrosion can Occur if Damaged**
  - Scratch
  - Stone chip
  - Mechanical abrasion
  - Sanding, Grinding
  - Chemical attack (pH: <4, >8)

- **Corrosion Typically Cosmetic**
  - Un-painted - White powder on surface
Galvanic Corrosion - Conditions

- Dis-similar Metals (or Materials)
- and
- Electrical Contact
- and
- Electrolyte (NaCl)

Corrosion Rate – typically “very slow”

Prevention

- Protective coatings
  - fasteners – common coatings
  - sheet or extrusion
- Seal interface crevice (exclude electrolyte)
- flexible sealer
CREVISE CORROSION - ALUMINUM

- **Crevice Corrosion**
  Chemical action between surfaces

- **Required conditions**
  Crevice - fraying surfaces
  and
  Electrolyte (NaCl)

- **Locations**
  lap joints
  spot welded joints
  or, surface mud accumulation
  (similar to steel, less aggressive in aluminum)

- **Prevention**
  Protective coatings
  sheet or extrusion
  Seal interface crevice – exclude electrolyte
  Flexible sealer
Filiform Corrosion (Form of crevice corrosion)

Chemical attack under coatings

Required conditions

Damaged coating (scratches, stone chips, sheet edges)

and

Electrolyte intrusion (NaCl)

(similar to steel, less aggressive in aluminum)

Corrosion Rate

Accelerated by surface marks from grinding, sanding

Prevention (or Mitigation)

Surface - Alloy selection (mitigation)

Surface conversion treatments

Coating durability

Edge - Seal crevices
FILIFORM CORROSION – GRINDING, SANDING

Vehicle Test Results

Laboratory Test: ASTM G85-A2 (Acidified Salt Fog)
- 5% NaCl
- pH 2.8-3.0 acetic acid
- 120 F.
- 500 Hrs. (6 Hr. cycle)
  - :45 - spray
  - 2:00 - dry
  - 3:15 - soak

Impact: grinding, sanding, factory coatings
COLLISION REPAIR
Aluminum Repair Considerations

- Shop Safety
  Dust Management (Combustion)

- Corrosion

- I-CAR / Aluminum Association Joint Studies
  Industry open issues / concerns
  Information
  Develop “Best Practices” Bulletins
ALUMINUM DUST MANAGEMENT

- **Fines**
  - Dust or powder
  - Grinding, sanding, polishing

- **Can be combustible when:**
  - Small particles < 500 micron
  - Suspended in air
  - Concentration
  - Ignition source
  - Incidences are rare

- **Control**
  - Dust collection system
  - Electrically grounded
  - Spark resistant
  - No smoking

Re: Nat Fire Protection Assoc. Std. No. 484
SUMMARY

✓ Multi-material vehicle designs – the new norm
  Aluminum and steel – Co-exist, important auto materials

✓ Aluminum 2025 - OEM production
  Closures - 24 % by 2025
  Body - 12 % by 2025

✓ Repair is similar to steel, but different
  Training – OEM, I-Car, …
  Equipment
  Many different aluminum grades
  OEM repair procedures should be followed

✓ Keep Shops SAFE!
  No Dust incidences
QUESTIONS?