UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

HIGH STRENGTH, DUCTILE WIDE GAP BRAZE JOINTS FOR STATIONARY TURBINE COMPONENT REPAIRS

by

Warren Martin Andre Miglietti

Submitted in partial fulfillment of the requirements for the degree

Philosophiae Doctor

in the Faculty of Engineering, the Built Environment and Information Technology
University of Pretoria

April 2008

ABSTRACT

Wide cracks in land-based Ni- or Co-base superalloy turbine components are difficult to repair successfully using conventional welding or brazing techniques. This project examined the feasibility of liquid phase diffusion brazing using novel Ni- and Co-base braze alloys containing Hf or Zr as melt point depressant for the repair of wide cracks in turbine components. An optimized braze cycle was developed and the joints were evaluated using various metallographic techniques and mechanical tests (elevated temperature tensile tests, creep rupture tests and low cycle fatigue tests). Microstructural examination revealed the presence of Hf- or Zr-rich intermetallic phases (most likely Ni_7Hf_2 or Ni_5Zr) in Ni-base braze joints. These intermetallic compounds were, however, observed to be significantly softer than the boride phases routinely found in commercially available braze alloys with boron as melt point depressant. As a result, the novel wide gap brazed joints displayed excellent mechanical properties (ranging from 80% to 100% of the base metal's properties). The low cycle fatigue properties of wide gap braze joints performed using a combination of MarM247 superalloy powder and Ni-Cr-Hf or Ni-Cr-Zr braze filler metals were found to be superior to those of the widely used Ni-Cr-B braze filler metals. Wide gap braze repair of FSX-414 Co-base superalloy using novel MarM509/MarM509B and MarM509/Co-Hf braze alloys resulted in high temperature tensile properties equivalent to those of weld repairs in the same parent material (using Nozzalloy filler metal). The creep rupture and low cycle fatigue (LCF) properties of the braze joints were superior to those of welds performed using MarM918 filler metal.

TABLE OF CONTENTS

CHAPTER 10 - EXPERIMENT 8

CHARACTERIZATION OF THE MICROSTRUCTURE AND PROPERTIES OF HYPO-EUTECTIC Ni-Cr-Hf AND Ni-Cr-Hf-B ALLOYS

CHAPTER 11 - EXPERIMENT 9

MICROPROBE ANALYSIS OF INTERMETALLIC PHASES

CHAPTER 12 - EXPERIMENT 10

DEVELOPMENT OF COMPLEX Ni-Cr-Hf BRAZE ALLOYS

CHAPTER 13 - EXPERIMENT 11

CHARACTERIZATION OF THE MICROSTRUCTURE AND MECHANICAL PROPERTIES OF ADH BRAZE JOINTS IN FSX-414 COBALT-BASE SUPERALLOY NOZZLE SEGMENTS USING NOVEL BRAZE ALLOYS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

Thank you to my wife Portia who had to endure me working many weekends to undertake the experiments and write up the thesis. Thank you to Kevin Pelletier and Jan Williams of Dirats Laboratories for the Scanning Electron Microscope analyses and tensile/stress rupture testing, respectively. In addition thanks to the people at Metcut and Westmoreland for the low cycle fatigue testing. Thanks to Joe Foroughi of the M&P lab and Louis Peluso of GRC for help with the Electron Microprobe analyses and a tremendous thanks to Ann Ritter of GRC for the help in developing and analyzing the phases that formed in the hypo-eutectic alloys and for help in developing and characterizing the microstructures of novel "near-eutectic" braze alloys in the as-cast condition

Thank you also to Prof Lugscheider of the RWTH Institute in Aachen, Germany, for introducing me to the concept of using Hf as a melt point depressant in Ni-base braze filler alloys, and similarly thank you to Dr Khorunov of the Paton Institute in Kiev, Ukraine, for introducing me to the concept of using Zr as a melt point depressant in Ni-base braze filler alloys.