Short Communication

Differential scanning calorimetry analysis on Cu precipitation in a high Cu austenitic stainless steel

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ABSTRACT

The Cu precipitation in a high Cu austenitic antibacterial stainless steel (3.8–5.0% Cu) was studied by using differential scanning calorimetry (DSC) analysis. The results indicated that DSC analysis could be used to detect the Cu precipitation in the experimental steel with different Cu additions. Two stages of precipitation were identified in the steel by DSC analysis, clustering of Cu-rich phases and dissolution/coarsening of the precipitates formed at the first stage. DSC analyses also showed that with increase of the Cu content in the steel, the start temperature of Cu precipitation was decreased and the peak area of Cu precipitation was enlarged. The activation energy for Cu precipitation in the steel was determined to be 181 kJ/mol, indicating that the process should be mainly related to the diffusion of Cu atoms in the steel.

1. Introduction

Copper (Cu) can be taken as an alloying element to add into steels to improve their mechanical properties and corrosion resistances as well as the cold form abilities [1–3]. Through adding proper amount of Cu element, tiny Cu-rich phase precipitates with nano-meters sizes could be formed in the steels, which should be responsible for the strength increase of the steels, even could offer an antibacterial function for stainless steels [4]. Therefore it can have significant importance to systematically study the process of Cu precipitation in the steels by different sensitive techniques of materials analyses, in order to provide more detailed information in different aspects for further development of the Cu-bearing steels. The study is especially meaningful for the antibacterial stainless steels, as the Cu precipitation plays the key role in producing the unique antibacterial functions.

Differential scanning calorimetry (DSC) is a widely used materials analysis technique that is sensitive to formation of the second phases in alloys. Recent studies have shown that DSC analysis could give both qualitative and quantitative descriptions of the precipitated phases in the studied alloys, for instance, volume fraction of the precipitates and the precipitation kinetics could also be deduced from the DSC scans. Additional structural information, particularly the size of the precipitates, may be obtainable from

the kinetic analysis by DSC analysis on the order of the reaction and the activation energy associated with the individual transformation. A major portion of the kinetic data could be obtained from the shift of the peak precipitation temperature with change of the heating rate in the non-isothermal DSC scans [1]. DSC analysis has been well used for study of nonferrous alloys with second phase hardening, such as aluminum alloys and magnesium alloys [5,6]. However, studies on the Cu precipitation in stainless steels by DSC analysis, especially on the antibacterial stainless steels with higher Cu content, are still limited.

In the present work, the Cu precipitation process in a Cu-bearing austenitic antibacterial stainless steel with different and relatively higher Cu content was studied using DSC analysis technique, focusing on the sequence of the Cu precipitation as well as the activation energy for precipitation, supplemented with transmission electron microscopy (TEM), in order to provide some additional information of Cu precipitation process in such type of steels and make a meaningful application of DSC technique in steels research.

2. Materials and experiments

2.1. Materials

The material used in this study was a newly designed type 317L Cu-bearing austenitic antibacterial stainless steel with following nominal chemical compositions (wt.%): Cr19, Ni13, Mo3.5, Fe in balance and different Cu additions of 3.8, 4.0, 4.5 and 5.0. The experimental steel was solution treated at 1040 °C for 0.5 h and then water quenched, in order to reach an over saturation of Cu in the steel matrix that could precipitate during followed aging

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