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Effect of Rare Earth Ce on Inclusions in Q345 Steel

Shiyao Han

School of Metallurgical and Ecological Engineering, University of Science and Technology Beijing, Beijing, 100083, China

Abstract: *Q345 steel is an important raw material for the production of suspension spring steel and valve spring steel. Improving its comprehensive mechanical properties and fatigue resistance and ensuring the production continuity of Q345 steel is a topic of general concern in the industry. The addition of rare earth can effectively control the number, size, morphology, composition and distribution of inclusions in Q345 steel, which is of great significance for improving the quality of Q345 steel. However, at present, the addition process of rare earth Ce in the production process of 55SiCr spring steel is faced with problems such as low yield and difficult continuous production of Shuikou nodules and blockage. However, adding rare earth slag to refining slag is an effective solution to improve the yield of rare earth Ce. However, there is still a lack of research in this direction in the industry. In order to improve the yield of rare earth Ce, determine the ratio of rare earth refining slag and achieve the best metallurgical effect, it is the main research direction of this project.*

Keywords: *Rare earth steel; Inclusion; Refining slag*

1. Introduction

Spring steel is in a special heat treatment process, due to the steel produces a certain elasticity, and specially used for the production of spring and elastic elements. Spring steel is widely used in transportation, machinery manufacturing, instruments and electronic accessories [1]. 55SiCr is a classic silicon chromium series spring steel, mainly used in the production of automotive suspension spring steel, valve spring steel. Long-term in alternating, torsion, mutation state and high temperature, may contact with corrosive medium service conditions [2], 55SiCr spring steel comprehensive mechanical properties and elastic resistance, corrosion resistance and fatigue resistance put forward strict requirements. This requires the spring steel to have excellent metallurgical quality: high cleanliness, good uniformity, dense organization, good surface quality control, etc., which is undoubtedly a challenge to the development of spring steel production process.

2. Q345 inclusion in steel brief introduction

The inclusions in steel have always been one of the main factors affecting the comprehensive mechanical properties of steel and reducing the quality of steel materials. In recent years, rare earth by virtue of its chemical activity and strong deoxygenation capacity, rare earth treatment process has become one of the important means of inclusion control in the industry in recent years.

In recent studies, rare earth has modified modified on modified been rich. A large number of studies have found that rare earth can effectively change the morphology and size of the inclusions, so as to improve the comprehensive performance of steel in many aspects.

Ren Hongru studied the influence of rare earth on the cleanliness, tissue and mechanical properties of Q345H steel. It is found that rare earth deoxygenation and desulfurization capacity are strong; MnS inclusion and Al2O3 inclusion can be changed into spherical or near spherical compound inclusion. It can effectively reduce the grain size and bead body sheet layer, improve the strength and toughness of Q345H steel, reduce the bending strength ratio, and improve the seismic performance of steel.

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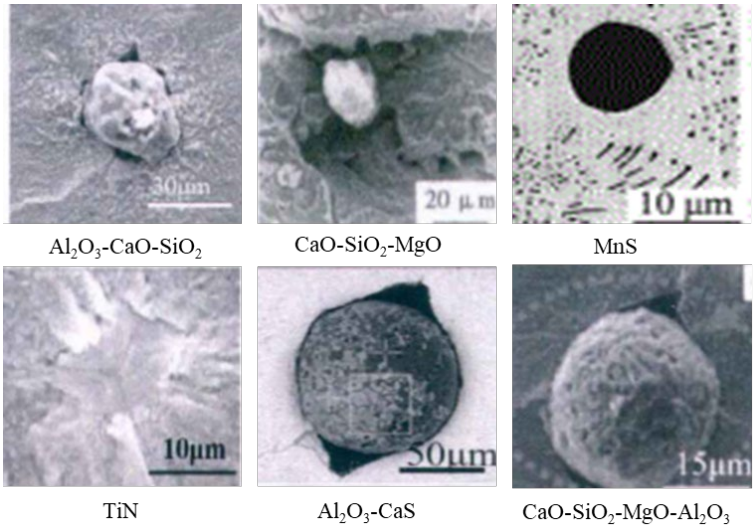

Figure 1: The morphology of the typical inclusion in several steels

The studied the influence of rare earth on the casting and rolling tissue of Q345B and the mechanical properties and impact toughness. It is found that the addition of rare earth elements can significantly improve the casting segregation of Q345B steel, improve the sharp impact work of Q345B hot rolled strip, improve the yield strength of Q345B hot rolled strip of about 20MPa, and the tensile strength of about 10MPa. At the same time, with the increase of intensity, the elongation rate also showed an increasing trend, and the average elongation rate increased from 24% to 31%.

Han Caixia found that rare earth on the one hand can change the shape of the crystal boundary inclusion in Q345 steel, making the inclusion from strip to ball, so as to improve the high temperature thermoplasticity of continuous casting billet. On the other hand, the rare earth element combines with S, and the high melting compound replaces MnS. At this time, the rare earth sulfide is favorable relative to the Mn-S compounds[3].

In the study of rare earth inclusions in rare earth Q345 steel, was found. Through the thermodynamic calculation, the main rare earth inclusions in Q345 steel exist in the form of Ce2O3, CeAlO3, Ce2O2S, and the nearly spherical rare earth inclusions can effectively improve the comprehensive performance of steel. However, a large number of experiments show that rare earth inclusions will also combine with Ca and other elements to produce multiple rare earth inclusions.

Due to the complex composition of rare earth inclusion, it is difficult to carry out thermodynamic calculation, and the mechanism of the formation of rare earth inclusion is not thorough, which has become one of the factors affecting the research of rare earth steel and restricting the development of rare earth steel. In this paper, Q345 steel with relatively pure composition was selected as the research material, take whether the rare earth is added as the variable, compare the generation of Q345 adding rare earth or not, combined with the factsage thermodynamic calculation and mismatch theory, and determine the formation mechanism and order of rare earth inclusion.

According to the deformation performance of rolling process, the inclusions can be divided into deformable plastic inclusion, brittle brittle inclusion and nondeformation inclusion without obvious change; according to inclusion size, the inclusions can be divided into micro inclusions with no harm to steel performance and macro inclusion to steel performance.

Different kinds of inclusions have different degrees of influence on the steel quality. For class A sulfide inclusion, the low melting point of FeS, is the main cause of steel. In order to eliminate its negative impact, it is a common method to add Mn to steel to form MnS with higher melting point. However, when the MnS MnS content exceeds a certain standard, cracks will result in the smelting production and rolling process; the welding performance of steel is affected in the welding process. However, MnS is better plastic, and it will deform along the rolling direction in the processing process of steel, which has a low impact on the performance of steel.

For class B inclusions, Al inclusions such as Al_2O_3 are mainly derived from a deoxy product of Al deoxy process. Al_2O_3 Class inclusion hardness is higher, belongs to the plastic inclusion, in the process of thermal processing, these plastic inclusion will form an irregular shape with edges and corners, scratch the surrounding steel matrix under the action of stress, and leave gaps or even cracks, resulting in stress

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concentration, the continuity of steel and fatigue performance caused great damage. In addition, Al_2O_3 inclusion will form a fatigue source under the action of long-term stress, produce fatigue cracks, and eventually make the work piece damage failure due to the expansion of fatigue cracks.

However, the inclusions are not completely harmful. For the inclusions such as TiN and VN, where their melting point is high,will be precipitated first in the condensation process of steel. If the small size can be controlled, and its uniform and dispersed distribution is guaranteed, this kind of inclusion will become the core center of steel, and make the steel be effectively enhanced by fine crystal reinforcement and precipitation reinforcement, so that the strength and comprehensive performance of steel are greatly improved. In addition, the use of this kind of inclusion of the strengthening effect, can make some steel to save part of the heat treatment link, so as to save resources, shorten the production time, so as to bring considerable economic benefits to the production enterprises.

3. Literature References

References are cited in the text just by square brackets [1]. (If square brackets are not available, slashes may be used instead. Two or more references at a time may be put in one set of brackets. The references are to be numbered in the order in which they are cited in the text and are to be listed at the end of the contribution under a heading References, see our example below[4].

Wilson et al. found that the free energy of rare earth oxide and rare earth sulfur oxide in steel is the least. In addition, the free energy of rare earth and As, Sn, Pb and C and N to form rare earth compounds is also small, indicating that rare earth may play a role in deoxygenation, desulfurization and removal of harmful impurities in steel.

Chen Fangming et al. found that the total oxide, sulfide and inclusion in rare earth treatment have decreased significantly. In addition, the fatigue life of steel has been significantly improved after rare earth treatment.

Yang Xiaohong et al. found that the addition of rare earth changed the long MnS and Al2O3 inclusions to circular and spindle shaped, which significantly improved the fatigue resistance of steel; Guo Fengfound that the addition of rare earth inclusion and changed to rare earth oxide, rare earth oxygen, sulfide and rare earth sulfide, and the rare earth inclusion was mainly spherical and oval, mass and long reduced.

Liu Chengjun et al. found that rare earth will form precipitate phase with C, N, H and Nb, Ti, V, and diffuse out in steel. In addition, the rare earth will also improve the casting organization, increase the isoaxial crystal rate, reduce and eliminate the columnar crystal, and reduce the dendrite segregation. In addition, the solubility of rare earth in steel is generally 10-5~10-6 order of magnitude, which also has a certain solid solution strengthening effect on steel. In addition, the solid solution amount of rare earth in steel is very small, mainly concentrated at the crystal boundary. A certain amount of rare earth can inhibit the precipitation of low melting point impurity elements such as, sulfur, arsenic, spread, secret, lead and tin in the grain boundary, or form compounds with high melting point with these elements to eliminate the harmful effects of these elements.

Li Gen et al. found that rare earth Ce can form fine high melting point particles with a diameter of less than 2 μ m in steel, and serve as the core center of steel to promote the liquid nucleus of steel, so that the grain size can be significantly refined.

In conclusion, the influence of rare earth on the inclusions in steel and steel is mainly reflected in the following aspects:

(1) Solid solution reinforcement and microalloying

The atomic radius of rare earth is greater than that of iron. When rare earth is consolidated in steel, it will change the phase change process of iron and improve the tissue, and affect the solubility of impurity elements and the desolvation amount is reduced. In addition, rare earth can form precipitation phase compounds with some elements in steel, and reinforce steel precipitation.

(2) Improve the grain boundary polarization

Some harmful elements in steel, such as As and Pb, have a low melting point and gather at the grain boundary during the cooling process of steel, which leads to quality problems such as thermal embrittlement of steel. Rare earth can be combined with harmful elements such as to reduce the aggregation of harmful elements on the grain boundary. In addition, rare earth will also occupy the grain

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boundary vacancy, so as to reduce the grain boundary energy and improve the grain boundary polarization.

(3) The modified inclusions

Rare earth can inclusion with steel, the shape of rare earth oxides, rare earth sulfide and trace Ca and MnS and Al2O3 as the core of composite inclusion, or generate spherical rare earth sulfide or sulfur oxide, reduce or completely replace the long strip inclusion, make the sulfide form to control, improve the plasticity of steel, especially the lateral impact direction, improve the anisotropy of steel.

(4) Purify the steel liquid

Rare earth has a strong binding force with oxygen, sulfur and other elements. Rare earth reacts with harmful elements such as oxygen and sulfur in the liquid steel to form inclusions, and then the inclusion gather and grow up and remove them from the liquid steel, so as to reduce harmful elements in steel.

(5) Refinement grains

The low melting point of rare earth makes the strong component supercooled element enriched in the liquid at the carbide crystallization edge through solute element redistribution during the solidification process, which improves the nucleation rate of carbide. At the same time, a large number of rare earth high melting compounds and the inclusion formed by S and O can be used as the crystal core substrate of primary carbide to form heterocrystal cores, which can increase the number of crystal cores and further refine the grains.

(6) Improve the corrosion resistance

Rare earth can denatured inclusion to reduce the electrode potential difference between it and the matrix and avoid spot corrosion; rare earth bias at the interface, including grain boundary, phase boundary and free surface, reduce the interface energy and avoid local corrosion; stabilize and compact surface rust layer organization, effectively reduce the corrosion rate[5].

4. Summary

To sum up, the effect of rare earth on steel is very obvious, which has a positive impact on the comprehensive mechanical properties, fatigue resistance and corrosion resistance of steel. The improvement of these properties is particularly critical for 55SiCr spring steel. However, in the production of rare earth steel, it is faced with the low yield of rare earth, the excessive addition of rare earth affects the quality of finished products, and the Shuikou nodules caused by the high viscosity of rare earth slag, which brings certain challenges to the continuous production and quality control of rare earth steel. Therefore, it is the key topic in the production of rare earth steel to determine the appropriate rare earth addition method, improve the yield of rare earth, and determine the appropriate amount of rare earth added.

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