Composition Analysis and Micro-Alloying Study of ZG25MnCrNi Casting Steel for Railway Wagon Bolsters and Side Frames

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Abstract: Due to the demand for high speed and heavy load, railroad wagons have increasingly stringent requirements for the reliability of vehicle structure materials. However, at present, there is a need to control the cost while obtaining enhanced performance of the material to meet the requirements of the service. This is an urgent problem in this field.Furthermore, there is a critical challenge in controlling the cost of the precursor in order to obtain a more excellent performance of the material to meet the service requirements. In this paper, we address the issue of the unclear composition of ZG25MnCrNi steel for railroad wagon rocker sidestands and the insufficient yield strength redundancy of this material. We employ a cluster composition analysis method to obtain the cluster formula of ZG25MnCrNi steel. This enables us to determine the precise composition of ZG25MnCrNi steel, which we then optimize through alloy reinforcement. This results in the production of new materials with enhanced performance. The new material with excellent performance was obtained through material preparation and analysis. The following results were obtained.

Keywords: ZG25MnCrNi; Cluster-plus-glue-atom Model; Mechanical properties; Microalloying; Microstructure

1 Introduction

The railroad wagon is a crucial component of cargo transportation. To meet the demands of high-speed and heavy loads, the standards for rolling stock reliability are becoming increasingly rigorous. The ZG25MnCrNi steel is utilized in railroad wagon bogies for the rocking pillow and sidestand, and it is essential to meet the heightened performance and reliability expectations. The domestic active rocker and sidestand are primarily constructed with B + steel, which is ZG25MnCrNi steel. This steel is required to have a yield strength greater than 345 MPa, and an impact absorption energy of at least 20 J when tested at -7 ℃. The main alloying elements for this steel are C, Si, Mn, Cr, and Ni. However, there is a serious shortage of domestic B + steel with the required yield strength, which presents a significant challenge for the active rocker and sidestand industry. The composition and organization of a material are closely related, with a change in composition resulting in a change in organization and performance. The current AAR M-201-05 "cast steel parts specification" of the standard only provides the range and carbon equivalent of the five major elements composing the material, namely C, Si, Cr, Mn, and Ni. The composition of CE and other alloying elements, such as Cr, Ni, Mo, and V, is based on the requirements of manufacturers. There is no calibration of the specific composition range, which leads to an inaccurate theory to guide the production of the target composition and the development of internal control standards. This results in fluctuations in material performance. It is therefore imperative to clarify the target composition of materials and internal control standards. Furthermore, it is well established that the addition of elements that can make steel microalloying in B+ alloy steel will result in significant changes to the microstructure and mechanical properties of B+ steel. One effective method to enhance the mechanical properties of ZG25MnCrNi for sidestand is to employ microalloying techniques.

ZG25MnCrNi steel is suitable for use in railroad wagon bogie rocker sidestands, with a carbon content of approximately 0.25 wt.%, and a high-temperature single-phase austenitic structure. This composition will satisfy the specific composition formula. Consequently, this paper will apply the cluster composition design method to analyze the compositional law of alloyed ZG25MnCrNi steel from the perspective of the chemical proximity program. This will entail the summary of its cluster formula and the sorting out of the role of elements Ti, Mo, V and other alloying elements in the steel. The microalloyed composition of ZG25MnCrNi steel will be analyzed using the "cluster plus connected atom model." The microalloying composition analysis involves the replacement of other elements in the cluster with Ti, Mo, and V microalloying elements. This process optimizes the composition of ZG25MnCrNi steel, resulting in enhanced grain refinement and superior performance.

2 Experimental procedure

The optimized and microalloyed compositions of ZG25MnCrNi steel, were prepared as specimens and subjected to testing and analysis. The specimens were prepared by melting in an electric arc furnace and a vacuum induction melting furnace. The as-cast samples were subjected to a normalizing heat treatment with a holding time of 900 °C for 3.5 hours. The microstructure of the samples was observed using a Leica DMi8A inverted metallographic microscope, a Zeiss SUPRA 55 field emission scanning electron microscope, and a Hitachi H-800 transmission electron microscope, respectively. The hardness of the cast and heat-treated specimens was determined using a HBE-3000 micro-Vickers hardness tester with a pressure of 500 g and a holding time of 15 s. The stress-strain curves were measured using an MTS series C43 electronic universal testing machine. The experiment used a JB-300s Charpy impact test pendulum machine to measure the low temperature impact work at -7 ℃.

3 Result and discussion (Bold, 10 pt., Arial)

1. Compositional analysis of the ZG25MnCrNi steel

The optimized ZG25MnCrNi steel class molecular composition formula for the C3Fe250Ni0.5Mn2.5Cr1Al0.25Si1.75, The composition of the alloy is 0.25C-97.82Fe-0.21Ni-0.96Mn-0.36Cr-0.05Al-0.35Si. The footnote of the element symbols indicates the corresponding atomic number, while the number before the element symbol indicates the corresponding mass percentage.

2.Result of Experimental

The refinement of microalloying elements, including grain refinement and pearlite lamellar refinement, has led to a significant improvement in the material's performance. The yield strength of tensile parts has increased significantly, up to 380 MPa, compared to the standard parts, which have been enhanced with Ti, Mo, and V elements. The tensile ratio of the parts has also been improved, reaching up to 28% and 29% with Ti and V elements, respectively, while the addition of Mo elements has resulted in a lower tensile ratio of 19%. Furthermore, the impact work at -7 ℃ has been enhanced, reaching up to 80 J, which is much higher than the standard. The tensile ratio of the parts after the addition of Ti and V elements is up to 28% and 29%, respectively, while that of the Mo elements is only 19%, which is below the standard of 24%. Furthermore, the impact work at -7 ℃ is up to 80 J, which is considerably higher than that of the standard. Following the addition of Ti and V elements, the tensile ratio can reach 28% and 29%, respectively. However, the addition of Mo elements results in a tensile ratio of only 19%, which is below the standard of 24%. Furthermore, the impact work at -7 ℃ can reach 80 J, which is significantly higher than the standard of 20 J. The tensile ratio at a temperature of -7 ℃ can reach 80 J, which is considerably higher than the standard of 20 J. Similarly, the sectional shrinkage can be as high as 73%, which is much higher than the standard of 36%..

Table 1 Comparison of properties of ZG25MnCrNi(B+) steel

Steels	R_m/MPa	R_{sl}MPa	A_{50}/%	Z/%	R_{el}/MPa
ZG25	≥450	≥230	≥22	≥32	≥25
B	≥485	≥260	≥24	≥36	≥20(-7℃)
B+	≥550	≥345	≥24	≥36	≥20(-7℃)
C	≥620	≥415	≥22	≥32	≥20(-18℃)
Sample of B+	613±4	358±12	27.3±1.1	64.5±0.9	27.5±3.5
optimized	573±5	359±10	28.1±1.0	67.7±1.2	39.5±7.7
With Ti	609±3	380±9	28.6±0.9	69.8±3.6	77.5±2.1
With Mo	590±10	388±12	19.1±4.5	60.9±3.7	41.5±10.6
With V	620±8	379±10	29.4±0.5	73.7±3.5	82.5±3.5