IMPROVEMENT OF THE MECHANICAL PROPERTIES OF ALLOYS BASED ON REDUCTION OF NON-METALLIC ADDITIVES

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In production facilities based on foundry technologies and in laboratories equipped for scientific research, a lot of work is currently being carried out to reduce various endogenous and exogenous non-metallic inclusions in the alloy when liquefying steel alloys and preparing finished and semi-finished cast products of various sizes from them. Naturally, reducing non-metallic inclusions in cast products improves the mechanical properties of the alloy. In particular, it significantly affects the hardness and wear resistance of the alloy. The reduction of non-metallic inclusions in a steel alloy depends on various factors, such as the type of alloy, the production process and the use of inspection methods. Some common methods that help reduce non-metallic inclusions in a steel alloy are listed below.

- Improving the quality of raw materials, using high-quality raw materials with fewer non-metallic inclusions:
- Using a metallurgical process based on argon gas purification helps to remove slag and reduce the number of non-metallic inclusions in steel:
- Controlling the casting process, proper casting control is an important factor in minimizing the introduction of harmful particles:
- Vacuum degassing system helps to remove inclusions and reduce the amount of hydrogen in steel:
- Ultrasonic testing, The use of ultrasonic testing methods after the production process helps to identify and analyze inclusions in steel:.

By using the above methods or by developing new methods, steelmakers can reduce the amount of non-metallic inclusions in steel alloys and ensure that the resulting steel is of high quality with consistent properties. In addition to the elements that are essential to the chemical composition, unexpected and harmful elements are also present, which have been found to adversely affect some of the mechanical properties of the alloy. Non-metallic inclusions are usually added to the cast composition in various ways and are divided into two main groups according to their origin.

Non-metallic elements (such as S, P, O, N, H) can significantly degrade the mechanical and technological properties of steel. Below are the main harmful effects of common non-metallic impurities in steels:

Sulfur (S) - Causes hot shortness – brittleness during hot working. Leads to **cracks** during forging or rolling. Forms FeS (iron sulfide) at grain boundaries, which promotes brittleness. Permissible Content: Usually ≤ 0.05%, high-quality steels ≤ 0.01%.

Phosphorus (P) - Causes cold shortness – brittleness at low temperatures. Reduces ductility and impact toughness. Negatively affects weldability. Permissible Content: ≤ 0.03% or less.

Oxygen (O) - Forms oxides (e.g., FeO, MnO) at grain boundaries, which reduce toughness. Promotes micro-cracks and internal flaws in castings. Most problematic during casting processes.

Nitrogen (N) - Forms nitrides at grain boundaries, leading to brittleness. Can cause strain ageing embrittlement. In tool steels, excess nitrogen can deteriorate the microstructure. Permissible Content: ≤ 0.008–0.015% depending on steel type.

Hydrogen (H) - Causes hydrogen embrittlement. Accumulates at grain boundaries, resulting in microcracks. A common issue during welding processes. Permissible Content: Extremely low, in the ppm range.

Those that originate from the steelmaking process are classified as “endogenous” and those that originate from external sources (refractories, slags, etc.) are classified as “exogenous”. In rare cases, exogenous inclusions do not react with the alloy for a sufficient amount of time in the steel, and thus significant levels of non-metals can be observed.

Steels are alloyed with suitable alloying elements such as Mn, Cr, Mo, V, Ti, Nb, Al and Ni, which provide the steel with the required mechanical properties and the required structure. This, in turn, affects mechanical properties such as hardness, ductility and wear resistance. It is widely recognized that non-metallic inclusions are the main elements present in ferroalloys. When ferroalloys are added to a steel alloy, they undergo a number of physical and chemical processes. Some of the inclusions in ferroalloys are poorly soluble and are removed to the surface of the alloy with slag, some are partially or completely dissolved in the steel, some react with other inclusions or elements to form new complex non-metallic inclusions, and some remain solid and act as nucleation sites or they collide with each other to form clusters. In addition, after adding ferroalloys to steel, inclusions are formed in areas with high concentrations of alloying elements and oxygen, and their behavior is affected by a number of factors, such as temperature, chemical composition of the steel, oxygen content, deoxidation process, residence time in the alloy, activity of the elements, inclusions, etc.

In the traditional case, harmful elements (P and S) are usually removed from the slag by adding Ca to the alloy, but by using various modifiers and changes in the processes of adding them to the alloy, the reduction of non-metals can be improved by several percent. Thus, by reducing non-metals in the alloy based on the application of proven and modern

technologies, it is possible to improve its various mechanical properties and increase the efficiency of cast products.

References

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