INFLUENCE OF THE HEAT TREATMENT ON THE FRACTURE TOUGHNESS OF A DUPLEX STAINLESS STEEL

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The effect of different heat treatments on the fracture toughness of a duplex stainless steel has been studied. An important loss of toughness has been detected in the temperature range between 675 and 900ºC, being maximum in the samples treated at 825ºC; sigma phase precipitation is considered to be responsible for this embrittlement.

INTRODUCTION

As its name implies a duplex austenoferritic stainless steel is one which contains two primary phases; austenite and ferrite. These phases are usually established by hot working in the two phases region. However, neither the austenite nor the ferrite are completely stable and their decomposition creates still more possible microstructures (1). The aim of the present work is to investigate the effect of different heat treatments on the fracture toughness of a duplex stainless plate.

EXPERIMENTAL PROCEDURE

The material used for this study was a duplex stainless steel conforming to SA 240 type UNS 31803 (0.02C, 22Cr, 5Ni, 3Mo) in the form of 13.5 mm thick plate. Different samples of this material were heat treated in the temperature range between 475 and 1200ºC for a variety of times up to 25 h followed by air cooling. Phases present in the microstructures were identified by metallographic etching and confirmed by both EDS analysis in a scanning electron microscope and X-ray diffractometry.

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More detailed description of the technique used will be given in another paper (2). Fracture toughness characterization was carried out by means of CTOD tests of L-T specimens machined from the heat treated coupons. Fractographic analysis consisted of scanning electron microscopy of the fracture surface of each broken specimen.

RESULTS

Figure 1 shows the effect of the various heat treatments on fracture toughness. Those samples which were heat treated at temperatures above 1000ºC (no included in the graph) exhibit a very slight decrease in toughness. This is a good agreement with the metallographic analysis where no precipitation of carbides or intermetallic compounds was found. However, in those samples treated in the temperature range between 675 and 900ºC an important loss of toughness (up to 96% compared to the as-received material) has been detected. A similar behaviour in another duplex stainless steel has been reported in a previous paper based upon Charpy impact testing (3). The more pronounced effect has been observed in those coupons treated at 825ºC where a strong embrittlement is observed after 2 h of treatment. This loss of toughness is associated with sigma phase precipitation (fig. 2a) that precipitates after a period of time as short as 15 minutes at this temperature (4). Owing to the typical C curve precipitation of this phase the rate of formation at temperatures below 825ºC is lower and no evidence of sigma phase is detected in the samples treated for a short time at 675ºC (2). Nevertheless these samples exhibit a marked carbide precipitation (fig. 2b) which produces a certain embrittlement of the material although smaller than that found in the 825ºC specimens. It is necessary a much longer exposure time to precipitate sigma and/or chi phases (4) which produces an ulterior loss of toughness.

Samples heat treated at 475ºC for a short time possess a level of thoughness slightly lower to that in the as-received material. Nevertheless, when the heat treatment time is increased to 24 h an appreciable decrease in toughness is observed. This embrittlement is attributed to spinodal decomposition into an iron rich alpha phase and a chromium rich phase and formation of alpha prime in these last regions after a period of time (1).

The scanning electron microscopy observations of the broken specimens are consistent with the fracture tests results. As figure 3 shows a marked change in fracture topography is observed. These samples which remain near unaffected by the heat treatment exhibit the whole fracture surface covered by ductile dimples while elongated fissures associated with the brittle phases are present in the low toughness specimens. More detail on this fractographic study will be given in another paper (5).

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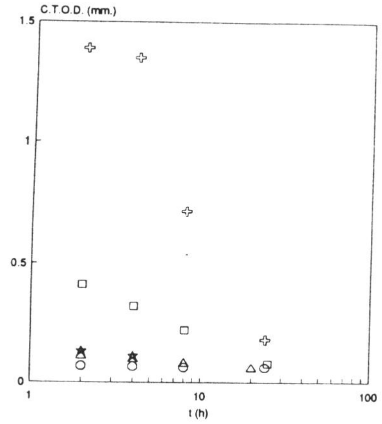

Fig.1. Effect of Heat Treatment on Fracture Toughness.

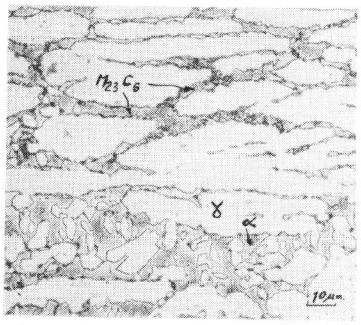

Fig.2a. Microstructure 675-2

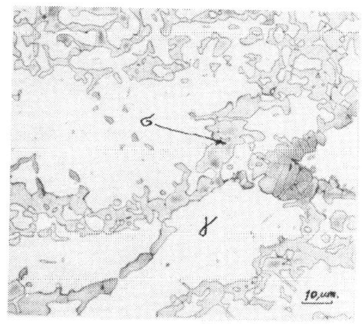

Fig.2b. Microstructure 825-24

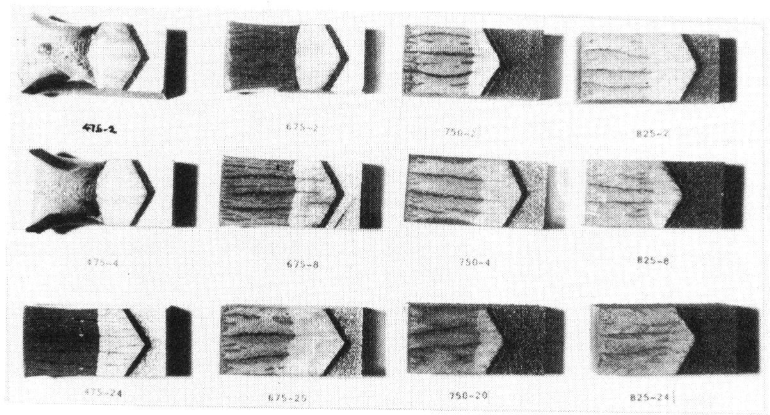

Fig.3. Change in Fracture Topography with Heat Treatment.