BRASS

&

PROPERTIES OF MATERIALS IN GENERAL

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Feb.2024

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Chapter One:

BRASS

INTRODUCTION:

Brass is usually the first-choice material for many of the components for equipment made in the general, electrical and precision engineering industries. Brass is specified because of the unique combination of properties, matched by no other material, that make it indispensable were a long, cost-effective service life is required. 2-brass is an alloy of copper and zinc, the amount of zinc varying from five to 45 per cent to create a range of brasses, each with unique properties, there are two distinct types of brass. Those with less than **35** per cent zinc are known as alpha brasses because only one solid solution (alpha) is present. These alloys are ductile at room temperature and ideal for cold working. Brasses with more than **35** per cent are called alpha-beta or duplex alloys and are ideal for hot working

The generic term brass' covers a wide range of copper-zinc alloys with differing combinations of properties, including:

- strength
- Ductility
- Hardness
- Conductivity
- Mach inability
- Wear resistance
- Color
- Corrosion resistance

* Brasses can easily be cast to shape or fabricated by extrusion, rolling, drawing, hot stamping and cold forming.

- The mach inability of brass sets the standard by which other materials are judged.
- Brasses are ideal for a very wide range of applications.
- Brass is frequently the cheapest material to select.
- The correct choice of brass is important if manufacturing and operating requirements are to be met in the most cost-effective way.

To suit every need, there are over sixty Standard compositions for brass with copper contents ranging from **58%** to **95%**.

Apart from the major alloying element, zinc, small additions (less than **5%**) of other alloying elements are made to modify the properties so that the resulting material is fit for a given purpose.

BRIEF HISTORY OF BRASS.

Brass has been made for almost as many centuries as copper but has only in the last millennium been appreciated as an engineering alloy. Initially, bronze was easier to make using native copper and tin and was ideal for the manufacture of utensils. Pre-dynastic Egyptians knew copper very well and in hieroglyphs copper was represented by the ankh symbol, also used to denote eternal life, an early appreciation of the lifetime cost-effectiveness of copper and its alloys. While tin was readily available for the manufacture of bronze, brass was little used except where its golden color was required. The Greeks knew brass as 'oreichalcos', a brilliant and white copper.

Before the 18th century, zinc metal could not be made since it melts at 420C and boils at about 950C, below the temperature needed to reduce zinc oxide with charcoal. In the absence of native zinc it was necessary to make brass by mixing ground smithsonite ore (calamine) with copper and beating the mixture in a crucible. The heat was sufficient to reduce the ore to metallic state but not melt the copper. The vapor from the zinc permeated the copper to form brass which could then be melted to give a uniform alloy.

TYPES OF BRASS.

Brasses are copper alloys in which the principal alloying constituent is zinc. Their properties depend primarily upon the proportion of zinc present but can be usefully modified by the introduction of additional elements to further improve specific characteristics such as strength, mach inability or resistance to particular forms of corrosion.

*Effect of zinc content

The problem of selecting the appropriate brass for any particular service from the range presented is simplified by division into alpha and alpha-beta brasses.

When up to about **35%** zinc is added to copper it dissolves to form a solid solution of uniform composition. Further increase in zinc content produces a mixture of the original solid solution (**alpha phase**) and a new solid solution of higher zinc content (**beta phase**).

Brasses containing between **35% - 45%** zinc consist of mixtures of these two phases and are known as alpha-beta of duplex brasses, the ratio of alpha to beta phase depending principally upon the zinc content. The inclusion of certain third elements – particularly aluminum, silicon or tin – gas the effect of increasing the beta phase content for any particular zinc content.

1-Alpha brasses.

The range of alloys, termed 'alpha brasses', or cold working brasses', contain a minimum **63%** of copper. They are characterized by their ductility at room temperature, and can be extensively deformed by rolling, drawing, bending, spinning, deep drawing, cold heading and thread rolling, The best known material in this group contains **30%** zinc and is often known as **'70/30'** or 'cartridge' brass, **CuZn30** – due to the ease with which the alloy, can be deep drawn for the manufacture of cartridge cases.

2-Duplex brasses.

The **'alpha-beta brasses'**, **'duplex brasses'** or 'hot working brasses' usually contain between **38%** and **42%** zinc. In contrast to the alloys of the first group, their ability to be deformed at room temperature is more limited. They are, however, significantly more workable than the alpha brasses at elevated temperatures and can be extruded into bars of complex section, either solid or hollow, and hot forged in closed dies (hot stamped) to complex shapes.

The ideal hot working temperature range is whilst the brass is cooling, between **750C** and **650C**, during which the alpha phase is being deposited (see Figure4). The mechanical working process breaks down the alpha phase into small particles as it is deposited, resulting in good mechanical properties.

*EFFECT OF ALLOYING ADDITIONS.

Alloying additions are made to the basic copper-zinc alloys for a variety of reasons: -

- To improve machinability.
- To improve strength and wear resistance.
- To improve corrosion resistance.
- For other special reasons.

• Lead

The addition most commonly made to brasses to modify their properties is lead, up to **3%** of which may be added to **alpha-beta brasses** to provide free-machining properties. The dose not from a solid solution with the copper and zinc but is present as a dispersed discontinuous phase distributed throughout the alloy. It has no effect on corrosion resistance lead is not added to wrought alpha brasses since, in the absence of sufficient beta phase, it gives rise to cracking during hot working.

• Tin

1% tin seawater service, corrosion resistance.

• Silicon

The strength wears resistance. Gas welding.

• Arsenic

Dezincification corrosion.

- **Nickel silvers**

10 to **20%** nickel silvery appearance.

Gillet zinc equivalent.

-CHOOSING THE RIGHT BRASS.

There are over sixty brasses speechified in EN standards.

So, it is essential to select the appropriate alloy for the application and fabrication route required.

*BRASSES FOR SPECIFIC MANUFACTURIG PROCESSES.

High-speed machining brasses.

Lead is added to brass to improve its mach inability. It also gas the effect of reducing the cold ductility of the metal so the amount of lead used depends on the exact combination of properties required. The lead exists as discrete particles in the matrix and causes the sward from the machining operation to be broken into fine chips rather than gong curls.

The casting and extrusion of these brasses must be carefully controlled to ensure that the lead particles are finely dispersed and the any iron or silicon impurities are retained in solution.

*BRASSES FOR HOT WORKING.

In order to select an appropriate brass, a little basic metallurgy of the brasses is useful.

When the alloy contains less than about **35% Zn**, the zinc stays in solid solution in the copper. Such brasses are known as single phase, or alpha brasses. They gave good ductility at ambient temperatures and are ideal for cold for cold working. When more zinc is added, a second phase, beta, is formed. And at room temperature the alloy is a mixture of the two phases. These brasses are known as two-phase, alpha/beta, or duplex brasses.

The combine maximum ductility at the stamping temperature (**650-750C**) to allow complex shapes to be formed, with strength and reasonable ductility at room temperature, the optimum compositions are in the region of **60% Cu** and **40%Zn.**

These are predominantly in the of **alpha** and **beta** phases at room temperature. And have a mixture of **alpha** and **beta** phases at room temperature. The precise choice of alloy will depend on the service requirements and other fabrication processes.

Cold working brasses are typically used to make semi-finished products such as **sheet**, **strip**, **foil, wire and tube**.

The gilding metals, **CW501L** (**CZ101**), **CW502L** (**CZ102**) And **CW503L** (**CZ103**) have excellent ductility, strength and corrosion resistance and are frequently chosen for co lour and durability for decorative architectural application and costume jeweler, For special purposes, where even better corrosion resistance is required, aluminum or arsenical brasses are available. A typical application would be for condenser tubes for use with brackish or seawater.

*BRASSES FOR ELECTRICAL APPLICATIONS.

Brass is widely used for contracts and terminals in electrical applications. Its electrical conductivity is good and it gases the great advantage that the thin oxide film which forms on exposure to the air is electrically conductive so that contact resistance does mot increase.

*BRASSES FOR ARCHITECTURAL APPLICATIONS.

Brasses containing aluminum or manganese are frequently sued for architectural applications because of the self-healing, attractive surface films which they exhibit.

*BRASSES FOR DECORATIVE APPLICATIONS.

For costume jeweler, decorative trims and other similar applications the low-zinc brasses or gilding metals mentioned above are recommended. They gave an attractive golden color which caries with copper content, and good tarnish resistance.

-MACHINABILITY.

Brass has excellent machinability; however, this can be improved by adding three per cent lead to give free-cutting high-speed machining brasses.

-STRENGTH.

Brasses are medium strength engineering materials. In the softened or annealed condition they are ductile and strong but, when gardened by cold working, their strength increases. The addition of small quantities of manganese, aluminum, tin, silicon, iron and nickel in brass produces a family of high tensile brasses that can have tensile strengths in excess of **$500MN/^2$. $750MN/m^2$** can be obtained in some alloys by extreme cold working Brasses have good impact resistance and do mot shatter or crack when subject to a high impact load.

-CONDUCTIVITY.

Brasses have good electrical and thermal conductivity. Combined with good corrosion resistance, this makes them ideal for the manufacture of electrical equipment. Condenser and heat exchanger tubing also makes use of the good thermal conductivity of copper alloys. Brasses do not spark when struck by other materials and are approved for use in hazardous environments, they are sols suitable for use at cryogenic temperatures since their properties are retained or slightly improved (mechanical values are available at-**197C**). strength is maintained up to **200C**.

-CORROSION RESISTANCE.

Brasses have excellent resistance to corrosion that makes them a natural, economic first choice for many applications.

Atmospheric exposure of the brasses results in the development of a superficial tarnish film. Outdoor exposure will ultimately result in the formation of a thin protective green 'patina' which is frequently seen as a visually attractive feature in buildings, but the brass will remain essentially unaffected for an unlimited period of time, i.e. it will not rust away like iron and steel. Seawater can be handled successfully providing the correct alloy is chosen, and there is a long history of the use of brass tube and tube fittings, steam condenser and desalination plant. High tensile brasses containing manganese have excellent resistance to atmospheric corrosion, continual exposure resulting in a gradual darkening of the bronze color.

****BRASS PRICES.**

The price of zinc is normally about half that of copper, although the relationship varies. Therefore the alloys containing the most zinc gave the lowest basic metal cost. The higher zinc brasses also lend themselves to relatively cheap production routes compared with the higher copper alloys. As a result the **60/40** hot working brasses are the most frequently ordered for general purposes, while the **70/30** and 64/36 brasses tend to dominate the brass sheet, strip, tube and wire markets. The higher copper materials tend to be used only if there is a particular advantage.

-WHY MAKE IT IN BRASS?

Brass is the best material from which to manufacture many components because of its unique combinations of properties. Good strength and ductility are combined with excellent corrosion resistance and superb mach inability.

Brasses set the standard by which the mach inability of other materials is judged and are also available in a very wide variety of product forms and sizes to allow minimum machining to finished dimensions.

Chapter Two:

Properties of Materials in General

• When selecting a material for an engineering application, a primary concern is to assure that its properties will be adequate for the anticipated operating conditions

• These may include:

– Mechanical characteristics

– Physical characteristics

– Features related to the service environment

– Ability to operate under extremes of temperature

–Resist corrosion

Mechanical Characteristics

• Strength

• Rigidity

• Resistance to fracture

• Ability to withstand vibrations or impacts

Physical Characteristics

• Weight

• Electrical properties

• Appearance

Material Selection

• Based on a comparison of the established design requirements and the tabulated record results that describe how common materials respond to various standard tests.

• It is important to know.

– Which properties are significant?

– How the test values were determined?

– What restrictions or limitations should be placed on their use?

– Various test procedures, their capabilities and their limitations

(Physical and Mechanical Properties)

1-Physical Properties

• Density (weight)

• Melting point

• Optical properties

– Transparency

– Opaqueness

– Color

• Thermal properties (specific heat)

– Coefficient of thermal expansion

– Thermal conductivity

– Electrical conductivity

• Magnetic properties

• In some cases, they are the prime reasons in selecting material.

2-Mechanical Properties

• Are usually determined by subjecting prepared specimens to standard laboratory tests.

• When sing the results _ keep in mind they were determined in specific conditions.

Mechanical Properties:

Strain

• When a force or load is applied to a component, the material is deformed or disported (*strained*), and internal relative forces (*stresses*) are transmitted through material

• If the weight W is suspended to a bar it will elongate by an amount of L

• **Unit strain**: the amount of elongation for each unit length:

e = L / L

– Units = in. /in., or m/m, or % therefore it is dimensionless

– Strain = change in length (∆l)/original length (lo)

Stress

• The force or load being transmitted divided by the cross sectional area transmitting the load

• **S = W / A**

– Stress = load / area

– Units = lbs/in2 (psi)

– Units = Newton/meter2 (N/m2)

Direction of force?

• **Compression** – pushing (buckling, a more common failure in compression).

• **Tension** – pulling.

• **Shear** – shoving/sliding.

• **Torsion** – twisting.

• **Bending** – tension (below neutral axis) and compression (above).

• **Fatigue** – combination of these stresses.

Static and Dynamic Loadings:

• **Static:** forces applied to a material are constant.

• **Dynamic:** forces applied to a material are changing during the time period.

Static Properties

• A number of standardized tests have been developed to determine them:

1-Tensile test:

• Strength properties.

• Ductility and brittleness.

• Toughness.

• True Stress – True Strain Curves.

• Strain Hardening and the Strain- Hardening Exponent.

• Damping Capacity.

2- Compression tests.

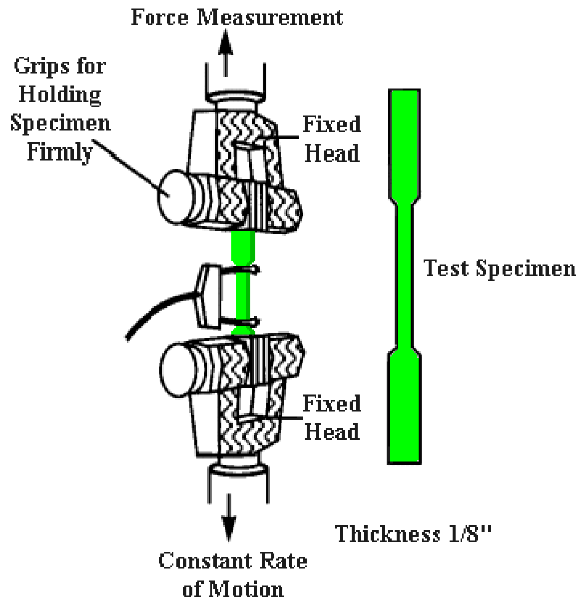
3- Hardness Testing:

- Brinell Hardness Test.
- The Rockwell Test.
- Vickers Hardness Test.
- Micro hardness Test.

Static Properties:

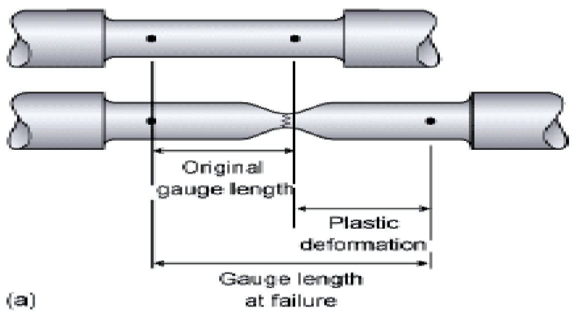
1-Tensile Test

- Tensile tests are simple, relatively inexpensive, and fully standardized.
- By applying a force on a material using a uniaxial load, the reaction of the material can be readily recorded and analyzed



• This data can then be used to predict how the material will react to forces being applied in practical situations such as in bridges, or in airframes

• A load (**W**) is applied and measured by the testing machine, while the elongation (_ **L**) is simultaneously monitored



Stress Properties

Engineering stress – engineering strain curve

• **Hooke's law**: The strain is directly proportional to the stress.

• This proportionality constant is known as **Young's modulus** or **modulus of elasticity.**

Modulus of Elasticity (E)

• E is the ratio of stress to strain but ***only*** in the ***elastic*** region! **(E = σ/ε).**

• It is a measure of stiffness.

• High E means high σ required for only small amounts of elastic deformation (Material is stiff).

• Low E means high σ results in a lot of elastic deformation (material is not very stiff).

– Steels: E _ 30 x 106 psi

– Brass: E _ 16 x 106 psi

– Aluminum: E _ 10 x 106 psi

E = Young's Modulus.

E = Modulus of Elasticity.

E = slope = rise/run.

$E = \Delta \sigma / \Delta \varepsilon$

• Modulus of Elasticity: some define this as a Mechanical Property,

• But it does not change with plastic deformation or heat treating, only alloying, which in effect gives a new material.

• So, it is a constant for a particular metal!

Yield Strength (YS)

• Change from elastic _ plastic

. **σ < YS** means ***elastic*** deformation.

– E = σ/ε when σ < YS

. **σ > YS** means ***plastic*** deformation.

• Low YS means material will deform permanently at low stresses.

Modulus of Resilience (MR)

• MR is the area under the **elastic** region of the σ-ε curve.

• It indicates the **energy** that can be absorbed **without** permanent deformation.

• **MR ≈ (YS) 2 / 2E**

• Units are **in-lbs/in3**

Ultimate Tensile Strength (UTS)

• UTS indicate maximum stress prior to failure.

• Deformation is uniform at **σ < UTS**.

• Deformation is non-uniform at **σ > UTS**.

• Generally, the more difference there is between YS and UTS, the more ductile the material is:

Ductility and Brittleness

• % Elongation is a measure of **ductility.**

• Total strain a material exhibits through failure.

• High elongation means large amounts of deformation without failure.

• % elongations < 5% generally reflect a “brittle” material

• High elongation = toughness

Modulus of Toughness (MT)

• MT is the area under the entire **σ-ε** curve.

• It indicates the total energy that can be absorbed even through failure.

• **MT = ε (YS + UTS) / 2**,

– Where ε = total strain or % εT / 100.

• Units are in-lbs/in3.

2-Hardness Testing:

-Brinell Hardness Test.

-The Rockwell Test.

-Vickers Hardness Test.

-Micro hardness Test.

Hardness

• Measure of a material’s resistance to penetration.

• most common stationary hardness tests:

- Brinell - stress test.

- Rockwell - strain test.

These tests measure the depth or area of an indentation made by an intender with a specific force applied for a specific time.

Other Hardness Tests:

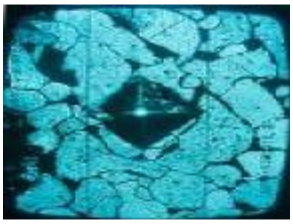
- Scleroscope - rebound of a top or hammer.

- Mohs - scratch test.

- Vickers (HV) and Knoop (HK) - similar to Brinell (stress tests).

-Micro hardness.

Micro hardness test involves using a diamond indenter to make a micro indentation into the surface of the test material; the indentation is measured optically and converted to a hardness value.



Dynamic Properties:

- Impact Test.
- Fatigue and the endurance limit.
- Fatigue failures.

Reference:

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