Advice & Counsel

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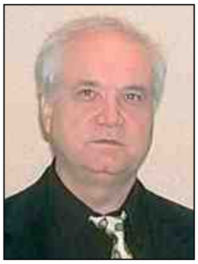

Magnesium

Dear Advice & Counsel,
I am the new foreman at an airline plating shop and my experience in metal finishing is minimal. I was wondering if you could provide me with a quick primer on the kinds of metals used in the airline aerospace industry.

Signed, New Guy

Dear New Guy,
I don't know about "quick", but here goes:

We'll start with magnesium. Table 1 is a summary of the properties of this metal.

Note the unusual property of solubility in methanol. When I was much younger I attended a seminar on corrosion held at Rock Island Arsenal (Dr. William Gilbert, if I remember correctly). Dr. Gilbert began his lesson on magnesium by placing a 3" × 6" sheet of the metal in methanol. By the time he finished his lesson an hour later, the magnesium had completely dissolved in the methanol! In the 50s, an aerospace company found out about this property the hard way. Their helicopter fuel tanks dissolved because the military added methanol to the aviation fuel in the wintertime.

Pure magnesium is not found in nature, as it is highly reactive and has a thin layer of oxide at all times. Pure magnesium metal burns with a characteristic brilliant white light, making it a useful ingredient in flares, but making it a difficult metal to machine, grind and polish. Pure magnesium in the form of powder or thin strips is flammable and in the case of powder can be explosive. Magnesium fires are difficult to put out. Ordinary extinguishing media such as water, carbon dioxide, halon or nitrogen are not effective. Flame temperatures of magnesium and magnesium alloys can reach 3,100°C (5,610°F). The most effective fire-fighting technique is to bury the fire with sand or other non-combustible material.

The metal is most commonly produced by electrolysis of magnesium salts obtained from sea water. Magnesium has a density of 1.74 g/cm^3, making it far lighter than aluminum or titanium. A clean magnesium surface reacts slowly with water at room temperature, releasing hydrogen bubbles. Magnesium also reacts exothermically with most acids, especially hydrochloric.

Magnesium is a popular alloying element for producing 2000, 5000, 6000 and 7000 series aluminum alloys. The magnesium can be found as finely dispersed inclusions of Mg_2Si. The presence of Mg_2Si adds strength to the alloy.

Magnesium alloys

In aerospace and most other applications requiring finishing, magnesium is used in the form of an alloy. Magnesium alloys tend to be referred to by short codes as specified in ASTM D 275. The nomenclature allows insight into the basic composition. Commonly employed alloying elements and nomenclature codes are shown in Table 2.

Aluminum-containing magnesium alloys are normally used for casting purposes. Zirconium-based alloys can be used at higher temperatures and are popular in aerospace, especially for the production of forged parts. Zirconium-based alloys containing yttrium and rare earth elements such as WE54 and WE43 (Mg 93.6%, Y 4%, Nd 2.25%, 0.15% Zr) can operate at temperatures up to 300°C and are reasonably corrosion-resistant. Yttrium-containing magnesium alloys may pose chem film treatment problems that can be resolved by modifying the preparation process steps. Another magnesium alloy that is commonly encountered in aerospace applications is AZ31B (Table 3).

Table 1
Properties of magnesium

Symbol, Atomic Number, Valence	Mg, 12, +2
Crystal Structure	HCP
Density	1.74g/cm^3
Melting Point	651ºC (1200ºF)
Soluble in	Methanol, water, most acids
Insoluble in	Chromic Acid, Alkali
Unusual properties	Flammable, explosive (powder)
Color	Silvery white

Table 2
Nomenclature codes

A = Aluminum
C = Copper
E = Rare earths*
H = Thorium
K = Zirconium
L = Lithium
M = Manganese
O = Silver
S = Silicon
T = Tin
W = Yttrium
Z = Zinc

*Rare earths: Neodymium (Nd), Ytterbium (Yb), Erbium (Er), Dysprosium (Dy), Gadolinium (Gd), Yttrium (Y)

*Example - Aerospace alloys**:*

WE54** (Y: 4.75 - 5.0%; Nd: 1.5 - 2.0%; Zr: 0.4% min; plus rare earths: 1 - 2%)
WE43 (Y: 3.7 - 4.3%, Zr: 0.4% min: plus rare earths: 2.4 - 4.4% of which Nd = 2 - 2.5%)
**Products of Magnesium Elektron, UK

Table 3
AZ31B magnesium alloy composition and properties

Aluminum	2.5 - 3.5%
Copper	0.05% max
Iron	0.005% max
Manganese	0.2% min
Nickel	0.005% max
Silicon	0.1% max
Zinc	0.6 - 1.4%
UTS	39 ksi (270 MPa)
Density	$1.77 g/cm^3$

AZ31B is produced in a wide variety of shapes from sheet and plate through bar forms. It is sometimes used as an alternative to aluminum alloys due to its high strength-to-weight ratio. As an example of a military application, the U.S. Army has determined that the AZ31B-H24 alloy has a better ballistic performance than 5083-H131 aluminum against the AP projectiles, while the currently used aluminum alloy offers better fragment protection. The Army is currently working on the generation of a military armor specification that will allow armor system manufacturers to qualify the use of magnesium alloys for use in armor on combat vehicles.

Heat treatment of magnesium alloys

Magnesium alloys may be heat treated to enhance the ultimate tensile strength. Shown in Table 4 is a commonly employ T-6 heat treatment and the resulting properties obtained.

Table 4
T-6 treatment of magnesium alloys

1. Solution Treat 4 - 8 hr at 525°C,
2. Air cool, hot water or polymer quench,
3. Age for 16 hr at 250°C,
4. Air cool.

Resulting physical properties:

Specific gravity	1.85
Melting range	545 - 640°C
Brinnell hardness	80 - 90
UTS	255 MPa
Elongation	2%

Corrosion resistance

Magnesium is a highly electronegative metal (-2+V), forming the corroding pole of any galvanic corrosion cell with most every other metal or alloy. Cleaned magnesium is even attacked by water, albeit slowly. For these reasons, magnesium parts are typically protected by a chem film coating or paint/powdercoat anodized or plated deposit. Alloys containing yttrium exhibit excellent salt spray performance, comparable to some aluminum alloys.

Finishing of magnesium alloys

Magnesium can be protected from corrosion by application of a variety of barrier films including chem film, anodized coatings and electroplated layers. Table 5 shows a variety of chem film processes that have been developed by Dow Chemical Company for magnesium alloys. Other proprietary finishes are also available.

Table 5
Chem film finishes for magnesium alloys

- As an Undercoat for Paint:
  Dow-1, Dow-4, Dow-7, Dow-18, Dow-19, Dow-20, Dow-22, Dow-23
- Stand-alone:
  Dow-1, Dow-21
- Touch-up:
  Dow-1, Dow-19

Magnesium is anodized for either corrosion resistance (using a silicate-dichromate seal) or as an undercoat to enhance paint adhesion. The mechanism of anodizing magnesium is significantly different from that for aluminum in that it occurs in alkaline solutions and by way of a sparking process. At potentials over a given voltage, usually near 50V DC (over 100V for some processes), sparks form on the surface of the magnesium anode. These sparks move over the surface and, where they travel, a film is produced. The film is produced in a chemical reaction between the magnesium alloy, oxygen, the electrolytes and other components of the anodizing bath.

Magnesium anodizing processes using chromium-bearing chemicals produce a "green" coating, while electrolytes that do not contain chromium tend to produce "white" coatings. Shown in Table 6 are commonly employed anodizing processes.

Magnesium can also be electroplated for a variety of purposes including the production of solar collectors. The electroplating process involves cleaning the alloy and processing it through a specially prepared pyrophosphate-based zincating solution to produce a thin zinc film by galvanic displacement analogous to the processing of aluminum for plating. P&SF

Table 6
Magnesium anodizing processes:

Acidic:	**Alkaline**:	**Proprietary processes**:
Dow-9	HAE	Tagnite®
Dow 17		Anomag®
Cr-22		Keronite®

References

1. Wikipedia
2. T.L. Jones, M.S. Burkins & W.A. Gooch, "An Analysis of Magnesium Alloy AZ31B-H24 for Ballistic Appications," U.S. Army Research Laboratory Report ARL-TR-4327, Aberdeen Proving Ground, MD, 2007; http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA474892&Location=U2&doc=GetTRDoc.pdf
3. Magnesium Elektron UK, Swinton, Manchester, UK; http://www.magnesium-elektron.com.

Test Your Plating I.Q. #463

By Dr. James H. Lindsay

Acid chloride zinc

1. An advantage of acid chloride zinc over other zinc plating processes is the greater ease of plating on ___________________ , ____________________ and _____________________ , as hydrogen does not tend to deposit in preference to zinc in this solution.

2. Which of the following are true? Increased zinc metal concentration leads to:
   a. Increased burning.
   b. Improved covering power.
   c. Improved throwing power.
   d. Higher plating current density.
   e. Increased drag-out costs.
   f. Decreased waste treatment costs.

3. Savings in energy costs are realized with acid chloride zinc because of the bath's ________________________________.

4. Name some disadvantages of using acid chloride zinc.

5. True or false: Ammonium-based solutions can be operated at higher current densities than potassium-based ones.

Answers on page 33.

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