Study on the organization and properties of medium-Mn steel with V

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Abstract: V is an important strengthening element in alloy steels, and its addition to the steel significantly improves the overall performance of the material. This paper describes the principle of V for optimizing the properties of medium-Mn steels. The excellent properties of V-containing Mn steels and their applications in practical industrial production are presented.

Key words: Medium-Mn Steel, V, Organization, Properties.

1. Introduction

Medium-Mn steels are mainly characterized by a low carbon medium alloy with a manganese content maintained between 3% ~ 12%[1]. Compared to the previous high-strength steel, the content of alloying elements has been reduced, so the cost has dropped significantly. Both C and Mn are the main strongly austenitic stabilizing elements in steel, and they significantly enlarge the austenite region, lower the A1 and A3 lines, and reduce the austenite transformation temperature, thus acting as grain refinement [2]. Among them, Mn can reduce the critical quenching rate of steel and improve the hardenability of steel[3]. At the same time, it can make the organization of the steel fine and uniform, and avoid the carbide agglomerates in the carburized layer. However, if the Mn content is too high, it will affect the welding performance of the material and thus have an impact on the safety of the steel structure. The composition of low-carbon medium manganese steel is designed so that the steel can be weldable and tough on the basis of maintaining high strength, which is beneficial to the application of the material in actual production.

In recent years, medium manganese steels have become the mainstay of the third generation of automotive steels by modifying them in different degrees and in different ways[4]. Professor Morris[5] in the USA studied that high strength plasticity can be obtained in mild steel by modulating its organization to ultrafine grain ferrite and austenite. In 2007, a researcher added "reverse-transformation austenite" to a steel containing about 6 wt.% Mn to further develop the properties of medium manganese steels. With the further research on the modification of medium manganese steel, its excellent performance is receiving more and more extensive attention. With the rapid development of China's further economic construction, the ship and marine industries are now ushering in the rapid development, and the further development of the marine industry for the requirements of ship and marine engineering steel has also increased. The ocean is a very harsh corrosive environment for various materials, and the sea water itself is a strong electrolyte. The content of atmospheric moisture and sodium chloride in the marine environment is very high, coupled with the influence of sunlight, sea breeze, including environmental temperature and humidity, will form a very harsh corrosive environment[6-11]. Due to the high concentration of sodium chloride and through the collaboration of various factors, a corrosive water film will adhere to the steel surface, and some highly corrosive substances in the environment will also be incorporated into the water film[12,13], further enhancing the corrosiveness and causing further damage to the steel, resulting in a corrosion failure situation. The medium-Mn steel can give full play to its excellent mechanical properties as a steel for marine engineering, while its corrosion resistance needs to be studied.

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Alloying elements can improve the properties of metals to varying degrees. Mn is good for enhancing the strength of the steel, but the large amount of Mn will lead to the formation of a large amount of Mn-rich compounds on the surface of the rust layer of medium manganese steel after corrosion[14], which is not conducive to the corrosion resistance of the steel itself, and the addition of other corrosion-resistant alloying elements will improve this problem. Among the alloying elements, Cr, Ni, Cu, V, etc. can improve the corrosion resistance of the material, and adding such elements to Mn steels will improve the corrosion resistance of Mn steels from the perspective of composition, and to maintain the mechanical properties of the material itself.V can refine the grain and improve the strength, toughness and welding properties. If it is present in the form of carbide, it reduces its hardenability. Tarek[15] developed a medium manganese steel containing Cr-Ni-V-Cu and investigated its corrosion resistance. A manganese steel exhibiting high corrosion resistance and excellent strength and good plastic toughness was obtained by the development of medium manganese steel alloying. Among the alloying elements mentioned above, N plays a role in enhancing pitting resistance in addition to the addition of Cr to obtain the expected high corrosion resistance, and the V alloy can enhance the denseness of the rust layer by refining the grain[16,17]. Grain refinement will contribute to a denser rust layer after corrosion, and a dense rust layer will give better protection to the substrate, thus enhancing the corrosion resistance of Mn steels[18,19].

In this paper, the organization and properties of manganese steels containing V are investigated.

2. The role of element V in medium-Mn steel

Adding V to medium manganese steel will form the intermediate phase VC[4]. When the N content in the steel is low, VC has a high solubility in austenite, usually at 1000 °C. When the austenitic phase ferrite transforms, VC tends to precipitate in the interphase and strengthen the steel at the same time. The precipitated VC phase is distributed linearly at the phase boundaries, and these lines are almost in parallel distribution. In addition to the strengthening effect of precipitation, there is a role in this process to optimize the steel properties by increasing the density of the precipitated phase through grain refinement. Fine-grain strengthening and precipitation strengthening are the main toughening modes of V alloying. Haiping Wu[20] found through their study that the addition of V with a mass fraction of 0.1-0.2% to medium-Mn steel resulted in less wear than high manganese steel at lower impact loads.

The VC precipitated in V-containing manganese steel is not only uniformly distributed in the austenite matrix in a large number of fine particles, but also has the presence of some large particles. VC is an important V alloy additive that can effectively improve the performance of steel. Adding it to medium manganese steel can not only improve the strength and toughness of steel, but also make steel with good weld ability, eliminate inclusions in steel extension and other effects.

3. Effect of V on the properties of medium-Mn steel

V is an important strengthening element in alloy steel[21]. The nature of VC formed by solidification in V-containing Mn steels is very stable, difficult to dissolve, hard and high melting point, uniformly distributed on the matrix tissue, and has a very obvious strengthening effect on Mn steels.Shizhong Wei[22] found that the vanadium to the carbon ratio and absolute content have an important effect on the morphology of vanadium carbide. Xiaoqin Cha[23] investigated the effect of vanadium on the fatigue properties of 38MnS steel using bending fatigue experiments in the hot forged and annealed states. It was shown that the fatigue resistance of 38MnS steel was effectively enhanced due to the addition of V.

VC is a refractory second phase particle, and it is difficult to dissolve completely in the austenite of medium manganese steel during solid solution treatment. The precipitation of vanadium-carbon compounds along the grain boundaries will effectively organize the grain boundary diffusion, thus acting to inhibit the grain boundary movement. This leads to the austenite grain growth received to prevent, will play a fine crystal strengthening effect on the medium manganese steel, improve the strength and toughness of the steel.

VC is extremely hard (2650 HV) and also has a high melting point, which when present in steel as second-phase particles not only increases the overall hardness of the steel, but also significantly improves the wear resistance of the steel[24]. Due to the unique properties of VC, V is considered to be one of the most significant alloying elements affecting the wear resistance of steel.

In the medium-Mn steel matrix, VC is uniformly and diffusely distributed in the tissue, which increases the overall deformation resistance of the tissue of the matrix, thus improving the yield strength of the material. In addition, it also improves the work-hardening ability of the medium manganese steel under stress, which enhances the overall performance of the material and enhances the wear resistance. Among the alloying elements, the effect of V on the yield strength of medium manganese steel is the most significant[25].

4. Conclusion

The presence of many VC particles, which are nano-sized particles and are uniformly distributed throughout the structure of Mn steels, can significantly improve the hardness and fracture toughness of the base alloy. VC is considered to be the alloying element with the greatest influence on the wear resistance and yield strength of steel. In summary, medium manganese steels containing V have better overall performance and can better cope with the actual production requirements.

Acknowledgments

Authors thank the foundation of Science and Technology research in Hebei Universities (ZD2018213), the Science and Technology Research and Development Projects of Handan City (19422111008-20) for the financial support of investigations.

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