Abdulla Aljunibi

NON-FERROUS METALS

CHARACTERISTICS OF NON-FERROUS METALS

The term "non-ferrous" refers to all metals which have elements other than iron as their base or principal constituent.

such metals as:
1, aluminum
2, titanium
3, copper
4, magnesium
5, as well as such alloyed metals as Monel and babbit.

ALUMINUM/ALUMINUM ALLOYS:

Commercially pure aluminum is
1, white lustrous metal
2, second in the scale of malleability
3, sixth in ductility
4, ranks high in its resistance to corrosion

Aluminum alloys in which the principal alloying elements are
1, manganese
2, chromium,
3, magnesium
4, silicon
show little attack in corrosive environments

The total percentage of alloying elements is seldom:
more than 6 or 7 percent in the wrought alloys.

Aluminum is one of the most widely used metals in modern aircraft construction because of its:
1, strength to weight ratio → density
2, light weight
(Strong material with light weight)

Aluminum melts at low temperature of 675°C.

Aluminum is :
1, nonmagnetic
2, excellent conductor.

aluminum has a tensile strength of :about 13 000 psi

By alloying with other metals, or by using heat-treating processes:
the tensile strength may be raised to as high as 65 000 psi

to within the strength range of structural steel.

strength may be approximately doubled by :
1, rolling
2, other cold working processes

Aluminum alloys, although strong, are easily worked because they are
1, malleable
2, ductile

They may be rolled into :
sheets as thin as 0.001 7 inch
or
drawn into wire 0.004 inch in diameter

Most aluminum alloy sheet stock used in aircraft construction range from:
0.016 to 0.096 inch in thickness

larger aircraft: thick as 0.356 inch

The various types of aluminum may be divided into two general classes:
1, casting alloys
(those suitable for casting in sand, permanent mold, or die castings)
2, wrought alloys
(those which may be shaped by rolling, drawing, or forging)

wrought alloys most widely used in aircraft construction in:
1, stringers
2, bulkheads
3, skin
4, rivets
5, extruded sections

Aluminum casting alloys are divided into two basic groups:
1, the physical properties of the alloys are determined by the alloying elements and cannot be changed after the metal is cast
(Can't change the property)

2, the alloying elements make it possible to heat treat the casting to produce the desired physical properties
(Can change the property by heat treatment)

The casting alloys are identified by a letter preceding the alloy number.

When a letter precedes a number, it indicates a slight variation in the composition of the original alloy.
Meaning:
This variation in composition is simply to impart some desirable quality.
M for example

When castings have been heat treated, the heat treatment and the composition of the casting is:
indicated by the letter T, followed by an alloying number

Aluminum alloy castings are produced by one of three basic methods:
1, sand mold
2, permanent mold
3, die cast

different types of alloys must be used for different types of castings

Sand castings and die castings require different rent types of alloys than those used in permanent molds.

Sand and permanent mold castings are:
1, parts produced by pouring molten metal into a previously prepared mold
2, the metal then solidify or freeze

If the mold is made of sand, the part is a sand casting

If it is a metallic mold (usually cast iron) the part is a permanent mold casting.

Sand and permanent castings are produced by
1, pouring liquid metal into the mold
2, the metal flowing under the force of gravity alone.

The two principal types of sand casting alloys are 112 and 212.

Little difference exists between the two metals from a mechanical properties standpoint, since both are adaptable to a wide range of products.

permanent mold process is a later development of the sand casting process, the major difference is :
the material from which the molds are made.

The advantage of this process is that there are fewer openings (called porosity) than in sand castings.

The sand and the binder, which is mixed with the sand to hold it together, give offa certain amount of gas which causes porosity in a sand casting.

Permanent mold castings are used to obtain :
1, higher mechanical properties
2, better surfaces
3, more accurate dimensions

Permanent mold castings
used to:
obtain higher mechanical properties
better surfaces, or more accurate dimensions.

There are two specific types of permanent mold castings:
1, permanent metal mold with metal cores
(The hole molded is made of metal)
2, semipermanent types containing sand cores.

Alloys
122, A132, and 142 are commonly used in permanent mold castings, the principal uses of which are in internal combustion engines.

Die castings
used in aircraft are usually :
1, aluminum
2, magnesium alloy

If weight is of primary importance:
magnesium alloy is used because it is lighter than aluminum alloy.

aluminum alloy is frequently used because it is :
stronger than most magnesium alloys

A die casting is produced by:
1, forcing molten metal under pressure into a metallic die not gravity
2, allowing it to solidify
3, then the die is opened
4, the part remove

Die castings are used where relatively:
large production of a given part is involved.

difference between permanent mold casting and die casting

in the permanent mold process :
the metal flows into the die under gravity

In the die casting operation :
the metal is forced under great pressure

any shape which can be forged can be cast.

WROUGHT ALUMINUM

Wrought aluminum and wrought aluminum alloys
divided into two general classes:
1, non-heat-treatable alloys
2, heat-treatable alloys.

Non-heat-treatable alloys are those in which the :
1, mechanical properties are determined by the amount of cold work introduced after the final annealing operation

2, The mechanical properties obtained by cold working are destroyed by any subsequent heating and cannot be restored except by additional cold working, which is not always possible.
(Will lose the strength if heated)

3, The "full hard" temper is produced by the maximum amount of cold work that is commercially possible.

heat-treatable aluminum alloys, the mechanical properties are obtained by

1, heat treating to a suitable temperature

2, holding at that temperature long enough to allow the alloying constituent to enter into solid solution

3, then quenching to hold the constituent in solution.

4, The metal is left in a ~~supersaturated~~ unstable state and is then age hardened either by natural aging at room temperature or by artificial aging at some elevated temperature.

Wrought aluminum and wrought aluminum alloys are designated by a four digit index system.

system is broken into three distinct groups:

1, 1xxx group

2, 2xxx through

3, 8xxx group

4, 9xxx group (which is currently unused).

The first digit of a designation identifies the alloy type

The second digit indicates specific alloy modifications

(if the second number is zero it would indicate no special control over individual impurities)

For

Digits 1 through 9,

however, when assigned consecutively as needed for the second number in this group, indicate the number of controls over individual impurities in the metal.

The last two digits of the 1xxx group are used to indicate the:
hundredths of 1 percent above the original 99 percent designated by the first digit.
Ex ; if the last two digits were 30, the alloy would contain 99 percent plus 0.30 percent of pure aluminum, or a total of 99.30 percent pure aluminum.

Examples of alloys in this group are:

- 1100—99.00 percent pure aluminum with one control over individual impurities.
- 1130—99.30 percent pure aluminum with one control over individual impurities.
- 1275—99.75 percent pure aluminum with two controls over individual impurities.

In the 2xxx through 8xxx groups,
the first digit indicates :
the major alloying element used in the formation of the alloy
as follows:

- 2xxx—copper
- 3xxx—manganese
- 4xxx—silicon
- 5xxx—magnesium
- 6xxx—magnesium and silicon
- 7xxx—zinc
- 8xxx—other elements

In the 2xxx through 8xxx alloy groups, the second digit in the alloy designation indicates :
alloy modifications

If the second digit is zero, it indicates the original alloy

digits 1 through 9 indicate alloy modifications

The last two of the four digits in the designation identify the different alloys in the group.

EFFECT OF ALLOYING ELEMENT

1000 series:

1, Made of 99 percent aluminum or higher
2, excellent for its corrosion resistance
3, high thermal and electrical conductivity
4, low mechanical properties, and excellent workability
5, Iron and silicon are major impurities.

2000 series:

1, Copper is the principal alloying element.
2, Solution heat treatment
3, optimum properties equal to mild steel
4, poor corrosion resistance unclad.
5, It is usually clad with 6000 or high purity alloy.
6, Its best known alloy is 2024.

3000 series:

1, Manganese is the principal alloying element of this group which is generally non-heat treatable.
2, percentage of manganese which will be alloy eff ctive is 1.5 percent.
3, most popular is 3003: which is of moderate strength and has good working characteristics

5000 series:

1, Magnesium is the principal alloying element.
2, has good welding and corrosion resistant characteristics.
3, High temperatures (over 150°F) or excessive cold working will increase susceptibility to corrosion (bad)

6000 series:

1, Silicon and magnesium form magnesium silicide which makes alloys heat treatable.

2, It is of medium strength, good forming qualities, and has corrosion resistant characteristic

7000 series:

1, Zinc is the principal alloying element

2, The most popular alloy of the series is 6061

3, When coupled with magnesium:

it results in heat-treatable alloys of very high strength. It usually has copper and chromium added.

4, The principal alloy of this group is 7075.

HARDNESS IDENTIFICATION

Where used, the temper designation follows the alloy designation and is separated from it by a dash: ex, 7075-T6

These designations are as follows:

- F - as fabricated
- O - annealed, recrystallized (wrought products only) → midterm
- H - strain hardened
- H1 (plus one or more digits) — strain hardened only → Fwa
- H2 (plus one or more digits) — strain hardened and partially annealed
- H3 (plus one or more digits) — strain hardened and stabilized

The digit following the designations H1, H2, and H3 indicates:
the degree of strain hardening

number 8 representing:
the ultimate tensile strength equal to that achieved by a cold reduction of approximately 75 percent following a full anneal

0 representing:
the annealed state.

MAGNESIUM/MAGNESIUM ALLOYS

Magnesium is :the world's lightest structural metal

Cooler: silvery white material

weighing only two-thirds as much as aluminum.

does not possess sufficient strength in its pure state for structural uses.
(Not strong by it self)

but when alloyed with:
1, zinc
2, aluminum
3, manganese
it produces an alloy having the highest strength to weight ratio → Density

Magnesium is probably more widely distributed in nature
(Easy to find Can be found any where)

can be obtained from: sea water

With about 10 million pounds of magnesium in 1 cubic mile of sea water

Some of today's aircraft require in excess of :
one-half ton of this metal for use in hundreds of vital spots. Skip

Some wing panels are fabricated entirely from magnesium alloys:
weigh 18 percent less than standard aluminum panels, and have flown hundreds of satisfactory hours.

Among the aircraft parts that have been made from magnesium with a substantial savings in weight are

1, nose wheel doors
2, flap cover skin
3, aileron cover skin
4, oil tanks
5, floorings
6, fuselage parts
7, wingtips
8, engine nacelles
9, instrument panels
10, radio masts
11, hydraulic fluid tanks
12, oxygen bottle cases
13, ducts
14, seats

Magnesium alloys possess good casting characteristics:
Their properties compare favorably with those of cast aluminum.

In forging: hydraulic presses are ordinarily used
under certain conditions:
forging can be accomplished in mechanical presses or by using drop hammers.

Magnesium alloys are subject to such treatments as
1, annealing
2, quenching
3, solution heat treatment
4, aging
5, stabilizing

The solution heat treatment is used to put as much of the alloying ingredients as possible :
1, into solid solution, which results in
2, high tensile strength and maximum ductility

Aging is applied to
castings following heat treatment where maximum hardness and yield strength are desired.

Magnesium embodies fire hazards of an unpredictable nature.

When in large sections, its high thermal conductivity makes it difficult to ignite and prevents it from burning. It will not burn until the melting point of 651°C is reached.

However, magnesium dust and fine chips are ignited easily

extinguished with:
1, extinguishing powder

Water or foam extinguisher cause magnesium to burn more rapidly and can cause explosions

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TITANIUM/TITANIUM ALLOYS
The use of titanium is widespread

It is used in many commercial enterprises and is in constant demand for such items as pumps, screens, and other tools and fixtures where corrosion attack is prevalent

In aircraft construction and repair, titanium is used for
1, fuselage skins
2, engine shrouds
3, firewalls
4, longerons
5, frames
6, , fittings
7, air ducts
8, fasteners.

Titanium is used for making engine parts
1, compressor disks
2, spacer rings
3, compressor blades and vanes
4, through bolts
5, turbine housings and liners
6, and miscellaneous hardware for turbine engines

Titanium, in appearance, is similar to stainless steel.
One quick method used to identify titanium is the spark test.

Titanium gives off a brilliant white trace ending in a brilliant white burst.

Another way of identification
identification can be accomplished by moistening the titanium and using it to draw a line on a piece of glass.

This will leave a dark line similar in appearance to a pencil mark

Titanium falls between aluminum and stainless steel in terms of:
1, elasticity
2, density
3, elevated temperature strength

It has a melting point of from
1 500°C to 1 735°C,
low thermal conductivity, and a low coefficient of expansion.

Titanium is
1, light
2, strong
3, resistant to stress corrosion cracking

Information about titanium:

- Titanium is approximately 60 percent heavier than aluminum
- 50 percent lighter than stainless steel.
- Because of the high melting point of titanium, high temperature properties are disappointing
- ultimate yield strength of titanium drops rapidly above 425°C.
- absorption of oxygen and nitrogen from the air at temperatures above 540°C makes the metal so brittle on long exposure that it soon becomes worthless
- However, titanium does have some merit for short time exposure up to 1 650°C where strength is not important. Aircraft firewalls demand this requirement.

- Titanium is nonmagnetic
- has an electrical resistance comparable to that of stainless steel.
- Heat treating and alloying do not develop the hardness of titanium to the high levels of some of the heat-treated alloys of steel
- It was only recently that a heat-treatable titanium alloy was developed.
- heating and rolling was the only method of forming that could be accomplished.
- it is possible to form the new alloy in the soft condition and heat treat it for hardness

Iron, molybdenum, and chromium
are used to stabilize titanium and produce alloys that will quench harden and age harden. (The titanium becomes very hard)

The addition of these metals also adds ductility.

The fatigue resistance of titanium is greater than that of aluminum or steel

Titanium becomes softer as the degree of purity is increased.

It is not practical to distinguish between the various grades of commercially pure or unalloyed titanium by chemical analysis; therefore, the grades are determined by mechanical properties.

TITANIUM DESIGNATIONS

The A-B-C classification of titanium al loys was established to provide a convenient and simple means of describing all titanium alloys.

Titanium and titanium alloys possess three basic types of crystals

A (alpha), B (beta),C (combined alpha and beta).

Their characteristics are:

- A (alpha) :

good weldability; tough and strong both cold and hot, and resistant to oxidation.

- B (beta):

1, bendability; excellent bend ductility
2, strong both cold and hot
3, but vulnerable to contamination.

- C (combined alpha and beta for compromise performances):

1, strong when cold and warm,
2, weak when hot
3, good bindability
4, good contamination resistance
5, excellent forgeability

commercially pure titanium and alloyed titanium

A-55:

has a yield strength of 55 000 to 80 000 psi

used for :

nonstructural aircraft parts and for all types of corrosion resistant applications, such as tubing.

Type A-70

titanium is closely related to type A-55

but has a yield strength of : 70 000 to 95 000 psi.

used :

where higher strength is required.

A-70 is specified for many moderately stressed aircraft parts

For many corrosion applications, it is used interchangeably with type A-55. Both type A-55 and type A-70 are weldable

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titanium base alloys

C-110M:

1, used for : primary structural members and aircraft skin

2, has 110 000 psi minimum yield strength

3, contains 8 percent manganese

Type A-110AT

1, Is a titanium alloy

2, contains 5 percent aluminum and 2.5 percent tin

3, has a high minimum yield strength at elevated temperatures with the excellent welding characteristics

(inherent in alpha-type titanium alloys.)

CORROSION CHARACTERISTICS OF TITANIUM

The resistance of the metal to corrosion is caused by the:
formation of a protective surface film of stable oxide or chemi-absorbed oxygen

Film is often produced by the :presence of oxygen and oxidizing agents.

Corrosion of titanium is uniform

Normally titanium is not subject to
1, stress corrosion
2, corrosion fatigue ↑
3, intergranular corrosion
4, galvanic corrosion

Laboratory tests with acid and saline solutions show titanium polarizes readily. The net effect, in general, is to decrease current flow in galvanic and corrosion cells. Corrosion currents on the surface of titanium and metallic couples are naturally restricted. This partly accounts for good resistance to many chemicals; also, the material may be used with some dissimilar metals with no harmful galvanic eff ct on either.

COPPER/COPPER ALLOYS

Copper is one of the most widely distributed metals

- only reddish colored metal
- is second only to silver in electrical conductivity

Its use as a structural material is limited because of its great weight.

characteristics:

- high electrical and heat conductivity, in many cases overbalance the weight factor.

Because it is very malleable and ductile: copper is ideal for making wire.

- Can be corroded by salt water
- but is not affected by fresh water

tensile strength

For cast copper :

1, about 25 000 psi

2, when cold rolled or cold drawn its tensile strength increases to a range of 40 000 to 67 000 psi.

Beryllium copper

one of the most successful of all the copper base alloys.

alloy containing about

1, 97 percent copper

2, 2 percent beryllium

3, sufficient nickel to increase the percentage of elongation.

The most valuable feature of this metal is:

- the physical properties can be greatly stepped up by heat treatment,
- the tensile strength rising from 70 000 psi in the annealed state to 200 000 psi in the heat-treated state.

The resistance of beryllium copper to fatigue and wear makes it suitable for :

1, diaphragms
2, precision bearings and bushings
3, ball cages
4, spring washers

Brass

Brass is a copper alloy

containing

1, zinc and
2, small amounts of aluminum
3, iron
4, lead
5, manganese
6, magnesium
7, nickel
8, phosphorous
9, tin.

Brass with a zinc content of :
30 to 35 percent is very ductile

If containing 45 percent zinc has relatively high strength.

Muntz metal

is a brass composed of 60 percent copper and 40 percent zinc.

It has excellent corrosion resistant qualities in salt water
(good corrosion resistance)

strength can be increased by heat treatment

As cast:

- this metal has an ultimate tensile strength of 50 000 psi
- can be elongated 18 percent.

used in making : bolts and nuts, as well as parts that come in contact with salt water

Red brass,
sometimes termed "bronze" because of its :
tin content
used in:fuel and oil line fittings

This metal has good
1, casting and finishing properties
2, machines freely

Bronzes are copper alloys containing tin
bronzes have up to 25 percent tin

but those with less than 11 percent are most useful for:
tube fittings in aircraft

copper alloys are the copper aluminum alloys:
aluminum bronzes rank very high in aircraft usage

would find greater usefulness in
structures ifit were not for their :strength to weight ratio as compared with
alloy steels

Wrought aluminum bronzes are almost as strong and ductile as medium
carbon steel

they possess a high degree of resistance to corrosion
1, by air
2, salt water
3, chemicals

They are readily
1, forged
2, hot or cold rolled
3, and many react to heat treatment

copper base alloys contain up to
16 percent of aluminum (usually 5 to 11 percent), to which other metals, such as iron, nickel, or manganese, may be added.

Aluminum bronzes have good
1, tearing qualities
2, great strength
3, hardness
4, resistance to both shock and fatigue

Because of these properties:
they are used for
1, diaphragms
2, gears
3, pumps

Aluminum bronzes are available in
1, rods
2, bars
3, plates
4, sheets
5, strips
6, forgings

Cast aluminum bronzes
using about
- 89 percent copper
- 9 percent aluminum,
- 2 percent of other elements

These alloys are useful in areas exposed to salt water and corrosive gases

have high
- strength combined with ductility,
- are resistant to corrosion, shock, and fatigue

Because of these properties, cast aluminum bronze is used in :
bearings and pump parts

Manganese bronze

an exceptionally:

1, high strength
2, tough
3, corrosion resistant copper zinc alloy

containing:

1, aluminum
2, manganese
3, iron
4, occasionally
5, nickel or tin

This metal can be formed:

1, extruded
2, drawn
3, rolled to any desired shape

In rod form, it is generally used for:

machined parts, for aircraft landing gears and brackets

Silicon bronze

composed of about

- 95 percent copper
- 3 percent silicon
- 2 percent manganese,
- zinc
- iron
- tin
- aluminum

Although not a bronze in the true sense because of its small tin content,

silicon bronze has :high strength and great corrosion resistance.

NICKEL/NICKEL ALLOYS

Nickel alloys can be welded or easily machined
two nickel alloys used in aircraft
1, Monel 2, Inconel

Monel
contains about
- 68 percent nickel
- 29 percent copper
- plus small amounts of iron and manganese

Some of the nickel Monel, especially the nickel Monels containing small amounts of aluminum,are :
heat-treatable to similar tensile strengths of steel

Nickel Monel is used in
- gears
- parts that require high strength and toughness

such as: exhaust systems that require high strength and corrosion resistance at elevated temperatures.

Monel
the leading high nickel alloy
combines the properties of
- high strength
- excellent corrosion resistance

metal consists of
- 68 percent nickel
- 29 percent copper
- 0.2 percent iron
- 1 percent manganese
- 1.8 percent of other elements

It cannot be hardened by heat treatment.

Monel is adaptable to

- casting
- hot or cold working
- can be successfully welded

When forged and annealed it has a :
tensile strength of 80 000 psi

This can be increased by cold working to 125 000 psi, sufficient for classification among the tough alloys

Monel has been successfully used for

- gears and chains to operate retractable landing gears
- for structural parts subject to corrosion

Monel is used for parts demanding both strength and high resistance to corrosion, such as

- exhaust manifolds
- carburetor needle valves and sleeves

K-MONEL
containing :

- mainly nickel
- copper
- aluminum

K - monel produced by :adding a small amount of aluminum to the Monel formula

It is :

- corrosion resistant
- capable of being hardened by heat treatment.

K-Monel has been successfully used for

- gears
- structural members in aircraft which are subjected to corrosive attacks

This alloy is nonmagnetic at all temperatures.

K-Monel sheet has been successfully welded by both

- oxyacetylene
- electric arc welding

INCONEL

Inconel alloys of nickel produce a

1, high strength

2, high temperature alloy containing :approximately

- 80 percent nickel,
- 14 percent chromium
- small amounts of iron and other elements

nickel Inconel alloys are frequently used in turbine engines because of their ability to maintain their strength and corrosion resistance under extremely high temperature conditions

Inconel and stainless steel are : similar in appearance and are frequently found in the same areas of the engine

Sometimes it is important to identify the difference between the metal samples

How to identify the differences:

common test is to

- apply one drop of cupric chloride and hydrochloric acid solution to the unknown metal and allow it to remain for 2 minutes.
- At the end of the soak period, a shiny spot indicates the material is nickel Inconel, and a copper colored spot indicates stainless steel.

SUBSTITUTION OF AIRCRAFT METALS

In selecting substitute metals for the repair and maintenance of aircraft, it is very important to check the appropriate structural repair manual

manufacturer's design structural members to meet a specific load requirement for a particular aircraft

Four requirements must be kept in mind when selecting substitute metals:
1, maintaining the original strength of the structure
2, aerodynamic smoothness
3, original weight, or keeping added weight to a minimum
4, original corrosion resistant properties of the metal

HEAT TREATMENT OF NON-FERROUS ALLOYS

ALUMINUM ALLOYS

pure aluminum is known as 1100.

- has a high degree of resistance to corrosion
- easily formed into intricate shapes
- It is relatively low in strength
- does not have the properties required for structural aircraft parts
- High strengths are generally obtained by the process of alloying.

The resulting alloys are

- less easily formed
- with some exceptions, have lower resistance to corrosion than 1100 aluminum.

Alloying is not the only method of increasing the strength of aluminum

aluminum becomes stronger and harder as it is

- rolled
- formed
- otherwise cold worked

Since the hardness depends on the amount of cold working done 1100 and some wrought aluminum alloys are available in several strain hardened tempers.

- The soft or annealed condition is designated O.
- If the material is strain hardened, it is said to be in the H condition.

The most widely used alloys in aircraft construction are hardened by heat treatment rather than by cold work.

These alloys are designated by a somewhat diff rent set of symbols:
- W - Solution heat treated, unstable temper
- T - Treated to produce stable tempers other than F, O, or H
- T2 - Annealed (cast products only)
- T3 - Solution heat treated and then cold worked
- T4 - Solution heat treated
- T5 - Artificially aged only
- T6 - Solution heat treated and then artificially aged
- T7 - Solution heat treated and then stabilized
- T8 - Solution heat treated, cold worked, and then artifi ially aged
- T9 - Solution heat treated, artificially aged, and then cold worked
- T10 - Artificially aged and then cold worked

ALCLAD ALUMINUM

Alclad and Pureclad:
- are used to designate sheets that consist of an aluminum alloy core coated with a layer of pure aluminum
- to a depth of approximately 51/2 percent on each side

pure aluminum coating affords a
- dual protection for the core,
- preventing contact with any corrosive agents,
- protecting the core electrolytically by preventing any attack caused by scratching or from other abrasions.

There are two types of heat treatments applicable to aluminum alloys
1, solution heat treatment
2, precipitation heat treatment

Some alloys, such as 2017 and 2024:
develop their full properties as a result of solution heat treatment followed by about 4 days of aging at room temperature

Other alloys, such as 2014 and 7075:
require both heat treatments

The alloys that require precipitation heat treatment (artificial aging):
to develop their full strength also age to a limited extent at room temperature; the rate and amount of strengthening depends upon the alloy

- Some reach their maximum natural or room temperature aging strength in a :
few days, and are designated as -T4 or -T3 temper.

- Others continue to age appreciably over a long period of time.

Because of this natural aging;
- the -W designation is specified only when the period of aging is indicated, for example, 7075-W (1/2 hour).

The hardening of an aluminum alloy by heat treatment consists of four distinct steps:
1, Heating to a predetermined temperature.
2, Soaking at temperature for a specified length of time
3, Rapidly quenching to a relatively low temperature
4, Aging or precipitation hardening either spontaneously at room temperature, or as a result of a low temperature thermal treatment.

The first three steps above are known as solution heat treatment

Room temperature hardening is known as natural aging, while hardening done at moderate temperatures is called artificial aging, or precipitation heat treatment.

SOLUTION HEAT TREATMENT

Temperature

- The temperatures used for solution heat treating vary with diff rent alloys and range from 440°C to 525°C.
- must be controlled within a very narrow range (±5.5°C) to obtain specified properties

If the temperature is too low: maximum strength will not be obtained.

When excessive temperatures are used:
1, there is danger of melting the low melting constituents of some alloys
2, consequent lowering of the physical properties of the alloy.

if melting does not occur, the use of higher than recommended temperatures promotes :
1, discoloration
2, increases quenching strains

Time at Temperature

referred to as soaking time

measured from the time the coldest metal reaches the :
minimum limit of the desired temperature range

soaking time varies, depending upon the
1, alloy
2, thickness
Time :
1, from 10 minutes for thin sheets
2, approximately 12 hours for heavy forgings

For the heavy sections, the nominal soaking time is approximately:

- 1 hour for each inch of cross-sectional thickness

Choose the minimum soaking time necessary to develop :
the required physical properties

An excessive soaking period aggravates high temperature
1, oxidation
2, copper and other soluble constituents into the protective cladding and may defeat the purpose of cladding.

QUENCHING
Parts produced from
1, sheet
2, extrusions
3, tubing
4, small forgings
5, similar type material
are generally quenched in a cold water bath

The temperature of the water before quenching should :
not exceed 30°C

Using a sufficient quantity of water keeps the temperature rise under 11°C.

Such a drastic quench ensures maximum resistance to corrosion.

Thickness (inch)	Time (minutes)
Up to .032	30
.032 to 1⁄8	30
1⁄8 to 1⁄4	40
Over 1⁄4	60

Note: Soaking time starts when the metal (or the molten bath) reaches a temperature within the range specified above.

Figure 2-2. Typical soaking times for heat treatment.

Hot Water Quenching

Large forgings and heavy sections: can be quenched in hot or boiling water

This type of quench

1, minimizes distortion

2, al leviates cracking which may be produced by the unequal temperatures obtained during the quench.

use of a hot water quench is permitted with these parts because: the temperature of the quench water does not critically aff ct the resistance to corrosion of the forging alloys.

resistance to corrosion of heavy sections is not as critical a factor as for thin sections.

Spray Quenching

High velocity water sprays are useful for parts formed from: clad sheet and for large sections of almost all alloys.

This type of quench: minimizes distortion and al leviates quench cracking

Don't use spray quenching on

2017 and 2024

Because: it will effect their corrosion resistance

Lag Between Soaking and Quenching (time)

The time interval between the removal of the material from the furnace and quenching is critical for some alloys and should be held to a minimum.

Allowing the metal to cool slightly before quenching promotes reprecipitation from the solid solution. The precipitation occurs along grain boundaries and in certain slip planes causing poorer formability.

REHEAT TREATMENT

treatment of material which has been previously heat treated is considered a reheat treatment

unclad heat-treatable alloys can be:
solution heat treated repeatedly without harmful eff cts.

The number of solution heat treatments allowed for clad sheet is:
limited due to increased diffusion of core and cladding with each reheating

Existing specifications allow one to three reheat treatments of clad sheet depending upon cladding thickness

STRAIGHTENING AFTER SOLUTION HEAT TREATMENT

Some warping occurs during solution heat treatment producing
1, kinks
2, buckles
3, waves
4, twists.

removed by:
straightening and flattening operations.

PRECIPITATION HEAT TREATING
Ask Dr. kamal

ANNEALING OF ALUMINUM ALLOYS

annealing procedure for aluminum alloys consists of

1, heating the alloys to an elevated temperature

2, holding or soaking them at this temperature for a length of time depending upon the mass of the metal

3, then cooling in still air

Annealing leaves the metal in the best condition for cold working.

when long forming operations are involved, the metal will take on a condition known as "mechanical hardness" and will resist further working.

It may be necessary to anneal a part several times during the forming process to avoid cracking

Aluminum alloys should not be used in the-annealed state for: parts or fittings.

Clad parts should be : heated as quickly and carefully as possible

since long exposure to heat tends to cause some of the constituents of the core to diffuse into the cladding. This reduces the corrosion resistance of the cladding.

HEAT TREATMENT OF ALUMINUM RIVETS

heated either in a

1, tubular containers in a salt bath,

2, or small screen wire baskets in an air furnace

rivets reach maximum strength in about 9 days after being driven.

The heat treatment of alloy 2017 rivets consists of

- subjecting the rivets to a temperature between 500°C to 510°C
- for approximately 30 minutes
- immediately quenching in cold water

MAGNESIUM ALLOYS

Magnesium alloy castings

- respond readily to heat treatment,
- about 95 percent of the magnesium used in aircraft construction is in the cast form

The heat treatment of magnesium alloy castings is

- similar to the heat treatment of aluminum alloys in that there are two types of heat treatment:

1, solution heat treatment
2, precipitation aging) heat treatment

Magnesium develops a negligible change in its properties when:
allowed to age naturally at room temperatures

Magnesium alloy castings are solution heat treated to improve :
tensile strength, ductility, and shock resistance

Solution heat-treatment temperatures for magnesium alloy castings :
- range from 390°C to 415°C,
- the exact range depending upon the type of alloy

The upper limit of each range listed in the specification is the maximum temperature to which the alloy may be heated without danger of melting the metal

soaking time ranges from : 10 to 18 hours

exact soaking time
depending upon the type of alloy as well as the thickness of the part

Soaking periods longer than 18 hours may be necessary for :
castings over 2 inches in thickness.

NEVER heat magnesium alloys in a salt bath as this may result in an explosion. fire hazard exists in the heat treatment of magnesium alloys

PRECIPITATION HEAT TREATMENT

After solution treatment, magnesium alloys may be given an:
aging treatment to increase hardness and yield strength.

aging treatments are used merely to

- relieve stress
- stabilize the alloys in order to prevent dimensional changes later
- especially during or after machining.

Both yield strength and hardness are improved somewhat by this treatment at the expense of a slight amount of ductility

The corrosion resistance is also improved, making it closer to the "as cast" alloy.

Precipitation heat treatment temperatures are considerably:
lower than solution heat-treatment

temperatures range from :
165°C to 260°C.

Soaking time ranges from :
4 to 18 hours.

TITANIUM

Titanium is heat treated for the following purposes:

1, Relief of stresses set up during cold forming

2, Annealing after hot working or cold working, or to provide maximum ductility for subsequent cold working.

3, Thermal hardening to improve strength.

ANNEALING OF TITANIUM

provides

1, toughness

2, ductility at room temperature

3, dimensional and structural stability at elevated temperatures

4, improved machinability

The full anneal is usually called for as preparation for further working

performed at :650–900°C

Time : 16 minutes to several hours, depending on the thickness of the material and the amount of cold work to be performed

The usual treatment for the commonly used alloys is:

- 705°C for
- 1 hour, followed by an air cool

full anneal generally results in sufficient scale formation to require the use of :

- caustic descaling, such as sodium hydride salt bath.

STRESS RELIEVING

Stress relieving is generally used to remove stress concentrations resulting from forming of titanium sheet.

performed at temperatures ranging from :345°C to 540°C

time:

- from a few minutes for a very thin sheet
- an hour or more for heavier sections.

typical stress relieving treatment is
480°C for 30 minutes, followed by an air cool.

The discoloration or scale which forms on the surface of the metal during stress relieving is easily removed by : pickling in acid solutions.

recommended solution contains :

- 10 to 20 percent nitric acid

and

- 1 to 3 percent hydrofluoric acid.
- solution should be at room temperature or slightly above

THERMAL HARDENING

Unalloyed titanium cannot be heat treated

but

the alloys commonly used in aircraft construction can be strengthened by:

- thermal treatment usually at some sacrifice in ductility.

For best results:

- a water quench from 790°C,
- followed by reheating to 480°C for 8 hours is recommended.

CASE HARDENING

chemical activity of titanium and its rapid absorption of :

1, oxygen
2, nitrogen
3, carbon

- at relatively low temperatures make case hardening advantageous for special applications.

Nitriding, carburizing, or carbonitriding can be used to produce a

- wear-resistant case of 0.000 1 to 0.000 2 inch in depth.

CASTING

Casting is formed by :

- melting the metal
- pouring it into a mold of the desired shape

Since plastic deformation of the metal does not occur, no alteration of the grain shape or orientation is possible.

The grain size of the metal can be controlled by the

- cooling rate
- the alloys of the metal
- thermal treatment

Castings are normally

- lower in strength
- more brittle than a wrought product of the same material

For intricate shapes or items with internal passages, such as

- turbine
- blades

casting may be the most economical process

Except for engine parts:
most metal components found on an aircraft are wrought instead of cast.

All metal products start in the form of casting

Wrought metals are converted from:

- cast ingots by plastic deformation.

For high strength aluminum alloys, an :
80 to 90 percent reduction (dimensional change in thickness) of the material is required to ;
obtain the high mechanical properties of a fully wrought structure

Cast iron
is a hard unmalleable pig iron
made by:
casting or pouring into a mold.

Cast aluminum alloy process:

- heated to its molten state and
- poured into a mold to give it the desired shape.

EXTRUDING

The extrusion process involves the

- forcing of metal through an opening in a die
- causing the metal to take the shape of the die opening

The shape of the die will be the cross section of an

- angle, channel, tube, or some other shape.

Some metals such as :

- lead, tin, and aluminum
- may be extruded cold

however,

- most metals are heated before extrusion.

The main advantage of the extrusion process is its : flexibility.

For example, because of its workability, aluminum can be economically extruded to more intricate shapes and larger sizes than is practical with other metals.

Extruded shapes are produced in

- very simple
- as well as extremely complex sections.

Ex:

In this process a cylinder of aluminum, for instance, is heated to 400–455°C and is then forced through the opening of a die by a hydraulic ram. The opening is the shape desired for the cross section of the finished extrusion.

Many structural parts, such as :

- channels
- angles
- T-sections
- Z-sections

are formed by the extrusion process.

Aluminum is the most extruded metal used in aircraft.

Aluminum is extruded at a temperature of 371–482°C

requires pressure of up to 80 000 psi (552 MPa).

COLD WORKING/HARDENING

Cold working applies to mechanical working performed at temperatures below the critical range

It results in a strain hardening of the metal

the metal becomes so hard it is difficult to continue the forming process without softening the metal by annealing

the errors attending shrinkage are eliminated in cold working, much more compact and better metal is obtained.

elastic limit, are increased; but the ductility decreases

Since this makes the metal more brittle:

it must be heated from time to time during certain operations to remove the undesirable eff cts of the working

there are several cold working processes:
the two with which the aviation mechanic will be principally concerned are
- cold rolling
- cold drawing

These processes give the metals :
desirable qualities which cannot be obtained by hot working

Cold rolling usually refers to the working of metal at : room temperature.

In this operation:
the materials that have been rolled to approximate sizes are pickled to remove the scale, after which they are passed through chilled finishing rolls.

This gives a :
smooth surface and also brings the pieces to accurate dimensions.

The principal forms of cold rolled stocks are
- sheets
- bars
- rods

Cold drawing is used in making
- seamless tubing
- wire: made from hot rolled rods of various diameters
- streamlined tie rods
- other forms of stock

rods are
- pickled in acid to remove scale
- dipped in lime water
- dried in a steam room where they remain until ready for drawing.

The lime coating adhering to the metal serves as a :lubricant during the drawing operation.

The size of the rod used for drawing depends upon the diameter wanted in the finished wire.

To reduce the rod to the desired size:

- it is drawn cold through a die.
- One end of the rod is filed or hammered to a point and slipped through the die opening

This series of operations is done by a mechanism known as a drawbench.

To reduce the rod gradually to the desired size:
it is necessary to draw the wire through successively smaller dies.

Because each of these drawings reduces the ductility of the wire, it must be annealed from time to time before further drawings can be accomplished.

Although cold working reduces the ductility, it increases the tensile strength of the wire.

In making seamless steel aircraft tubing

- the tubing is cold drawn through a ring shaped die
- with a mandrel or metal bar inside the tubing
- to support it while the drawing operations are being performed

This
forces the metal to fl w between the die and the mandrel
and
affords a means of controlling the wall thickness and the inside and outside diameters.

TESTING OF NON-FERROUS METALS

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