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EFFECT OF SIGMA PHASE PRECIPITATION ON THE MECHANICAL PROPERTIES OF Z3CN20.09M STAINLESS STEEL USED FOR PRIMARY COOLANT PIPES OF NUCLEAR POWER PLANT

Bin Yang[1,2(*)], Yongqiang Wang[2], Jun Han[3], Huanchun Wu[2]
[1]Collaborative Innovation Center of Steel Technology, U. of Sci. and Tech. Beijing, Beijing 100083, China
[2]State Key Laboratory for Advanced Metals and Materials, U. of Sci. and Tech. Beijing, Beijing 100083, China
[(*)]*Email:* byang@ustb.edu.cn

ABSTRACT

The content of the phase precipitated in the Z3CN20.09M cast austenite stainless steel (CASS) was calculated by Image-pro Plus 6.0 software. And then a time-temperature-precipitation diagram for the phase was got. The results showed that the σ phase was precipitated in the steel during 600-840°C. The fastest precipitation velocity for the phase occurs at 750℃. Moreover, the σ phase formed in the ferrite by the following process $\alpha \rightarrow M_{23}C_6+\gamma_2$ and/or $\alpha \rightarrow \sigma+\gamma_2$. The results also showed that the yield and ultimate tensile strengths of aged specimens increased comparing with those of the unaged ones. It was found that the increase of the strengths is due to the hard and brittle $(\sigma+\gamma_2)$ structure which decomposed from α phase in the steel.

Keywords: cast duplex stainless steel, sigma phase, mechanical properties.

INTRODUCTION

Duplex stainless steels (DSSs) would suffer a loss of toughness and deterioration in corrosion resistance when they are exposed to the temperature region between 600 and 1000℃. The main reason is some undesirable phases, such as Sigma (σ), carbides and nitrides precipitate in DSSs in this case. Among all phases precipitated in a DSS, the harmfulness of Sigma phase on the mechanical and corrosion resistance properties of the DSS is the most prominent. There is very little information available on the precipitation of Sigma phase and its effect on the mechanical, corrosion resistance and wear properties of the Z3CN20.09M CDSS. The aim of this work is to elucidate the precipitation behavior of Sigma phase in a Z3CN20.09M CDSS and to investigate its influence on the mechanical property of the steel.

The specimens with diameter of 16 mm and length of 4 mm were isothermally aged from 550°C to 950°C at intervals of 50°C and then quenched by water. The aging periods were less than 5 min for every chosen temperature mentioned above. A liquid salt bath was used to guarantee rapid heating during the aging process. The microstructures and fracture micrographs of specimens were observed by CIKONG 4XCE optical microscopy (OM) and ZEISS SUPRA55 scanning electron microscopy (SEM) respectively. The precipitates in this steel were detected by JEOL JEM-2010 transmission electron microscopy (TEM). Volume fractions of precipitates and ferrite phase in the samples were obtained through the quantitative metallography analysis software (Image-Pro Plus).

Cylindrical specimens with diameter of 5 mm and gage length of 25 mm were machined for tensile tests. The tensile tests were carried out in a CMT 4105 servo-hydraulic testing machine with a maximum load of 100 kN at an engineering strain rate of 1×10^{-3} s^{-1}. The Charpy impact with a gauge cross-section of 10 mm × 10 mm and a gauge length of 55 mm tests were carried out at room temperature by using JB-30B impact machine with a maximum capacity of 300 J. The hardness–and micro-hardness of the ferrite and austenite in the specimens were measured in XHV-1000 hardness and 401MVD microhardness instrument respectively.

RESULTS AND CONCLUSIONS

The tensile strength (TS, R_m), yield strength (YS, $R_{p0.2}$) and ductility (in terms of percent elongation) *versus* aging time for all tested specimens are shown in Fig. 1. The TS and YS of aged specimens dropped with the increase of aging time at 700°C until 4 h comparing with those of un-aged ones. However, the TS and YS of specimens aged from 10 to 24 h increased markedly, as well as the ductility increased initially and reached a peak value at 4h and then reduced with increasing of aging time from 10 to 24 h. The result is different from the general law in which the TS and YS of DSS increase with increasing aging time.

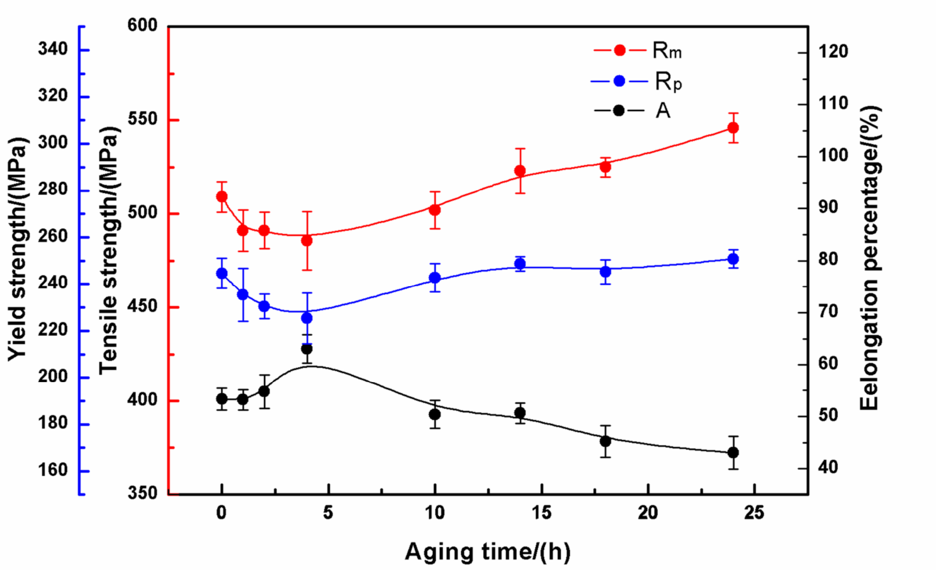

Fig. 1 - Tensile strength, yield strength and elongation of the specimens aged at 700°C for different times from 1 to 24 h

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