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Exploring the Applications and Advancements of Copper and Copper Alloys in Modern Manufacturing Processes

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Abstract

For industrial uses, copper represents one of the greatest technical materials offered. This review paper discusses on the history of copper and copper alloys, salient features of wrought and cast copper alloys, physical and chemical characteristics of copper alloys, classification of copper alloys, design for manufacturing of copper alloys, mechanical properties of cast copper alloys, role of lead in copper alloys and applications of copper alloys in various engineering industries. Copper continues to be an important factor in the development of technology, with applications ranging from its conventional use in electrical wiring and plumbing to its more recent use in additive manufacturing and nanotechnology. The article focuses on the latest findings and advancements in copper-based materials research, including alloy creation, processing methods, and their effects on improving manufacturing efficiency, sustainability, and performance. It also looks at how recycling and environmental effects are related to copper materials, highlighting how crucial sustainable practices are to the manufacturing sector. This article lays the groundwork for future developments and applications by offering insightful information about how copper and its alloys are changing in the context of contemporary manufacturing through a thorough analysis of the literature and case studies.

Keywords: Copper, copper alloys, classification, copper development association, manufacturing

INTRODUCTION

Copper is the backbone of the electrical industry. It is also the major metal in a high number of highly important engineering alloys, namely the brasses and bronzes. When annealed, pure copper reveals an elongation of over 60% and a tensile strength of almost 200 MPa. The copper alloys are also well-suited to all types of methods of manufacturing, such as welding, machining, and casting. Sadly, copper weighs more than iron. The strength/weight ratio for copper alloys is often greater than that of the weaker magnesium and aluminum alloys, given the fact that strengths can be high [1, 2].

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Copper comes from two principal sources. They are ores and copper scrap [3, 4]. Most copper is derived from copper sulfide ore deposits from which the copper sulfide is concentrated by various ore-dressing procedures to yield a product that can be smelted at a profit.

Bus conductors, waveguides, vacuum seals, microwave components, coaxial cables and tubes than others, klystrons, microwave tubes, rectifiers, radio parts, printing rolls, rivets, and auto parts are all made of wrought copper compounds., bus bars, radiator cores and tanks, lamp fixtures, fasteners, locks, hinges, ammunition components, pins, brazing rod, condenser plates, heat exchanger tubing, hot forgings, bellows, diaphragms, fuse clips, springs, welding equipment, nuts, bolts, stringers and threaded members, machine parts, marine protective sheathing and fastening, communication relays, ferrules, and resistors [5-7].

Cast copper alloys are processed to manufacture electrical and thermal conductors, safety tools, molds for plastic parts, cams, bushings, bearings, valves, gears, flanges, pipe fittings, pump castings, plumbing goods, water pump impellers and housings, ornamental fixtures, belts, corrosion-resistant castings, marine fittings, piston rings, seal rings, steam fittings, worms, bushings, valve seats and guides, pickling hooks, and elbows used for sea water corrosion resistance. Copper is an ancient metal and famous for its distinctive reddish brown color. The Copper Development Association (CDA) has a designation system that is used for categorization of copper and its alloys. In this system, numbers from C100 through C799 designate wrought alloys and numbers from C800 to C999 Cast alloys [2]. In addition to becoming widely used in experimental plasma confinement devices, pure copper and a few specific diluted alloys have also been suggested for several types of uses in fusion power reactors where a high level of thermal or electrical conductivity is demanded [12].

COPPER AND COPPER ALLOYS HISTORY

For more than a century, the history of metals and metallurgical engineering—also known as "Archaeometallurgy"—has been something of intense interest. It bases itself in the history of civilizations. In the late 19th and early 20th centuries, metal artifact typologies were commonly employed for ancient sequences as a result of the good preservation of metal items and the contemporary values associated with those metals [11]. Castings composed of copper alloy were historically some of the first metallic items that humans manufactured from molten metal. Copper has been used in artifacts from ancient times as it is a naturally occurring metal. As early as 3000 B.C., artists are known to have melted and cast copper. However, metallurgical discoveries over the last several centuries have made copper more available and endowed with a wider range of useful attributes, which have allowed copper alloys to realize their full potential as casting materials. It is noteworthy that a higher proportion of castings formed in these alloys are the result of sand casting methods. Using copper alloys for castings has multiple built-in technical benefits. Some of these include: electrical and thermal conductivity, corrosion resistance, appearance, nontoxicity, and bearing qualities [5, 11].

UNALLOYED COPPER

Unalloyed copper is a metal with high electrical conductivity, hence used to a larger extent in the electrical industry. Electrolytic tough pitch (ETP) copper serves to produce wire, rod, plate, and strip. It is the simplest priced industrial copper. The nominal oxygen percentage of ETP copper is 0.04%. High conductivity and oxygen-free: OFHC copper is made by casting ETP copper in a monitored reducing environment, where removes hydrogen and oxygen fracture. [2, 6]. Copper may be alloyed with many elements, singly and in combinations, with beneficial effects on the properties of the alloy. Therefore, it is not surprise that there are many different kinds of alloys that can be made use of for casting. The variety of alloying possibilities is so numerous that their classification necessititates separation of the metals into major groups differing broadly from each other in composition. Copper Development Association System: CDAS has classified copper alloys into two groups: Wrought alloys and Cast alloys. Copper base alloys have a low enough freezing range so that they may be cast in permanent molds or dies under pressure. These alloys have been found favorable in view of the requirement of resistance to tearing, pressure tightness, and good mechanical properties. Rapid cooling of copper alloys in metal molds favors better properties than slow cooling in sand molds [2, 5, 8].

SALIENT FEATURES OF ALLOYED COPPER

Copper is widely used in its unalloyed condition as well as in alloys with other metals. In the unalloyed form, it has an extraordinary combination of properties which make it the basic material in the electrical industry, some of those properties being its high electrical conductivity and corrosion resistance, ease of fabrication, reasonable tensile strength, controllable annealing properties, and general soldering and joining characteristics [3, 9]. The wide variety of brasses and bronzes it forms with other metals, however, also have associated useful properties that make alloyed copper indispensable for many additional engineering applications. Copper comes from two principal sources: ores and copper scrap [4, 5]. Most copper is derived from copper sulfide ore deposits from which the copper sulfide is concentrated by various ore-dressing procedures to yield a product that can be smelted at a profit.

PHYSICAL CHARACTERISTICS OF COPPER AND COPPER ALLOYS

Ornaments and coins were fashioned from it throughout the history of mankind. Copper still has a lot of cosmetic applications, even though almost majority of it is used for drainage and electrical uses. No other metal has the same hue as copper [10]. Copper alloys such as bronze and bronze are not as vivid orange as copper. Since copper bends easily it is typically alloyed with other metals to make it a bit stronger. Normally, it is alloyed with tin and/or zinc, but it may also be mixed with silver and nickel. When mixed with considerable amounts of tin, the alloy is known as bronze, and when mixed with considerable amounts of zinc the alloy is known as brass [2]. Copper may also be alloyed with both tin and zinc. However, no demarcation is drawn between brass and bronze. Other names given to alloyed copper are Monel Metal which is an alloy of copper and nickel, German silver: an alloy of copper and silver. Half breed is a copper and silver alloy. A natural mixing of copper and silver is known to as halfbreed. Copper is ductile and malleable and a very good conductor of electricity, second after Silver. Additionally, copper is employed in pigments, fungicides, and insecticides that but synthetic compounds have mostly superseded it recently [5, 6].

One contemporary metal is copper. Plenty of options exist for copper and copper alloys to suit the demands in modern living. They are typically invisible supplying vital services within equipment in homes, offices, commercial buildings, and workplaces. They are frequently observed in plumbing systems and high-quality roofs. They are among the most essential components for furnishing the means of maintaining a house, a business, and an industry. Among common metals, copper is certainly the most able to change. The surface luster and warm color of copper and copper alloys makes them beautiful to look at and this means they find widespread use in architecture. The unique combination of properties offered by copper and its alloys results in benefits when they are used in many industries. In many instances, only a copper base material can meet the ideal property combination required. There may be no better alternative material choice – other material types such as iron base alloys, nickel base alloys, aluminium alloys and alloys based upon titanium do not, in very many cases, combine all the required properties or their cost may be too high [7].

CLASSIFICATION OF COPPER AND COPPER ALLOYS

Copper is an ancient metal and has distinctive reddish brown color. The Copper Development Association (CDA) provides a set of designations for copper and its alloys. In this system, numbers from C100 through C799 designate wrought alloys and numbers from C800 to C999 Cast alloys. The common wrought copper alloys are listed below in Table 1. Commonly Cast Copper alloys are listed below in Table 2. A minimum of 99.3% or more copper is contained in coppers. Low copper alloys have a content of less than 99.3% copper but over 96% copper and are not included into any of the other alloys made from copper categories. Wrought coppers are referred to based on the amount of impurity and oxygen they contain. They are Electrolytic Tough-Pitch, Oxygen-Free, and Phosphorus Deoxidized Wrought Coppers [2].

WROUGHT COPPER ALLOYS

Wrought copper alloys are used to produce bus conductors, waveguides, vacuum seals, transistor components, coaxial cables and tubes, klystrons, microwave tubes, rectifiers, radio parts, printing rolls, rivets, auto parts, bus bars, radiator cores and tanks, lamp fixtures, fasteners, locks, hinges, ammunition components. Besides, they are used to produce pins, brazing rod, condenser plates, heat exchanger tubing, hot forgings, bellows, diaphragms, fuse clips, springs, welding equipment, nuts, bolts, stringers and threaded members, machine parts, marine protective sheathing and fastening, communication relays, ferrules, and resistors. The common wrought copper alloys are listed below in Table 1 [2].

CAST COPPER ALLOYS

Cast copper alloys are processed to manufacture electrical and thermal conductors, safety tools, molds for plastic parts, cams, bushings, bearings, valves, gears, flanges, pipe fittings, pump castings, plumbing goods, water pump impellers and housings, ornamental fixtures, belts, corrosion-resistant castings, marine fittings, piston rings, seal rings, steam fittings, worms, bushings, valve seats and guides, pickling hooks, and elbows used for sea water corrosion resistance. Commonly Cast Copper alloys are listed below in Table 2 [2].

PHYSICAL AND MECHANICAL PROPERTIES OF CAST COPPER ALLOYS

The physical and mechanical qualities of cast copper alloys are listed below. While not all properties apply to all alloys, none of the alloy groups have this range, which occurs in uncommon combinations. Strong resistance to corrosion, which enhances its long-term cost-effectiveness and durability. favorable mechanical qualities that range from the soft and ductile qualities of natural copper to the mechanical attributes of manganese bronze, which is comparable to those of tempered and quenched steel. Furthermore, practically all copper alloys can maintain their mechanical qualities at low temperatures, such as impact toughness [4, 5]. superior electrical and thermal conductivity comparison to all other metals, with one notable exception of silver. Copper alloys with poor conductivity nonetheless transfer heat and electricity quicker than other corrosion-resistant materials, but copper's conductivity decreasing with alloying [6]. resistance to biofouling, as copper slows the development of marine creatures.

Table 1. Wrought copper alloys [2].

Serial Number	Wrought Copper Alloy Type	Commercial Name
1	Copper-Zinc	Brasses
2	Copper-Zinc-Lead	Leaded Brasses
3	Copper-Zinc-Tin	Tin Brasses
4	Copper-Tin	Phosphor Bronzes
5	Copper-Aluminium	Aluminium Bronzes
6	Copper-Silicon	Silicon Bronzes
7	Copper-Nickel	Nickel Brasses
8	Copper-Nickel-Zinc	Nickel Silver

Table 2. Cast copper alloys [2].

Serial Number	Cast Copper Alloy Type
1	Cast Coppers
2	Cast High-Copper Alloys
3	Cast Brasses
4	Cast-Manganese-Bronze Alloys
5	Cast Copper-Zinc-Silicon Alloys
6	Cast Copper-Tin Alloys
7	Cast Copper-Tin-Lead Alloys
8	Cast Copper-Tin-Nickel Alloys
9	Cast Copper-Aluminium-Iron Alloys
10	Cast Copper-Nickel-Iron Alloys
11	Cast Copper-Nickel-Zinc Alloys

This feature is exclusive to copper alloys and diminishes with alloying; yet, it continues to be useful in many alloys, including copper-nickel alloys. little wear and friction, such in the case of the high leaded tin bronzes that are poured into sleeve bearings and show less wear than steel. Good castability, as nearly all copper alloys can be permanently moulded and die cast using a centrifugal force, and all of them can be sand cast [7]. Many unleaded alloys, such as nickel-aluminum bronze alloys, are easily machinable at suggested feeds and speeds with the right apparatus. Leaded copper alloys are free cutting alloys at high processing speeds. Post-casting processing ease, since high tolerance control and a smooth surface may be easily attained. Further, a lot of cast copper alloys are highly polished, and brazing, welding, plating, and soldering are all done often. wide selection of alloys, since distinct alloys may be good fits for a particular application based on environmental corrosivity and design stresses. comparable prices to other metals because of their high yield, cheap cost of machining, and less demand for paint or other surface interventions [8].

DESIGN FOR MANUFACTURING CAST COPPER ALLOYS

The design and casting of copper alloys is effective when communication exists between the design engineer and foundry. The mechanical and physical properties of section size, wall thickness, and surface polish that could possibly be attained depend on the alloy selection and casting technique. Each alloy and casting process combination results in a different set of properties. All alternatives will be taken into view early in the design phase, leading to a design and component that take use of the ability to adapt that copper alloys provide, granted that foundry and engineering professionals can collaborate on the raw or perfect product [2, 8].

ROLE OF LEAD IN CAST COPPER ALLOYS

Many cast copper alloys are frequently enhanced with lead. Since lead is not soluble in copper, there will be no noticeable degree of genuine alloying. Some components of an alloy crystallize at a greater temperature than others during the solidification of debris, creating dendrites, which are tree-like patterns [1, 8]. Micropores can occur because the tiny gaps between the dendrites contact with one another. The solidification process is what led to the development of this micro porosity. Lead's function is to close these intradendritic pores. This gives a casting that is pressure-tight, which is crucial for applications demanding fluid handling. Additionally, because it lubricates cutting tool edges and encourages the creation of small, easily removed discontinuous chips, it allow the machining of castings at faster rates without the need for cooling solutions. As a result, the machined surface finish is better. Lead is also essential for maintaining lubrication in items like cast copper bushings and bearings. It decreases ductility but does not negatively impact strength unless larger quantities are present. Copper alloys with lead can be brazed and soldered, but not forged [7].

APPLICATIONS OF COPPER AND COPPER ALLOYS

Electrolytic Tough-Pitch Copper.[2]

Electrolytic Tough-Pitch Copper: It is of Type ETP, CDA 110 has a minimum of 99.9% copper and nominal 0.04% oxygen content. The normal limits of oxygen in ETP copper are between 0.02 and 0.05%. Among the industrial coppers, it is less costly and commonly used in the manufacturing of wire, rod, aside plate, and strip.

The oxygen converts some impurity elements to their oxides; on casting the oxygen forms an even dispersion of blowholes, that prevents pipe cavities from forming. Upon hot working, these small blowholes are welded together [2, 6].

Oxygen Free Copper

Oxygen free copper can be produced from electro refined cathode copper by melting and casting under a reducing atmosphere of carbon monoxide and nitrogen so that oxygen is prevented from entering the copper. The electrical conductivity of Oxygen free, 99.95% copper is about the same as ETP copper. If selected cathodes of high purity copper are remelted, 99.99% oxygen free copper can be produced, and is preferred for many electronics applications. Due to the special processing of the oxygen free coppers, they are more expensive than the ETP coppers [2, 8].

Deoxidized Copper

With the addition of sufficient phosphorus, all the available oxygen in the copper will be converted to Phosphorus Pentoxide. Since phosphorized high conductivity coppers contain very little retained phosphorus normally less than 0.009%, the high conductivity of copper is maintained. Higher levels of phosphorus are used in the deoxidized high phosphorus copper; CDA 122, so that these alloys may contain as high as 0.040 residual phosphorus, resulting in a lower electrical conductivity of about 85% IACS. The excess phosphorus in the copper prevents the adsorption of oxygen during hot working and annealing and allows this material to be welded [2].

Copper- Zinc Alloys

Copper-Zinc alloys are categorized as brasses. The copper-zinc brasses consist of a series of alloys of copper with up to about 40% zinc. It also contains elements such as silicon, aluminum, and tin; manganese, among nickel, and results are called alloy brass. Brasses are also able to be nickel and chromium plated and has sufficient thermal conductivity to be used for heat transfer media. The best combination of ductility and strength occurs at 70% copper and 30% zinc, and hence this alloy can be used for its excellent deep drawing ability. The 70% copper and 30% zinc alloy is descriptively called as Cartridge Brass and used for other applications such as radiator cores and tanks, and lamp fixtures. Copper-60% and Zinc-40% is otherwise called as Muntz metal. Numerous kinds of brasses are given slight amounts of lead, ranging from 0.50 to 3%, which improves their machinability; these brasses are thus referred to as leaded brass. The addition of 1% tin to cartridge brass: 70% Copper and 30% Zinc, improves its corrosion resistance in sea water. Since the British Admiralty adopted this alloy in the 1920s, it became known as Admiralty Brass [2]. It was later found that small additions of arsenic, around 0.04% could almost eliminate a common corrosion condition called Dezincification and hence arsenical admiralty brass was used for a long time for marine condensers. Subsequently, it came to light that the brass's surface was coated with self-healing protective oxide when alum was used in place of lead. The hard aluminium type oxide film makes the alloy more resistant than admiralty brass to the impingement of high velocity water. Today, a 77.5% Copper- 20.5% Zinc-2% Aluminium alloy: Aluminium brass; with an arsenic addition to inhibit dezincification has replaced admiralty brass for marine condensers. The addition of 1% Tin to Muntz metal improves its corrosion resistance and forms an alloy called Naval Brass [2, 9, 10].

Brasses

High brasses contain 60% to 80% Copper, and 40% to 60% Zinc. These brasses, because of their high zinc contents have increased strengths. Small additions of alloying elements, such as 1% tin, to the brasses do not greatly affect their mechanical properties. However, multiple additions of manganese, iron, and tin, for example, to convert Muntz metal to manganese bronze significantly increase the strength of the muntz metal. Because of its increased strength, manganese bronze is best worked in the hot condition. The addition of up to about 3% lead to improve the machinability of brasses has practically no effect on the tensile strength and hardness of the leaded brasses [6]. However ductility and hence cold working ability of the brasses is reduced by the lead additions. Unalloyed brasses are used to make coins, medals, bullet jackets, primers, plaques, jewellery base for gold plate, screen cloth, weather stripping, lipstick cases, marine hardware, angles, chains, fasteners, heat exchanger tubing and radiator cores. Besides, such brasses are processed to manufacture battery caps, musical instruments, clock dials, pump lines, flexible hose, and flashlight shells. Alloy brasses are processed to produce distilling tubes, aircraft turnbuckle barrels, propeller shafts, connecting rods, shafts, wear plates, clutch disks, and ferrules [7].

Copper - Tin Alloys

Alloys consisting of principally copper and tin are properly called tin bronzes. The tin bronzes are marketed as "phosphor bronzes" as phosphorus is typically added to these materials as a deoxidizing agent during foundry. These alloys possess desirable properties such as high strength, wear resistance, and good seawater corrosion resistance. Wrought copper tin bronzes containing from 1.25% to 10% tin are termed phosphor bronzes since they usually contain up to about 0.1% phosphorus, which is added to improve castability and act as a deoxidizer. Higher tin levels than approximately 10 percent in cast copper-tin bronzed render copper-tin alloys unusable; yet, moulds with tin percentages of up to 16% are utilized in high-strength bearings and gear shafts. Gear-blank castings are often made by centrifugal casting process to ensure for soundness. Tin levels of about 10% are common for bearings, with variable quantities of lead being added to improve plasticity and adaptability for bearing surfaces [3, 7].

Bronzes

Aluminium Bronzes are processed to make condenser, evaporator and heat exchanger tubes, distiller tubes, ferrules, bolts, pump parts, shafts, tie rods, overlay on steel for wearing surface, nuts, structural components, condenser tube and piping systems, mixing troughs and blending chambers, bushings and bearings, worm gears, cams, forming rolls, dies, plunger tips, glass sealing and porcelain enameling [8]. Propeller shafts, anchor bolts and screws, cable clamps, cap screws, machine screws, maritime devices, nuts, pole-line hardware, rivets, U-bolts, electrical cables, heat exchanger tubing, welding rod, and hydraulic pressure lines are all produced from sil bronze. The following items are made with the phosphor bronzes: welding rod, heavy bars and plates for acute compression, bridge and expansion plates and fittings, flexible hose, pole-line hardware, bellows, bourdon tubing, cotter pins, lock washers, wire brushes, chemical hardware, textile machinery, and articles requiring good spring qualities, resiliency, fatigue resistance, good wear, and corrosive rebellion. [3,8].

Copper - Aluminium Alloys

Copper-Aluminium alloys are called aluminium bronzes, although a better name would be aluminium brasses. These alloys are quite hard, have high tensile strengths, and are tough. Because of the self-healing aluminum oxide surface finish, they are resistant to wear and fatigue whilst also having outstanding resistant to corrosion.. Aluminium bronzes containing up to about 10% aluminium and with additions of about 5% Iron and 5% Nickel is exceptionally strong and tough, and have excellent corrosion and oxidation resistance at elevated temperatures. These alloys are used for high-strength bearings and gear wheels and can be used for dies for deep drawing some types of stainless steels [2, 8].

Copper - Silicon Alloys

Copper-Silicon alloys are usually referred to as silicon bronzes or by their trade names such as Everdur or Herculoy. Most silicon bronzes contain between 1% to 3% silicon. Iron and manganese can be added in little amounts to enhance their qualities. Because silicon bronzes are robust to corrosion and have a higher strength and robustness than low carbon steels, them are used in engineering. For many uses they are low-cost substitutes for the tin bronzes since, except about impingement attack, they have good seawater corrosion resistance. These alloys can be cast or hot- or cold-worked [2, 5].

Copper - Beryllium Alloys

Copper-Beryllium alloys contain between 0.6% to 2% Beryllium with additions of cobalt from 0.20 to 2.5%. The highest breaking point ever achieved in commercial copper alloys, 212 ksi, can be obtained by heat-treating these precipitation-hardenable alloys. Copper Beryllium alloys are used for tools, which require high hardness and non-sparking characteristics such as may be needed in the chemical industry. These alloys' strength, durability, fatigue resistance, and corrosion resistance have made them a good choice for usage in springs, gears, lungs, and valves [9]. They are also used for electrical contacts and molds for forming plastics. Even though these alloys contain only a small amount of beryllium, their cost is relatively high and thus their use is only justified when other lower-cost alloys will not meet the engineering requirement of an application. Bellows, diaphragms, washers, fasteners, roll pins, switches, welding equipment, fuse clips, relay parts, electrical conductors, resistance welding electrodes, seam welding steels, an electrode holder jaws, cable connectors, current-carrying arms and shafts, circuit breaker parts, molds, spot welding tips, flash welding electrodes, electrical and temperature conductors requiring authority, and switch contacts are all made of copper-beryllium metals [2].

Copper - Nickel Alloys

Copper-Nickel alloys: Nickel is added to copper to form a series of solid-solution alloys of approximately 10, 20, and 30% Nickel called Cupronickels. Copper's resistance to oxidation, oxidation, and strength are all increased by the nickel compounds. The cupronickels are used for marine condensers and tubing for conducting sea water because of their moderately high to high strength and resistance to the corrosive and erosive effects of high velocity sea water. Since the cupronickels do not work-harden rapidly, they are used for condenser tubes and plates, heat exchangers, and a wide variety of chemical process equipment [10]. Copper-Nickel alloys are processed to manufacture condensers, condenser plates, evaporator and heat exchanger tubing, ferrules, salt water piping systems, communication relays, electrical springs, resistors, high strength constructional parts for sea water corrosion resistance, hydrophone cases, mooring cable wire, retainer rings, screws, pins for ocean telephone cable applications, brazing alloy, lead frames, control and sensing bellows.

Ternary Copper - Nickel – Zinc Alloys

Copper-Nickel-Zinc alloys are commercially called as Nickel Silvers. These alloys are essentially ternary copper-nickel-zinc alloys and do not contain silver. The zinc content of the nickel silvers ranges from about 17% to 27% Zinc, while their nickel content varies from about 8% to 18%. As the nickel content is increased, the colour of the nickel silvers varies from soft ivory to silvery whiteA variety of items are made with copper-nickel-zinc alloys, including base for silver plate, attire jewelry, radio dials, springs, resistance a wire, key blanks, watch plates as well, etching stock, hollow ware, name plates, plater's bars, surface flat ware, truss wire, zippers, bows, the lens parts, and core bars [7,9, 12].

CONCLUSION

Copper is an important metal in metallurgical engineering industries. It is concluded that copper is widely used in its unalloyed condition as well as in alloys with other metals. In the unalloyed form, it has an extraordinary combination of properties, which make it the basic material in the electrical industry, some of those properties being its high electrical conductivity and corrosion resistance, ease of fabrication, reasonable tensile strength, controllable annealing properties, and general soldering and joining characteristics. It has wider applications in various industries. The uses of copper and its alloys and compounds will continue to change, as they have over thousands of years, to meet modern challenges. As an essential service material that is environmentally friendly, fully recyclable and fully sustainable, there is no viable alternative to copper, the 21st century metal.

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