UNIT-III

PART A

1. What makes nitriding different from rest of case hardening process, besides composition?

Nitriding will be performed in nitrogen atmosphere unlike other hardening process. Nitriding will form carbo nitride which is a very hard compound, which will prove wear resistance.

2. What is the difference between malleable and spheroidal cast iron?

Malleable cast irons are used for hot rolling and forging. Spheroidal cast iron are used for machining operations like turning and milling.

3. What are the primary groups of plain carbon steels?

Low carbon steel, mild steel and high carbon steel.

4. What is meant by precipitation hardening?

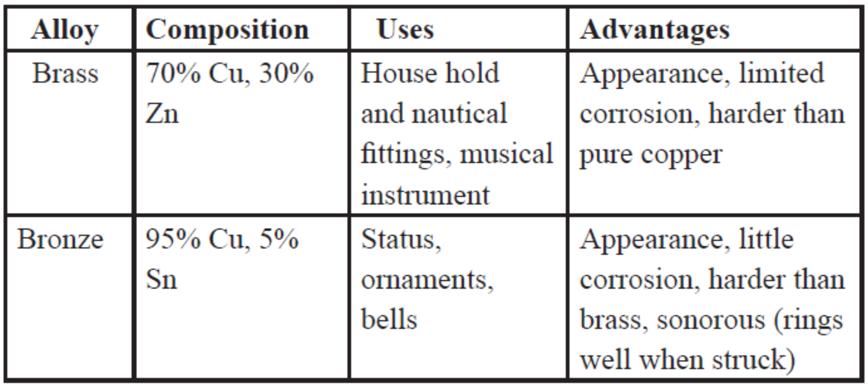
Precipitation hardening, also called age or particle hardening, is a heat treatment process that helps make metals stronger. The process does this by producing uniformly dispersed particles within a metal's grain structure that help hinder motion and thereby strengthen it—particularly if the metal is malleable.

5. What is effect of Si in steel?
   It increases strength without limiting grain size. Used to promote large grain sizes used in magnetic applications. Used in spring steels.
6. What are brasses and bronze?
   Brasses are alloys of copper and zinc and may contain small amount of other alloying elements. Traditional bronze is a copper alloy with with up to 10% tin. The tin in bronze makes it more resistant to wear than unalloyed copper. Bronzes today are usually stronger and more resistant to corrosion than brass.

7. What are the effects of adding Si in steels? (Apr/May 2017)

Deoxidize, fine grain size, increases fatigue strength and increase wear properties.

8. Differentiate brass from bronze?



Alloy	Composition	Uses	Advantages
Brass	70% Cu, 30% Zn	House hold and nautical fittings, musical instrument	Appearance, limited corrosion, harder than pure copper
Bronze	95% Cu, 5% Sn	Status, ornaments, bells	Appearance, little corrosion, harder than brass, sonorous (rings well when struck)

9. Which type of stainless steel is non magnetic? (Nov/Dec 2017)
   Austenitic steels are non magnetic in nature

10. What is the role of boron in steel alloying? (Nov/Dec 2017)
    The role of boron in steel is to enhance the hardness level through enhancing the hardenability.

11. What is HSLA? Explain with respect to composition, properties and application.
    High-strength low-alloy steel (HSLA) is a type of alloy steel that provides better mechanical properties or greater resistance to corrosion than carbon steel. HSLA steels vary from other steels in that they are not made to meet a specific chemical composition but rather to specific mechanical properties. They have carbon content between 0.05–0.25% to retain formability and weldability. Other alloying elements include up to 2.0% manganesesmall quantities of copper, nickel, niobium, nitrogen, vanadium, chromium, molybdenum, titanium, calcium, rare earth elements, or zirconium. They are used in cars, trucks, cranes, bridges, roller coasters and other structures that are designed to handle large amounts of stress or need a good strength-to-weight ratio. HSLA steel cross-sections and structures are usually 20 to 30% lighter than carbon steel with the same strength.

12. Explain briefly the effect of ferrite stabilizer on the eutectoid temperature and composition.
    Stabilizing ferrite decreasing the temperature range, in which austenite exists. The elements having the same crystal structure as the ferrite lower the A4 point and increases A3 point. These elements lower the solubility of carbon in austenite, causing increase of amount of carbides in the steel. Ferrite stabilizers are chromium, tungsten, molybdenum, vanadium, aluminum and silicon.

13. Which type of stainless steel is used for surgical instruments.

Martensitic stainless steel is used to make surgical instruments.

14. What is the typical constituent microstructure of bearing alloy

The alloy mentioned in the patent was 89% Tin, 9% Antimony and 2% Copper, which is amazingly close to today's very popular ASTM B-23 Grade 2 "Babbitt" was originally applied to Tin-base alloys, it is now used to describe bearing metals with Lead or other metals as the major element.

15. What are the primary effects of chromium and copper as alloying elements in steel
Chromium stabilizes ferrite, increases corrosion resistance and increases hardness.
Copper will increase the ductility and increases fracture toughness.

16. What are super alloys
Super alloys are the alloys of Nickel and tungsten which is used in high temperature application.

17. What are the effects of alloying additions on steel?
To increase Strength, Hardness, Toughness, Properties

18. What are the various types of Tool steels? Plain carbon
Low alloy
High speed
High Chromium High Carbon steels

19. Write short notes on types of stainless steels. (May 2009) Austenite Stainless steel: They have austenite structure retained at room temperature.
Ferrite stainless steel: They have ferrite structure at all room temperatures up to their melting points. Martensitic stainless steels.

20. How Bearing alloys classified?
White metal
Copper base
Aluminium base

PART B

1. Brief on the influence of alloying elements: Co, Ni, Mo and V

Co:

- Increases hardness
- Increases hardenability
- Increases wear resistance
- Increases high temperature hardness
- Increases creep resistance

Ni:

- Increases hardness
- Increases hardenability
- Increases wear resistance
- Increases high temperature hardness

- Increases creep resistance

Mo:

- Increases work hardenability
- Decreases critical cooling rate
- Induces ductility.
- Reduced cold cracking

V:

- Increases the critical cooling rate
- Increase hardenability
- Increases wear resistance
- Improves surface hardness depth.

2. List the types and their typical applications of tool steel.

Refer question no. 8

3. Brief the precipitation hardening and ageing treatment of Al-Cu alloy.

Refer question no. 9

4. Write a short notes on : HSLA steel, maraging steel, stainless steel.

Refer question no. 8 and 11 in part-A

5. Discuss the characteristics of copper and its alloys, their properties and applications.

Refer question no. 17 and 19.

6. What are tool steel? Explain its types.

Refer question no. 8 and 18.

7. Explain age hardening of Al-Cu with the help of phase diagram.

Refer question no. 9

8. Classify stainless steel and tool steel and explain the following:

Maraging steel:

Maraging steels (a portmanteau of "martensitic" and "aging") are steels (iron alloys) that are known for possessing superior strength and toughness without losing malleability, although they cannot hold a good cutting edge. Aging refers to the extended heat-treatment process. These steels are a special class of low-carbon ultra-high-strength steels that derive their strength not from carbon, but from precipitation of intermetallic compounds. The principal alloying element is 15 to 25 wt.% nickel.[1] Secondary alloying elements, which include cobalt, molybdenum, and titanium, are added to produce intermetallic precipitates,.[1] Original development (by Bieber of Inco in the late 1950s) was carried out on 20 and 25 wt.% Ni steels to which small additions of Al, Ti, and Nb were made; a rise in the price of cobalt in the late 1970s led to the development of cobalt-free maraging steels

Spheroidal graphite iron:

Ductile iron, also known as ductile cast iron, nodular cast iron, spheroidal graphite iron,spheroidal graphite cast iron and SG iron, is a type of cast iron. Ductile iron is not a single material but part of a group of materials which can be produced with a wide range of properties through control of their microstructure. The common defining characteristic of this group of materials is the shape of the graphite. In ductile irons, graphite is in the form of nodules rather than flakes as in grey iron. Whereas sharp graphite flakes create stress concentration points within the metal matrix, rounded nodules inhibit the creation of cracks, thus providing the enhanced ductility that gives the alloy its name. Nodule formation is achieved by adding nodulizing elements, most commonly magnesium (magnesium boils at 1100 °C and iron melts at 1500 °C) and, less often now, cerium (usually in the form of mischmetal). Tellurium has also been used. Yttrium, often a component of mischmetal, has also been studied as a possible nodulizer.

High speed steel in terms of composition, property and use.

High-speed steel (HSS or HS) is a subset of tool steels, commonly used in tool bits and cutting tools.

1. It is often used in power-saw blades and drill bits. It is superior to the older high-carbon steel tools used extensively through the 1940s in that it can withstand higher temperatures without losing its temper (hardness). This property allows HSS to cut faster than high carbon steel, hence the name high-speed steel. At room temperature, in their generally recommended heat treatment, HSS grades generally display high hardness (above Rockwell hardness 60) and abrasion resistance (generally linked to tungsten and vanadium content often used in HSS) compared with common carbon and tool steels. Alloys are tungsten, molubdenum and cobalt.

9. With part of phase diagram and relevant graphs explain precipitation hardening treatment of Al-Cu alloys.

Age hardenabale alloys are one of the most important classes of alloys bothfrom the practical and scientific points of view: from a practical viewpoint,they are important because they show that by a suitable heat treatmentof solutionising and aging, it is possible to improve mechanical properties;from a scientific viewpoint, in age hardenable alloys, the correlation betweenmicrostructure and mechanical properties as well as the methodology of manipulationof the microstructures through appropriate phase transformationis very clearly seen.

In Fig. 1 we show the hardness in certain Al-Cu alloys as a function of agingtime at, say, 130˚C. These alloys were initially solution treated in the singlephase α region, quenched to room temperature and then aged at the giventemperature. As is clear from these figures, the hardness increases with timeat least in the initial stages of the aging treatment; however, in all alloys, thehardness starts dropping after some time; this drop in hardness with time isknown as overaging. As shown in Fig. 2, broadly similar behaviour is alsoobserved in Al-Cu alloys aged at 190˚C. However, at this high temeprature,the overaging sets in much earlier; further, the changes in hardness are moremonotonous (with no pleateau regions).

In Fig. 3 and Fig. 4, we show the aging curves; however, this time, we also su-perimpose the different phases that precipitate out of the matrix at these temperatures for the given times on the aging curves. There is a clear correlation between the phases that form and the change in hardness; typical increases in hardness are associated with the formation of GP (Guinier-Preston) zones and 00 precipitates; in most cases, the formation of 0 leads to a decrease in hardness.

Immediately after quenching to room temperature the only contribution to strengthening (that is, resistance to the movement of dislocations) comes from the solid solution: copper atoms at the aluminium sites which resist the movement of dislocations. However, as the GP zones form, the elastic stresses associated with the coherent GP zones resists the movement of dislocations contributing to hardness.As the aging time increases, the coherent 00 phases that form, due to the mist strains that they produce, manage to resist the movement of dislocationsand hence lead to further hardening. Finally the formation of semicoherent 0 can also increase the strength; however, in the case of both 00 and 0 if the particles are coarser or the volume fractions of these phases are smaller (and hence are further apart) it leads to a decrease in hardness since the dislocations can bow between the precipitates and hence move in the matrix contributing the plastic deformation.We also notice that at the higher temperature the peak hardness (the highesthardness that is achieved before overaging) is lower; this is because the lower driving force at the higher temperature for the formation of the 00 phaseleads to a coarsely dispersed phase with lower volume fractions. In the following sections, we discuss in detail the thermodynamics and kinetics of precipitation in age-hardenable Al-Cu alloys.

1. In Fig. 5, we show the Al-rich portion of the Al-Cu phase diagram (schematically). From the phase diagram, it is clear that the Al with a few percent copper is cooled from high temperature leads to the formation of amicrostructure in which the phase precipitates out of the supersaturated matrix. However, if an alloy of composition Al - 4 wt.%Cu is solutionisedat say, 540C, and the resultant phase is rapidly quenched to room temperature, the solid solution is largely retained; if this alloy is kept at roomtemperature (or at any temperature below 180C), a metastable phase knownas Guinier- Preston zones (GP zones) is formed. Similarly, the aging treatment at other temperatures can produce other precipitates such as 00 and 0.The solvus for these metastable phases in shown in Fig. 6. Further, in Fig. 6,we also show the corresponding time-temperature-transformation curves forthese metastable phase as well as the stable phase. In the following sections. we describe the crystallography and interface structure of all these phases aswell as the reasons for their formation.

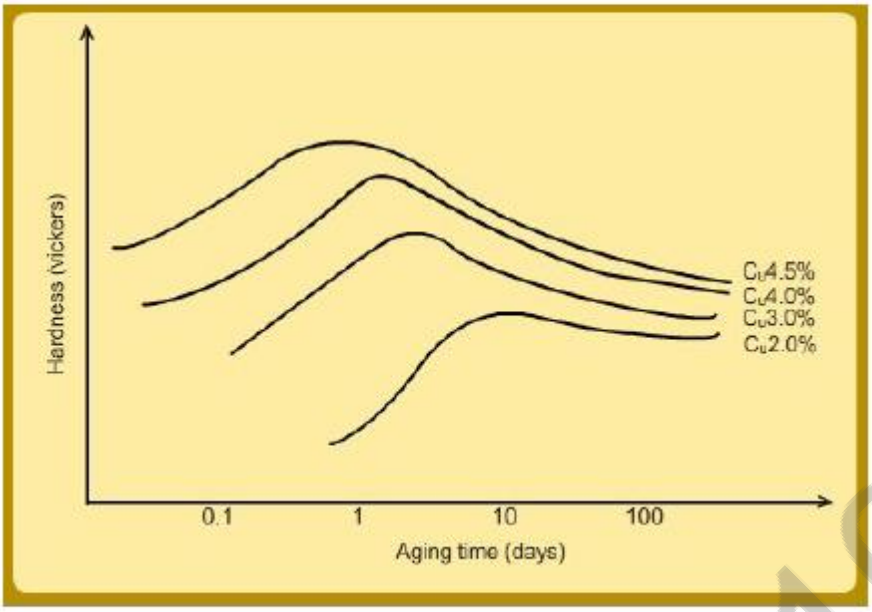


Figure 2: Aging curves at 190° C for Al-Cu system.

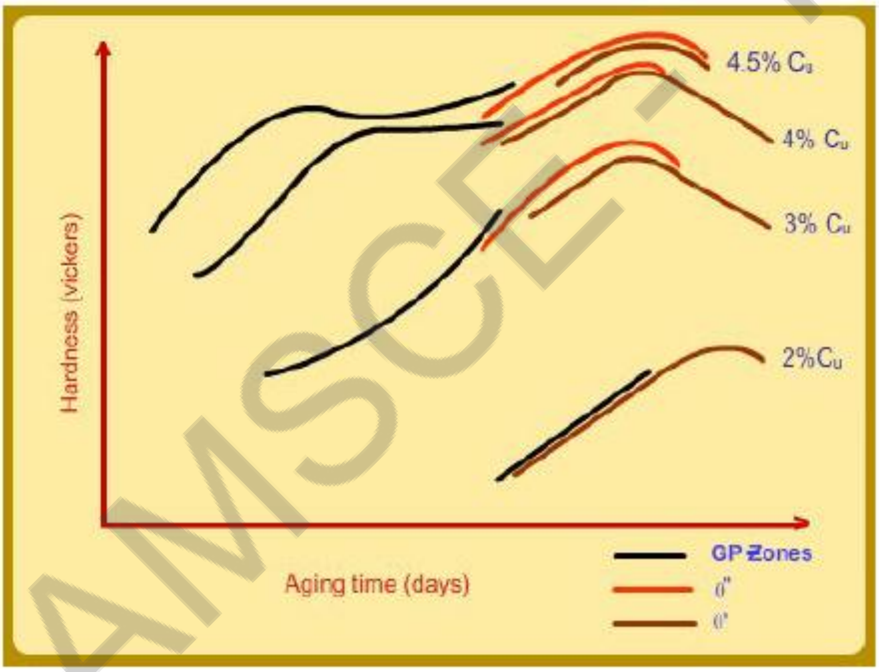


Figure 3: Aging curves with phases: 130°

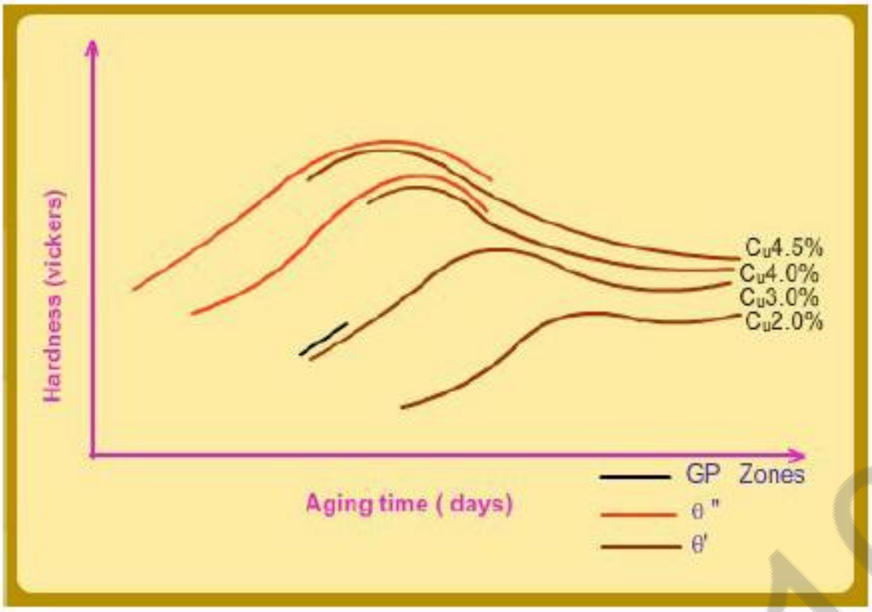


Figure 4: Aging curves with phases: 190°

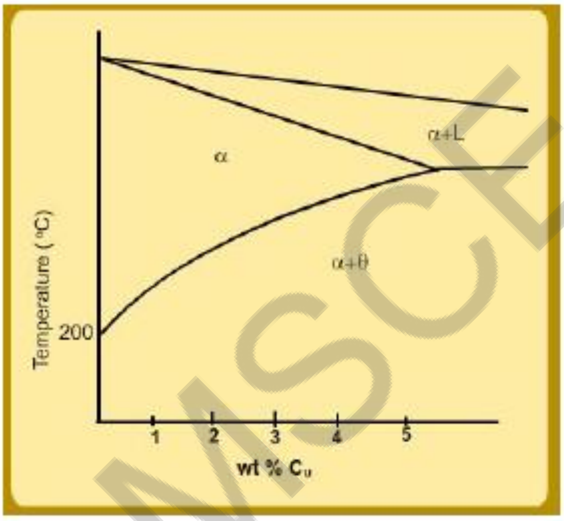


Figure 5: Al-rich portion of Al-Cu phase diagram.

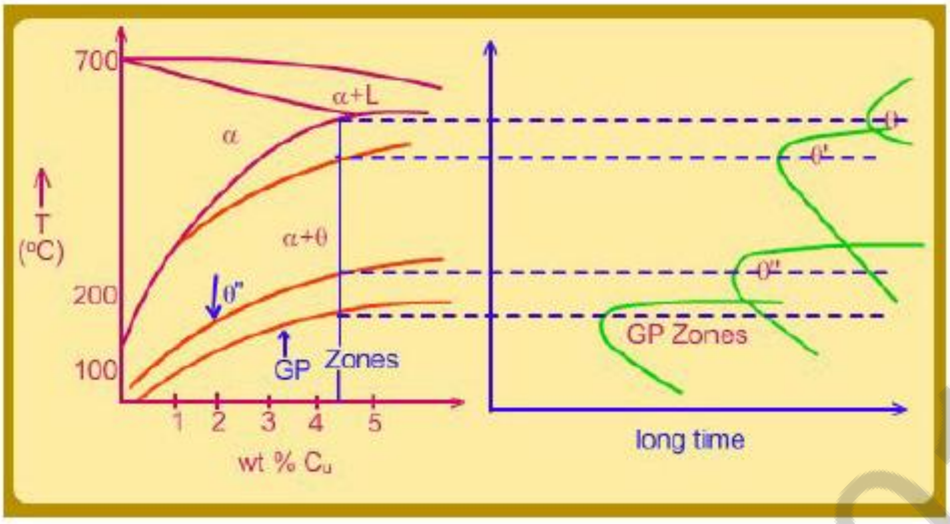


Figure 6: Metastable phases along with their TTT diagrams for Al-rich Al-Cu alloys.

10. Brief on the influence of alloying elements in steel under classification of carbide former and non carbide former.

Carbon:
Carbon is alloyed with base metal Iron to make steel which affects the hardness and strength of material. Thus the addition of carbon enables a wide range of hardness and strength.

Manganese:Manganese is added to improve hot working properties and increase strength, toughness and hardenability. Manganese, like nickel, is an austenite forming element and can been used as a substitute for nickel. Chromium:

Chromium is added to the steel to increase corrosion resistance. The resistance increases as more chromium is added. ‘Stainless Steel’ has approximately 11% chromium and a very marked degree of general corrosion resistance when compared with steels with a lower percentage of chromium. When added to low alloy steels, chromium can increase the response to heat treatment, thus improving hardenability and strength.

Nickel:

Nickel is added in large amounts, over about 8%, to high chromium stainless steel to form the most important class of corrosion and heat resistant steels. These are the austenitic stainless steels, where the tendency of nickel to form austenite is responsible for a great toughness and high strength at both high and low temperatures. Nickel also improves resistance to oxidation and corrosion. It increases toughness at low temperatures when added in smaller amounts to alloy steels.

Molybdenum:

Molybdenum, when added to chromium-nickel steels, improves resistance to pitting corrosion especially by chlorides and sulphur chemicals. When added to low alloy steels, molybdenum improves high temperature strengths and hardness. When added to chromium steels it greatly diminishes the tendency of steels to decay in service or in heat treatment.

Titanium:

Used as stabilizing elements in stainless steels. Each has a high affinity for carbon and forms carbides, which are uniformly dispersed throughout the steel. Thus, localized precipitation of carbides at grain boundaries is prevented. Compared to chromium, carbon has higher affinity to titanium to form inter-granular carbides and hence accompanying loss of corrosion resistance at the grain boundaries.

Phosphorus:

Phosphorus is usually added with sulphur to improve machinability in low alloy steels, phosphorus, in small amounts, increases strength and corrosion resistance. Experimental work shows that phosphorus present in steel increases strength. Phosphorus additions are known to increase the tendency to cracking during welding. Sulphur:

When added in small amounts sulphur improves machinability but does not cause hot shortness. Hot shortness is reduced by the addition of manganese, which combines with the sulphur to form manganese sulphide. As manganese sulphide has a higher melting point than iron sulphide, which would form if manganese were not present, the weak spots at the grain boundaries are greatly reduced during hot working.

Selenium:

Selenium is added to improve machinability.

Niobium (Columbium):

Niobium is added to steel in order to stabilise carbon, and as such performs in the same way as described for titanium. Niobium also has the effect of strengthening steels and alloys for high temperature service.

Nitrogen:

Nitrogen has the effect of increasing the austenitic stability of stainless steels and is, as in the case of nickel, an austenite forming element. Yield strength is greatly improved when nitrogen is added to austenitic stainless steels.

Silicon:

Silicon is used as a deoxidizing (killing) agent in the melting of steel, as a result, most steels contain a small percentage of silicon. Silicon contributes to hardening of the ferritic phase in steels and for this reason silicon killed steels are somewhat harder and stiffer than aluminum killed steels.

Cobalt:

Cobalt becomes highly radioactive when exposed to the intense radiation of nuclear reactors, and as a result, any stainless steel that is in nuclear service will have a cobalt restriction, usually approximately 0.2% maximum. This problem is emphasized because there is residual cobalt content in the nickel used in producing these steels.

Tantalum:

Chemically similar to niobium and has similar effects. Copper:

Copper is normally present in stainless steels as a residual element. However it is added to a few alloys to produce precipitation-hardening properties.

Vandium:

Increases strength, hardness, wear resistance and resistance to shock impact. It retards grain growth, permitting higher quenching temperatures. It also enhances the red-hardness properties of high-speed metal cutting tools

Tungsten:

Increases strength, wear resistance, hardness and toughness. Tungsten steels have superior hot-working and greater cutting efficiency at elevated temperatures.

11. List the types and their typical application of stainless steel.

In the early nineteen hundreds, metallurgists noticed that chromium had a greater attraction to oxygen than iron did so they added the element chromium to steel. Studies prove that when at least 10% chromium was added, the chrome united with oxygen to form a very tight transparent layer over the steel surface that prevented rusting by precluding further oxidation. This transparent layer is self-healing when damaged by scratches, wear or denting. Stainless steels are materials of enduring beauty. These steels also withstand the corrosive attack of many acids. They possess strength and toughness at both extremes of the temperature scale, yet can be fabricated into intricate shapes for many uses. Because of this outstanding versatility, stainless deserves careful consideration for any product where one or more of the following requirements are involved: Corrosion Resistance Strength at Elevated Temperatures Strength and Ductility at Cryogenic Temperatures Oxidation Resistance at High Temperatures Appearance Abrasion Resistance Let's Go to Class There are more than 250 different stainless steels. These various grades of stainless are divided into five major families or classes. The general classes have been developed to consolidate the chemistries and mechanical properties required to meet specific customer application needs. Martensitic Stainless Steels These steels of the 400 series usually contain a minimum of 11.5% up to 18% chromium and have higher levels of carbon than ferritics. They are capable of being heat treated to a wide range of useful hardness and strength levels, and are used extensively in cutlery, sports knives and multipurpose tools. Ferritic Stainless Steels This group of steels in the 400 series contains 10.5% to 20% chromium for corrosion resistance and resistance to scaling at elevated temperatures. They are nonhardenable by heat treating and are always magnetic. Ferritic stainless is used in applications where resistance to corrosion is important, such as automotive emission control exhaust systems. Austenitic Stainless Steels Austenitic stainless steels are the most specified grades produced because of their excellent formability and corrosion resistance. All 200 and 300 series steels are austenitic and contain 15% to 30% chromium and 2% to 20% nickel for enhanced surface quality, formability and increased corrosion and wear resistance. They are non-magnetic in the annealed condition and depending on the composition, primarily the nickel content, they become slightly magnetic when cold worked. These steels are used for automotive trim, cookware, processing equipment and a variety of industrial applications

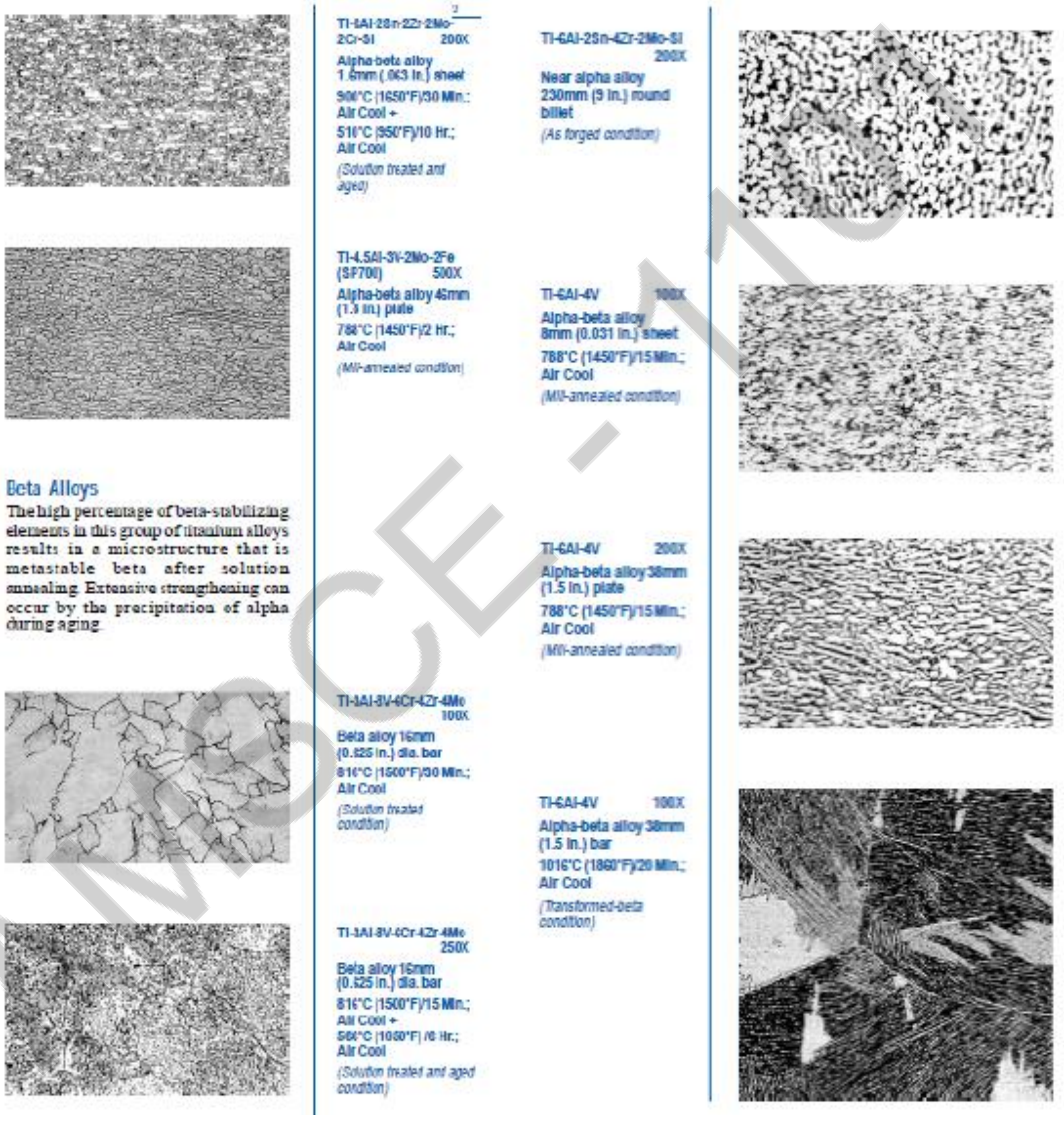
Precipitation-Hardening Stainless Steels There are two general areas of PH grade stainless steels; martensitic and semi-austenitic. The martensitic group includes 17-4 PH® and 15-5 PH® chromiumnickel, with columbium and copper additions. They develop their high strength and hardness through heat treatment, which precipitates the copper. The martensitic PH steels are used in aerospace, chemical and petrochemical, and food processing applications. The semi-austenitic grades are 17-7 PH® and PH 15-7 Mo®. They are austenitic in the annealed state, but martensitic in the hardened condition. 17-7 PH stainless has excellent high strength and fatigue properties, and is used in aerospace components. PH 15-7 Mo stainless is used in applications requiring high strength and hardness, such as retaining rings, springs and aircraft bulkheads. Duplex Stainless Steels These alloys have a mixture of austenite and ferrite in their structure. They exhibit characteristics of both phases with higher strength and ductility. Nitrogen is added to second generation duplex alloys and provides strength and increased weldability. AK Steel’s NITRONIC® 19D has good cyclic oxidation, high strength and excellent stress corrosion resistance, and the 2205 alloy provides very good pitting and uniform corrosion resistance, high strength and high resistance to stress corrosion cracking.

12. What are the types of titanium alloy their compositon properties and application.

Titanium has been recognized as an element (Symbol Ti; atomic number 22; and atomic weight 47.9) for at least 200 years. However, commercial production of titanium did not begin until the 1950’s. At that time, titanium was recognized for its strategic importance as a unique lightweight, high strength alloyed, structurally efficient metal for critical, high-performance aircraft, such as jet engine and airframe components. The worldwide production of this originally exotic, “Space Age” metal and its alloys has since grown to more than 50 million pounds annually. Increased metal sponge and mill product production capacity and efficiency, improved manufacturing technologies, a vastly expanded market base and demand have dramatically lowered the price of titanium products. Today, titanium alloys are common, readily available engineered metals that compete directly with stainless and specialty steels, copper alloys, nickel based alloys and composites. As the ninth most abundant element in the Earth’s Crust and fourth most abundant structural metal, the current worldwide supply of feedstock ore for producing titanium metal is virtually unlimited. Significant unused worldwide sponge, melting and processing capacity for titanium can accommodate continued growth into new, high-volume applications. In addition to its attractive high strength to-density characteristics for aerospace use, titanium’s exceptional corrosion resistance derived from its protective oxide film has motivated extensive application in seawater, marine, brine and aggressive industrial chemical service over the past fifty years. Today, titanium and its alloys are extensively used for aerospace, industrial and consumer applications. In addition to aircraft engines and airframes, titanium is also used in the following applications: missiles; spacecraft; chemical and petrochemical production; hydrocarbon production and processing; power generation; desalination; nuclear waste storage; pollution control; ore leaching and metal recovery; offshore, marine deepsea applications, and Navy ship components; armor plate applications; anodes, automotive components, food and pharmaceutical processing; recreation and sports equipment; medical implants and surgical devices; as well as many other areas. This booklet presents an overview of commercial titanium alloys offered by RMI Titanium Company. The purpose of this publication is to provide fundamental mechanical and physical property data, incentives for their selection, and basic guidelines for successful fabrication and use. Additional technical information can be found in the sources referenced in the back of this booklet. Further information, assistance, analysis and application support for titanium and its alloys, can be readily obtained by contacting RMI Titanium Company headquartered in Niles, Ohio, USA, or any of its facilities and offices worldwide listed in this booklet.

Titanium and its alloys exhibit a unique combination of mechanical and physical properties and corrosion resistance which have made them desirable for critical, demanding aerospace, industrial, chemical and energy industry service. Of the primary attributes of these alloys listed in Table 1, titanium’s elevated strength-todensity represents the traditional primary incentive for selection and design into aerospace engines and airframe structures and components. Its exceptional corrosion/erosion resistance provides the prime motivation for chemical process, marine and industrial use. Figure 1 reveals the superior structural efficiency of high strength titanium alloys compared to structural steels and aluminum alloys, especially as service temperatures increase. Titanium alloys also offer attractive elevated temperature properties for application in hot gas turbine and auto engine components, where more creep resistant alloys can be selected for temperatures as high as 600˚C (1100˚F) [see Figure 2]. The family of titanium alloys offers a wide spectrum of strength and combinations of strength and fracture toughness as shown in Figure 3. This permits optimized alloy selection which can be tailored for a critical component based on whether it is controlled by strength and S-N fatigue, or toughness and crack growth (i.e., critical flaw size) in service. Titanium alloys also exhibit excellent S-N fatigue strength and life in air, which remains relatively unaffected by seawater (Figure 4) and other environments. Most titanium alloys can be processed to provide high fracture toughness with minimal environmental degradation (i.e., good SCC resistance) if required.

RMI titanium mill products, available in both commercially pure and alloy grades, can be grouped into three categories according to the predominant phase or phases in their microstructure … alpha, alpha-beta, and beta. Although each of these three general alloy types requires specific and different mill processing methodologies, each offers a unique suite of properties which may be advantageous for a given application. In pure titanium, the alpha phase … characterized by a hexagonal close packed crystalline structure … is stable from room temperature to approximately 882˚C (1620˚F). The beta phase in pure titanium has a body-centered cubic structure and is stable from approximately 882˚C (1620˚F) to the melting point of about 1688˚C (3040˚F). Effects of Alloying Elements The selective addition of alloying elements to titanium enables a wide range of physical and mechanical properties to be obtained. Basic effects of a number of alloying elements are as follows: 1. Certain alloying additions, notably aluminum and interstitials (O, N,C), tend to stabilize the alpha phase, i.e., raise the temperature at which the alloy will be transformed completely to the beta phase. This temperature is known as the beta transus temperature. 2. Most alloying additions … such as chromium, niobium, copper, iron, manganese, molybdenum, tantalum, vanadium … stabilize the beta phase by lowering the temperature of transformation (from alpha to beta). 3. Some elements … notably tin and zirconium … behave as neutral solutes in titanium and have little effect on the transformation temperature, acting as strengtheners of the alpha phase. Titanium alloy microstructures are characterized by the various alloy additions and processing. A description of the various types of alloys and typical photomicrographs of various mill products manufactured are illustrated. Alpha Alloys The single-phase and near single-phase alpha alloys of titanium exhibit good weldability. The generally high aluminum content of this group of alloys assures excellent strength characteristics and oxidation resistance at elevated temperatures (in the range of 316-593˚C (600 - 1100˚F)). Alpha alloys cannot be heat-treated to develop higher strength since they are singlephase alloys. Alpha-Beta Alloys The addition of controlled amounts of beta-stabilizing alloying elements causes some beta phase to persist below the beta transus temperature, down to room temperature … resulting in a twophase system. Even small amounts of beta stabilizers will stabilize the beta phase at room temperature. A group of alloys designed with high amounts of alpha stabilizers and with a small amount of beta stabilizers are alphabeta alloys, usually called high alpha or near alpha alloys. As larger amounts of beta stabilizers are added, a higher percentage of the beta phase is retained at room temperature. Such two-phase titanium alloys can be significantly strengthened by heat treatment … quenching from a temperature high in the alpha-beta range, followed by an aging cycle at a somewhat lower temperature. The transformation of the beta phase … which would normally occur on slow cooling is suppressed by the quenching. The aging cycle causes the precipitation of fine alpha particles from the metastable beta, imparting a structure that is stronger than the annealed alpha-beta structure. Beta Alloys The high percentage of beta-stabilizing elements in this group of titanium alloys results in a microstructure that is metastable beta after solution annealing. Extensive strengthening can occur by the precipitation of alpha during aging.



Ti-6Al-2Sn-2Zr-2Mo-2Cr-Si 200X
Alpha-beta alloy 1.6mm (.063 in.) sheet
900°C (1650°F)/30 Min.; Air Cool +
510°C (950°F)/10 Hr.; Air Cool
(Solution treated and aged)

Ti-4.5Al-3V-2Mo-2Fe (SP700) 500X
Alpha-beta alloy 45mm (1.3 in.) plate
788°C (1450°F)/2 Hr.; Air Cool
(Mill-annealed condition)

Beta Alloys

The high percentage of beta-stabilizing elements in this group of titanium alloys results in a microstructure that is metastable beta after solution annealing. Extensive strengthening can occur by the precipitation of alpha during aging.

Ti-3Al-8V-6Cr-4Zr-4Mo 100X
Beta alloy 16mm (0.625 in.) dia. bar
816°C (1500°F)/30 Min.; Air Cool
(Solution treated condition)

Ti-3Al-8V-6Cr-4Zr-4Mo 250X
Beta alloy 16mm (0.625 in.) dia. bar
816°C (1500°F)/15 Min.; Air Cool +
566°C (1050°F) /6 Hr.; Air Cool
(Solution treated and aged condition)

Ti-6Al-2Sn-4Zr-2Mo-Si 200X
Near alpha alloy 230mm (9 in.) round billet
(As forged condition)

Ti-6Al-4V 100X
Alpha-beta alloy 8mm (0.031 in.) sheet
788°C (1450°F)/15 Min.; Air Cool
(Mill-annealed condition)

Ti-6Al-4V 200X
Alpha-beta alloy 38mm (1.5 in.) plate
788°C (1450°F)/15 Min.; Air Cool
(Mill-annealed condition)

Ti-6Al-4V 100X
Alpha-beta alloy 38mm (1.5 in.) bar
1016°C (1860°F)/20 Min.; Air Cool
(Transformed-beta condition)

13. Brief on the precipitation hardening and ageing treatment of Al- Cu alloy.

Age hardenabale alloys are one of the most important classes of alloys bothfrom the practical and scientific points of view: from a practical viewpoint,they are important because they show that by a suitable heat treatmentof solutionising and aging, it is possible to improve mechanical properties;from a scientific viewpoint, in age hardenable alloys, the correlation betweenmicrostructure and mechanical properties as well as the methodology of manipulationof the microstructures through appropriate phase transformationis very clearly seen. In Fig. 1 we show the hardness in certain Al-Cu alloys as a function of agingtime at, say, 130˚C. These alloys were initially solution treated in the singlephase α region, quenched to room temperature and then aged at the giventemperature. As is clear from these figures, the hardness increases with timeat least in the initial stages of the aging treatment; however, in all alloys, thehardness starts dropping after some time; this drop in hardness with time isknown as overaging. As shown in Fig. 2, broadly similar behaviour is alsoobserved in Al-Cu alloys aged at 190˚C. However, at this high temeprature,the overaging sets in much earlier; further, the changes in hardness are moremonotonous (with no pleateau regions).

In Fig. 3 and Fig. 4, we show the aging curves; however, this time, we also su-perimpose the different phases that precipitate out of the matrix at these temperatures for the given times on the aging curves. There is a clear correlationbetween the phases that form and the change in hardness; typical increasesin hardness are associated with the formation of GP (Guinier-Preston) zonesand 00 precipitates; in most cases, the formation of 0 leads to a decrease inhardness.

Immediately after quenching to room temperature the only contribution tostrengthening (that is, resistance to the movement of dislocations) comesfrom the solid solution: copper atoms at the aluminium sites which resist themovement of dislocations. However, as the GP zones form, the elastic stressesassociated with the coherent GP zones resists the movement of dislocationscontributing to hardness.As the aging time increases, the coherent 00 phases that form, due to the mist strains that they produce, manage to resist the movement of dislocationsand hence lead to further hardening.Finally the formation of semicoherent 0 can also increase the strength; however, in the case of both 00 and 0 if the particles are coarser or the volumefractions of these phases are smaller (and hence are further apart) it leads to adecrease in hardness since the dislocations can bow between the precipitates and hence move in the matrix contributing the plastic deformation.We also notice that at the higher temperature the peak hardness (the highesthardness that is achieved before overaging) is lower; this is because the lowerdriving force at the higher temperature for the formation of the 00 phaseleads to a coarsely dispersed phase with lower volume fractions.In the following sections, we discuss in detail the thermodynamics and kinetics of precipitation in age-hardenable Al-Cu alloys. In Fig. 5, we show the Al-rich portion of the Al-Cu phase diagram (schematically). From the phase diagram, it is clear that the Al with a few percent copper is cooled from high temperature leads to the formation of amicrostructure in which the phase precipitates out of the supersaturated matrix.

However, if an alloy of composition Al - 4 wt.%Cu is solutionisedat say, 540C, and the resultant phase is rapidly quenched to room temperature, the solid solution is largely retained; if this alloy is kept at roomtemperature (or at any temperature below 180C), a metastable phase knownas Guinier- Preston zones (GP zones) is formed. Similarly, the aging treatment at other temperatures can produce other precipitates such as 00 and 0.The solvus for these metastable phases in shown in Fig. 6. Further, in Fig. 6,we also show the corresponding time-temperature-transformation curves forthese metastable phase as well as the stable phase. In the following sections. we describe the crystallography and interface structure of all these phases aswell as the reasons for their formation.

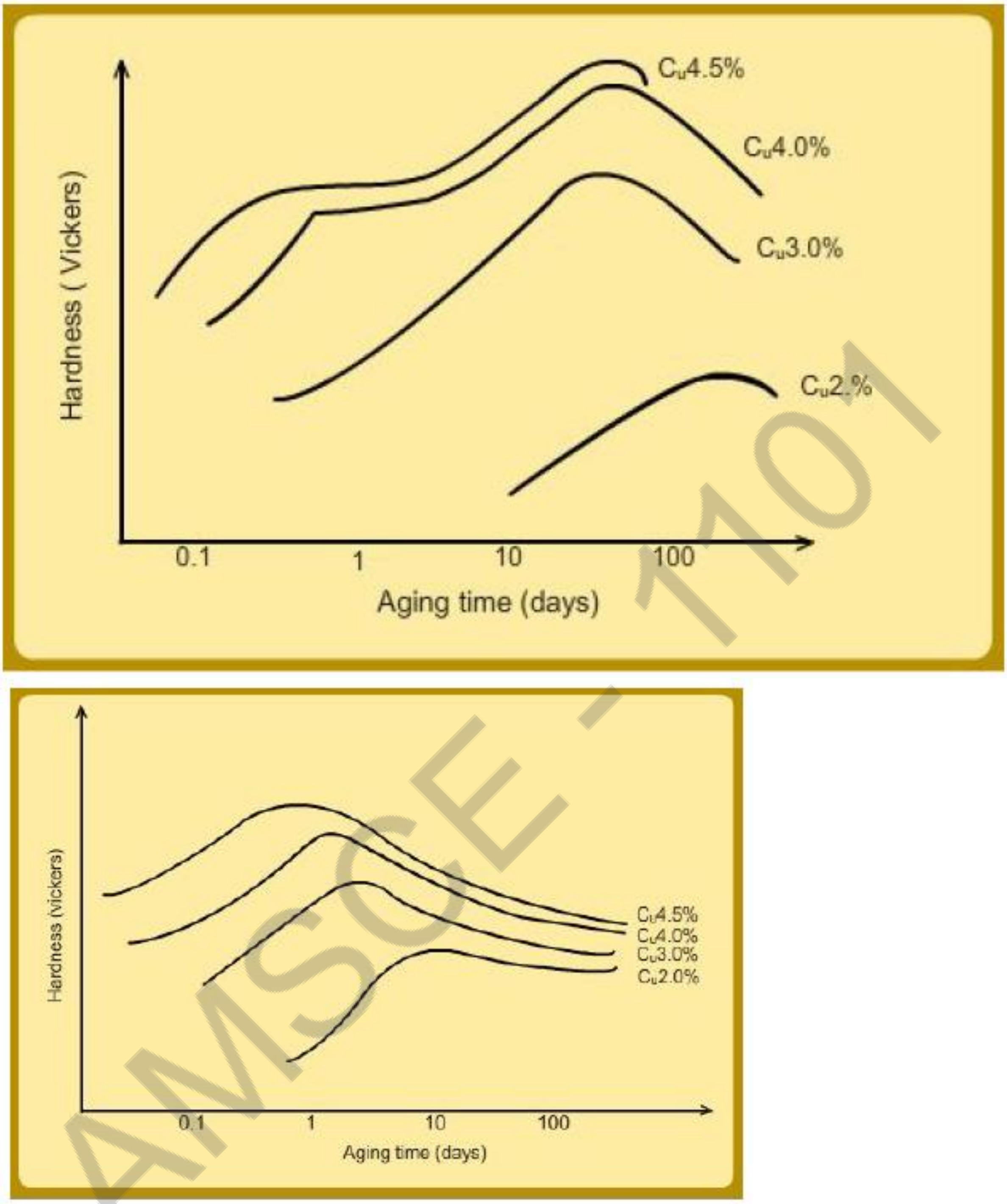


Figure 2: Aging curves at 190° C for Al-Cu system.

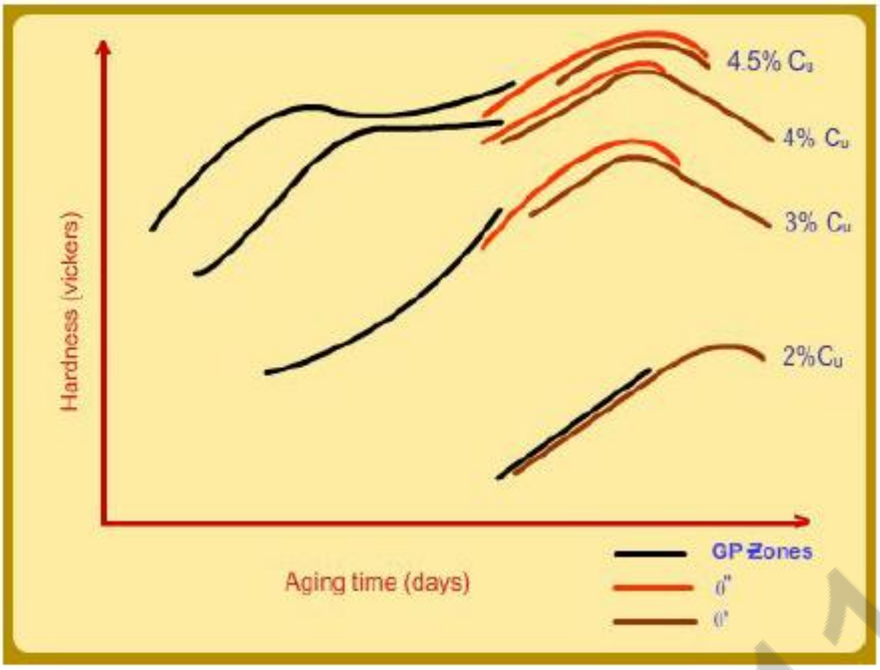


Figure 3: Aging curves with phases: 130°

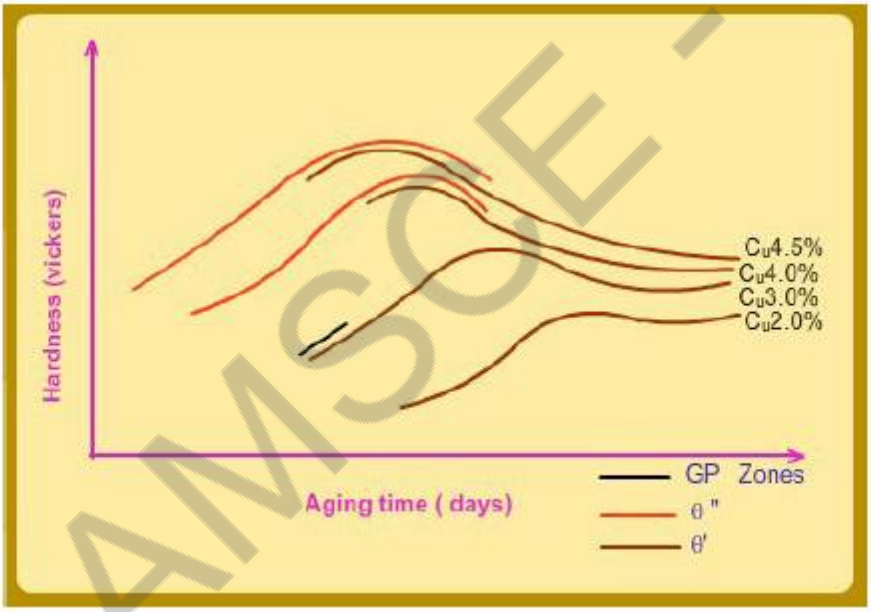


Figure 4: Aging curves with phases: 190°

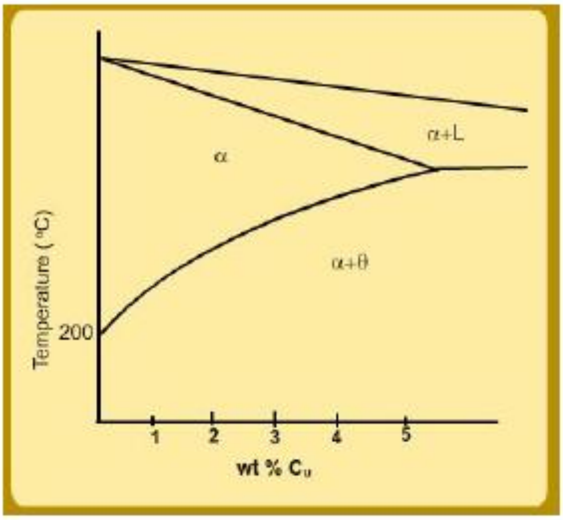


Figure 5: Al-rich portion of Al-Cu phase diagram.

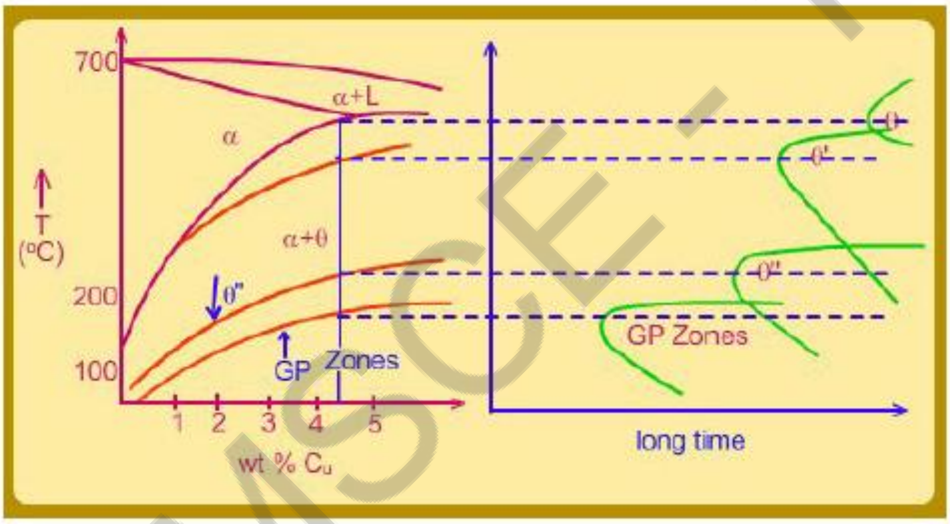


Figure 6: Metastable phases along with their TTT diagrams for Al-rich Al-Cu alloys.

14. With a neat sketch, explain precipitation hardening.

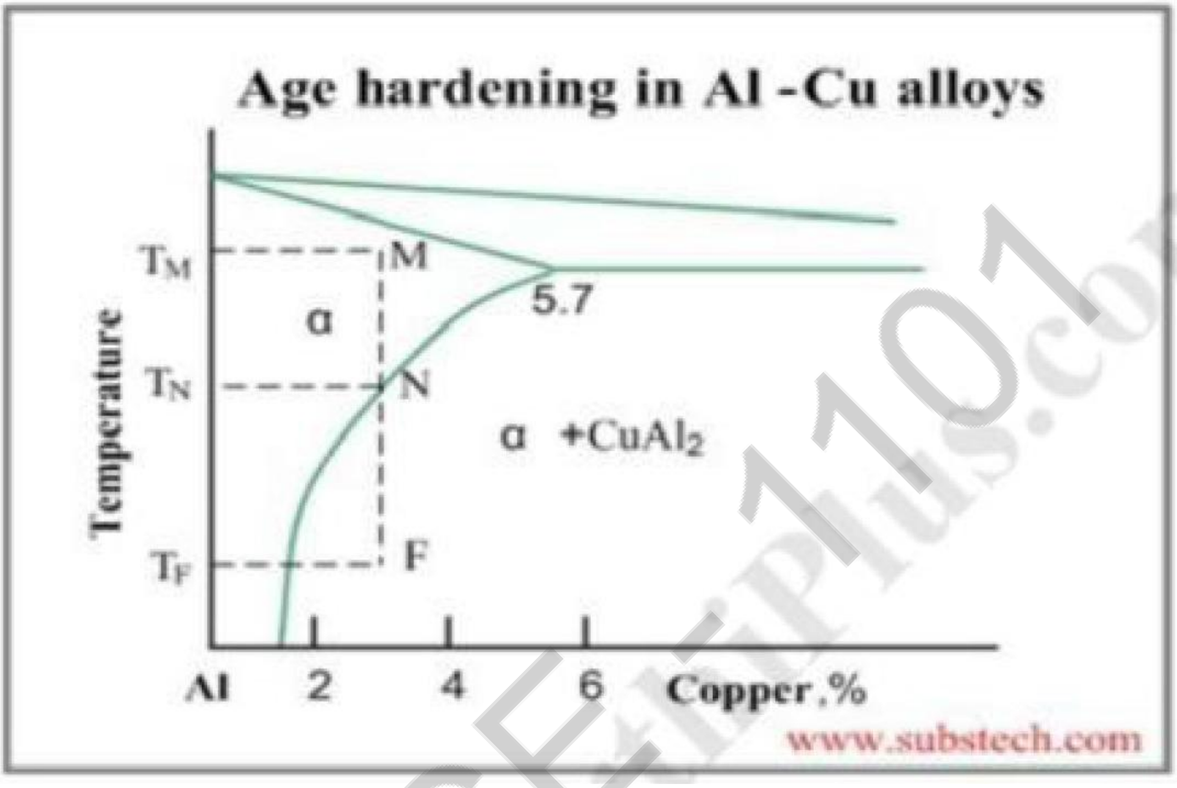
Solid solution hardening- strengthening by dissolving an alloying element.

Atoms of solute element distort the crystal lattice, resisting the dislocations motion. Interstitial elements are more effective in solid solution hardening, than substitution elements.

Dispersion strengthening – strengthening by adding second phase into metal matrix.

The second phase boundaries resist the dislocations motions, increasing the material strength. The strengthening effect may be significant if fine hard particles are added to a soft ductile matrix (composite materials).

Hardening by result of Spinodal decomposition. Spinodal structure is characterized by strains on the coherent boundaries between the Spinodal phases causing hardening of the alloy.



Precipitation hardening (age hardening) – strengthening by precipitation of fine particles of a second phase from a supersaturated solid solution.

The second phase boundaries resist the dislocations motions, increasing the material strength. The age hardening mechanism in Al-Cu alloys may be illustrated by the phase diagram of Al-Cu system. When an alloy Al-3% Cu is heated up to the temperature TM, all CuAl2 particles are dissolved and the alloy exists in form of single phase solid solution (α-phase). This operation is called solution treatment.

Slow cooling of the alloy will cause formation of relatively coarse particles of CuAl2 intermetallic phase, starting from the temperature TN. However if the cooling rate is high (quenching), solid solution will retain even at room temperature TF. Solid solution in this non-equilibrium state is called supersaturated solid solution.

Obtaining of supersaturated solid solution is possible when cooling is considerably faster, than diffusion processes. As the diffusion coefficient is strongly dependent on the temperature, the precipitation of CuAl2 from supersaturated solution is much faster at elevated temperatures (lower than TN). This process is called artificial aging. It takes usually a time from several hours to one aging. Natural aging takes several days or more.

Precipitation from supersaturated solid solution occurred in several steps:

Segregation of Cu atoms into plane clusters. These clusters are called Guinier-Preston1 zones (G-P1 zones).

Diffusion of Cu atoms to the G –P1zones and formation larger clusters, called GP2 zones or θ” phase. This phase is coherent with the matrix.

Formation of ‘θ’ phase which is partially coherent with the matrix. This phase provides maximum hardening.

15. State the composition, properties and uses of bearing alloys.

It is preferred over the term “white metal”, because the latter term may refer to various bearing alloys, lead- or tin-based alloys, or zinc die-casting metal. Babbitt metal is most commonly used as a thin surface layer in a complex, multi-metal structure, but its original use was as a cast-in-placebulk bearing material. Babbitt metal is characterized by its resistance to galling. Babbitt metal is soft and easily damaged, which suggests that it might be unsuitable for a bearing surface. However, its structure is made up of small hard crystals dispersed in a softer metal, which makes it a metal matrix composite. As the bearing wears, the softer metal erodes somewhat, which creates paths for lubricant between the hard high spots that provide the actual bearing surface. When tin is used as the softer metal, friction causes the tin to melt and function as a lubricant, which protects the bearing from wear when other lubricants are absent.

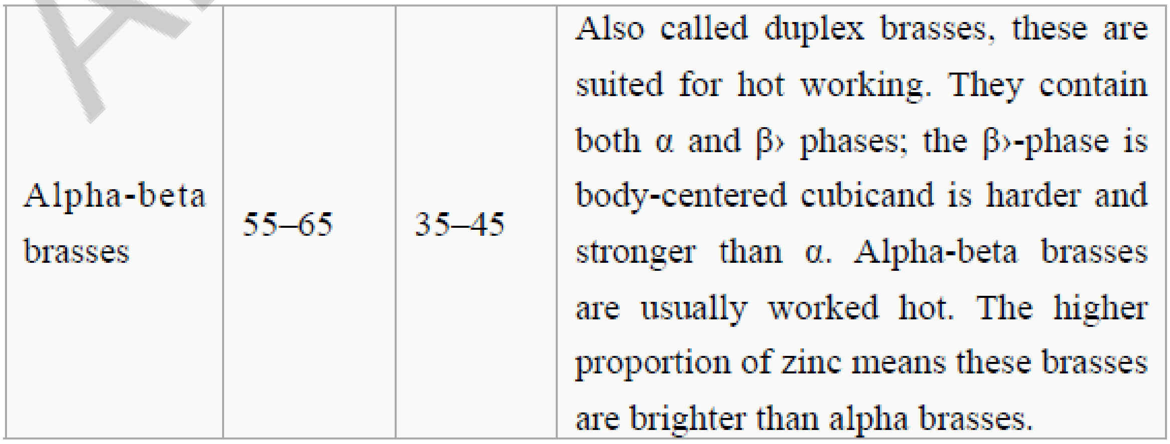
Internal combustion engines use Babbitt metal which is primarily tin-based because it can withstand cyclic loading. Lead-based Babbitt tends to work-harden and develop cracks but it is suitable for constant-turning tools such as saw blades.

16. Write short notes about the following materials in terms of compositon, properties and application.

i) Maraging steel

The common, non-stainless grades contain 17–19 wt.% nickel, 8–12 wt.% cobalt, 3–5 wt.% molybdenum, and 0.2–1.6 wt.% titanium. Addition of chromium produces stainless grades resistant to corrosion. This also indirectly increases hardenability as they require less nickel: high-chromium, high-nickel steels are generally austenitic and unable to transform to martensite when heat treated, while lower-nickel steels can transform to martensite. Alternative variants of Ni-reduced maraging steels are based on alloys of Fe and Mn plus minor additions of Al, Ni, and Ti where compositions between Fe-9wt.% Mn to Fe-15wt.% Mn have been used. The Mn has a similar effect as Ni, i.e. it stabilizes the austenite phase. Hence, depending on their Mn content, Fe-Mn maraging steels can be fully martensitic after quenching them from the high temperature austenite phase or they can contain retained austenite. The latter effect enables the design of maraging-TRIP steels where TRIP stands for Transformation-Induced-Plasticity.

ii) Alpha beta brasses



Alpha-beta brasses	55–65	35–45	Also called duplex brasses, these are suited for hot working. They contain both α and β› phases; the β›-phase is body-centered cubicand is harder and stronger than α. Alpha-beta brasses are usually worked hot. The higher proportion of zinc means these brasses are brighter than alpha brasses.

iii) Austenitic stainless steel

These are alloys containing chromium and nickel, and sometimes molybdenum and nitrogen, structured around the Type 302 composition of iron, 18% chromium, and 8% nickel. 200 Series austenitic stainless steels replace the majority of their nickel content with manganese to reduce cost. Austenitic steels are not hardenable by heat treatment. The most familiar stainless steel is probably SAE 304 stainless steel, also called 18/8 or A2 stainless steel. Type 304 surgical stainless steel is an austenitic steel containing 18-20% chromium and 8-10% nickel.

Alloy 20 (Carpenter 20) is an austenitic stainless steel possessing excellent resistance to hot sulfuric acid and many other aggressive environments which would readily attack type 316 stainless.This alloy exhibits superior resistance to stress-corrosion cracking in boiling 20-40% sulfuric acid. Alloy 20 has excellent mechanical properties and the presence of Niobium in the alloy minimizes the precipitation of carbides during welding.

Austenitic stainless steel can be tested by nondestructive testing using the dye penetrant inspection method but not the magnetic particle inspection method. Eddy-current testingmay also be used. It is the primary stainless steel used in aviation construction. Chemical and steel industry-applicable grades are SAE steel grades 308, 308L, 316, 316L, 316LN (nitrogen bearing), 312, 309L, and 310L. “L” denotes a carbon percentage less than 0.03%, mostly used for corrosion heat resistance and reducing sensitivity to chromium carbide formation. Another grade, 312, is used for dissimilar steel welding, also known as universal alloy steel as unknown composition steels can be welded. For high temperature applications at greater than 600°C, grades 309 and 310 are preferred. Grade 316 is alloyed with molybdenum (~2–3%) for high-temperature strength, pitting and crevice corrosion resistance.

iv) Ferrite stainless steels.

Ferritic steels are high chromium, magnetic stainless steels that have a low carbon content. Known for their good ductility, resistance to corrosion and stress corrosion cracking, ferritic steels are commonly used in automotive applications, kitchenware, and industrial equipment

17. What is cupronickel? Explain its application.

Cupronickel (also known as copper-nickel) is an alloy of copper that contains nickel and strengthening elements, such as iron and manganese. Despite its high copper content, cupronickel is silver in colour.

Due to the specific properties of nickel and copper alloys, they are applied in various domains of industry e.g. mint industry, armaments industry, desalination industry, marine engineering, extensively used in the chemical, petrochemical and electrical industries.[1]

Cupronickel is highly resistant to corrosion in seawater because its electrode potential is adjusted to be neutral with regard to seawater. For this reason, it is used for piping, heat exchangers and condensers in seawater systems, marine hardware, and sometimes for the propellers, crankshafts and hulls of premium tugboats, fishing boats and other working boats.

Another common use of cupronickel is in silver-coloured modern-circulated coins. A typical mix is 75% copper, 25% nickel, and a trace amount of manganese. In the past, true silver coins were debased with cupronickel. Marine engineering

Cupronickel alloys are used for marine applications due to their resistance to seawater corrosion, good fabricability, and their effectiveness in lowering macrofouling levels. Alloys ranging in composition from 90% Cu–10% Ni to 70% Cu–30% Ni are commonly specified in heat exchanger or condenser tubes in a wide variety of marine applications.

Important marine applications for cupronickel include:

Shipbuilding and repair: Cupronickel alloys are used in seawater cooling, bilge and ballast, sanitary, fire fighting, inert gas, hydraulic and pneumatic chiller systems.

Desalination plants: Cupronickel alloys are used in brine heaters, heat rejection and recovery, and in evaporator tubing.

Offshore oil and gas platforms and processing and FPSO vessels: Cupronickel alloys are used in systems and splash zone sheathings.

Power generation: Cupronickel alloys are used in steam turbine condensers, oil coolers, auxiliary cooling systems and high pressure pre-heaters at nuclear and fossil fuel power plants

Seawater system design: Cupronickel alloys are used in tubular heat exchangers and condensers, piping and high pressure systems.

Seawater system components: Cupronickel alloys are used in condenser and heat exchanger tubes, tubesheets, piping, fittings, pumps, and water boxes.

Hulls of boats and ships

Five Swiss francs

The successful use of cupronickel in coinage is due to its corrosion resistance, electrical conductivity, durability, malleability, low allergy risk, ease of stamping (metalworking), antimicrobial properties and recyclability.

In Europe, Switzerland pioneered the nickel *billon* coinage in 1850, with the addition of silver. In 1968, Switzerland adopted the far cheaper 75:25 copper to nickel ratio then being used by the Belgians, the United States, and Germany. From 1947 to 2012, all “silver” coinage in the UK was made from cupronickel, but from 2012 onwards the two smallest cupronickel denominations were replaced with lower-cost nickel-plated steel coins.

In part due to silver hoarding in the Civil War, the United States Mint first used cupronickel for circulating coinage in three-cent pieces starting in 1865, and then for five-cent pieces starting in 1866. Prior to these dates, both denominations had been made only in silver in the United States. Cupronickel is the cladding on either side of United States half-dollars (50¢) since 1971, and all quarters (25¢) and dimes (10¢) made after 1964. Currently, some circulating coins, such as the United States Jefferson nickel (5¢),[13] the Swiss franc, and the South Korean 500 and 100 won are made of solid cupronickel (75/25 ratio).[14]

Other usage

Single-core thermocouple cables use a single conductor pair of thermocouple conductors such as iron-constantan, copper constantan or nickel-chromium/nickel-aluminium. These have the heating element of constantan or nickel-chromium alloy within a sheath of copper, cupronickel or stainless steel.

Cupronickel is used in cryogenic applications. Its combination of good ductility retention and thermal conductivity at very low temperatures is advantageous for low-temperature processing and storage equipment as well as for heat exchangers at cryogenic plants.

Beginning around the turn of the 20th century, bullet jackets were commonly made from this material. It was soon replaced with gilding metal to reduce metal fouling in the bore.

Currently, cupronickel remains the basic material for silver-plated cutlery. It is commonly used for mechanical and electrical equipment, medical equipment, zippers, jewelry items, and as material for strings for string instruments. Fender Musical Instruments used “CuNiFe” magnets in their “Wide Range Humbucker” pickup for various Telecaster and Starcaster guitars during the 1970s.

For high-quality cylinder locks and locking systems, cylinder cores are made from wear-resistant cupronickel.

Properties

Important properties of cupronickel alloys include corrosion resistance, inherent resistance to macrofouling, good tensile strength, excellent ductility when annealed, thermal conductivity and expansion characteristics amenable for heat exchangers and condensers, good thermal conductivity and ductility at cryogenic temperatures and beneficial antimicrobial touch surface properties.

ii) Effect of si on steel discuss

Silicon - Usually only small amounts (0.20%) are present in rolled steel when it is used as a deoxidizer. However, in steel castings, 0.35 to 1.00% is commonly present. Silicon dissolves in iron and tends to strengthen it. Weld metal usually contains approximately 0.50% silicon as a deoxidizer. Some filler metals may contain up to 1% to provide enhanced cleaning and deoxidation for welding on contaminated surfaces. When these filler metals are used for welding on clean surfaces, the resulting weld metal strength will be markedly increased. The resulting decrease in ductility could resent cracking problems.

18. Write short notes on the following.

i) Tool steels

Tool steel refers to a variety of carbon and alloy steels that are particularly well-suited to be made into tools. Their suitability comes from their distinctive hardness, resistance to abrasion and deformation and their ability to hold a cutting edge at elevated temperatures. As a result, tool steels are suited for their use in the shaping of other materials.

With a carbon content between 0.5% and 1.5%, tool steels are manufactured under carefully controlled conditions to produce the required quality. The presence of carbides in their matrix plays the dominant role in the qualities of tool steel. The four major alloying elements in tool steel that form carbides are: tungsten, chromium, vanadium and molybdenum. The rate of dissolution of the different carbides into the austenite form of the iron determines the high temperature performance of steel (slower is better, making for a heat resistant steel). Proper heat treatment of these steels is important for adequate performance.[1] The manganese content is often kept low to minimize the possibility of cracking during water quenching.

There are six groups of tool steels: water-hardened, cold-worked, shock-resistant, high-speed, hot-work, and special purpose. The choice of group to select depends on cost, working temperature, required surface hardness, strength, shock resistance, and toughness requirements.[2] The more severe the service condition (higher temperature, abrasiveness, corrosiveness, loading), the higher the alloy content and consequent amount of carbides required for the tool steel.

Tool steels are used for cutting, pressing, extruding, and coining of metals and other materials. Their use, such as the production of injection molds, is essential, due to their resistance to abrasion, which is an important criterion for a mold that will be used to produce hundreds of thousands of moldings of a product or part.

The AISI-SAE grades of tool steel is the most common scale used to identify various grades of tool steel. Individual alloys within a grade are given a number; for example: A2, O1, etc.

ii) White malleable iron

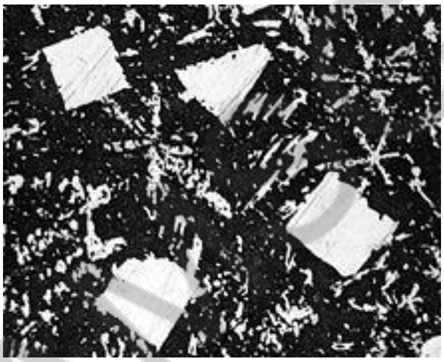
Malleable iron is cast as white iron, the structure being a metastable carbide in a pearlitic matrix. Through an annealing heat treatment, the brittle structure as first cast is transformed into the malleable form. Carbon agglomerates into small roughly spherical aggregates of graphite leaving a matrix of ferrite or pearlite according to the exact heat treatment used. Three basic types of malleable iron are recognized within the casting industry: *blackheart* malleable iron, *whiteheart* malleable iron and *pearlitic* malleable iron.

iii) Bearing alloys

It is preferred over the term “white metal”, because the latter term may refer to various bearing alloys, lead- or tin-based alloys, or zinc die-casting metal. Microstructure of babbitt

Babbitt metal is most commonly used as a thin surface layer in a complex, multi-metal structure, but its original use was as a cast-in-placebulk bearing material. Babbitt metal is characterized by its resistance to galling. Babbitt metal is soft and easily damaged, which suggests that it might be unsuitable for a bearing surface. However, its structure is made up of small hard crystals dispersed in a softer metal, which makes it a metal matrix composite. As the bearing wears, the softer metal erodes somewhat, which creates paths for lubricant between the hard high spots that provide the actual bearing surface. When tin is used as the softer metal, friction causes the tin to melt and function as a lubricant, which protects the bearing from wear when other lubricants are absent.

Internal combustion engines use Babbitt metal which is primarily tin-based because it can withstand cyclic loading. Lead-based Babbitt tends to work-harden and develop cracks but it is suitable for constant-turning tools such as sawblades.



19. Discuss the composition, properties and typical applications of any four copper alloys. (Apr/May 2017)

Brass- Brass is formed out of copper mixed with 45% zinc, a little percentage of lead to provide machinability and tin for strength. Where the zinc component is extra, the strength of the alloy increases. There are mainly three types of copper-zinc alloy- copper zinc alloy, Copper-zinc-tin alloy and copper-zinc-lead alloy.

Typical uses of brass are electrical components, fittings, locks, door handles, architecture etc.

Bronze- Bronzes are one brazing alloy of copper made out of amalgamating tin and one of the phosphorous elements- aluminum, nickel, magnesium etc. It is sued for its properties of corrosion resistance, strength etc and generally used for architecture, manufacturing springs, fittings, connectors, terminals etc.

Nickel silvers- This kind of metal has a very misleading appearance, much like silver which leads to its confusing name. They are a mixture of copper with nickel, zinc and sometimes lead.

They are used to fashion coins, jewelry, name plates, keys etc.

Copper nickel- Copper mixed with nickel forms this variant and is generally what is sued for pipes, boat sheathing etc.

20. Brief on the influence of alloying elements in steel under classification of alpha and gamma stabilizers: (Nov/Dec 2017)

Carbon: Carbon is alloyed with base metal Iron to make steel which affects the hardness and strength of material. Thus the addition of carbon enables a wide range of hardness and strength.

Manganese:Manganese is added to improve hot working properties and increase strength, toughness and hardenability. Manganese, like nickel, is an austenite forming element and can been used as a substitute for nickel.

Chromium: Chromium is added to the steel to increase corrosion resistance. The resistance increases as more chromium is added. ‘Stainless Steel’ has approximately 11% chromium and a very marked degree of general corrosion resistance when compared with steels with a lower percentage of chromium. When added to low alloy steels, chromium can increase the response to heat treatment, thus improving hardenability and strength.

Nickel: Nickel is added in large amounts, over about 8%, to high chromium stainless steel to form the most important class of corrosion and heat resistant steels. These are the austenitic stainless steels, where the tendency of nickel to form austenite is responsible for a great toughness and high strength at both high and low temperatures. Nickel also improves resistance to oxidation and corrosion. It increases toughness at low temperatures when added in smaller amounts to alloy steels.

Molybdenum: Molybdenum, when added to chromium-nickel steels, improves resistance to pitting corrosion especially by chlorides and sulphur chemicals. When added to low alloy steels, molybdenum improves high temperature strengths and hardness. When added to chromium steels it greatly diminishes the tendency of steels to decay in service or in heat treatment.

Titanium: Used as stabilizing elements in stainless steels. Each has a high affinity for carbon and forms carbides, which are uniformly dispersed throughout the steel. Thus, localized precipitation of carbides at grain boundaries is prevented. Compared to chromium, carbon has higher affinity to titanium to form inter-granular carbides and hence accompanying loss of corrosion resistance at the grain boundaries.

Phosphorus: Phosphorus is usually added with sulphur to improve machinability in low alloy steels, phosphorus, in small amounts, increases strength and corrosion resistance. Experimental work shows that phosphorus present in steel increases strength. Phosphorus additions are known to increase the tendency to cracking during welding.

Sulphur: When added in small amounts sulphur improves machinability but does not cause hot shortness. Hot shortness is reduced by the addition of manganese, which combines with the sulphur to form manganese sulphide. As manganese sulphide has a higher melting point than iron sulphide, which would form if manganese were not present, the weak spots at the grain boundaries are greatly reduced during hot working.

Selenium: Selenium is added to improve machinability.

Niobium (Columbium): Niobium is added to steel in order to stabilise carbon, and as such performs in the same way as described for titanium. Niobium also has the effect of strengthening steels and alloys for high temperature service.

Nitrogen: Nitrogen has the effect of increasing the austenitic stability of stainless steels and is, as in the case of nickel, an austenite forming element. Yield strength is greatly improved when nitrogen is added to austenitic stainless steels.

Silicon: Silicon is used as a deoxidizing (killing) agent in the melting of steel, as a result, most steels contain a small percentage of silicon. Silicon contributes to hardening of the ferritic phase in steels and for this reason silicon killed steels are somewhat harder and stiffer than aluminum killed steels.

Cobalt: Cobalt becomes highly radioactive when exposed to the intense radiation of nuclear reactors, and as a result, any stainless steel that is in nuclear service will have a cobalt restriction, usually approximately 0.2% maximum. This problem is emphasized because there is residual cobalt content in the nickel used in producing these steels.

Tantalum: Chemically similar to niobium and has similar effects.

Copper: Copper is normally present in stainless steels as a residual element. However it is added to a few alloys to produce precipitation-hardening properties.

Vandium: Increases strength, hardness, wear resistance and resistance to shock impact. It retards grain growth, permitting higher quenching temperatures. It also enhances the red-hardness properties of high-speed metal cutting tools
Tungsten: Increases strength, wear resistance, hardness and toughness. Tungsten steels have superior hot-working and greater cutting efficiency at elevated temperatures.

21. What are the classification of aluminium alloys and state the applications of any THREE alloy.

Aluminium alloys can be classified into the following types

(i) Aluminium -Copper alloy

(ii) Aluminium - Silicon alloy

(iii) Aluminium - Magnesium alloy

(iv) Aluminium - Manganese alloy

(v) Aluminium- Magnesium- Silicon alloy

(i) Aluminium- Copper alloy:
Copper has been the most common alloying element almost since the beginning of the aluminum industry, and a variety of alloys in which copper is the major addition were developed. In the cast alloys the basic structure consists of cored dendrites of aluminum solid solution, with a variety of constituents at the grain boundaries or interdendritic spaces, forming a brittle, more or less continuous network of eutectics. Wrought products consist of a matrix of aluminum solid solution with the other soluble and insoluble constituents dispersed within it. Copper has been the most common alloying element almost since the beginning of the aluminum industry, and a variety of alloys in which copper is the major addition were developed. Most of these alloys fall within one of the following groups:

a. Cast alloys with 5% Cu, often with small amounts of silicon and magnesium.

b. Cast alloys with 7-8% Cu, which often contain large amounts of iron and silicon and appreciable amounts of manganese, chromium, zinc, tin, etc.

c. Cast alloys with 10-14% Cu. These alloys may contain small amounts of magnesium (0.10-0.30% Mg), iron up to 1.5%, up to 5% Si and smaller amounts of nickel, manganese, chromium.

d. Wrought alloys with 5-6% Cu and often small amounts of manganese, silicon, cadmium, bismuth, tin, lithium, vanadium

and zirconium. Alloys of this type containing lead, bismuth, and cadmium have superior machinability.

e. Durals, whose basic composition is 4-4.5% Cu, 0.5-1.5% Mg, 0.5- 1.0% Mn, sometimes with silicon additions.

f. Copper alloys containing nickel, which can be subdivided in two groups: the Y alloy type, whose basic composition is 4% Cu, 2% Ni, 1.5% Mg; and the Hyduminiums, which usually have lower copper contents and in which iron replaces 30me of the nickel.

(ii) Aluminium- Silicon alloy

Castings are the main use of aluminum-silicon alloys, although some sheet or wire is made for welding and brazing, and some of the piston alloys are extruded for forging stock. Often the brazing sheet has only a cladding of aluminum-silicon alloy and the core consists of some other high melting alloy. The copper-free alloys are used for low- to medium-strength castings with good corrosion resistance; the copper-bearing for medium- to high-strength castings, where corrosion resistance is not critical. Because of their excellent castability, it is possible to produce reliable castings, even in complex shapes, in which the minimum mechanical properties obtained in poorly fed sections are higher than in castings made from higher-strength but lower-castability alloys.

Silicon is the main alloying element; it imparts high fluidity and low shrinkage, which result in good castability and weldability. The low thermal expansion coefficient is exploited for pistons, the high hardness of the silicon particles for wear resistance. The maximum amount of silicon in cast alloys is of the order of 22-24% Si, but alloys made by powder metallurgy may go as high as 40-50% Si.

(iii) Aluminium-Magnesium alloy

The magnesium in the commercial alloys ranges all the way from 0.5 to 12- 13% Mg, the low-magnesium alloys having the best formability, the high-magnesium reasonably good castability and high strength. It is normal practice to prepare these alloys from the higher grades of aluminum (99.7 or better) to obtain maximum corrosion resistance and reflectivity; thus the iron and silicon contents are usually lower than in other aluminum alloys. Iron and zirconium are sometimes added to increase the recrystallisation temperature; silicon to improve the fluidity; manganese or chromium to correct for the corroding effect of iron. Copper is added to reduce pitting corrosion by enhancing general corrosion; zinc has little or no effect on corrosion but enhances castability and strength.

In the early days antimony was added, and to its oxide was attributed the corrosion resistance to seawater but later experiments disproved antimony`s effectiveness. Titanium and titanium plus boron are often added as grain refiners; beryllium and sometimes lithium to reduce oxidation of magnesium at high temperature, and especially in the molten state. Lead has been added to improve machinability, supposedly without loss of strength or corrosion resistance.

In the aluminum-magnesium commercial alloys solidification starts with the aluminum as primary crystals and usually growing as dendrites, with the other constituents segregating at the grain boundaries or between the dendrite arms. In alloys with more than 10% Mg and more than 0.5% Si, Mg2Si crystals may be primary, in the form of cubes or hexagons. If iron, iron plus manganese or iron plus chromium is above 1-2% (depending on magnesium content), primary crystals of FeAl3, (FeMn)Al6, (FeMn)3Si2Al15, (FeCr)Al7, or (FeCr)4Si4Al13 may form. These primary crystals do not have a substantial effect on strength but affect appreciably the formability, fatigue resistance and surface finish. The claim that magnesium additions reduce the size of FeAl3, and Co2Al9 primary crystals is doubtful.

The solid solubility of magnesium in commercial alloys ranges from 2% Mg at room temperature up to 14-15% at 720K. Therefore most magnesium is in solution and only non equilibrium conditions or annealing produces Mg5Al8 as divorced eutectic at the boundaries in cast alloys, as globules in annealed or age hardened material.

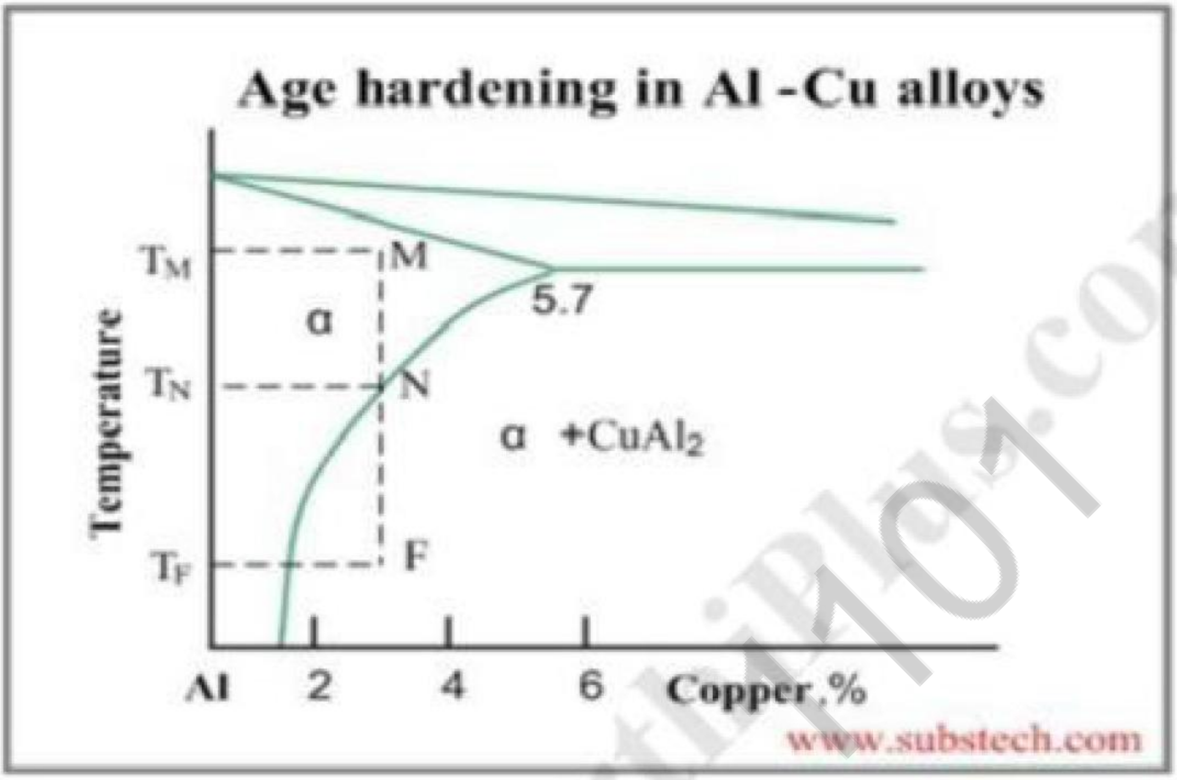
Silicon usually forms Mg2Si, mostly insoluble, especially in the alloys with more than 3-4% magnesium. Iron may form Fe2SiAl8 in low-magnesium, high-silicon alloys; FeAl3 in the absence of chromium or manganese; (FeMn)Al6 or (FeMn)3Si2Al15 when manganese is present; (FeCr)Al7 or (FeCr)4Si4Al13 when chromium is present. Copper has been detected as CuMgAl2 and Cu2FeAl7. Zinc is seldom out of solution and then forms Mg3Zn3Al2; titanium, boron and beryllium are mostly in solution.

In most of the commercial alloys other elements are present only in small amounts, and their effect on physical properties is submerged by that of magnesium, so that the properties of the commercial alloys are within error of testing of those of the binary alloys.Magnesium is the main factor that controls mechanical properties, but all other alloying elements contribute to it.

22. Brief on the mechanism of ageing treatment of Al-Cu alloy.

Age hardenabale alloys are one of the most important classes of alloys both from the practical and scientific points of view: from a practical view point, they are important because they show that by a suitable heat treatment of solutionizing and aging, it is possible to improve mechanical properties; from a scientific viewpoint, in age hardenable alloys, the correlation between micrsotructure and mechanical properties as well as the methodology of manipulation of the microstructures through appropriate phase transformation is very clearly seen.

In Figure we show the Al-rich portion of the Al-Cu phase diagram (schematically). From the phase diagram, it is clear that the Al with a few percent copper is cooled from high temperature leads to the formation of a microstructure in which the phase precipitates out of the supersaturated matrix. However, if an alloy of composition Al - 4 wt.% Cu is solutionized at say, 540oC, and the resultant phase is rapidly quenched to room temperature, the solid solution is largely retained; if this alloy is kept at room temperature (or at any temperature below 180oC), a meta stable phase known as Guinier-Preston zones (GP zones) is formed.


Age hardening in Al -Cu alloys
Temperature
T_M
T_N
T_F
M
N
F
5.7
α
α +CuAl$_2$
Al
2
4
6
Copper,%
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