COMPARISON OF PROPERTIES OF 5 IMPORTANT ENGINEERING METALS:

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Abstract Body: *This article provides a detailed comparison of the properties of six major industrial metals: iron (Fe), copper (Cu), nickel (Ni), aluminum (Al) and titanium (Ti), and copper (Cu). Each metal is examined for its physical and chemical properties, such as appearance, structure, susceptibility to corrosion and reactivity. Furthermore, the article explores the various uses and applications of these metals in sectors such as manufacturing, aerospace and electrical engineering. The comparison reveals the unique properties of each metal and highlights their importance in various engineering applications.*

Keywords: *iron, chemical, oxide, temperature, metal, melting, copper, nickel, aluminum, titanium.*

Fe

Iron is a malleable metal that has a silvery white hue and is highly chemically reactive. The crystal lattice of a simple substance has a cubic body-centered structure. Iron is susceptible to corrosion under conditions of high temperature and high humidity in the air. In pure oxygen, iron burns, and in a finely dispersed state, it ignites spontaneously in air. Among ores containing iron, raw materials for industrial production are hematite; goethite; magnetite. Goethite and hydrogoethite form formations in the weathering crust hundreds of meters in size. In the shelf zone and lakes, colloidal solutions of minerals form oolites (bean iron ores) as a result of precipitation. Iron smelting is carried out by roasting crushed ore with clay. The mixture is formed into pellets and processed in a hydrogen reduction furnace. Further smelting of iron is carried out in electric furnaces. In its pure form, this material is soft, so carbon is added to the composition to increase strength.

Depending on the components of the ligature, the properties of the materials change. The melting point of iron also changes in the presence of ligature components. The specific heat of fusion of steel is 84 kJ. This indicator means that at the melting temperature of steel, 84 kJ of energy is needed to transfer 1 kg of an alloy from a crystalline to a liquid state. silicon. It is distinguished by low electrical properties, low strength, and is easily susceptible to corrosion. Connections from various metals alloys. Specific heat of fusion of cast iron with a capacity of 96–140 kJ. Cast iron contains up to 4% waste, 1.5% manganese, up to 4.5% silicon and impurities in the form of sulfur and phosphorus. connect white and gray alloys. An iron carbide compound appears in the white part. This alloy is brittle and hard. It is used for the manufacture of structures and parts. The gray alloy containing carbon in the form of graphite is easy to machine. Cast iron is smelted from iron ore in blast furnaces. The melting of the ore is accompanied by a reduction reaction of iron from oxides with carbon. Most substances can melt with an increase in volume when heated. For cast iron with a volume of 1000 cm^3, this figure is 988–994 cm^3. Cast iron is a raw material to produce steel, characterized by a carbon content (not higher than 2.14%). According to the chemical composition, steel is distinguished: alloyed; carbon.

Iron has a silvery color, is quite ductile, but is capable of increasing hardness through its interaction with other elements (for example, with carbon). It also has magnetic properties. In a humid environment, iron can corrode, that is, rust. Although absolutely pure metal is more resistant to moisture, if it contains impurities, it is they that provoke corrosion. Iron interacts well with an acidic environment, it can even form salts of iron acid (provided that it is a strong oxidizing agent). In air, it quickly becomes covered with an oxide film, which protects it from interactions.

Also, this element has a number of chemical properties. Iron, like the rest of the elements of the periodic table, has the charge of the atomic nucleus, which corresponds to the serial number +26. There are 26 electrons around the nucleus. In general, if we consider the properties of iron - a chemical element, then it is a metal with a low active ability. Interacting with weaker oxidizing agents, iron forms compounds where it is divalent (that is, its oxidation state is +2). And if with strong oxidizing agents, then the oxidation state of iron reaches +3 (that is, its valence becomes equal to 3). When interacting with chemical elements that are not metals, Fe acts as a reducing agent in relation to them, while its oxidation state becomes, in addition to +2 and +3, even +4, +5, +6. Such compounds have very strong oxidizing properties. The interaction of Fe with halogens leads to the formation of salts. The elements fluorine and chlorine oxidize it to +3. Bromine is up to +2 or +3 (it all depends on the conditions for the implementation of a chemical transformation when interacting with iron). Interacting with iodine, the element is oxidized to +2. By heating iron and sulfur, iron sulfide is obtained with a valence of 2. If ferrum is melted and combined with carbon, phosphorus, silicon, boron, nitrogen, then compounds called alloys will be obtained. Iron is a metal, so it also interacts with acids (this was also briefly discussed a little higher). For example, sulfuric and nitric acids, having a high concentration, in an environment with a low temperature, do not affect iron. But as soon as it rises, a reaction occurs, as a result of which iron is oxidized to +3. The higher the acid concentration, the higher the temperature must be given. Heating 2-valent iron in water, we get its oxide and hydrogen. Also, Fe has the ability to displace metals that have reduced activity from aqueous solutions of salts. At the same time, it is oxidized to +2. When the temperature rises, iron restores metals from oxides.

The uses and properties of iron are closely related. Due to its ferromagnetism, it is used to make magnets - both weaker for domestic purposes (souvenir fridge magnets, etc.), and stronger - for industrial purposes. Due to the fact that the metal in question has high strength and hardness, it has been used since ancient times for the manufacture of weapons, armor and other military and household tools. By the way, even in ancient Egypt meteorite iron was known, the properties of which are superior to those of ordinary metal. Also, such a special iron was used in ancient Rome. They made elite weapons from it. A shield or sword made of meteorite metal could only be owned by a very rich and noble person.

Cu

The 29th element of the periodic table is a pinkish metal with a golden metallic sheen, which is called copper. Pure metal is soft, so it is often used with impurities. Plastic: stretchable to micron diameters. Initially, ancient peoples mined copper from malachite ore. Copper found active use during the discovery and widespread use of electricity. This metal has excellent electrically conductive properties. Copper is a compound of a huge number of crystals of silver, calcium, gold, lead, nickel. The metals that make up cuprum are easy to process and relatively plastic. The elementary cell of the structural lattice is a cubic form. Each of the cells is a compound of 4 atoms. During mining, the ore is saturated with a huge number of impurities. They affect the technical characteristics of the remelted metal, its structure. Copper is quite widely represented in the earth's crust, in sedimentary rocks, in the waters of marine and freshwater bodies, and in shales. It is distributed both in the form of compounds, and in an independent version.

Copper acquires its characteristic color as a result of interaction with oxygen and the formation of a thin oxide film. Thinner plates look greenish-blue when viewed through the light. The most pronounced physical properties of copper are: high electrical and thermal conductivity (second only to silver), softness, ductility, easy drawing and processing, corrosion resistance. Of the other characteristics of copper, it is worth noting good immunity to external natural factors (temperature, ultraviolet, chemical exposure) and a pleasant appearance (possibility of patting). In cases where it is necessary to use a harder material, brass and bronze are used - alloys of copper with zinc and tin, respectively. Copper products have a high density and can be rolled into wire, rod or sheet of any thickness.

In compounds, copper comes in two oxidation states: the less stable Cu+ and the much more stable Cu2+, which produces blue and blue-green salts. Under unusual conditions, compounds with an oxidation state of +3 and even +5 can be obtained. The latter occurs in salts of the cupbororane anion Cu(B11H11)23- obtained in 1994. Copper (II) carbonate has a green color, which is the reason for the greening of elements of buildings, monuments and copper products. Copper (II) sulfate, when hydrated, gives blue crystals of copper sulfate CuSO4 · 5H2O, is used as a fungicide. There is also unstable copper (I) sulfate. There are two stable copper oxides - copper (I) oxide Cu2O and copper (II) oxide CuO. Copper oxides are used to produce barium yttrium copper oxide (YBa2Cu3O7-δ), which is the basis for producing superconductors. Copper (I) chloride - colorless crystals (white powder in mass) with a density of 4.11 g / cm³. Stable when dry. In the presence of moisture, it is easily oxidized by atmospheric oxygen, acquiring a blue-green color. Can be synthesized by reduction of Copper (II) chloride with sodium sulfite in aqueous solution.

The metal content in ores does not exceed 2%. Therefore, they are enriched before melting. There are two ways to obtain copper: pyro- and hydrometallurgical.

Metal and copper alloys are analyzed by the following branches:

a) Electrical engineering, radio electronics. Cables (power, others), wires. winding in transformers. Heat exchange devices (heating radiators, air conditioners, computer coolers, laptop heat pipes);

b) Instrumentation, mechanical engineering. From alloys of copper with zinc, tin, aluminum make parts, machine components. Without it, it is impossible to create galvanic cells and batteries;

c) Pipes. For transporting steam, water, gas. In energy, shipbuilding, for domestic needs.

Copper is the most widely used catalyst for the polymerization of acetylene. Because of this, copper pipelines for transporting acetylene can only be used if the copper content in the alloy of the pipe material is not more than 64%.

Ni

Nickel is the twenty-eighth element in the Periodic Table. Designation - Ni from the Latin "niccolum". Located in the fourth period, VIIIB group. Refers to metals. The nuclear charge is 28. Metal nickel has a silvery color with a yellowish tint, is very hard, polishes well, and is attracted by a magnet. It is characterized by high corrosion resistance - stable in the atmosphere, in water, in alkalis and a number of acids. It actively dissolves in nitric acid. The chemical resistance of nickel is due to its tendency to passivation - to the formation of oxide films on the surface, which have a strong protective effect. Almost all nickel is obtained from garnierite (green nickel ore) and pyrites.

A significant part of nickel is obtained from copper-nickel sulfide ores. From enriched raw materials, matte is first prepared - a sulfide material containing, in addition to nickel, also impurities of iron, cobalt, copper and a number of other metals. Nickel concentrate is obtained by flotation method. Next, the matte is usually processed to separate iron and copper impurities, and then fired and the resulting oxide is reduced to metal. There are also hydrometallurgical methods for obtaining nickel, in which a solution of ammonia or sulfuric acid is used to extract it from the ore. For additional purification, black nickel is subjected to electrochemical refining.

Nickel is a grayish-white metal, malleable and malleable, highly polishable. It crystallizes in a face-centered cubic lattice, although some impurities are able to stabilize the metastable hexagonal structure. Unlike iron and cobalt, nickel is less magnetized and loses its ferromagnetic properties at a much lower temperature. Nickel has good malleability and ductility. Due to these characteristics, it can be easily rolled. It is quite easy to get thin sheets and small pipes from it. At temperatures from 0 to 631 K, nickel becomes ferromagnetic. This process occurs due to the special structure of the outer shells of the nickel atom. The mechanical characteristics of nickel depend on the presence of impurities. Sulfur, lead, bismuth, zinc, and antimony are considered the most dangerous and harmful.

If nickel is saturated with gases, then its mechanical properties will become worse. Nickel metal has the following thermal conductivity: 90.1 W/(m•K) (at 25°C). The electrical conductivity of nickel is 11,500,000 Sim/m.

Alloys with the addition of chromium - nichrome - are heat-resistant, therefore they are used for the manufacture of structural elements of gas turbines, jet engine parts, and equipment for nuclear reactors. In the process of adding molybdenum, alloys are obtained that are resistant to acids and other aggressive compounds (dry chlorine). Alloys containing aluminum, iron, copper and cobalt - alnico and magnico - have the properties of permanent magnets and are used in the manufacture of various radio measuring instruments and electrical engineering. Products from Invar - an alloy with the addition of iron (Ni - 35 percent, Fe - 65%) have the property of practically not stretching when heated. World production of nickel in 1887 was only 600 tons. The metal was used to make coins. But since the 1980s , the nickel industry has been actively developing. The impetus was the high corrosion resistance of the metal, and, most importantly, its alloys.

One of the main areas of nickel consumption is alkaline batteries (accumulators). It is updated on the wave of interest in the production of electric vehicles. Today, the main battery component is cobalt, but it is expensive, supplies from Africa are problematic. More efficient samples with the dominance of lithium and nickel have been developed. It has been established that due to nickel, the power of the batteries increases. At the same time, its price is six times less than cobalt, and the supply is 20 times higher.

Al

Aluminum is the 13th element of the periodic table. It is in the third period, III group, the main subgroup. In terms of the degree of prevalence in the earth, aluminum occupies a leading position among all metals and the third among the elements of the periodic table. According to studies by various scientists, its concentration in the soil ranges from 7.4 to 8.1%. The molar mass of an atom is 26.9815386 g/mol. The substance has a high chemical activity, so it is most often found in the form of compounds. Aluminum contains radioactive isotopes that decay over 720,000 years. They are formed during the splitting of argon nuclei by high-energy cosmic rays. There are three electrons on the outer energy level, which determine the constant valency III. In reactions with substances, aluminum enters an excited state and is able to donate all three electrons, forming covalent bonds. Like other active metals, aluminum is a powerful reducing agent. The main raw material for the production of aluminum is bauxite. Their deposits are concentrated in the tropics and subtropics.

Aluminum is a silvery-white light metal, the technical composition melts at a temperature of 658 degrees, pure - at 660, and it boils at 2518.8. Plasticity also belongs to the physical properties. It is very high for a substance: 35% and 50% for an industrial and natural alloy, respectively. It can be rolled out to the state of foil or a thin sheet. Young's modulus for aluminum is 70 GPa, Poisson's ratio is 0.34. It perfectly reflects light, conducts heat and electricity. The substance can interact with almost all metals, forms alloys with silicon, magnesium, copper. Under normal conditions, aluminum is covered with a strong thin oxide film, so it is not affected by conventional oxidizing agents. But it reacts to dilute sulfuric solutions.

When reacting with oxygen, aluminum oxide is formed, its formula is $4Al + 3O_2 = 2Al_2O_3$. Fluoride substances: $2Al + 3F_2 = 2AlF_3$. Sulfide is formed upon interaction with sulfur: $2Al + 3S = Al_2S_3$, $2Al + N_2 = 2AlN$ is a metal nitride, $4Al + 3C = Al_4C_3$ is a carbide after reaction with carbon. The characteristic oxidation state of aluminum is plus three, but its atoms can form additional bonds. When interacting with alkalis, tetrahydroxoaluminate (or other aluminates) is formed: $2Al + 2NaOH + 6H_2O = 2Na(Al(OH)_4) + 3H_2$. The metal can be dissolved in dilute sulfuric acid: $2Al + 3H_2SO_4 = Al_2(SO_4)_3 + 3H_2$.

Aluminum has lightness (density 2.7 g/cm3); silver grey; high electrical conductivity; malleability; plasticity; melting point - 658°C; boiling point - 2518.8 ° C. Tin containers, foil, wire, alloys are made from metal. Aluminum is used in the manufacture of microcircuits, mirrors, and composite materials. Aluminum is paramagnetic. Metal is attracted to a magnet only in the presence of a magnetic field. Aluminum is in first place among metals and in third place among all elements in terms of prevalence in the earth's crust. Approximately 8% of the mass of the earth's crust is precisely this metal. Aluminum is found in the tissues of animals and plants as a trace element. In nature, it is found in a bound form in the form of rocks, minerals. The stone shell of the earth, which is at the base of the continents, is formed precisely by aluminosilicates and silicates.

D. I. Mendeleev wrote that "metal aluminum, having great lightness and strength and low variability in air, is very suitable for some products". Aluminum is one of the most common and cheapest metals. Without it, it is difficult to imagine modern life. No wonder aluminum is called the metal of the 20th century. It lends itself well to processing: forging, stamping, rolling, drawing, pressing. Pure aluminum is a soft metal; it is used to make electrical wires, structural parts, food foil, kitchen utensils and "silver" paint. This beautiful and light metal is widely used in construction and aviation technology. Aluminum reflects light very well. Therefore, it is used for the manufacture of mirrors - by metal deposition in a vacuum.

Ti

Titanium is a chemical element with an atomic number of 22, an atomic weight of 47.88, a light silvery-white metal. Density 4.51 g/cm3, Tmelt=1668+(-)5°C, Tboil=3260°C. This material combines lightness, strength, high corrosion resistance, low coefficient of thermal expansion, and the ability to work in a wide temperature range.

In the periodic system of elements of D. I. Mendeleev, Ti is located in group IV of the 4th period at number 22. In the most important and most stable compounds, the metal is tetravalent. It looks like steel. Titanium is a transition element. This metal melts at a fairly high temperature (1668 ± 4 °C) and boils at 3300 °C , the latent heat of melting and evaporation is almost twice that of iron. Two allotropic modifications of titanium are known (two varieties of this metal having the same chemical composition, but different structure and properties). Low-temperature alpha modification, existing up to 882.5 ° C and high-temperature beta modification, stable from 882.5 ° C and up to the melting point. In terms of density and specific heat capacity, titanium occupies an intermediate position between the two main structural metals: aluminum and iron. It is also worth noting that its mechanical strength is about twice that of pure iron and almost six times that of aluminum. But this material can actively absorb oxygen, nitrogen and hydrogen, which sharply reduce the plastic properties of the metal. With carbon, titanium forms refractory carbides with high hardness. Titanium has a low thermal conductivity, which is 13 times less than the thermal conductivity of aluminum and 4 times less than iron. The coefficient of thermal expansion at room temperature is relatively small, it increases with increasing temperature. The elastic moduli of titanium are small and exhibit significant anisotropy. Elastic moduli characterize the ability of a material to deform elastically when a force is applied to it. Anisotropy is the difference in elasticity properties depending on the direction of the force. As the temperature rises to 350°C, the elastic moduli decrease almost linearly. The small value of the modulus of elasticity Ti is its significant disadvantage, because in some cases, in order to obtain sufficiently rigid structures, it is necessary to use large sections of products compared to those that follow from the strength conditions.

Titanium has a rather high electrical resistivity, which, depending on the content of impurities, ranges from 42•10-8 to 80•10-6 Ohm•cm. At temperatures below 0.45 K, it becomes a superconductor. Titanium is a paramagnetic metal. Usually, in paramagnetic substances, the magnetic susceptibility decreases when heated. Magnetic susceptibility characterizes the relationship between the magnetization of a substance and the magnetic field in this substance. This material is an exception to this rule - its susceptibility increases significantly with temperature.

The main part of titanium is spent on the needs of aviation and rocket technology and marine shipbuilding. It, as well as ferrotitanium, is used as an alloying additive to high-quality steels and as a deoxidizer. Technical titanium is used for the manufacture of tanks, chemical reactors, pipelines, fittings, pumps, valves and other products operating in aggressive environments. Grids and other parts of electrovacuum devices operating at high temperatures are made from compact titanium. In terms of use as a structural material, Ti is in 4th place, second only to Al, Fe, and Mg. Titanium aluminides are very resistant to oxidation and heat-resistant, which in turn determined their use in aviation and automotive industry as structural materials. The biological safety of this metal makes it an excellent material for the food industry and reconstructive surgery.

USED RESOURCES:

1. “Physical Properties of Materials for Engineers”, Lawrence H. Van Vlack
2. “Materials Science and Engineering”, William D, Callister Jr., David G. Rethwisch
3. “Mechanical Metallurgy”, George E. Dieter