Aluminum Extrusions

Designing to the Limits of Your Imagination!

Brought to you by:
Aluminum Extruders Council
www.aec.org
ET Foundation
www.etfoundation.org

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Introduction

The Shape is the Idea!

Almost any shape can be produced using aluminum extrusion …
Introduction

**Aluminum Extrusion: Alloy + Geometry = Performance**

The right shape, utilizing the right alloy, can then be enhanced and perfected through additional fabrication and finishing to yield an effective product solution...allowing you to design to the limits of your imagination!
Introduction

Aluminum: a material with outstanding physical characteristics

Aluminum Extrusion: often the most functional, cost effective and quickest path between function and form

– Incredibly versatile, capable of converting ideas to reality quickly and inexpensively

– A near-net shape process for complex forms, with close tolerances

Together they optimize component and product designs!
Presentation Agenda

This presentation provides both a conceptual and a practical understanding of how to creatively address product challenges with aluminum extrusions

- Advantages of Aluminum and Aluminum Extrusion
  - The Extrusion Process

- Key Design Variables
  - Alloys
  - Shapes
  - Tolerances
  - Fabrication
  - Finishing

- Case Examples

- Aluminum Extrusion Design Competition

- Additional Resources

- Sample Q&As
Learning Objectives

At the end of this presentation, you should be able to:

1. Develop a basic understanding of the aluminum extrusion process and material attributes.
2. Apply best practices in extruded part design, to optimize functionality and production economics.
3. Understand the key variables and limitations for aluminum extrusion design.
4. Choose additional resources key to the design and specification of extrusion-based components.
5. Recognize the range of applications where extrusions can have meaningful impact.
6. Demonstrate knowledge by entering a design in the Aluminum Extrusion Design Competition.
Why Aluminum Extrusions?

Advantages of Aluminum

• Lightweight
• Strong
• High Strength-to-Weight Ratio
• Resilient
• Corrosion-Resistant
• Heat Conductive
• Reflective
• Electrically Conductive
• Non-Magnetic
• Non-Sparking
• Non-Combustible
• Cold Strength
• Fully Recyclable

Advantages of Extrusion

• Tailored performance – put metal where it is needed
• Suitable for complex, integral shapes,
• Produced to close tolerances
• Attractive, wide range of finishes
• Virtually seamless
• Easy to fabricate
• Joinable by various methods
• Suitable for easy-assembly designs
• Produced with uniform quality
• Cost Effective
• Short production lead times
Advantages of Aluminum

**Strong**
 Appropriately alloyed and tempered, aluminum can be stronger than some steels, with ultimate tensile strengths as high as 80,000 psi to 90,000 psi or more.

**High Strength-to-Weight Ratio**
 The standard aluminum frame for the 2014 Corvette C7 is over 90 pounds lighter, yet 60% stiffer than the prior steel frame.
Advantages of Aluminum

Corrosion-Resistant

• Excellent corrosion resistance in a wide variety of environments and contact with a myriad of substances.
• It *develops its own inert aluminum oxide film, which is self-protective*, blocking further oxidation.

Cold Strength

• Advantages are *not impaired* by cold. Aluminum gains strength and ductility as temperatures are reduced, making it a preferred metal for cryogenic (low-temperature) applications.
• Steel and plastics get brittle when the temperature drops… *aluminum gets stronger and tougher!*

©Action Graphics, Inc.
Advantages of Aluminum

Electrically Conductive
Volume for volume, aluminum carries electricity about 62% as well as copper. **On a weight basis, aluminum can be twice as conductive as copper**, and aluminum is often the most economical choice.

Heat Conductive
Conducts – and dissipates - heat better than any other common metal on both a weight and cost basis.
Advantages of Aluminum

Sustainable & Fully Recyclable

• Can be recycled over and over without degradation of its innate properties

• Recycling requires only 8% of the energy necessary to produce virgin aluminum

• Extrusions can contain as much as 80%, recycled content. Actual feedstock in 2010 contained 53% recycled content.

Source: Aluminum Association Life Cycle Assessment of Semi-Finished Aluminum Products in North America, Dec. 2013
Advantages of Aluminum Extrusion

The Extrusion Process

The Extrusion Process is similar to this toy Play-Doh Press. The dough is warmed to a soft, malleable state and then forced through a die to make the shape.
Advantages of Aluminum Extrusion

The Extrusion Process - how are HOLLOW Shapes Extruded?

The PlayDoh flows through the opening between the part of the die that forms the outside diameter and the inside “mandrel” supported by two horizontal supports.

The PlayDoh SEPARATES into two tube halves and “welds” back together due to the pressure needed to make it flow through the annular opening into a tube shape.
Advantages of Aluminum Extrusion

Aluminum Extrusion Press

Courtesy of Bonnell Aluminum
Advantages of Aluminum Extrusion

The Extrusion Process

Feedstock: heated aluminum alloy “billet”

Steel die and supporting tooling

Desired final “profile” or shape

Source: Rio Tinto Alcan
Advantages of Aluminum Extrusion

The Extrusion Process

- Container Housing
- Bolster
- Backer
- Die Ring
- Pressure Ring

Source: Rio Tinto Alcan
Advantages of Aluminum Extrusion

The Extrusion Process – Handling Equipment
Advantages of Aluminum Extrusion

Produced to Close Tolerances
• The ability to hold tight tolerances over the full extruded lengths are routine and the ability of aluminum extruders to meet even more critical dimensions is keeping pace with advances in technology.

Suitable for Complex, Integral Shapes
• Shapes can combine functions that would otherwise require the production and joining of several different parts, reducing part counts and costs.
Advantages of Aluminum Extrusion

Joinable by Various Methods
Aluminum extrusions can be joined to other aluminum products or to different materials by all major methods, including adhesive bonding, welding, soldering, brazing, bolts, rivets, clips, clinching and slide-on, snap-together or interlocking joints.

Suitable for easy-to-assemble designs
Aluminum extrusions with integral connection points have been widely used for elaborate framing, such as the scaffolding for the Statue of Liberty renovation and the recent repair of the Washington Monument.
Advantages of Aluminum Extrusion

**Cost-effective**
- The diversity of shapes permitted by the extrusion process cuts down or eliminates many machining and joining operations.
- Tooling costs are modest in comparison with other processes.

**Time-saving**
- Extrusion’s modest tool costs, with short lead times facilitate the use of custom shapes to create a signature design solution with differentiation and enhanced function.

<table>
<thead>
<tr>
<th>Process</th>
<th>Typical Part Tooling Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum Extrusion</td>
<td>$500 to $5000</td>
</tr>
<tr>
<td>Stampings</td>
<td>$5000 and up</td>
</tr>
<tr>
<td>Injection Molding</td>
<td>$25,000 and up</td>
</tr>
<tr>
<td>Die Castings</td>
<td>$25,000 and up</td>
</tr>
<tr>
<td>Roll Forming</td>
<td>$30,000 and up</td>
</tr>
</tbody>
</table>

**Typical Tooling Lead Time (weeks)**

- **Aluminum Extrusion**: 1 week
- **Stampings**: 4 weeks
- **Roll Forming**: 8 weeks
- **Die Castings**: 12 weeks
- **Injection Molding**: 20 weeks
Some Limitations of the Aluminum Extrusion Process

Every manufacturing process has its limitations. Some things to consider when designing with aluminum extrusions:

- **Circle Size**
  - The circumscribing circle diameter (CCD) that the profile could fit through

- **Weight per Foot (Wt/Ft)**
  - Too heavy? Too light?
  - The design is greatly enhanced if the profile kept under 8” and the wt/ft is 3 lbs or less

- **Shape Constraints**
  - High tongue ratios (width of fin vs. height)
  - Somewhat balanced wall thicknesses
  - Other
## Some Limitations of the Aluminum Extrusion Process

### Press Availability Chart

<table>
<thead>
<tr>
<th>Cross Section Area in sq inches</th>
<th>Circumscribed Circle Size in inches</th>
<th>Corresponding Profile weight (lbs/ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;1</td>
<td>1 to 7</td>
</tr>
<tr>
<td>&lt;.050</td>
<td>L</td>
<td>x</td>
</tr>
<tr>
<td>.050 to .100</td>
<td>G</td>
<td>G</td>
</tr>
<tr>
<td>.100 to 1.0</td>
<td>W</td>
<td>W</td>
</tr>
<tr>
<td>1.0 to 2.5</td>
<td>x</td>
<td>W</td>
</tr>
<tr>
<td>2.5 to 10</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>&gt;10</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

- **L**: Limited Availability
- **G**: Generally Available
- **W**: Widely Available
- **x**: Not available

- **NOTE**: There are many presses available with up to 7" diameter containers.
- There are fewer presses available with 7" to 10" diameter containers.
- There are even fewer presses available with 10" to 14" diameter containers.
- There are very few presses available with greater than 14" diameter containers.
Alloy + Geometry = Performance

The right shape, utilizing the right alloy, can then be enhanced and perfected through additional fabrication and finishing to yield an effective product solution!
# Key Design Variables

Tailored performance: Aluminum extrusions can be produced in different alloys and processed to different tempers to achieve desired mechanical properties.

## Alloys & Tempers

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Major Alloying Elements and Alloy Characteristics</th>
<th>Typical Extrusion Tempers</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000 Series</td>
<td>Minimum 99% Aluminum High corrosion resistance. Excellent finishability. Easily joined by all methods. Low strength, poor machinability. Excellent workability. High electrical conductivity.</td>
<td>F</td>
<td>Extruded and air cooled</td>
</tr>
<tr>
<td>3000 Series</td>
<td>Manganese Low to medium strength. Good corrosion resistance. Poor machinability. Good workability.</td>
<td>H112</td>
<td>Strain-hardened; used for nonheat-treatable alloys</td>
</tr>
<tr>
<td>4000 Series</td>
<td>Silicon Not available as extruded products</td>
<td>T1</td>
<td>Cooled from an elevated temperature/naturally aged</td>
</tr>
<tr>
<td>5000 Series</td>
<td>Magnesium Low to moderate strength. Excellent marine corrosion resistance. Very good weldability.</td>
<td>T4</td>
<td>Solution heat-treated and naturally aged</td>
</tr>
</tbody>
</table>
Key Design Variables

Strength is one key consideration …
6XXX alloy series
### Key Design Variables: Alloys

<table>
<thead>
<tr>
<th></th>
<th>Yield Strength (min)</th>
<th>Surface Quality</th>
<th>Bending</th>
<th>Machining (based on chips, finish)</th>
<th>Joining</th>
<th>Extrudability/Processing/Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>6060 – T61/6063-T6</td>
<td>25 ksi</td>
<td>Excellent finish &amp; corrosion resistance</td>
<td>Good in T6, VG in T1/T4</td>
<td>C</td>
<td>B</td>
<td>100 - Superior extrudability, easy quench</td>
</tr>
<tr>
<td>6005A – T61</td>
<td>38 ksi</td>
<td>Superior corrosion resistance</td>
<td>Good in T6, VG in T1/T4</td>
<td>C : continuous chip, good finish</td>
<td>C</td>
<td>95 - Superior extrudability &amp; quench vs. 6061/6082</td>
</tr>
<tr>
<td>6061-T6</td>
<td>38 ksi</td>
<td>Good corrosion resistance</td>
<td>Manageable in T6511, VG in T1/T4</td>
<td>C</td>
<td>B</td>
<td>80 - Good extrudability, quench demanding</td>
</tr>
<tr>
<td>6082-T6</td>
<td>38 ksi</td>
<td>Good corrosion resistance</td>
<td>Manageable in T6511</td>
<td>C</td>
<td>B</td>
<td>80 – Good extrudability, very quench demanding</td>
</tr>
<tr>
<td>7005-T53</td>
<td>44 ksi</td>
<td>Zn precludes good anodize Stress corrosion</td>
<td>Acceptable in T53</td>
<td>B : curled chip, good-exc. finish</td>
<td>D</td>
<td>50 - ½ speed; quench, special ageing</td>
</tr>
</tbody>
</table>

Source: Rio Tinto Alcan
Key Design Variables: Shapes

Shape Classifications (per Aluminum Association)

- **Solids**
  - Semi-hollow
    - Class I
    - Class II

- **Hollows**
  - Class I
    - (Balanced round int. > 1”)
  - Class II
    - (< 5”, > 0.11”)
  - Class III
Key Design Variables: Shapes

Good Design Practices

- Balance walls
- Avoid/minimize hollows
- Generous tapers

Uniformity

- Practice symmetry/minimize asymmetrical detail
- Use grooves, webs, and ribs
- Minimize perimeter/cross-section ratio

Symmetry

Smooth Transitions

- Enhance visual surfaces
Key Design Variables: Shapes

Extrusion Design Hint

Where possible, re-design the profile to reduce cost (for example, a single void hollow die with smoothed transitions vs. a multiple void hollow die)

Or, in this case, 10% less cost, lighter, and less likely to have die break.
**Key Design Variables: Shapes**

**Extrusion Design Hint**
Screw slots are often simple to incorporate in the profile

Screw slots can often eliminate the need for a more expensive hollow die (which also extrudes more slowly, further increasing cost)

- Self tapping screw
- Thread cutting screw

![Diagram of screw slots and corresponding design options]

60°

This!

Not this!
Extrusion Design Hint
Complex hollow dies can be simplified by splitting single profile into multiple profiles

Key Design Variables: Shapes
Key Design Variables: Tolerances

Aluminum extrusions are produced to close tolerances

Every process has its deviation from nominal.

With castings, for example, it’s shrinkage and draft.

For the aluminum extrusion process, dimensional tolerances are more an evolution than they are fixed.

Improvements in die construction and press practices can provide for even tighter dimensional tolerances than standard on aluminum profiles.

For many applications, standard aluminum extrusion dimensional tolerances have proven to be more precise than those for most competing processes.

Courtesy of Werner Extrusion Solutions LLC
Key Design Variables: Tolerances

Tolerances
Tolerance tables, are available in Aluminum Standards & Data published by The Aluminum Association.

Tight than standard tolerances will often be required for some applications, and can be achieved by many extruders.

Source: The Aluminum Association
Key Design Variables: Tolerances

The key – which are the critical dimensions?

- These?
Key Design Variables: Tolerances

… or these

- Hollow/Gap Dimensions - Column 4-9
Key Design Variables: Fabrication

Fabrication & Assembly
Extrusions can be machined, formed and assembled with a wide variety of familiar technologies. Yet some processes – particularly bending and welding – benefit from prior extrusion fabrication experience.
Key Design Variables: Fabrication

Fabrication

- Sawing
- Punching/piercing/drilling
- Machining
- Bending
- Welding
- Milling
- Tumbling
Key Design Variables: Fabrication

Bending

- Capable of complex bending to create unique shapes
- Multiple bending technologies: Stretch bending, CNC bending, chain bending
- Can be bent in both T4 and T5 conditions
Joining

The rapid increase in automotive aluminum content – and in multi-material solutions – has led to a dynamic evolution in material joining technology. In response, a comprehensive Aluminum Joining Manual, has recently been developed.

The manual addresses:
• Adhesive Bonding
• Beam Welding
• Brazing
• Mechanical Joining
• Resistance Welding
• Fusion
• Combined Joining
• Joining Dissimilar Materials

To access, go to: www.aec.org/library/joining_manual.cfm
Key Design Variables: Finishing

As soon as mill-finish aluminum is exposed to the atmosphere, an oxide layer begins to form at the surface.

For many applications, aluminum profiles require no more protection than this thin, transparent oxide film.

However, aluminum profiles can be treated with a wide range of finishes wherever additional protection or an enhanced appearance is desired.

- Mechanical Finishes
- Pretreatment
- Chemical Finishes
- Anodizing
- Liquid Coatings
- Powder Coatings
Key Design Variables: Finishing

Mechanical Finishes

• Available in a variety of textures, produced by a variety of mechanical methods, such as:
  – Sanding
  – Polishing
  – Grinding
  – Buffing
  – Blasting

Polishing machine: Emmebi Srl
Pretreatment

• Refers to a specific process used to prepare the surface of the aluminum profile for subsequent finishing.
• For profiles to be liquid painted or powder coated, this process usually includes cleaning/etching of the aluminum and the application of a pretreatment coating.
Key Design Variables: Finishing

Chemical Finishes

– Etching
  • Application of a caustic solution
  • Yields a frosted, silver-white surface appearance
  • Minimizes the effect of die lines

– Bright Dipping
  • Produces a very shiny, specular (mirror) finish
  • Almost always followed by anodizing immediately after the final rinse, both to protect the smooth surface and to present a wide range of colors.

Bright dip colored profiles
Key Design Variables: Finishing

Anodizing

- Is not a coating; instead it is an electrochemical process that forms a durable, porus anodic oxide layer on the surface of the aluminum, adding to the protection provided by its natural oxide film.

- This allows aluminum profiles to retain their metallic luster while accepting durable and vibrant color.
Key Design Variables: Finishing

Liquid Coatings

- Include a broad range of paints, such as polyesters, acrylics, siliconized polyesters, and fluoro polymers

- Available in a virtually unlimited array of colors

- Two basic types of paint lines – vertical and horizontal.

Vertical liquid paint line
Key Design Variables: Finishing

Powder Coatings

- Provide a durable finish with little or no use of solvents
- Gaining use where volatile organic compounds (VOCs) are problematic
- Show performance characteristics similar to liquid coatings when both are based on the same resin chemistry (e.g. a polyester powder and liquid coating perform equally when subjected to the same weathering and physical property requirements).

Multicolor vertical powder coating line
Case Examples

Often we end up breaking (or at least bending) the “rules” to meet particular product challenges, striving to meet multiple objectives.

From a raw materials perspective, aluminum is often costlier* than alternate materials per pound, e.g.:

- Global Carbon Steel Price: $714/MT
- Aluminum (LME): $1,838/MT

**Realistic economic comparisons should consider:**

- Aluminum’s lower density (1/3 that of steel) and offsets from:
- Weight reduction, including that of secondary elements
- Reduced processing & assembly costs from “designed-in” functionality
- Maintenance savings
- End-of-life costs/credits

*e.g. June 2014; Source: ycharts.com; Worldsteelprices.com
Case Examples

Steel Beam & Channel vs. Custom Aluminum Profile

Solar Mounting Structure

13 feet long with wind load of 128 lb/ft.

Four solutions were reviewed, 3 steel options and one aluminum extrusion option.

Because of aluminum’s light weight and high-strength-to-weight ratio, the extruded aluminum solution offered the lowest cost option – even though the raw material cost is higher than steel. And, aluminum is corrosion resistant, looks attractive and is 100% recyclable, adding to its value.

Source: Werner Extrusion Solutions
Examples of Aluminum Extrusions

Building & Construction Industry

The extrusions used in this skylight system incorporate building-integrated photovoltaic (BIPV) insulating glass modules.

The system also uses an extruded aluminum vertical façade structurally supported by aluminum extrusions, which seamlessly combines with the BIPV panels for a dramatic and breathtaking effect.

The fully-integrated system uses strong, load-bearing aluminum extrusions to construct a skylight/atrium envelope that saves and generates energy, while enhancing building design.

Photos courtesy of Schüco International KG
Case Example: Building & Construction

Edith Green-Wendell Wyatt Federal Bldg
Portland, OR

Challenge:
Renovate this 35 year old, 520,000 sq. ft. federal office building to achieve dramatic reductions in energy use and water consumption.
Case Example: Building & Construction

Results: 55-60% reduction in energy use vs. pre-retrofit
- “Reedlike” aluminum extrusions shade direct sunlight on the West façade
- Vegetation being grown on the “reeds” for additional shading
- Roof mount PV – provides 15% of energy need
- Double glazed windows, “smart” lighting

Architect: Cutler Anderson   Façade: Benson Industries

Photos: Nic Lehoux
Examples of Aluminum Extrusions

Solar Energy Industry

Nevada Solar One
Concentrated Solar Power Plant

This 64-megawatt solar field is concentrating the sun’s energy via parabolic mirrors onto collection tubes containing thermal oil, which is heated to 800 degrees F and then piped to a central conventional steam turbine plant which runs generators to produce electricity.

There is almost 8 million lbs. of aluminum extrusions in the framework supporting these parabolic mirror support structures.

Photos By Gossamer
Space Frames. Used By Permission of Acciona Solar Power
Examples of Aluminum Extrusions

Telecommunications Industry

- Extruded from 6061 alloy
- Machined in a 5 axis CNC fixture
- Straightlined mechanical finish applied
- No anodic coating applied
Examples of Aluminum Extrusions

Transportation Industry

Strong, lightweight aluminum extrusions are used in transportation applications.

- Aluminum is only about 1/3 as heavy as iron, steel, copper or brass.
- Thus, in applications where volume remains the same regardless of metal used, aluminum goes about three times as far as the other metals.

Ford Motor Co.

Classic Trailers, Inc.
Case Example: Automotive

Mercedes SL Floor Assembly

- Weight reduction was a major objective for the most recent redesign of the Mercedes SL, precipitating a shift to an aluminum-intensive (89% of the bodyshell) design with a resulting 300 lb (140 Kg) weight reduction
Case Example: Automotive

Mercedes SL Floor Assembly

Objective:
• Weight reduction was a major objective for the most recent redesign of the Mercedes SL, precipitating a shift to an aluminum-intensive (89% of the bodyshell) design with a resulting 300 lb (140 Kg) weight reduction.

Results: Extruded Floor Panel
• 3 multi-void hollows, characterized by variable wall thicknesses
• Joined by Friction Stir Welding
• Weight reduction of 6.4 lbs
• Height reduction providing additional interior space
Case Example: Automotive

Lincoln MKZ Panoramic Retractable Roof

- 10,000 per year
- Existing design in steel, 28 parts, stamping-intensive, requiring high investment

Objectives:

- Cost neutral
- 25% weight reduction
- Part count reduction for reduced labor cost
Case Example: Automotive

Approach & Results

• 6 pieces only – 2 extrusions + 4 small aluminum stampings
• 20% weight savings
• Cost neutral with investment reduction for volume
• 22 piece part reduction; reduced labor cost

Assessment

- ✔ Weight reduction
- ☐ Packaging efficiency
- ✔ Cost reduction
- ✔ Build process/
- Manufacturability
- ✔ Serviceability
- ☐ Quality

Patent Application Submitted for Structure and Integration Applications
Case Example: Medical

**Accuray** TomoTherapy System for Radiation Oncology

- **Issue** – 64 mechanical “leaves”, coupled to a pneumatic actuator, open and close to deliver the prescribed radiation dosage. Occasional breakage of the machined steel couplings caused machine shut down.

- **Objectives**
  - redesign the couplings for improved system up-time
  - reduce part cost and manufacturing complexity. Existing steel couplings were machined using EDM, requiring multiple manufacturing steps and yielding a relatively high cost.
Case Example: Medical

- **Approach**
  - Replace EDM steel coupling with an aluminum extrusion, 6063 alloy, machined and hard coat anodized
  - Tweak part design for improved strength and durability
  - Laser etch identification on each part for traceability

- **Results**
  - No failures through 10 million cycle test regimen
  - “snap fit” assembly cut labor by 30 to 60 minutes per assembly; eliminated a tool used for assembly
  - Component manufacturing cost cut by nearly 90%; production time cut by 75%

Credits: Alexandria Industries
Case example: Medical

Hercules Patient Positioning System™

• Issue
When caregivers have to reposition a hospital or nursing home patient, it often causes discomfort to the patient ... and possible discomfort or injury to the caregivers. There is also a loss of dignity for the patient and a drain on multiple caregivers’ time.

• Objectives
Develop a system that could be used with existing hospital beds that would allow a single caregiver to reposition a patient in 10 seconds with the push of a button!
Case example: Medical

- **Approach**
  - Develop a compact drive assembly – the Hercules Patient Repositioning System™ -- that can be added to existing hospital beds; when activated, the drive draws a special sheet into its aluminum housing, thereby gently repositioning the patient.
  - Utilize 7 custom extrusions to create the assembly, maintaining a minimal footprint while handling 600 in/lbs of torque

- **Results**
  - Ready acceptance by hospitals
  - Winner, 2014 Medical Design Excellence Award
  - Winner, 2014 ET Foundation Aluminum Extrusion Design Competition, Professional Category

The Morel Company
Case Example: Lighting

Center Mount LED Lighting Fixture

- **Issue** -- Develop a heat sink for a new, array-style center mount LED light fixture for Medical/Examination applications. This application requires dimming from 10% to 100%, a 3700 lumen output, 60,000 hour life and electromagnetic compatibility.

- **Objectives**
  - reduce mass
  - preserve, or improve heat dissipation effectiveness
  - source in North America for supply chain efficiency

Original heat sink

Courtesy of Almag Aluminum Inc.
Case example: Lighting

- **Approach**
  - Replace solid center hub with hollow section with uniform wall center web to ensure structural performance
  - Replace solid sections to be drilled for screw attachment with integral screw bosses
  - Utilize 6360 alloy for thermal conductivity, and to facilitate high tongue ratios and tight tolerances

- **Results**
  - 47% weight reduction
  - 4% increase in surface area, for improved heat dissipation
  - Elimination of secondary drilling operations, reducing total cost and speeding manufacturing

Assessment
- Weight reduction
- Packaging efficiency
- Cost reduction
- Build process/Manufacturability
- Serviceability
- Quality

Original heat sink
Redesign

Courtesy of Almag Aluminum
Case example: Consumer Products

Apple Watch Sport

• Issue
  – When developing the exciting new Apple Watch Sport, Apple designers wanted a material that was light, strong ... and of course strikingly attractive.
  – Need for a strong casing to withstand everyday use

Want to see more?
https://youtu.be/ibklpzKai-o
Case example: Consumer Products

Apple Watch Sport

• Approach
  – Their answer: aluminum extrusion of a custom alloy.
  – Apple worked with its suppliers to develop a proprietary Magnesium/Zinc alloy.

• Results
  – 60% stronger, yet still meets Apple’s aesthetic targets
  – Improved performance and appearance
  – The resulting aluminum alloy is extruded, machined, buffed, bead blasted and then anodized to create a case designed to look smart over time.
2019 Aluminum Extrusion Design Competition

Entry Deadline: April 1, 2019

Open to:
• Students studying design, engineering, architecture or related field
  – Must be enrolled in and attending high school, college, graduate school, trade or technical school

Learning Opportunity:
Apply what you've learned about design and engineering by entering the International Aluminum Extrusion Design Competition. It's an excellent opportunity for a hands-on learning experience with the potential for professional recognition and earned scholarships.
2019 Aluminum Extrusion Design Competition

Student Class Scholarship Awards
Enter the competition to receive the recognition you so richly deserve; gain pride and a sense of accomplishment. And, of course, there are the scholarships totaling $8,500!

Student Class Scholarships:
1st place $3000
2nd place $2000
3rd place $1000
Bonnell Sustainable Design Award: $2,500

Student scholarships are sponsored by:

www.Bonnellaluminum.com
2019 Bonnell Sustainable Design Challenge

The Bonnell Aluminum Sustainable Design Award will be offered in addition to the First-, Second-, and Third-Place Scholarship Awards. The award will be presented to the entry that, in addition to the four basic competition judging criteria, also addresses the following:

• Design must be a viable extrusion-based product that meets the demands of the environment while contributing to the quality of life for its intended users

• Entry addresses the technical aspects of extrusion design:
  – Demonstrates the entrant’s knowledge and application of aluminum extrusions
  – Designer takes into consideration the limitations of the extrusion process.

• Quality of the design aesthetics in the intended target market place.

For details visit www.ETFdesign.org
Aluminum Extrusion Design Competition
Past Winners

2018 First Place - $3,000 Scholarship

• “N-FORMER” – Outdoor interactive informational box
  – Solar powered with touchscreen and speaker
  – Built-in adjustable height feature

• Sydney Smith, Purdue University, West Lafayette, Indiana
Aluminum Extrusion Design Competition
Past Winners

2017 First Place - $3,000 Scholarship

- “AXIAL” – Bike cargo rack
- Garen Gibbs, Purdue University, West Lafayette, Indiana
Aluminum Extrusion Design Competition
Past Winners

2016 First Place - $3,000 Scholarship

• Dynamic Arm Support Apparatus (DASA)
• Aubree DeLozier, Christopher Sylvester, Stephon Giscombe, Rachel Hernandez, Brad Clark
• University of Alabama – Huntsville
Aluminum Extrusion Design Competition
Past Winners

2018 Second Place - $2,000 Scholarship

“Extension” Prosthetic Device for Musicians
Tessa Barnes; Southern Illinois University, Carbondale, Illinois
Bonnell Aluminum
2018 SUSTAINABLE DESIGN AWARD
$2,500 Scholarship

BLADE—user-friendly aquaponics system
Jon Beldner; Purdue University, West Lafayette, Indiana
Aluminum Extrusion Design Competition
Past Winners

2018 Third Place - $1,000 Scholarship

“Foldo” Folding Wheelbarrow
Bheumsoo (Kyle) Kim; Purdue University, West Lafayette, Indiana
Aluminum Extrusion Design Competition
Past Winners

2018 High School Honorable Mention
$500 Scholarship

“AlumShoe” Aluminum Track for Vehicles
Emma Jacobs; Sherwood High School; Sherwood, Oregon
2019 Aluminum Extrusion Design Competition

• More information at www.ETFdesign.org
  – Website contains contest details, design resources, and more.
  – Download the Call for Entries, including Entry Form from the website

• Entry Deadline: April 1, 2019

• General aluminum extrusion information and resources: www.AEC.org
Conclusion

Aluminum extrusions provide a great resource for your next product design

- They are lightweight, strong, corrosion resistant, fully recyclable ... a sustainable material

- They utilize tailored alloys, accommodate complex shapes, can incorporate multiple functions and are easy to fabricate, providing a custom design response quickly and at minimal cost -- making aluminum extrusions the cost effective solution

- While there are important nuances to the extrusion process, available fabrication/finishing options, alloy selection, and extrusion design details, there are a wealth of resources to help you push the envelope and make superior product design decisions

- Take advantage of the available resources and contact an aluminum extrusion expert as early in your design process as possible
Additional Resources

For more Information and Training

Purchase the Aluminum Design Manual 2015 edition from the Aluminum Association (aluminum.org)

Reference other resources available from the Aluminum Association
Aluminum Standards and Data: nominal and specified chemical compositions of alloys; typical mechanical and physical properties; mechanical property limits; definitions, and dimensional tolerances for semi-fabricated products

Utilize ASCE Aluminum Design Manual training
– go to www.asce.org/continuing_education/
  Under “My Learning” choose “Browse course catalog” and search for “2015 Aluminum Design Manual” to see a list of “Aluminum Structural Design with the 2015 Aluminum Design Manual” courses.
Additional Resources

For more Information and Training

• Utilize the Aluminum Extruders Council website (aec.org) for webinars or other key information

• Extrusion Applications
• Extrusion Design Resources
• Sustainability Info
• Find an Extruder search
• And more!

About AEC:
The Aluminum Extruders Council (AEC) is an international trade association dedicated to advancing the effective use of aluminum extrusion in North America. AEC is committed to bringing comprehensive information about extrusion's characteristics, applications, environmental benefits, design and technology to users, product designers, engineers and the academic community. Further, AEC is focused on enhancing the ability of its members to meet the emerging demands of the market through sharing knowledge and best practices.

AEC Buyers’ Guide (www.AECguide.org)
AEC Aluminum Extrusion Manual (www.AECmanual.org)
<table>
<thead>
<tr>
<th>QUESTION</th>
<th>ANSWER</th>
<th>QUESTION</th>
<th>ANSWER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Are aluminum extrusions limited to simple standard shapes or are complex integral shapes possible?</td>
<td>Complex shapes are possible and easily done</td>
<td>It is necessary to chemically treat aluminum to create a protective oxide coating?</td>
<td>No</td>
</tr>
<tr>
<td>As aluminum is subjected to colder temperature it gets (circle those that apply):</td>
<td>Tougher, brittle, stronger, more ductile, smaller</td>
<td>Hollows can only be created in aluminum extrusions by subsequently drilling or otherwise creating the voids?</td>
<td>No</td>
</tr>
<tr>
<td>It is always easier to extrude simple shapes and then subsequently fabricate and assemble complex features than to incorporate this into the extrusion design?</td>
<td>No</td>
<td>Can aluminum be welded or brazed?</td>
<td>Yes</td>
</tr>
<tr>
<td>Are aluminum extrusion tooling costs generally lower than competitive manufacturing processes?</td>
<td>Yes</td>
<td>Lead times for aluminum extrusion tooling is often in excess of 5 weeks?</td>
<td>No</td>
</tr>
<tr>
<td>What is the most common alloy series used for aluminum extrusions?</td>
<td>6xxx series (Mg-Si-based)</td>
<td>Is anodizing applied like liquid paint?</td>
<td>No</td>
</tr>
<tr>
<td>Aluminum is about _ % as heavy as iron, steel, copper and brass?</td>
<td>33%</td>
<td>Can aluminum be powder painted?</td>
<td>Yes</td>
</tr>
<tr>
<td>What types of ultimate tensile stresses are possible for appropriately alloyed and heat treated aluminum?</td>
<td>80,000 – 90,000 psi</td>
<td>Aluminum extrusions can only be generally made in small sizes that would fit within a 5 inch circumscribing circle?</td>
<td>No</td>
</tr>
<tr>
<td>Is aluminum generally corrosion resistant?</td>
<td>Yes</td>
<td>On an equal weight basis, can aluminum be twice as conductive as copper?</td>
<td>Yes</td>
</tr>
<tr>
<td>Does aluminum conduct heat better than other common metals on both a weight and cost basis?</td>
<td>Yes</td>
<td>Aluminum is magnetic?</td>
<td>No</td>
</tr>
<tr>
<td>Properly produced and treated, what % reflectivity is possible with aluminum?</td>
<td>80%</td>
<td>Aluminum by nature is non-sparking?</td>
<td>Yes</td>
</tr>
<tr>
<td>Volume for volume, aluminum is less than 50% as electrically conductive as copper?</td>
<td>No – it is 62%!</td>
<td>Will solid aluminum support combustion?</td>
<td>No</td>
</tr>
</tbody>
</table>