

7th International Symposium on SUPERALLOY 718 and DERIVATIVES 2010

**Pittsburgh, Pennsylvania, USA
10 – 13 October 2010**

Volume 1 of 2

Editors:

E. A. Ott

A. Banik

T. P. Gabb

X. Liu

G. P. Sjoberg

J. R. Groh

I. Dempster

R. Helmink

A. Mitchell

A. Wusatowska-Sarnek

ISBN: 978-1-61782-770-9

Printed from e-media with permission by:

Curran Associates, Inc.
57 Morehouse Lane
Red Hook, NY 12571



Some format issues inherent in the e-media version may also appear in this print version.

Copyright© (2010) by the Minerals, Metals & Materials Society
All rights reserved.

Printed by Curran Associates, Inc. (2011)

For permission requests, please contact John Wiley & Sons
at the address below.

John Wiley & Sons
111 River Street
Hoboken, NJ 07030-5774

Phone: (201) 748-6000
Fax: (201) 748-6088

info@wiley.com

Additional copies of this publication are available from:

Curran Associates, Inc.
57 Morehouse Lane
Red Hook, NY 12571 USA
Phone: 845-758-0400
Fax: 845-758-2633
Email: curran@proceedings.com
Web: www.proceedings.com

TABLE OF CONTENTS

7th International Symposium on Superalloy 718 and Derivatives

| | |
|----------------------------|----|
| Preface | x |
| Organizing Committee | xi |

Reception and Keynote Presentations

| | |
|--|---|
| Introducing New Materials into Aero Engines-Risks and Rewards, A Users Perspective | 3 |
| <i>M. Thomas, S. Murray, and D. Furrer</i> | |

| | |
|---|----|
| Superalloys, the Most Successful Alloy System of Modern Times-Past, Present, and Future | 13 |
| <i>A. Kracke</i> | |

Raw Materials and Casting Technology

| | |
|--|----|
| An Overview of SMPC Research Programs to Improve Remelt Ingot Quality..... | 53 |
| <i>R. Williamson</i> | |

| | |
|---|----|
| Considering the Solidification Structure of VAR Ingots in the Numerical Simulation of the Cogging Process | 65 |
| <i>J. Terhaar, J. Poppenhäuser, D. Bokelmann, H. Schafstall, and K. Kelkar</i> | |

| | |
|--|----|
| Solidification Front Tilt Angle Effect on Potential Nucleation Sites for Freckling in the Remelt of Ni-Base Superalloys | 79 |
| <i>J. Valdes, X. Liu, P. King, C. Cowen, and P. Jablonski</i> | |

| | |
|--|----|
| Assessment of Test Methods for Freckle Formation in Ni-base Superalloy Ingot | 95 |
| <i>K. Kajikawa, M. Tanaka, S. Suzuki, and H. Yamada</i> | |

| | |
|--|-----|
| Quantitative Characterization of Two-Stage Homogenization Treatment of Alloy 718 | 107 |
| <i>Z. Miao, A. Shan, W. Wang, J. Lu, W. Xu, and H. Song</i> | |

| | |
|--|-----|
| Casting Superalloys for Structural Applications..... | 117 |
| <i>G. Sjöberg</i> | |

| | |
|---|-----|
| Castability of 718Plus® Alloy for Structural Gas Turbine Engine Components | 131 |
| <i>B. Peterson, V. Krishnan, D. Brayshaw, R. Helmink, S. Oppenheimer, E. Ott, R. Benn, and M. Uchic</i> | |

| | |
|--|-----|
| Selection of Heat Treatment Parameters for a Cast Allvac 718Plus® Alloy..... | 147 |
| <i>O. Caballero, K. Celaya, T. Gomez-Acebo, and A. Lopez</i> | |

| | |
|-------------------------------------|-----|
| Primary Carbides in Alloy 718 | 161 |
| <i>A. Mitchell</i> | |

| | |
|--|-----|
| Application of Confocal Scanning Laser Microscope in Studying Solidification Behavior of Alloy 718 | 169 |
| <i>H. Song, Z. Miao, A. Shan, W. Xu, and J. Lu</i> | |

Wrought Processing and Alloy Development

| | |
|---|-----|
| Effect of Process Modeling on Product Quality of Superalloy Forgings..... | 183 |
| <i>M. Stockinger, M. Riedler, and D. Huber</i> | |
| Influence of Both γ Distribution and Grain Size on the Tensile Properties of Udimet 720Li At Room Temperature..... | 199 |
| <i>J. Vaunois, J. Cormier, P. Villechaise, A. Devaux, and B. Flageolet</i> | |
| Effect of Compound Jacketing Rolling on Microstructure and Mechanical Properties of Superalloy GH4720Li.... | 215 |
| <i>J. Qu, M. Wang, J. Dong, G. Wu, and J. Zhang</i> | |
| Properties of New C&W Superalloys for High Temperature Disk Applications | 223 |
| <i>A. Devaux, E. Georges, and P. Héritier</i> | |
| Manufacture and Property Evaluation of Super Alloy 44Ni-14Cr-1.8Nb-1.7Ti-1.5Mo-0.3V-Fe (Modified 706)-an Experience..... | 237 |
| <i>U. Gururaja, P. Sarkar, and M. Rao</i> | |
| Grain Boundary Engineering of Allvac 718Plus® for Aerospace Engine Applications | 243 |
| <i>P. Lin, V. Provenzano, G. Palumbo, T. Gabb, and J. Telesman</i> | |
| Grain Boundary Engineering the Mechanical Properties of Allvac 718Plus™ Superalloy | 255 |
| <i>T. Gabb, J. Telesman, A. Garg, P. Lin, V. Provenzano, R. Heard, and H. Miller</i> | |
| An Advanced Cast/Wrought Technology for GH720Li Alloy Disk from Fine Grain Ingot | 271 |
| <i>Y. Zhao, S. Fu, S. Zhang, X. Tang, N. Liu, and G. Zhang</i> | |
| Research on Inconel 718 Type Alloys with Improvement of Temperature Capability | 281 |
| <i>S. Fu, J. Dong, M. Zhang, N. Wang, and X. Xie</i> | |
| FE Simulation of Microstructure Evolution during Ring Rolling Process of INCONEL Alloy 783..... | 297 |
| <i>J. Yeom, E. Jung, J. Kim, J. Hong, N. Park, K. Kim, J. Lee, and S. Choi</i> | |
| Effect of Temperature and Strain during Forging on Subsequent Delta Phase Precipitation during Solution Annealing in ATI 718Plus® Alloy | 307 |
| <i>E. McDevitt</i> | |
| Toughness as a Function of Thermo-Mechanical Processing and Heat Treatment in 718Plus® Superalloy | 321 |
| <i>S. Oppenheimer, E. McDevitt, and W. Cao</i> | |
| Modeling the Hot Forging of Nickel-Based Superalloys: IN718 and Alloy 718Plus®..... | 331 |
| <i>E. Marin, D. Bammann, A. Brown, H. ElKadiri, R. Costley, P. Wang, and M. Horstemeyer</i> | |
| The Microstructure and Mechanical Properties of Inconel 718 Fine Grain Ring Forging | 343 |
| <i>Z. Wang, D. Zhou, Q. Deng, G. Chen, and W. Xie</i> | |
| Numerical Simulation of Hot Die Forging for IN 718 Disc | 351 |
| <i>X. Lu, J. Du, Q. Deng, G. Chen, and X. Liu</i> | |
| The Effect of Process-Route Variations on the Tensile Properties of Closed-Die Waspaloy forgings, via Statistical Modeling Techniques..... | 363 |
| <i>A. Latinwo, B. Wynne, and M. Rainforth</i> | |
| Microstructure and Properties of Fine Grain IN718 Alloy Bar Products Produced by Continuous Rolling | 371 |
| <i>G. Chen, Q. Wang, F. Liu, Z. Wang, J. Dong, and X. Xie</i> | |

| | |
|---|-----|
| Effect of Thermomechanical Working on the Microstructure and Mechanical Properties of Hot Pressed Superalloy Inconel 718..... | 383 |
| <i>A. Nowotnik, and J. Sieniawski</i> | |

Fabrication and Novel Production Technology and Development

| | |
|--|-----|
| An Overview of Ni Base Additive Fabrication Technologies for Aerospace Applications..... | 399 |
| <i>C. English, S. Tewari, and D. Abbott</i> | |
| Linear Friction Welding of Allvac® 718Plus® Superalloy..... | 413 |
| <i>K. Vishwakarma, O. Ojo, P. Wanjara, and M. Chaturvedi</i> | |
| Transient Liquid Phase Bonding of Newly Developed HAYNES 282 Superalloy | 427 |
| <i>A. Ghoneim, and O. Ojo</i> | |
| Investigation of Homogenization and its Influence on the Repair Welding of Cast Allvac 718Plus® | 439 |
| <i>J. Andersson, G. Sjöberg, and J. Larsson</i> | |
| Additively Manufactured INCONEL® Alloy 718 | 455 |
| <i>R. Benn, and R. Salva</i> | |
| Simulations of Temperatures, Residual Stresses, and Porosity Measurements in Spray Formed Super Alloys Tubes | 471 |
| <i>R. Ristau, A. Becker, V. Uhlenwinkel, and R. Kienzler</i> | |
| Flowforming of a Nickel Based Superalloy | 487 |
| <i>S. Rhodes, J. Valencia, J. Ryan, S. Stawarz, and C. Humiston</i> | |
| Clad Stainless Steels and High-Ni-Alloys for Welded Tube Application | 499 |
| <i>W. Bretz</i> | |
| Improved Superalloy Grinding Performance with Novel CBN Crystals..... | 509 |
| <i>S. Kompella, and K. Zhang</i> | |

Alloy Applications and Characterization

| | |
|---|-----|
| Additive Manufacturing for Superalloys-Producibility and Cost | 521 |
| <i>J. Moor, A. Debicci, B. Lagow, S. Tewari, and M. Kinsella</i> | |
| Hot Ductility Study of HAYNES® 282® Superalloy | 539 |
| <i>J. Andersson, G. Sjöberg, and M. Chaturvedi</i> | |
| The Creep and Fatigue Behavior of Haynes 282 at Elevated Temperatures | 555 |
| <i>S. Longanbach, and C. Boehlert</i> | |
| Effect of Microstructure on the High Temperature Fatigue Properties of Two Ni-based Superalloys..... | 559 |
| <i>G. Muralidharan, R. Battiste, E. Kenik, J. Bentley, and B. Bunting</i> | |
| Numerical Simulation of the Simultaneous Precipitation of δ and γ Phases in the Ni-Base Superalloy ATI Allvac® 718Plus® | 569 |
| <i>R. Radis, G. Zickler, M. Stockinger, C. Sommitsch, and E. Kozeschnik</i> | |
| Alloy 718 for Oilfield Applications..... | 579 |
| <i>J. deBarbadillo, and S. Mannan</i> | |

| | |
|--|-----|
| Characterization of Microstructures Containing Abnormal Grain Growth Zones in Alloy 718..... | 595 |
| <i>B. Flagelet, O. Yousfi, Y. Dahan, P. Villechaise, and J. Cormier</i> | |
| A TEM Study of Creep Deformation Mechanisms in Allvac 718Plus®..... | 607 |
| <i>R. Unocic, K. Unocic, R. Hayes, G. Daehn, and M. Mills</i> | |
| Effects of Al and Ti on Haynes 282 with Fixed Gamma Prime Content..... | 617 |
| <i>P. Jablonski, C. Cowen, and J. Hawk</i> | |
| Time-Temperature-Transformation Diagram of Alloy 945..... | 629 |
| <i>S. Mannan</i> | |
| Long Term Thermal Exposure of HAYNES 282 Alloy | 645 |
| <i>L. Pike</i> | |

Microstructure, Properties, and Characterization

| | |
|---|-----|
| Modeling and Simulation of Alloy 718 Microstructure and Mechanical Properties | 663 |
| <i>D. Furrer, R. Goetz, and G. Shen</i> | |
| Aging Effects on the γ' and γ'' Precipitates of Inconel 718 Superalloy | 679 |
| <i>H. Bor, C. Wei, H. Nguyen, A. Yeh, and C. Kuo</i> | |
| Overview on 718Plus® Assessment within VITAL R&D Project..... | 689 |
| <i>O. Ruiz, G. Sjoberg, and T. Gomez-Acebo</i> | |
| Hold-Time Fatigue Crack Growth of Allvac 718Plus®..... | 705 |
| <i>M. Hörnqvist, L. Viskari, K. Stiller, and G. Sjöberg</i> | |
| Atomic-Level Characterization of Grain-Boundary Segregation and Elemental Site-Location in Ni-Base Superalloy by Aberration-Corrected Scanning Transmission Electron Microscopy | 719 |
| <i>M. Watanabe</i> | |
| Effect of Nickel Content on Delta Solvus Temperature and Mechanical Properties of Alloy 718..... | 725 |
| <i>R. Frank, C. Roberts, and J. Zhang</i> | |
| Evolution of Delta Phase Microstructure in Alloy 718..... | 737 |
| <i>S. Mahadevan, S. Nalawade, J. Singh, A. Verma, B. Paul, and K. Ramaswamy</i> | |
| An Integrated Approach to Relate Hot Forging Process Controlled Microstructure of IN718 Aerospace Components to Fatigue Life | 751 |
| <i>M. Stoschka, M. Riedler, M. Stockinger, H. Maderbacher, and W. Eichlseder</i> | |
| The Effect of Primary γ' Distribution on Grain Growth Behavior of GH720Li Alloy | 767 |
| <i>M. Zhang, J. Dong, Z. Bi, Q. Yu, and Y. Zhang</i> | |
| Systematic Evaluation of Microstructural Effects on the Mechanical Properties of ATI 718Plus® Alloy | 781 |
| <i>R. Kearsey, J. Tsang, P. Au, S. Oppenheimer, and E. McDevitt</i> | |
| Microstructural Evolution of ATI718Plus® Contoured Rings When Exposed to Heat Treatment Procedures | 799 |
| <i>O. Covarrubias</i> | |
| Serrated Yielding in Alloy 718..... | 809 |
| <i>S. Nalawade, S. Mahadevan, J. Singh, K. Ramaswamy, and A. Verma</i> | |

| | |
|--|-----|
| Effect of Serrated Grain Boundaries on the Creep Property of Inconel 718 Superalloy | 825 |
| <i>A. Yeh, K. Lu, C. Kuo, H. Bor, and C. Wei</i> | |
| Influence of B and Zr on Microstructure and Mechanical Properties of Alloy 718 | 837 |
| <i>T. Fedorova, J. Rösler, B. Gehrmann, and J. Klöwer</i> | |
| Structure-Property Relationships in Waspaloy via Small Angle Scattering and Electrical Resistivity Measurements..... | 847 |
| <i>R. Whelchel, R. Gerhardt, and K. Littrell</i> | |

Micro-Characterization, Corrosion, and Environmental Effects

| | |
|--|-----|
| Oxidation of Superalloys in Extreme Environments | 861 |
| <i>B. Pint, S. Dryepondt, and K. Unocic</i> | |
| Microstructure Evolution in the Nickel Base Superalloy Allvac 718Plus® | 877 |
| <i>K. Löhnert, and F. Pyczak</i> | |
| Effect of the LCF Loading Cycle Characteristics on the Fatigue Life of Inconel 718 at High Temperature | 893 |
| <i>F.Taina, M. Pasqualon, V. Velay, D.Delagnes, and P. Lours</i> | |
| Machining Conditions Impact on the Fatigue Life of Waspaloy-Impact of Grain Size | 907 |
| <i>N. Ben Salah, and S. Engin</i> | |
| Oil-Grade Alloy 718 in Oil Field Drilling Applications..... | 923 |
| <i>J. Xu, H. John, G. Wiese, and X. Liu</i> | |
| On the Influence of Temperature on Hydrogen Embrittlement Susceptibility of Alloy 718 | 933 |
| <i>F. Galliano, B. Ter-Ovanessian, E. Andrieu, J. Cloué, C. Beret-Blanc, and G. Odemer</i> | |
| Cast Alloys for Advanced Ultra Supercritical Steam Turbines | 947 |
| <i>G. Holcomb, P. Jablonski, and P. Wang</i> | |
| Effect of Phosphorus on Microstructure and Mechanical Properties of IN718 Alloy after Hot Corrosion and Oxidation..... | 961 |
| <i>Z. Hu, X. Lou, W. Sun, L. Yu, S. Wang, and W. Zhang</i> | |
| Effect of Microstructure and Environment on the High-Temperature Oxidation Behavior of Alloy 718Plus® | 977 |
| <i>K. Unocic, R. Unocic, B. Pint, and R. Hayes</i> | |
| Surface Modification of Inconel 718 Superalloy by Plasma Immersion Ion Implantation..... | 993 |
| <i>A. Hirschmann, M. Silva, C. Neto, M. Ueda, C. Mello, M. Barboza, and A. Couto</i> | |
| Author Index | |
| Subject Index | |
| Alloys Index | |