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Stainless steel Strengthening Mechanism using Heat Treatment

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A B S T R A C T

Stainless steel, also called inox. It is an alloy of metals including chromium and nickel, which enhances corrosion resistance. The purpose is to protect the surface from chromium and nickel oxide particles. These particles are larger than iron particles. What prevents the latter is to cover them from the action of oxygen and iron oxide, known as rust. To obtain a high-quality and homogeneous chrome-oxide or nickel-oxide surface, which is the prerequisite for corrosion resistance, furniture structures must undergo special treatment. Chlorine is the worst enemy of stainless steel. It can damage it. That's why it is recommended for places near the beaches - sea salt is sodium-chloride, the metal surface should be as smooth as possible to achieve maximum corrosion resistance. In this paper you will study the properties of stainless steel, and the mechanism of strengthening it to obtain the highest resistance under the most extreme conditions.

Keywords: stainless steel , strengthening mechanism, heat treatment

1. Introduction

Stainless steel is a steel alloy containing at least 10.5% chromium (Cr). The distinctive feature of stainless steel is its high resistance to corrosion. Corrosion is an electrochemical process in which metals react with the environment. It is not a noble metal that can remain inert (do not react with the environment, do not corrode) in most environments such as stainless steel and platinum rhodium.

The factor providing high corrosion resistance in stainless steel. When it comes into contact with air, a dense and brilliant layer of carbonate and very transparent chromium oxide is formed on the surface of the material that is firmly attached to the surface. This very thin amorphous layer provides the necessary passivity and protects the internal and external structure from chemical reactions and provides steel.

The material is used during its processing or if the layer above it wears off, this layer has the advantage of repairing itself and restoring its previous feature.

This amorphous layer, which is also formed in materials such as titanium (Ti) and aluminum (Al), greatly increases the value of stainless steel. The chromium content of at least 10.5% added to stainless steel ensures that the surface and internal structure of the steel are resistant to external factors and prevents rust. Low alloy types of stainless steel are suitable for atmospheric conditions and natural water; high alloy types are resistant even to acids, alkaline solutions and chlorides. In addition to their excellent corrosion resistance, stainless steel types are available with different mechanical properties.

Its contents include carbon (C), nickel (Ni), molybdenum (Mo), sulfur (S), titanium (Ti), copper (Cu), vanadium (V), niobium (Nb), nitrogen (N), wolfram (W) The elements are changed by adding or removing elements such as Mangan (Mn).

This is the main element that provides corrosion resistance in chromium (Cr) stainless steel. Ferrite is a stabilizing metal, so it always has an internal structure with ferrite alloys up to lean FE alloys (20% chromium) at room temperatures. When chromium (Cr) exceeds 20% Cr, the sigma phase begins. Chromium (Cr) is a strong carbide builder. Carbon (C) is a stabilizing element of austenite. It increases the yield strength and tensile strength and adds hardness and toughness to stainless steel materials. Nickel (Ni) is a stabilizing element of austenite. When nickel (Ni) reaches 8%, the austenite zone expands well and the internal austenitic structure remains. It significantly increases the resistance to corrosion and oxidation. It increases the strength and impact resistance at high or low temperatures. Silicon (Si) increases the resistance to oxidation, it is necessarily included in heat-resistant grades, ferrite is a balancing element.

Aluminum (Al) is also used in heat-resistant alloys and strengthens the effect of silicon (Si). Molybdenum (Mo) strengthens the passivity (negativity) of stainless steel in acidic and chloride environments and increases corrosion resistance. Wolfram (W) is a ferrite stabilizer and carbide builder. It is added to the alloy to increase the mechanical properties of the material. Titanium (Ti) and Niobium (Nb) form very stable carbides, and are added to austenitic stainless steels to prevent sensitization. Manganese (Mn) is also an austenite stabilizer like nickel (Ni). It increases the strength and toughness of stainless steel. In some qualities, nickel (Ni) replaces it to reduce the cost. Nitrogen (N) is basically an austenite stabilizer and its effect is like carbon (C). In order to reduce the cost, some austenitic stainless steels replace nickel (Ni) when reducing. Copper (Cu) is a weak austenite stabilizer. It is added to the composition of austenitic stainless steels to increase corrosion resistance in some environments. Sulfur (S) is added to increase the machinability of stainless steel. But it reduces corrosion resistance and weldability. There are types of stainless steel that can be used at low and high temperatures. While standard grades of austenitic stainless steel retain properties up to 700°C, the amounts of nickel (Ni) and chromium (Cr) can increase up to 1150°C. You can find detailed information about the qualities in the quality section of our website. 3AS stocks have materials suitable for all types of heat resistance. There are grades suitable for cutting, welding, hot and cold forming and machining repair. The areas of application of stainless steel are diversified by adding or removing the various elements mentioned above. There is a different grade of stainless steel for almost every application. For the correct use of stainless steel, the most suitable grade of stainless steel should be preferred. Otherwise, the material will not give the desired result even if it is of more efficient quality. You can contact the 3AS team to get the best quality of stainless steel according to the areas of use. Due to the mechanical strength of stainless steel, in places where ordinary steel materials are used, materials with smaller diameters and thicknesses are used to reduce costs.

Using stainless steel of the correct quality is more efficient than alternative materials, regardless of the area of use. Although it is more expensive than steel in terms of price, it is a material that requires low maintenance, is cheap, easy to maintain, long-lasting and durable. The overall cost of life is low, so stainless steel is more economical than carbon steel in the long run. The fact that stainless steel is hygienic and easy to clean leads to this material frequently appearing in medical instruments, kitchen utensils, household goods, food and pharmaceuticals. Stainless steel is an indispensable and alternative material for these types of sectors. Stainless steel comes with many different surface options. The aesthetic appearance of these surfaces and their easy maintenance are preferred over alternative materials. Stainless steel materials can be processed as stones, polished, satin and glossy. Certain grades of stainless steel can be polished to a mirror shine. A patterned surface can be given to stainless steel materials. With these features, stainless steel appears in every area of decoration. Stainless steel is an environmentally friendly material and is completely recyclable.

2. Types of stainless steel

2.1 Austenitic stainless steel

Austenitic stainless steel is a chemical corrosion (corrosion) and high temperature resistant material that contains at least 10.5% to 26% chromium (Cr) in its alloy,and nickel (Ni) in amounts ranging from 8% to 36% at least. Nickel (Ni) makes the steel structure completely austenitic. Nickel (Ni) gives ductility, the ability to work in a wide temperature range and good weldability.

Fig1.shows Austenitic stainless steel

It has no magnetic properties. These alloys have excellent formability, corrosion resistance and weldability. Due to the low carbon (C) they contain, they cannot be subjected to heat treatment. The most popular and used grades of stainless steel are in this group. It is the richest group in terms of the number of quality and proportion of alloying elements. AISI 304 is the most widely used type of stainless steel.

2.2 Martensitic Stainless Steel

Martensitic stainless steel contains between 12.5 to 18% chromium (Cr) and 0.10 to 1% carbon (C). These alloys can be used in a wide range, and can be heat treated to achieve high hardness levels. The entire martensitic group is magnetic. AISI 420 quality is the most widely used quality of the group. Almost all martensitic groups, except AISI 410, can be hardened by heat treatment. Hardening feature of martensitic group. Ideal for use in places where high fatigue resistance is required.

The lowest carbon content is found in AISI 410 quality and this is rarely found in our country, only in sheet form. AISI 431 quality is increasingly preferred due to the improved corrosion resistance thanks to the addition of nickel. It is also possible to harden this quality by heat treatment. After heat treatment, they can obtain hardness degrees from 45 to 60 Rockwell.

2.3 Duplex stainless steel

The microstructure of duplex stainless steel consists of a mixture of austenite and ferritin. It is a steel containing 16% to 28% high chromium (Cr), 4.5 to 8% medium amount of nickel (Ni), 2.5 to 5% molybdenum. The most commonly used qualities in the duplex group are 1.4462 and 1.4362.

Fig2.shows duplex stainless steel

Due to its internal structure, it has good strength and good corrosion resistance at the same time. The nickel (Ni) content in it is at most 8% and this proportion is not enough to completely form the internal structure of austenite. This group of high-alloy stainless steels, which consists of approximately equal amounts of two phases of ferrite and austenite, is called duplex. At the same time, both are ferritic and have an austenitic structure. They maintain magnetism and provide high mechanical properties and high corrosion resistance. Tensile corrosion resistance is very high. It has higher mechanical strength than austenitic and ferritic steels. It has high molybdenum content. It provides longer durability than 316 series in acidic and marine environments. It has better tensile corrosion resistance than austenitic and better tensile strength than ferritic.

3. Stainless Steel Reinforcement

3.1 Heat treatment of martensitic stainless steel

The heat treatment of stainless steel strip is to eliminate the work hardening after cold rolling, so that the finished stainless steel strip can achieve the specified mechanical properties.

In the production of stainless steel strip, the commonly used heat treatment methods are as follows:

(1) Quenching, for austenitic steel, austenitic stainless steel and martensitic, quenching is a softening heat treatment process.

In order to eliminate the effects of the hot rolling process, the hot rolled austenitic, austenitic and austenitic ferritic strip steel should be quenched. The quenching process is to heat the steel strip in a direct furnace first, and the heating temperature is generally 1050 ~ 1150 ° C, so that the carbides in the steel can be completely dissolved and a uniform austenite structure can be obtained. Then it is quickly cooled especially with water. If it is cooled slowly after heating, it is possible for carbides to precipitate from the solid solution in the temperature range of 900 ~ 450 ° C, which makes the stainless steel sensitive to intergranular corrosion.

The quenching of cold rolled stainless steel strip can be used as intermediate heat treatment or final heat treatment. As the final heat treatment, the heating temperature should be within 1100 ~ 1150 ° C.

(2) Cold rolled, annealed, martensitic, ferrite and martensitic ferrite steel coils need to be annealed. The annealing is carried out in an electrically heated furnace or a gas jacket furnace in air or in a protective gas. The annealing temperature of ferritic steel and martensitic steel is 750 ~ 900 â. Then the furnace is cooled or air cooled.

(3) Cold treatment. In order to greatly strengthen martensitic steel, ferritic martensitic steel and austenitic martensitic steel, cold treatment is required. Cold treatment is to immerse the cold rolled or heat treated stainless steel strip in a low temperature medium of -40 ~ -70 ° C, and let it stand at this temperature for a period of time. Strong quenching (below the martensite MS point) transforms austenite into martensite. After cold treatment to reduce internal stress, temper (or age) at 350~500°C. Liquid carbon dioxide, solid, liquid oxygen, liquid nitrogen or liquefied air are commonly used as cooling media.

The disadvantages of stainless steel strip heat treatment include:

(1) Gas corrosion is black dotted pits on the surface of the strip. If the residual emulsion, oil, salt, dirt, etc. on the surface of the strip are not cleaned, part or the entire surface of the strip will be corroded (stay in the furnace for a long time) by the gas. At high temperatures, the gas corrosion on the surface of the strip is more serious.

(2) High temperature, the surface of the strip turns dark brown when the temperature rises. Although the iron oxide scale on the surface falls off, it is not easy to clean by pickling. The reason for this defect is that the heating temperature of the metal is too high or the residence time in the furnace is too long. Excessive heat may cause intergranular corrosion.

(3) Overheating. When the temperature is high, the surface of the steel strip has a light gray metallic luster. The iron oxide scale is difficult to wash off during the pickling process, and the steel strip is gray after pickling. The reason for insufficient heating is that the heating temperature is low or the speed of the strip passing through the furnace is too fast.

(4) Damage to the gutter, which refers to the black dot-shaped pits that are easy to see on the lower surface of the steel strip after pickling. This defect is that there are small burrs on the working surface of the roller table, which will damage the surface of the strip. Therefore, the rollers in the furnace should be grounded and replaced regularly.

Table1.shows heat treatment methods

Heat treatment methods	Stainless steel grade 440C	416 grade stainless steel	420 grade stainless steel	Stainless steel grade 410	304 stainless steel	Stainless steel grade 17-4ph
Steel	✔	✔	✔	✔	✔	✕
Cooling	✔	✔	✔	✔	✕	✔
ventilation	✔	✔	✔	✔	✔	✔
normalization	✕	✕	✔	✕	✕	✕
getting older	✕	✕	✕	✕	✔	✕
Stress relief	✕	✕	✕	✔	✕	✕
Case stiffness	✕	✔	✕	✔	✕	✕
Solution Treatment	✕	✕	✕	✕	✔	✕
hardening of sediment	✕	✕	✕	✕	✕	✔
carbonation	✕	✕	✔	✕	✕	✕
Nitra	✕	✕	✕	✕	✔	✕
carbonate nitration	✕	✕	✕	✕	✕	✕
cryotherapy	✕	✕	✕	✕	✕	✕
induction hardening	✕	✕	✕	✕	✕	✕
thermal processing						

4. Conclusion

When we talk about materials with wide applications in construction, home, energy and architecture, one of the materials that comes to mind is stainless steel. There is no doubt that stainless steel has many applications in the modern world. Stainless steel is one of the common metals with various applications in many sectors. It has many properties that make it ideal for this purpose. For example, it is anti-rust and anti-stain. Stainless steel was obtained by mistake due to the addition of chromium to iron. By studying the properties of stainless steel and its strengthening mechanism, it was found that the best way to strengthen it is through heat treatment, which gives more resistance and stability.

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