Original Article: Review of Steel Material Engineering and Its Application in Industry

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ABSTRACT

According to an old definition, steels are alloys of iron and carbon in which the amount of carbon varies up to 1.7% and elements such as manganese, silicon in amounts less than 1%, and phosphorus and sulfur in small amounts, and also there are elements as alloy elements. Having high strength and good flexibility distinguishes steels from other alloys and non-metallic materials, and steels are very resistant to variable actions and impacts. Simple carbon steels are steels whose alloy percentage is very small. These types of steels have the highest amount of consumption in all types of steels. These steels are divided into three categories, which are explained in the next sheet. Due to the wide use of iron alloys (cast iron and steel) in the industry, we can understand the importance of this goal in human life. Iron, which is a very soft and flexible element, is found in nature as iron ore, which is hard and brittle and it has the tendency is to be combined with other elements, especially carbon. Steel is the most widely used and recycled metal material on earth. From high-temperature stainless steels to plain carbon products, these carbon steels in various forms and alloys offer various properties to meet a wide range of applications. Likewise, because of the combination of the properties of this metal of high strength and relatively low production cost, this widely used metal material is now used in countless products.

Introduction

Construction

The largest consumption of steel is in the construction industry. Stable metal structures can be built quickly and at low cost. Steel in its various forms and alloys can be designed to meet the needs of unique projects, allowing it to be incorporated into infrastructure in all environments. Depending on the conditions the structure is exposed to, the steel can be alloyed or given different surface treatments for protection. The development of efficient steel production techniques in the late 20th century contributed to the growth of railroads around the world, as well as the rise of high-rise buildings. Many famous historical structures such as the Empire State Building contain steel as a primary construction material [1].

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Transportation

Engineering steels are forged steels designed to have a certain level of elasticity, strength, ductility, and corrosion resistance. They are used in general engineering and manufacturing sectors, but mainly for transportation vehicles. Steel accounts for more than 50% of the weight of an average car [2]. Advanced High Strength Steels (AHSS) are used in vehicles. Steel is a light material that requires less production energy and reduces carbon dioxide emissions.

Energy

All subsets of the energy sector, including nuclear, wind energy, electricity, and natural gas, require steel for infrastructure. Steel is further used for resource extraction, including in offshore platforms, land and mining equipment, cranes, and forklifts. According to the required environments, carbon, micro alloy, high strength, and stainless steels are all used in the production of offshore platforms and pipelines. In addition, many other energy projects rely on large amounts of steel: Oil and gas wells and platforms, pipelines, power turbine components, switchboards, wind turbines, electromagnetic transmission towers, transformer cores, and electromagnetic shields.

The world's largest steel industry

Automobile manufacturing is known as the largest industry in the world and a large part of the products in this industry are produced with alloy steels. As much as you are familiar with the automotive industry, you are familiar with the uses of steel in this industry. Global and Iranian car manufacturers need to improve the quality of their products [3]. In the automotive industry, steel is used in many parts, 40% of which are used in the body structure, panels, doors, and trunk for high strength and energy absorption in case of an accident. 12% is in suspension and high strength steel strip is used. Concerning the sensitivity in the production of their cars, the world's major car manufacturers buy steel with reputable brands and steel with desired alloys. The available steels in Iran due to the sanctions and the non-entry of steels made in the accredited factories are the steels made in the countries of India, China, and Iran, and a limited number of steels from the accredited factories are available in Iran [4].

High strength micro alloy steel

In this type of steel, each alloy element is less than 0.1%, which usually includes one of niobium, vanadium, and titanium elements. Micro alloy steels have yield strength above 320 MPa and tensile strength above 440 MPa, and for this reason, they are classified as high strength steels (Figure 1).

Stainless steel

Steels that have at least 10.5% chromium and are known to have very good corrosion resistance are stainless steels. In addition to chromium, nickel is an important alloying element in stainless steels that provides corrosion resistance and strength at low temperatures by lowering the DBTT (soft to brittle transition temperature) for stainless steel. The types of steel known as stainless steel and non-steel in the market refer to ferritic and austenitic stainless steels, respectively [5].

Hypereutectoid steels

The amount of carbon in these alloys is between 0.8-0.25 percent. In this alloy, when the temperature reaches the transformation degree, the primary ferrite is separated from the austenite, and due to the lower solubility of ferrite for the carbon element, a further decrease in temperature while increasing the solid content of ferrite causes the remaining austenite to be enriched with carbon. This important thing continues until reaching the temperature of eutectoid and austenite will be transformed. Due to the structure order of several alloys, the temperature will be lower than the eutectoid temperature of primary ferrites with a mixture of ferrite and eutectoid cementite called pearlite. In brief, if we cool the hypereutectoid steel, the ferrite is deposited at the grain boundary and it is the same everywhere [6].

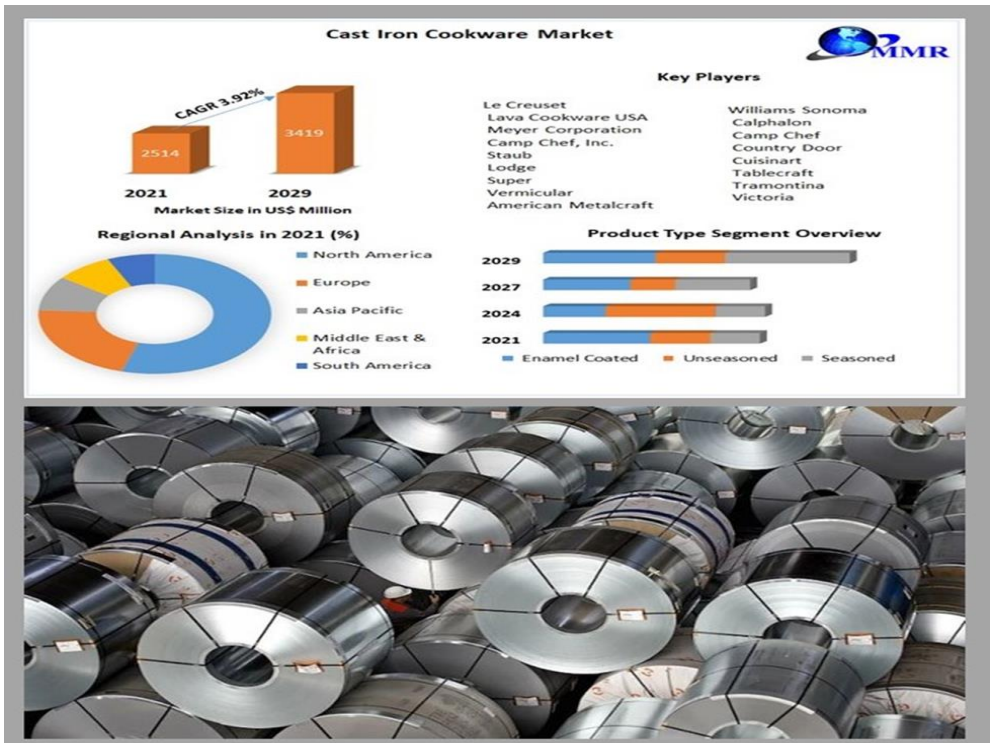

Figure 1: High strength micro alloy steel.

Classification of steel based on production method

The production method directly affects both the quality and properties of steel. Therefore, it is possible to control the properties and microstructure through the control of the production method. Common methods in steel production include open furnace method, Bessemer method, alkaline oxygen furnace, and electric furnace. About 70% of the world's steel is produced by the alkaline oxygen furnace or BOF method. This method is actually an optimized Bessemer method. The electric furnace method also produces very high-quality steels, which include tool and stainless steels. However, it costs much more than other methods and only 30% of the world's steel is produced in this way [7].

All types of steel based on the final work

In addition to maintenance and improvement the quality of the steel, finishing also helps in creating a suitable finished surface. Steels are divided into cold-rolled steel and hot-rolled steel according to the type of final work. All cold working provides a more suitable surface.

Classification of steel based on shape

Steels are the most widely used metals in industrial and construction applications. This metal is used in various forms in different industries and construction. Steel ingot is the first form that steel takes. Rebar, beam, pipe, sheet, profile, etc. are the other forms of steel that are popular in construction [8].

Types of steel based on deoxygenation method

Some steels contain significant amounts of oxygen. This amount of oxygen may be around 0.02 to 0.04% in some cases, but even this small amount is harmful. Steel whose oxygen has not been removed is referred to as rimmed steel. Because the boiling steel contains oxygen, it reacts with carbon and produces porosity and CO gas cavities, which is harmful. This naming is due to the fact that in boiling steel, a state similar to boiling is created due to the CO release. If some of the steel's oxygen is removed, it is called semi-killed steel, and steel

that has all its oxygen removed is known as killed steel. There is another type of steel that has a state between semi-quiet and quiescent steel, and it is called capped steel [9].

Buoyancy, sedimentation, and concentration separation

The use of different alloy elements in metal melting always faces a major problem, and that is the difference in the specific weight of iron and the used alloy element. The lighter alloy element melts and enters the slag, and it deviates from the desired properties of the ingot. The heavier element also settles in the bottom of the pot and repeats the mentioned problem in a similar way.

Steel section thickness

The discussion of the thickness of the produced section is important in two ways. The first case, as mentioned above, is related to concentration separation. The thicker the section, the harder it is to control the properties. The second case and problem of thick sections is reducing the possibility of steel hardening in its center. As the sample becomes thicker, due to less contact with the cooling medium such as water, the heat transfer is done at a slower rate and the steel center does not harden [10].

Lack of up-to-date equipment and facilities

To produce certain steels, very high purity and the maximum removal of elements such as sulfur and phosphorus are required. Preparing blinds with high purification capability of these elements is sometimes very expensive and not economical. The existence of these factors has caused that despite the production of conventional steels by blast furnace methods and direct regeneration in factories such as Isfahan Iron Smelter and Khuzestan Steel, it is not possible to produce some steels in the country at the moment.

Heat treatable steel

There are many steels that can be heat treated. Such steels can be used to make cranks, bolts and nuts, gears, rollers for steel and cement industries, etc.

Heat treatable steels include the following

- A516 steel;
- Mo40 steel;
- CK45 steel;
- Bearing steel;
- VCN 200 steel;
- VCN 150 steel;
- Hot-worked steel 1.2344;
- 304 stainless steel;
- Cementation steel;
- Air dry steel.

In the following, we will describe each one.

A516 steel

By adding small amounts of alloy elements such as silicon, phosphorus, sulfur, and manganese at the highest permitted levels, we reach a high-quality carbon steel sheet that has bending and lensing properties. A516 steel is one of the categories of refractory alloy sheets. This carbon steel sheet produced is used in welding pressure vessels where final toughness is very important. Furthermore, these sheets have a tensile strength of 55 to 90 MPa. The reason for the popularity of this steel sheet is its changeability and flexibility.

MO40 steel

MO40 steel is a type of chromium-molybdenum alloy steel used to make industrial equipment that is subjected to impact, pressure, and heat. This steel is classified as a low carbon alloy, which has high tensile strength as well as high hardness resistance. The hardness of MO40 steel is very high and this steel is used when resistance to hardness and tensile strength are important. The properties of this

steel are ease of forming and formability of steel, excellent welding ability.

CK45 steel

This steel is a group of heat treated alloy steels produced in German DIN standard and also known as 1.1191. CK45 steel is one of the medium carbon steels, which has chemical compounds such as 0.65 manganese, 0.25 silicon, and 0.45 carbon. This steel is subjected to forging operation at 650-700 annealing temperature and at 850-1100 ℃, and it is used in the condition of return, quenching, uniformization, and use [11].

Bearing steel

The material of this type of steel is high carbon chromium alloy steel. The application of bearing steel is in parts that should be used in vertical and static stresses and sections that are subject to heavy loads and wear. Bearing steel includes characteristics such as excellent wear resistance, good strength and toughness, high hardness, and hardenability.

VCN 200 steel

This steel is one of the grades of VCN steel, which is a family of heat treatment alloy steels. VCN 200 steel is also known as 1.6580. Due to have 2% chromium element and 2% nickel element, it can withstand a lot of pressure.

This steel has many properties, some of which include the following:

- Heat treatment capability;
- Parts with high tension and cross section;
- Very high strength;
- High hardness and wear resistance.

VCN 150 steel

VCN 150 steel has high strength and hardness, which has good hardenability. Likewise, this steel has a good hardening ability and is a famous product due to its ability to create high strength in heat treatment conditions and its good hardness. This steel is one of the most widely used steels in the Iranian market, which is also known as 1.6582 steel.

Hot-worked steel 1.2344

The production and design of this type of steel is for applications whose temperature is higher than 316 degrees Celsius. For example, by placing cold tool steels in the temperature range of 316℃, it softens and reduces their strength. In addition, high-speed steels that are used as cutting tools do not soften at this temperature, but due to their toughness and resistance to thermal shock, they are not suitable for high-temperature applications. Hot-worked steels have a small volume of carbon alloy, the maximum toughness, and elements such as W, CO, and MO to resist the steel from softening at high temperature. The addition of vanadium alloy element increases the thermal resistance and the wear resistance of steel.

Heat-worked steels are divided into the following two main groups.

- The main element used in the first group is Molbiden alloy.
- The main element used in the second group is tungsten alloy.

Usually, the use of steels with molybdenum alloy show better toughness and resistance to thermal shock compared to steels with tungsten alloy. Likewise, steels with tungsten alloy have better resistance to softening and thermal fatigue, but due to their low toughness, they are used in specific and limited applications.

304 stainless steel

Type 304 stainless steel rebar is called non-magnetic steel due to its lack of magnetic properties. It is also an affordable grade of steel that makes it a great choice for projects that require a lot of corrosion resistance and strength. This rebar is the most widely used grade of steel rebar due to its excellent resistance to most chemicals and industrial environments. Nice and widely used thicknesses of 304 steel rebar in sizes 1.6, 2, 2.5, etc. up to 5 mm are produced and sold in

the market. Furthermore, this rebar is produced from size 5 to 300 mils in the form of 6 or 4 meter branches according to the request of consumers [12].

Cementation steel

The word cementation means surface hardening, which is a type of heat treatment in which the cross-section hardens, but its core remains unchanged. In this case, we mention that the surface is hard and the core is soft.

Cementation steels are divided into the following two general types

- Nickel-containing cements and
- Non-nickel cements.

This steel has different grades, and the price and specifications of each of these grades are different. One of the most widely used grades of cementation steel is cement steel 1.5920 and cement steel 1.7131.

Air dry steel

These steels are classified as tool steel and are placed and used in the form of cutting tool steel. This steel is used to make various cutting tools such as electric saw blades and lathe blades, drills, gear cutting tools, drills, milling cutters, and other sections [13].

Conclusion

In these steels, as can be seen in the background, there are layers of Fe_3l and ferrite, which in total form a background of 100% pearlite. However, these layers are compact in some places and spaced out in some places, which is the inconsistency in tool steels in terms of different parts. They are in different forms. Pearlite, which is hard and breaks the phase in these steels, does not allow operations and workability, and the production of parts with 0.8% carbon is done only through casting, which is used in the manufacture of parts such as metal cutting tools, transportation Railways are rolling machines. Normally, steel containing 0.2% carbon is used to make wires, pipes, and sheets, and steel containing 0.2 to 0.6% carbon is used for rails, boilers, and building infrastructure, and steel 0.6 to 1.5% carbon is used for other industrial tools. Steel is widely used in the construction of roads, railways, other infrastructure, household appliances, and buildings. Most large modern structures such as stadiums and skyscrapers, bridges, and airports are supported by a steel framework. Even those with concrete structure use steel to strengthen the structure.

Steel is by far the most widely used material for building the world's infrastructure and industries, and is also used to make almost everything from sewing needles to oil tankers. Some other uses of steel are:

- Different types of steel are used in car body, doors, engine, suspension system, and car interior. On average, 50% of a car is made of steel.
- Due to its high tensile strength and low cost, steel is used in buildings and their framing, infrastructure, tools, ships, trains, machines, electrical appliances, and weapons.
- Steel reduces CO_2 emissions. It is environmentally friendly and sustainable and has a long shelf life.
- Stainless steels are used for marine pipelines, cutlery, surgical implants, and solar cells.
- Steels are used to package and protect goods against exposure to water, air, and light.

The progress of science and the emergence of a new category of materials called composites have shown a very high potential to be used as steels in many cases. These materials have low weight and high corrosion resistance. However, steels are always known as a superior engineering material and can maintain their position.

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