THE EFFECTS OF DEFORMATION (STRAIN) AND GRAIN SIZE ON CARBIDE PRECIPITATION AND SENSITIZATION BEHAVIOR IN 304 STAINLESS STEEL

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DEDICATION

To dedicate this thesis to solely one individual would be very selfish of me. Therefore, it is dedicated to the following:

- to Holy Name Cathedral School for taking me in when no one else would and for giving me a solid foundation.

- to Sister Mary Paulus for her faith, encouragement, patience, piano-playing, and mouth-washings with soap.

- to my Godchildren, Evelyn Franco and Jesus Manuel "Chuyito" Guzman, for bringing out the child in me every time.

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ABSTRACT

The simultaneous effects of strain and grain size on carbide precipitation and sensitization development in 304 stainless steel having a constant carbon composition of 0.051% were studied. Three different grain sized (150 μm, 40 μm, and 15 μm) materials uniaxially deformed to 10% and 20% strain and aged in the sensitization range of 625°C and 775°C were used in this investigation.

At 625°C, straining of the 150 μm grain size material produced a systematic increase in carbide precipitation, sensitization development, and desensitization. Such findings were confirmed by electrochemical potentiokinetic testing (EPR) which showed a higher degree of sensitization and faster healing in the 20% strained samples. Transmission electron microscope (TEM) micrographs revealed a greater continuity of carbides along the grain boundary in the 20% strained samples versus the unstrained samples. At the 15 μm grain size, these strain effects were found to reverse with the sensitization-desensitization process occurring much faster at the higher strain.

At 775°C, the results obtained for 150 μm and 15 μm grain size material were kinetically consistent with

those obtained at 625°C even though they appear to contradict each other. A higher aging temperature was found to also accelerate the sensitization-desensitization process for both grain sizes

(150 to 15 μm) especially at the smaller grain size. The addition of strain further accelerated this process.

Chromium diffusion kinetics play an important role in the sensitization-desensitization process. In the large grain size(150 μm) stainless steel, the kinetics are greatly influenced by matrix diffusion while at the small grain size(15 μm), grain boundary diffusion predominates. A log-log plot of the inverse of the sensitization-desensitization interval versus the inverse of the grain size showed that extrapolating the data yields an extremely short time for sensitization and desensitization to occur ($\approx 10^{-3}$ h) for a grain size of ≈ 0.1 μm. The convergence of the points on this graph suggest that there is no"classical" sensitization behavior at very small grain sizes(in the sub-micron range) since sensitization-desensitization becomes "instantaneous".

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INTRODUCTION

1.1 Overview

Many commmercial materials are subject to drastic changes when they undergo thermomechanical (TM) processing and fabrication treatments. These processes can have a profound effect on the microstructure of the material. Such microstructural characteristics include grain size, deformation, and chemical composition. Changing any of these variables is bound to produce a wide variety of material properties, some favorable and others not so favorable. Such parameters are extremely crucial in austenitic stainless steels since they are susceptible to intergranular corrosion (IG) and intergranular stress corrosion cracking (IGSCC) in certain aqueous environments.

IG and IGSCC in stainless steels occur because of the depletion of chromium in the grain boundary due to precipitation of chromium rich carbides ($Cr_{23}C_6$) on the grain boundary interface. This phenomenon is known as sensitization.