## Description

**Image**

**Caption**

Super light luggage with magnesium sheet faces and extruded edging.

**The material**

Magnesium is a metal almost indistinguishable from aluminum in color, but of lower density. It is the lightest of the light-metal trio (with partners aluminum and titanium) and light it is: a computer case made from magnesium is barely two thirds as heavy as one made from aluminum. It, aluminum and magnesium are the mainstays of airframe engineering. Only beryllium is lighter, but its expense and potential toxicity limit its use to special applications only. Magnesium is flammable, but this is only a problem when it is in the form of powder or very thin sheet. It costs more than aluminum but nothing like as much as titanium. Magnesium and its alloys have a hexagonal crystal structure (unlike aluminum) restricting their ability to be rolled or forged at room temperature. They can however be extruded, forged and rolled above 350 C. This partly accounts for the low consumption of wrought products -- they account for about 25% of Mg alloy consumption.

**Composition (summary)**

Mg+alloying elements, e.g. Al, Mn, Si, Zn, Cu, Li, rare earth elements

## General properties

| | | | | |
|---|---|---|---|---|
| Density | 93.6 | - | 122 | lb/ft^3 |
| Price | * 1.42 | - | 1.56 | USD/lb |
| Date first used | 1950 | | | |

## Mechanical properties

| | | | | |
|---|---|---|---|---|
| Young's modulus | 6.09 | - | 6.82 | 10^6 psi |
| Shear modulus | 2.32 | - | 2.76 | 10^6 psi |
| Bulk modulus | 5.08 | - | 5.95 | 10^6 psi |
| Poisson's ratio | 0.29 | - | 0.31 | |
| Yield strength (elastic limit) | 16.7 | - | 59.5 | ksi |
| Tensile strength | 26.8 | - | 65.3 | ksi |
| Compressive strength | 16.7 | - | 59.5 | ksi |
| Elongation | 3.5 | - | 18 | % strain |
| Hardness - Vickers | 43 | - | 135 | HV |
| Fatigue strength at 10^7 cycles | * 13.1 | - | 32.6 | ksi |
| Fracture toughness | * 10.9 | - | 16.4 | ksi.in^0.5 |
| Mechanical loss coefficient (tan delta) | 9e-4 | - | 0.02 | |

## Thermal properties

| | | | | |
|---|---|---|---|---|
| Melting point | 836 | - | 1.2e3 | °F |

| | | | | |
|---|---|---|---|---|
| Maximum service temperature | 248 | - | 392 | °F |
| Minimum service temperature | -118 | - | -63.7 | °F |
| Thermal conductor or insulator? | Good conductor | | | |
| Thermal conductivity | 28.9 | - | 72.8 | BTU.ft/h.ft^2.F |
| Specific heat capacity | 0.228 | - | 0.253 | BTU/lb.°F |
| Thermal expansion coefficient | 13.7 | - | 15.6 | µstrain/°F |

## Electrical properties

| | | | | |
|---|---|---|---|---|
| Electrical conductor or insulator? | Good conductor | | | |
| Electrical resistivity | 4.15 | - | 15 | µohm.cm |

## Optical properties

| | |
|---|---|
| Transparency | Opaque |

## Processability

| | | | |
|---|---|---|---|
| Castability | 4 | - | 5 |
| Formability | 2 | - | 3 |
| Machinability | 5 | | |
| Weldability | 4 | | |
| Solder/brazability | 2 | - | 3 |

## Durability: water and aqueous solutions

| | |
|---|---|
| Water (fresh) | Excellent |
| Water (salt) | Limited use |
| Soils, acidic (peat) | Limited use |
| Soils, alkaline (clay) | Limited use |
| Wine | Limited use |

## Durability: acids

| | |
|---|---|
| Acetic acid (10%) | Limited use |
| Acetic acid (glacial) | Unacceptable |
| Citric acid (10%) | Limited use |
| Hydrochloric acid (10%) | Unacceptable |
| Hydrochloric acid (36%) | Unacceptable |
| Hydrofluoric acid (40%) | Acceptable |
| Nitric acid (10%) | Unacceptable |
| Nitric acid (70%) | Unacceptable |
| Phosphoric acid (10%) | Unacceptable |
| Phosphoric acid (85%) | Unacceptable |
| Sulfuric acid (10%) | Unacceptable |
| Sulfuric acid (70%) | Unacceptable |

## Durability: alkalis

| | |
|---|---|
| Sodium hydroxide (10%) | Acceptable |
| Sodium hydroxide (60%) | Acceptable |

## Durability: fuels, oils and solvents

| | |
|---|---|
| Amyl acetate | Excellent |
| Benzene | Excellent |
| Carbon tetrachloride | Excellent |
| Chloroform | Excellent |
| Crude oil | Limited use |
| Diesel oil | Excellent |
| Lubricating oil | Excellent |
| Paraffin oil (kerosene) | Excellent |

| | |
|---|---|
| Petrol (gasoline) | Excellent |
| Silicone fluids | Excellent |
| Toluene | Excellent |
| Turpentine | Excellent |
| Vegetable oils (general) | Excellent |
| White spirit | Excellent |

## Durability: alcohols, aldehydes, ketones

| | |
|---|---|
| Acetaldehyde | Excellent |
| Acetone | Excellent |
| Ethyl alcohol (ethanol) | Excellent |
| Ethylene glycol | Excellent |
| Formaldehyde (40%) | Excellent |
| Glycerol | Excellent |
| Methyl alcohol (methanol) | Excellent |

## Durability: halogens and gases

| | |
|---|---|
| Chlorine gas (dry) | Limited use |
| Fluorine (gas) | Acceptable |
| O2 (oxygen gas) | Unacceptable |
| Sulfur dioxide (gas) | Excellent |

## Durability: built environments

| | |
|---|---|
| Industrial atmosphere | Acceptable |
| Rural atmosphere | Excellent |
| Marine atmosphere | Limited use |
| UV radiation (sunlight) | Excellent |

## Durability: flammability

| | |
|---|---|
| Flammability | Non-flammable |

## Durability: thermal environments

| | |
|---|---|
| Tolerance to cryogenic temperatures | Unacceptable |
| Tolerance up to 150 C (302 F) | Acceptable |
| Tolerance up to 250 C (482 F) | Unacceptable |
| Tolerance up to 450 C (842 F) | Unacceptable |
| Tolerance up to 850 C (1562 F) | Unacceptable |
| Tolerance above 850 C (1562 F) | Unacceptable |

## Geo-economic data for principal component

| | | | | | |
|---|---|---|---|---|---|
| Annual world production | | 5.61e5 | | | ton/yr |
| Reserves | | 2.36e15 | - | 2.5e15 | I. ton |

## Primary material production: energy, CO2 and water

| | | | | | |
|---|---|---|---|---|---|
| Embodied energy, primary production | * | 3.19e4 | - | 3.51e4 | kcal/lb |
| CO2 footprint, primary production | * | 33.6 | - | 37.1 | lb/lb |
| Water usage | * | 112 | - | 123 | gal(US)/lb |
| Eco-indicator 99 | | 790 | | | millipoints/kg |

## Material processing: energy

| | | | | | |
|---|---|---|---|---|---|
| Extrusion, foil rolling energy | * | 1.27e3 | - | 1.4e3 | kcal/lb |
| Rough rolling, forging energy | * | 649 | - | 717 | kcal/lb |
| Wire drawing energy | * | 4.67e3 | - | 5.16e3 | kcal/lb |
| Metal powder forming energy | * | 2.17e3 | - | 2.62e3 | kcal/lb |
| Vaporization energy | * | 1.57e6 | - | 1.73e6 | kcal/lb |

| | | | | |
|---|---|---|---|---|
| Coarse machining energy (per unit wt removed) | * 144 | - | 159 | kcal/lb |
| Fine machining energy (per unit wt removed) | * 978 | - | 1.08e3 | kcal/lb |
| Grinding energy (per unit wt removed) | * 1.91e3 | - | 2.1e3 | kcal/lb |
| Non-conventional machining energy (per unit wt removed) | 1.57e4 | - | 1.73e4 | kcal/lb |

## Material processing: CO2 footprint

| | | | | |
|---|---|---|---|---|
| Extrusion, foil rolling CO2 | * 0.877 | - | 0.97 | lb/lb |
| Rough rolling, forging CO2 | * 0.449 | - | 0.497 | lb/lb |
| Wire drawing CO2 | * 3.23 | - | 3.57 | lb/lb |
| Metal powder forming CO2 | * 1.6 | - | 1.94 | lb/lb |
| Vaporization CO2 | * 1.08e3 | - | 1.2e3 | lb/lb |
| Coarse machining CO2 (per unit wt removed) | * 0.0998 | - | 0.11 | lb/lb |
| Fine machining CO2 (per unit wt removed) | * 0.678 | - | 0.749 | lb/lb |
| Grinding CO2 (per unit wt removed) | * 1.32 | - | 1.46 | lb/lb |
| Non-conventional machining CO2 (per unit wt removed) | 10.8 | - | 12 | lb/lb |

## Material recycling: energy, CO2 and recycle fraction

| | | | | |
|---|---|---|---|---|
| Recycle | ✓ | | | |
| Embodied energy, recycling | * 4.89e3 | - | 5.4e3 | kcal/lb |
| CO2 footprint, recycling | * 3.54 | - | 3.92 | lb/lb |
| Recycle fraction in current supply | 9.2 | - | 11.4 | % |
| Downcycle | ✓ | | | |
| Combust for energy recovery | ✗ | | | |
| Landfill | ✓ | | | |
| Biodegrade | ✗ | | | |
| Toxicity rating | Non-toxic | | | |
| A renewable resource? | ✗ | | | |

**Environmental notes**

Magnesium is the fifth most abundant metal in the Earth's crust, and the third in its oceans - and it can be extracted economically from both (the Dead Sea, thick with dissolved salts - is the best source of all). But its extraction is very energy intensive, consuming three times more per unit weight than commodity polymers and nearly twice as much as aluminum. It can be recycled, and doing this uses barely one fifth as much energy.

## Supporting information

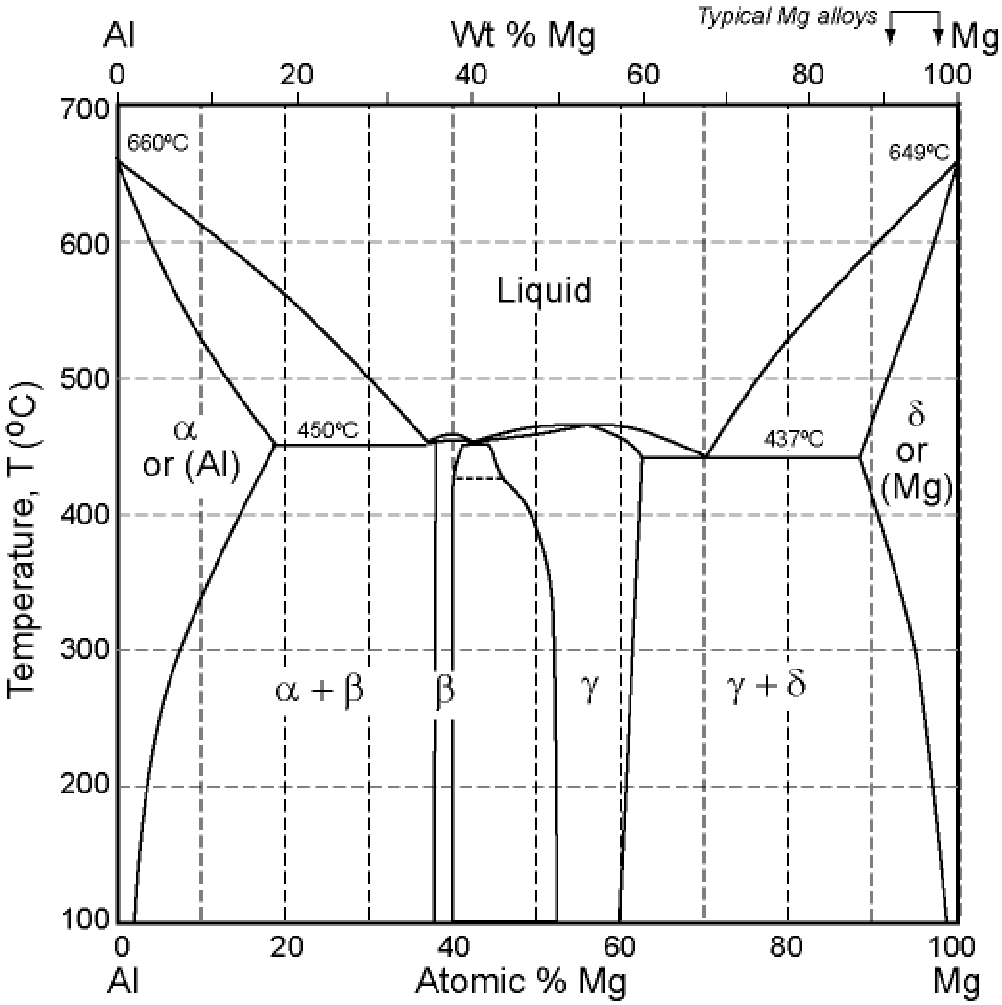
**Design guidelines**

Magnesium has a low density, good mechanical damping, much better thermal conductivity than steel, less good electrical conductivity than copper and aluminum, but still good. It survives well in the protected environment of a house or office, but it corrodes badly in salt water and acids; even sweat is enough to tarnish it, requiring coatings for protection. It is easy to machine, but because of its low stiffness, parts must be firmly clamped while doing so. Magnesium alloys are designed for specific forming purposes: AZ31B, for instance, is designed for extrusions. Most magnesium alloys can be welded using TIG or MIG methods; and soldering and adhesive bonding are both feasible. Spot and seam welds are possible but only in low stress applications; riveting is better, provided aluminum rivets are used to avoid galvanic corrosion.

**Technical notes**

The classification system of the American Society for Testing Materials (ASTM) is the most widely used. In this system, the first two letters indicate the principal alloying elements, thus: A = aluminum, C = copper, E = rare earths, K = zirconium, L = lithium, M = manganese, S = silicon, Z = zinc. The letter corresponding to the element present in the greatest quantity is used first; if they are equal, they are listed alphabetically. The letters are followed by numbers that list the amount of the principal alloying elements in weight % rounded to the nearest whole number; thus AZ91 means the alloy 90% Mg, 9% Al and 1% Zn; LA141 means the alloy 85% Mg, 14% Li and 1% Al.

**Phase diagram**




### Phase diagram description

Wrought magnesium alloys are based on alloys of magnesium (Mg) with 3 - 8% aluminum (Al), some with additions of zinc, manganese or copper. This is the magnesium - aluminum phase diagram.

**Typical uses**

Aerospace; automotive; sports goods such as bicycles; nuclear fuel cans; vibration damping and shielding of machine tools; engine case castings; crank cases; transmission housings; automotive wheels; ladders; housings for electronic equipment, particularly mobile phone and portable computer chassis; camera bodies; office equipment; marine hardware and lawnmowers.

**Tradenames**

Electron, Dowmetal, Revere alloy, Eclipsalloy

## Links

Reference

ProcessUniverse

Producers