Aluminum Alloy Technology and Future Developments

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Why does one choose high strength aluminum alloys?

- Low density
- Good corrosion resistance
- Tensile and compression strength up to 700MPa
- Excellent electrical and thermal conductivity
- Very easy to machine
Why does one **NOT** choose high strength aluminum alloys?

- Strength & stiffness
- Galvanic corrosion resistance
- Elevated temperature requirements
- Fatigue and FCG limitations
High strength Al alloy development continues to address applications…

Alloy performance is tailored to specific applications even on the same platform.

Critical Metallic Material Property Requirements for Commercial Transport Applications

Upper Wing
- Upper Wing (Compression)
- Skins and Stringers: Fcy, E, S/N, K1c/Kapp, da/dn, Corr, Fus, E

Lower Wing
- Lower Wing (Tension)
- Skins and Stringers: da/dn, S/N, K1c/Kapp, Fus, Corr

Horizontal Stabilizer (same as wings)
- However, E is more important
- Upper (tension)
- Lower (compression)

Thick Product
- Upper Wing
- Fuselage
- Lower Wing
- Space & Military
Al-Li Alloys Relative to Ti-6-4

Al-Li Extrusions

Al-Li enhance galvanic corrosion resistance.
Elevated Temperature Improvement – Alloy Design for AM

**As-Cast Ingot**
- Very large grains
- Primary particles >1mm
- Multiple phases formed

**As-Atomized Powder**
- Refined grains
- 48μm particles (D$_{50}$)

**As-Built Part**
- ~500 nm cells
- <1% porosity
- Nano-scale dispersoids
Powder Metallurgy Al Alloys Extend Temperature Capability

Inflection point extended by ~80°C versus IM alloys.
Additive Manufacturing will Offer a new Process Route

Rapidly solidified Al alloys have been studied for many years, AM and new compositions could facilitate production

Turbocharger Intake Wheel

Heat Exchanger
Alcoa’s Signature Stress Relief SSR™ for Forgings

SSR™ includes rules developed from practice and FEA simulation of solution heat treatment, quench, and cold-work to design cold work processes.
Design for Fatigue Life using Residual Stress Maps

- Put the material (weight) where it is needed to increase fatigue life.
- Avoid material (weight) where in the past one assumed high tensile residual stress.

\[ \sigma_{\text{res}} = 17920 \text{ psi} \]
\[ \sigma_{\text{forg}} = 2120 \text{ psi} \]
Advanced Hybrid Structures

Advanced Fuselage Concept

Large scale fuselage panel simulation

Advanced Fuselage Concept

Edge of FML strap

Edge of FML strap

>3X life increase over at 25% higher stress

Built-up panel w/ FML reinf. straps

Baseline 2524-T3 / 7150-T7511

Adv. Alloy 2199-T8E74 / 2099-T8E67

Adv. Alloy 2XXX-T8-1 / 2099-T8E57

Half Crack Length, a [mm]

N [Cycles]
Extrusion capability to reduce installed cost

Extrusions for complex, engineered shapes

- High Hollow Shapes
- Seat Track
- Stretch-Formed Frame
- Stiffened Panels (~20” wide x 160” long)
Friction Stir Welding Joins Different Alloys

The ability to machine and join aluminum enables novel design and performance solutions.
Abstract

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New product development using aluminum and its alloys continues to progress at rapid pace to address a wide variety of markets and applications. Many of these advancements build on known strengths of aluminum such as light weight, electrical and thermal conductivity, machinability, near-net part manufacture and corrosion resistance. Anticipating ever more demanding applications, there are a number of initiatives to increase aluminum performance and reduce life-cycle costs via alloy technology and manufacturing processes including Al-Li and Elevated Temperature Alloys, Friction Stir Welding, Advanced Forming, Large Integral Parts and Surface Treatments. The talk will review Al current art and talk about future developments.
Residual Stress Model Verification

Residual stress FEA predictions cross plotted with measurements from hole drills
The Alcoa Very Thick Plate (VTP) Stretcher is a $190 million investment at its Davenport Works, Iowa, facility to expand its product offerings in the aerospace and industrial markets.