

# Table of Contents

## Preface

## Chapter 1: Microstructure of Alloys

|                                                                                                                                                                                                                                          |     |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| <b>The 3D Imaging and Metrology of Microstructural Elements in Innovative Materials for Clean Energy Systems and Aeronautics</b><br>A. Kruk and A. Czyrska-Filemonowicz                                                                  | 3   |
| <b>Metallography Evaluation of Cast and Wrought Ni-Base Superalloys</b><br>J. Belan, A. Vaško, L. Kuchariková and E. Tillová                                                                                                             | 9   |
| <b>Effect of Long-Term Aging on Microstructural Restoration in Cast Nickel Base Superalloy, GTD-111</b><br>C. Paa-Rai, J. Norachan, P. Wangyao, S. Polsilapa and G. Lothongkum                                                           | 15  |
| <b>Effect of Temperature Dropping during Solution Treatment in Rejuvenation Heat Treatment and its Long-Term Heating Simulation on Microstructures of Nickel Base Alloy, Udimet 520</b><br>K. Saelor and P. Wangyao                      | 22  |
| <b>Long-Term Gamma Prime Phase Stability after Various Heat Treatment Conditions with Temperature Dropping during Solution Treatment in Cast Nickel Base Superalloy, Grade Inconel-738</b><br>S. Polsilapa, A. Promboopha and P. Wangyao | 30  |
| <b>Effect of Precipitation Aging Temperatures on Reheat Treated Microstructures and its Phase Stability after Long-Term Exposure in Cast Nickel Base Superalloy, Grade Inconel 738</b><br>N. Kontikame, S. Polsilapa and P. Wangyao      | 36  |
| <b>Effect of Solution Treatment Temperature on the Grain Growth Behavior of Fine Grained FGH96 Superalloy</b><br>Y.F. Feng, X.M. Zhou, J.W. Zou, X.F. Wang, G.F. Tian and W.X. Wang                                                      | 41  |
| <b>Effect of Strain Hardening on Precipitation Kinetics in ATI 718Plus</b><br>B. Hassan, Y. Jansen, S. Nouveau and J. Corney                                                                                                             | 49  |
| <b>Oxidation Behavior of a Disk Powder Metallurgy Superalloy</b><br>K.X. Dong, C. Yuan, S. Gao and J.T. Guo                                                                                                                              | 55  |
| <b>Morphology Evolution of Grain Boundary Carbides in Highly Twinned Inconel Alloy 600</b><br>H. Li, J.R. Ma, X.R. Liu, S. Xia, W.Q. Liu and B.X. Zhou                                                                                   | 64  |
| <b>Morphological Evolution of Carbides in DZ125 Superalloy during Heat Treatment</b><br>L.R. Liu, S. Han, Y.F. Pu, Z.J. Peng and M.J. Zhang                                                                                              | 70  |
| <b>Microstructure and Property Calculation of Three Typical Second Generation Single Crystal Superalloys</b><br>X.D. Yue, J.R. Li, X.G. Wang and Z.X. Shi                                                                                | 76  |
| <b>The Precipitation Behavior of <math>\gamma'</math> Phase in Single Crystal Ni-Based DD6 Superalloy for Turbine Blade</b><br>Y.P. Xue, J.R. Li, J.Q. Zhao and J.C. Xiong                                                               | 83  |
| <b>A Review of Rafting in Nickel-Based Single Crystal Superalloys</b><br>Z.Y. Yu, Z.F. Yue, W. Cao and X.M. Wang                                                                                                                         | 94  |
| <b>The Influence of <math>\gamma/\gamma'</math> Morphology on the Rafting and Stress Distribution of Nickel-Based Superalloys Loaded in <math>[0\ 0\ 1]</math> Direction</b><br>X.M. Wang, M.Y. Cao, S.W. Li, Z.Y. Yu and Z.F. Yue       | 103 |

## Chapter 2: Mechanical Behaviour and Deformation Modelling

|                                                                                                                                               |     |
|-----------------------------------------------------------------------------------------------------------------------------------------------|-----|
| <b>Small Ring Testing of High Temperature Materials</b><br>C.J. Hyde, T.H. Hyde and W. Sun                                                    | 111 |
| <b>Stabilities of Microstructure and Mechanical Properties during Long-Term Aging on FGH95 Superalloy</b><br>X.Q. Wang, G.J. Ma and Z.C. Peng | 119 |

|                                                                                                                                            |     |
|--------------------------------------------------------------------------------------------------------------------------------------------|-----|
| <b>Influence of Dynamic Strain Ageing and Long Term Ageing on Deformation and Fracture Behaviors of Alloy 617</b>                          |     |
| G.C. Chai, M. Calmunger, S. Johansson, J. Moverare and J. Odqvist                                                                          | 124 |
| <b>Influences of W and Al on the Microstructure and Stress-Rupture Property of Re-Free Ni-Based Single Crystal Superalloys</b>             |     |
| J.Y. Chen, Q. Li, M.J. Zhang, X. Tang and C.B. Xiao                                                                                        | 130 |
| <b>Long Time High Temperature Stress Rupture Strength Behavior and Structure Stability Study on Ni-Base Superalloy Nimonic 80A</b>         |     |
| X.F. Chen, Z.H. Yao, M.C. Zhang, X.S. Xie, Q.Y. Yu, J.J. Song, L.F. Ding and H.W. Shen                                                     | 136 |
| <b>Degradation of the Strength of Grains and Grain Boundaries of Ni-Base Superalloy under Creep and Creep-Fatigue Loadings</b>             |     |
| T. Murakoshi, H. Sakamoto, T. Shinozaki, K. Suzuki and H. Miura                                                                            | 141 |
| <b>Creep Processes in MAR-M247 Nickel-Base Superalloy</b>                                                                                  |     |
| M. Kvapilová, K. Kuchařová, K. Hrbáček and V. Šklenička                                                                                    | 145 |
| <b>Microstructure Evolution and Stress Rupture Properties of DD6 Single Crystal Superalloy after Overheating</b>                           |     |
| S.Z. Liu, Z.X. Shi, M. Han and J.R. Li                                                                                                     | 149 |
| <b>Microstructure Evolution and Creep Properties of a Single Crystal Nickel-Based Superalloy with Various Orientations</b>                 |     |
| S.G. Tian, Y. Su, H.C. Yu and D.L. Shu                                                                                                     | 155 |
| <b>High Temperature Rupture Life of Nickel-Based Superalloy under Directional Solidification with High Temperature Gradient</b>            |     |
| W.G. Zhang, Z.J. Liu, S.K. Feng, F.Z. Yang and L. Liu                                                                                      | 161 |
| <b>Creep Behavior of a Ru-Free Nickel-Based Single Crystal Superalloy at Medium Temperatures</b>                                           |     |
| S. Liang and Z.X. Liu                                                                                                                      | 169 |
| <b>Mechanical Behaviour of Materials during Creep with Changing Loads</b>                                                                  |     |
| G. Angella, R. Donnini, D. Ripamonti and M. Maldini                                                                                        | 175 |
| <b>Interaction of Creep and High Cycle Fatigue of IN 713LC Superalloy</b>                                                                  |     |
| V. Horník, M. Šmíd, P. Hutař, L. Kunz and K. Hrbáček                                                                                       | 181 |
| <b>Failure Assessment of the First Stage High Pressure Turbine Blades</b>                                                                  |     |
| C. Wang, D.Q. Shi and X.G. Yang                                                                                                            | 185 |
| <b>Fatigue Crack Initiation in Nickel-Based Superalloy MAR-M247 at High Temperature</b>                                                    |     |
| I. Šulák and K. Obrtlík                                                                                                                    | 190 |
| <b>Effect of Maximum Temperature on the Thermal Fatigue Behavior of Superalloy GH536</b>                                                   |     |
| J. Chen, D.Q. Shi, G.L. Miao and X.G. Yang                                                                                                 | 194 |
| <b>Characteristics of Microscopic Inclusions and their Influence on Fatigue Crack Propagation in FGH96 Superalloy</b>                      |     |
| J. Hou and J.X. Dong                                                                                                                       | 199 |
| <b>Initiation and Propagation Behaviors of Small Crack in a Polycrystalline Ni-Base Superalloy under Thermo-Mechanical Fatigue Loading</b> |     |
| Y. Yamazaki                                                                                                                                | 211 |
| <b>Effect of Frequency on the Fatigue Behavior of IN718 Superalloy</b>                                                                     |     |
| J.H. Du, X.D. Lu and Q. Deng                                                                                                               | 217 |
| <b>Surface Roughness Effects on the Fatigue Behavior of As-Machined Inconel718</b>                                                         |     |
| H. Javadi, W. Jomaa, D. Texier, M. Brochu and P. Bocher                                                                                    | 225 |
| <b>Crystal Plasticity Simulations of Haynes 230, an Analysis of Single Crystal and Polycrystalline Experiments</b>                         |     |
| P.G. Luccarelli, S. Foletti, G. Pataky and H. Sehitoglu                                                                                    | 229 |
| <b>Fatigue Crack Propagation in Haynes 230: A Comparison between Single and Polycrystal Crack Closure Levels</b>                           |     |
| S. Beretta, S. Foletti, S. Rabbolini and H. Sehitoglu                                                                                      | 233 |
| <b>Fatigue Crack Growth in Flow Formed INCONEL 718</b>                                                                                     |     |
| C. Coleman, M.R. Bache and C. Boettcher                                                                                                    | 239 |

### **Chapter 3: Solidification and Processing**

|                                                                                                                                                              |     |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| <b>Effect of Hot Isostatic Pressing on Microstructures and Mechanical Properties of IN738LC Superalloy</b>                                                   |     |
| Q.G. He, J. Liu, L.X. Li, Z.H. Gao, X.Y. Shi and G.X. Yang                                                                                                   | 247 |
| <b>Effects of HIP Process on the Microstructure and Mechanical Properties of a Cast Superalloy</b>                                                           |     |
| J.X. Yang, Y. Sun and D.L. Zhou                                                                                                                              | 253 |
| <b>Microstructure Study of Nickel-Based Superalloys after Deep Cold Rolling</b>                                                                              |     |
| B. Nagarajan and S. Castagne                                                                                                                                 | 257 |
| <b>Analysis of Deformation and Internal Defect in Flat-Wedge Cross-Wedge Rolling of GH4169 Superalloy</b>                                                    |     |
| Y. Chen, H.Y. Gan, S.H. Zhang, M. Cheng and H.W. Song                                                                                                        | 263 |
| <b>A Novel Unified Dislocation-Density Based Model for Hot Deformation Behavior of a Nickel-Based Superalloy</b>                                             |     |
| Y.C. Lin and D.X. Wen                                                                                                                                        | 269 |
| <b>Hot Deformation Behavior of AA-FGH720Li Superalloy</b>                                                                                                    |     |
| X.Q. Wang, Z.C. Peng and M.C. Zhang                                                                                                                          | 274 |
| <b>The Addition of Zr in Nickel-Based Inconel 718 Superalloy to Prevent Hot Cracks Propagation</b>                                                           |     |
| H. Zhao, Q.B. Liu, G. Lee and D.W. Yao                                                                                                                       | 280 |
| <b>Precision Casting of GTD222 Component with Complex Thin-Wall Structure</b>                                                                                |     |
| G.L. Zhu, W. Wang, R. Wang, G.X. Wang, A.P. Dong, D.H. Wang, Z. Shi, Y. Li and G. Zhang                                                                      | 286 |
| <b>Early Instability Phenomena of IN792 DS Superalloy</b>                                                                                                    |     |
| R. Montanari, O. Tassa and A. Varone                                                                                                                         | 290 |
| <b>Simulation and Experimental Studies on Grain Selection Behavior of DD5 Single Crystal Superalloy</b>                                                      |     |
| Y.H. Yan, J.W. Liu, Z.H. Jia, S. Qiu, Z. Guo, K. Liu, A.L. Ma and L. Xu                                                                                      | 296 |
| <b>Microstructures of Low Angle Boundaries of a Third Generation Single Crystal Superalloy DD9</b>                                                           |     |
| W.P. Yang, J.R. Li, S.Z. Liu, J.Q. Zhao, Z.X. Shi and X.G. Wang                                                                                              | 305 |
| <b>The Effect of Process Parameters in Interdendritic-Melt Solidification Control Technique on the Microstructure and Properties of a Ni-Base Superalloy</b> |     |
| L. Zheng, G.Q. Zhang, D. Daisenberger, Z. Li and C.B. Xiao                                                                                                   | 314 |
| <b>Effect of Low-Angle Boundary on Microstructure and Stress Rupture Property of a Third Generation Single Crystal Superalloy DD10</b>                       |     |
| H.F. Li, L.J. Liu, M. Xue and L.M. Cao                                                                                                                       | 320 |
| <b>Study on the Formation of Stray Grains during Directional Solidification of Nickel-Based Superalloys</b>                                                  |     |
| M.R. Ridolfi, O. Tassa and G. de Rosa                                                                                                                        | 327 |

## Chapter 4: Welding and Laser Deposition

|                                                                                                             |     |
|-------------------------------------------------------------------------------------------------------------|-----|
| <b>Thermal Cycle Simulation of Welding Process in INC 738 LC Superalloy</b>                                 |     |
| Z. Boucherzoug and S. Cherif                                                                                | 335 |
| <b>Welding of IN792 DS Superalloy by High Energy Density Techniques</b>                                     |     |
| G. Angella, G. Barbieri, R. Donnini, R. Montanari and A. Varone                                             | 340 |
| <b>IN792 DS Superalloy: Optimization of EB Welding and Post-Welding Heat Treatments</b>                     |     |
| G. Barbieri, P. Soltani, S. Kaciulis, R. Montanari and A. Varone                                            | 352 |
| <b>The Microstructure of Inconel Alloys Used for Repair Welding</b>                                         |     |
| D. Jandová, J. Kasl and M. Matějová                                                                         | 358 |
| <b>Linear Friction Welding of IN718 to Ti6Al4V</b>                                                          |     |
| P. Wanjara, J. Gholipour, K. Watanabe, K. Nezaki, Y. Tian and M. Brochu                                     | 364 |
| <b>Measurement of Residual Stresses in Linear Friction Welded In-Service Inconel 718 Superalloy</b>         |     |
| M. Smith, L. Bichler and D. Sediako                                                                         | 370 |
| <b>Investigation of Impact Behavior of TIG Welded Inconel 718 at Aircraft Engine Operating Temperatures</b> |     |
| Y. Uzunonut                                                                                                 | 377 |

|                                                                                                                                                                                            |     |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| <b>Crack Growth Studies in a Welded Ni-Base Superalloy</b><br>A.H.S. Iyer, K. Stiller and M. Hörnqvist Colliander                                                                          | 382 |
| <b>Evaluation on the Corrosion and Wear Resistance of Welding Zone Welded with Plasma Transferred Arc Welding Method</b><br>J.H. Jeong, K.M. Moon, S.Y. Lee and M.H. Lee                   | 386 |
| <b>Structure Formation in Ni Superalloys during High-Speed Direct Laser Deposition</b><br>O.G. Klimova-Korsmik, G.A. Turichin, E. Zemlyakov, K. Babkin, P. Petrovsky and A. Travyanov      | 393 |
| <b>Preliminary Experimental Study of Laser Cladding Repair on Directionally Solidified Blades</b><br>W. Fu, Q.L. Deng and H.Y. Fang                                                        | 399 |
| <b>Effect of Build Orientation and Post Processing of a Direct Laser Deposited Nickel Superalloy as Determined by the Small Punch Creep Test</b><br>S. Jeffs, R.J. Lancaster and S. Davies | 407 |
| <b>A Study on the Microstructural Characterization of René 142 Deposited Atop René 125 Processed through Scanning Laser Epitaxy</b><br>A. Basak and S. Das                                 | 416 |
| <b>Brazing Inconel 600 Using the VZ-2150 Filler for Plate Heat Exchanger</b><br>C.H. Hsu and R.K. Shiue                                                                                    | 422 |
| <b>Brazing Inconel 600 to Manufacture the Plate Heat Exchanger</b><br>H.W. Lu, S.K. Chou and R.K. Shiue                                                                                    | 426 |

## Chapter 5: Thermal Barrier Coatings

|                                                                                                                                                                                              |     |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| <b>Phase Stability, Structure and Thermodynamics of Modified Ni- and Fe-Aluminides</b><br>S. Santra                                                                                          | 433 |
| <b>Durability of Amorphous and Crystalline BMAS Thermal Barrier Coatings Produced by Plasma Spraying</b><br>L. Čelko, D. Jech, K. Dvořák, I. Šulák, L. Klakurková and K. Obrtlík             | 488 |
| <b>Formation of Thermally Sprayed Coatings on Grid-Like Structure Substrate</b><br>D. Jech, L. Čelko, L. Klakurková, K. Slámečka, M. Horynová and J. Švejcar                                 | 492 |
| <b>Research on the Stability of Thermal Barrier Coatings under Thermal Cyclic Loading</b><br>J. Sun, Y.Q. Xu, W.Z. Li and K. Lv                                                              | 496 |
| <b>Interdiffusion Databanks of <math>\gamma</math>, <math>\gamma'</math> and <math>\beta</math> Phases in NiAl-Based Ternary Systems</b><br>L.J. Zhang, J. Chen, W.M. Chen, N. Ta and Q. Li  | 502 |
| <b>Cyclic Oxidation Performance of Si-Aluminide/MCrAlY Coating on Ni-Base GTD-111 Superalloy</b><br>K. Shirvani and S.V. Miraboutalebi                                                       | 533 |
| <b>The Study of High Temperature Oxidation Performance of Thermal Barrier Coatings Prepared by Plasma Spraying and Laser Remelting</b><br>Y.Q. Hua, W. SHUAI, W. Liu, R.F. Chen and J.D. Cao | 539 |
| <b>Diffusion-Controlled Growth and Microstructural Evolution of Aluminide Coatings on Superalloys and Steel</b><br>A. Paul                                                                   | 546 |
| <b>Sintering Study of NiCrAlY</b><br>R.J. Takahashi, J.M.K. Assis, F.P. Neto, A.M. Mello and D.A.P. Reis                                                                                     | 575 |
| <b>Effect of Double Electron Beam Remelting on Microstructure of HVOF and CGDS Bond Coat</b><br>P. Gavendová Krajňáková, I. Dlouhy, J. Čížek, J. Čupera and R. Shvab                         | 580 |
| <b>EBSD Analysis and Assessment of Porosity in Thermal Barrier Coatings Produced by Axial Suspension Plasma Spraying (ASPS)</b><br>U. Klement, J. Ekberg and A. Ganvir                       | 585 |
| <b>Development of the Advanced TBC for High Efficiency Gas Turbine</b><br>T. Torigoe, Y. Okajima, I. Okada, J. Masada and K. Tsukagoshi                                                      | 591 |
| <b>Material and Mechanical Aspects of CMAS Damage Progression on Thermal Barrier Coatings and its Non-Destructive Detection</b><br>Y. Hayashi, S. Lokachari, S. Yamagishi and M. Okazaki     | 598 |

|                                                                                                                                                                                                                                                                             |     |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| <b>Failure Mechanism of Yttria Stabilized Zirconia Atmospheric Plasma Sprayed Thermal Barrier Coatings Subjected to Calcia-Magnesia-Alumino-Silicate Environmental Attack</b><br>L. Čelko, D. Jech, P. Komarov, M. Remešová, K. Dvořák, I. Šulák, B. Smetana and K. Obrtlík | 604 |
| <b>Degradation of YSZ/EUCOR TBC Coating System during High Temperature Low Cycle Fatigue Tests</b><br>I. Šulák, K. Obrtlík, L. Čelko and P. Gejdoš                                                                                                                          | 610 |
| <b>The Application of the Small Punch Tensile Test to Evaluate the Ductile to Brittle Transition of a Thermally Sprayed CoNiCrAlY Coating</b><br>G.A. Jackson, W. Sun and D.G. McCartney                                                                                    | 614 |
| <b>Measurement of Young's Modulus of Thermal Barrier Coatings by Suspended Coupled Flexural Resonance Method</b><br>S.Z. Zhang, H.Y. Qi, H.W. Yang, C.C. Zhang and J.Y. Gao                                                                                                 | 626 |
| <b>The High Temperature Creep Properties of a Thermally Sprayed CoNiCrAlY Coating via Small Punch Creep Testing</b><br>G.A. Jackson, H. Chen, W. Sun and D.G. McCartney                                                                                                     | 631 |
| <b>Investigation on Fracture Toughness of Coating/Substrate Interface - Case Study: Thermally Sprayed Nickel Based Superalloy on Variety of Substrates</b><br>S. Abualigaledari, M. Salimi Jazi and F. Azarmi                                                               | 643 |
| <b>Thermomechanical and Thermal Gradient Mechanical Fatigue Lifetime of Thermal Barrier Coating Systems</b><br>Z.J. Zhou, C.P. Li, G. CHEN, X. HUA and Y. Li                                                                                                                | 647 |
| <b>Thermo-Mechanical and Low Cycle Fatigue Failure Behavior Relevant to Temperature Regime in a TBCed Superalloy Specimen</b><br>M. Okazaki, S. Yamagishi and Y. Yonaguni                                                                                                   | 655 |

## **Chapter 6: Machining Processes**

|                                                                                                                                                                                               |     |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| <b>Specific Cutting Force in Turning of Sintered Nickel Alloy</b><br>G. Struzikiewicz and K. Rumian                                                                                           | 663 |
| <b>Manufacturing of Axisymmetric Components out of Superalloys and Hard-to-Deform Steels by Roll Forming</b><br>S. Mukhtarov, A. Ganeev, M. Nagimov, R. Shakhov, V. Valitov and F.Z. Utyashev | 669 |
| <b>Influence of Coolant Application Direction on the Cutting Performance of Ceramic Tool in High-Speed Air-Jet-Assisted Machining of Inconel 718</b><br>T. Obikawa and M. Yamaguchi           | 675 |
| <b>Experimental Study on the Relationship of Discharge Parameters with Crack Arrest Effects in Inconel 625 Alloy by Electropulsing Treatment</b><br>J. Yu and Y.C. Liu                        | 682 |
| <b>Machinability of Inconel 625 Aerospace Material Using Cryogenically Treated WEDM</b><br>A. Goyal, A. Pandey and P. Sharma                                                                  | 689 |
| <b>Experimental Study on Electro-Discharge Machining of Nickel-Based Superalloy</b><br>Y. Li, J.J. Fu and L.G. Yang                                                                           | 694 |