6th International Special Emphasis Symposium on

Superalloys 718, 625, 706, and Derivatives

TECHNICAL PROGRAM

Sunday Evening, October 2, 2005

6:30 - 7:45 PM Welcoming Reception

Invited Overviews

Introduction by: Robert E. Schafrik, General Manager, EMPL, GE Aircraft Engines, Cincinnati, OH 45215 USA

8:00 PM

Allvac®718Plus™, Superalloy for the Next Forty Years: *Richard L. Kennedy*[1]; [1]ATI Allvac

Allvac®718Plus™ alloy is a new nickel base Superalloy with a highly desirable combination of excellent mechanical properties, increased temperature capability, good fabricability and moderate cost. This highly desirable combination of characteristics positions the alloy to very effectively fill the longstanding gap between the two most widely used wrought superalloys, 718 and Waspaloy. This paper will review the development of alloy 718Plus, which has progressed over the last eight years, including the effects of chemistry, heat treatment, processing and structure on mechanical properties. The current production status and capability of the alloy will also be discussed along with ongoing applications development. Comparisons will be made to 718, Waspaloy and other superalloys illustrating that alloy 718Plus is the best available candidate to sustain the advances in engine development made possible over the forty-plus year life of alloy 718.

8:30 PM
Extending the Size of Alloy 718 Rotating Components: *Robin C. Schwant*[1]; J. Jay Jackson[1]; Ling Yang[1]; Martin Morra[2]; [1]GE Energy; [2]GE Global Research Center

GE introduced the use of Alloy 718 in its heavy-duty gas turbine rotors in the late 1990's. The size of these parts is an order of magnitude larger than those used in aircraft engines. The challenges associated with production of very large 718 ingots and forgings are discussed. The issues include segregation, grain growth, microstructure and production equipment size limitations. Property distributions and comparisons to another turbine wheel material, Alloy 706, are included.

Monday AM, October 3, 2005
Melting and Solidification

Session Chairs: Shailesh J. Patel, Special Metals Corporation; Laurence A. Jackman, ATI Allvac

8:30 AM
Alloy 718 Large Ingots Studies: *Carlo Malara*[1]; John F. Radavich[2]; [1]Foroni SpA; [2]Micro-Met Laboratories, Inc.

8:50 AM
Metals Affordability Initiative: Application of Allvac Alloy 718Plus™ for Aircraft Engine Static Structural Components: *Eric Allen Ott*[1]; Howard W. Sizek[2]; [1]General Electric Company; [2]Air Force Research Laboratory

9:10 AM
Advancing Alloy 718 Vacuum Arc Remelting Technology Through Model-Based Controls: *Rodney L. Williamson*[1]; Joseph J. Beaman[2]; Frank J. Zanner[3]; John J. deBarbadillo[4]; [1]Sandia National Laboratories; [2]University of Texas; [3]Zan Tek Enterprises; [4]Special Metals Corporation

9:30 AM
Alloy 718 Forging Development for Land-Based Gas Turbines: *J. Jay Jackson*[1]; Jean-Francois Uginet[2]; [1]GE Energy; [2]Aubert & Duval Holding

9:50 AM
Clean Metal Nucleated Casting of Superalloys: *William T. Carter*[1]; Joseph J. Jackson[1]; Robin M. Forbes Jones[2]; Ramesh S. Minisandram[2]; [1]General Electric Company; [2]ATI Allvac

10:10 AM
Modification of Alloy 706 for High Temperature Steam Turbine Rotor Application: *Shinya Imano*[1]; Takashi Shibata[2]; Tsukasa Azuma[2]; Tatsuya Takahashi[2]; Hiroyuki Doi[1]; [1]Hitachi; [2]Japan Steel Works

10:30 AM Break

10:50 AM
Optimizing the Forging of Critical Aircraft Parts by the Use of Finite Element Coupled Microstructure Modelling: *Martin Stockinger*[1]; Johann Tockner[1]; [1]Bohler Schmiedetechnik GmbH & Co KG

11:10 AM
Probabilistic Life of IN718 for Aircraft Engine Disks: *Stephane Deyber*[1]; Franck Alexandre[2]; André Pineau[2]; Julien Vaissaud[2]; [1]Snecma Moteurs; [2]Ecole des Mines de Paris

11:30 AM
Processing of Rolling Technologies for IN718: *Michael Walter*[1]; Arnold Tatschl[1]; [1]Böhler-Edelstahl

11:50 AM
Mechanical Properties of Counter-Gravity Cast IN718: *Sanjay Shendye*[1]; Blair King[1]; Paul McQuay[2]; [1]Metal Casting Technology, Inc.; [2]Hitchiner Manufacturing Company, Inc.

12:10 PM
The Role of Niobium in Wrought Precipitation-Hardened Nickel-Base Alloys: *Gaylord D. Smith*[1]; Shailesh J. Patel[1]; [1]Special Metals Corporation

Monday PM, October 3, 2005
Allvac 718Plus Development

Session Chairs: Jon R. Groh, GE; Daniel F. Paulonis, Pratt & Whitney

1:30 PM
Structure and Property Comparison of Alloy 718Plus™ and Waspaloy Forgings: *Ian Dempster*[1]; Wei-Di Cao[2]; Richard Kennedy[2]; Betsy Bond[2]; Jose Aurrecoechea[3]; [1]Wyman-Gordon Forgings; [2]ATI Allvac; [3]Solar Turbines Incorporated

1:50 PM
Solidification and Solid State Phase Transformation of Allvac® 718Plus™ Alloy: *Wei-Di Cao*[1]; [1]ATI Allvac

2:10 PM
Structure Stability Study on a New Developed Modified 718 Alloy—Allvac® 718Plus™: *Xishan Xie*[1]; [1]University of Science and Technology Beijing

2:30 PM
Press Forging of Alloy 718Plus™: *Joe Lemsky*[1]; Kevin Kloske[2]; Tom Bayha[3]; Howard Sizek[4]; [1]Ladish Company, Inc.; [2]Pratt & Whitney; [3]ATI Allvac; [4]Air Force Research Laboratory

2:50 PM
IsoCon Processing of Alloy 718Plus™: *Joe Lemsky*[1]; Kevin Kloske[2]; Tom Bayha[3]; [1]Ladish Company, Inc.; [2]Pratt & Whitney; [3]ATI Allvac

3:10 PM Break

3:30 PM
A T-T-T Diagram of a New Developed Modified 718 Alloy—Allvac® 718Plus™: *Xishan Xie*[1]; [1]University of Science and Technology Beijing

3:50 PM
Evaluation of Allvac® 718Plus™ in the Cold Worked and Heat Treated Condition: *Betsy J. Bond*[1]; [1]ATI Allvac

4:10 PM
Application of Direct Aging to Allvac® 718Plus™ Alloy for Improved Performance: *Wei-Di Cao*[1]; Richard L. Kennedy[1]; [1]ATI Allvac

4:30 PM
Investment Casting of Allvac® 718Plus™ Alloy: *Kevin E. Kloske*[1]; Min Lu[2]; Thomas D. Bayha[3]; [1]Pratt & Whitney; [2]PCC Structurals, Inc.; [3]ATI Allvac

4:50 PM
Effect of Thermal-Mechanical Treatment on the Fatigue Crack Propagation Behavior of Newly Developed Allvac® 718Plus™ Alloy: *Xingbo Liu*[1]; Jing Xu[1]; Nate Deem[1]; Keh-Minn Chang[1]; Ever J. Barbero[1]; Wei-Di Cao[2]; Richard L. Kennedy[2]; Tadeu Carneiro[3]; [1]West Virginia University; [2]ATI Allvac; [3]Companhia Brasileira de Metalurgia e Mineração

5:10 PM
Properties and Microstructure of Allvac® 718Plus™ Rolled Sheet: *Thomas D. Bayha*[1]; David Bergstrom[2]; [1]ATI Allvac; [2]ATI Allegheny Ludlum

Tuesday AM, October 4, 2005
Processing Effects and Physical Metallurgy

Session Chairs: Alec Mitchell, University of British Columbia; John J. Schirra, Pratt & Whitney

8:30 AM
Characteristics of VIM/VAR Processed Alloy 718 Ingot and Their Effects on the Billet Cogging Process: *Nho-Kwang Park*[1]; J. -T. Yeom[1]; X. -X. Cui[1]; [1]Korea Institute of Machinery & Materials

8:50 AM
Freckle-Defects in VAR-Ingots of Ni-Base Superalloys: Simulations and Predictions: David Robert Poirier[1]; Pil K. Sung[1]; *Robert G. Erdmann*[1]; [1]University of Arizona

9:10 AM
Analysis of Microstructural Properties of IN718 After High Speed Forging: *Lars Renhof*[1]; Susanne Guder[1]; Ewald Werner[1]; Martin Stockinger[2]; [1]Technical University Munich; [2]Boehler Schmiedetechnik

9:30 AM
Combined Effects of Large Reductions and Heating Temperatures-Times on Grain Size Control of Alloy-718 Rolled Rings: *Jorge A. Manriquez*[1]; Jorge Cardenas[2]; Hugo Guajardo[2]; Chris Harwood[2]; [1]Tecnologico de Monterrey; [2]Frisa-Wyman Gordon

9:50 AM
The Use and Performance of Wrought 625 Alloy in Primary Surface Recuperators for Gas Turbine Engines: *James M. Rakowski*[1]; Charles Stinner[1]; [1]Allegheny Ludlum

10:10 AM
The Effect of Nb, Ti, Al on Precipitation and Strengthening Behavior on 718 Type Superalloys: *Xishan Xie*[1]; [1]University of Science and Technology Beijing

10:30 AM Break

10:50 AM
Primary Carbide Precipitation in IN718: *Alec Mitchell*[1]; [1]University of British Columbia

11:10 AM
The Effect of Sheet Processing on the Elevated Temperature Strength and Creep Behavior of INCONEL Alloy 718: *Carl J. Boehlert*[1]; Nate Eisinger[2]; [1]Michigan State University; [2]Special Metals Corporation

11:30 AM
Effect of Thermo-Mechanical Processing on the Microstructure and Grain Size of Annealed Alloy 718: *Sarwan Mannan*[1]; Donald Dobbs[1]; [1]Special Metals Corporation

11:50 AM
Predicting Microstructural Transitions via Computer Modeling and The Importance of Strain and Temperature in IN718 Forging Design: Andrew Haynes[1]; *Tim Howson*[2]; [1]Pratt & Whitney; [2]Wyman-Gordon Forgings

12:10 PM
Metallurgical Evaluation of Spray Deposited and Ring Rolled IN718: *Guoqing Zhang*[1]; [1]BIAM

Tuesday PM, October 4, 2005
Physical Metallurgy

Session Chairs: Robin C. Schwant, General Electric Company; Gaylord Smith, Special Metals Corporation

1:30 PM
A Structural Comparison of Alloy 718Plus™ to Alloy 718: *John F. Radavich*[1]; Tadeu Carneiro[2]; [1]Micro-Met Laboratories, Inc.; [2]Reference Metals Company Inc

1:50 PM
Carbides and Their Influence on Notched Low Cycle Fatigue Behavior of Fine-Grained IN718 Gas Turbine Disk Material: *Prabir R. Bhowal*[1]; Agnieszka Wusatowska-Sarnek[1]; [1]Pratt & Whitney

2:10 PM
Characterization of the Effect of Discrete Laves Particles on Low Cycle Fatigue Lives in Premium Grade Forged and Heat-Treated Inconel 718: *Robert A. Grelotti*[1]; Paul D. Genereux[1]; John J. Schirra[1]; [1]Pratt & Whitney

2:30 PM
Effect of Delta-Phase on the Hot Ductility of Wrought Alloy 718: *Göran P. Sjöberg*[1]; Tomas Antonsson[2]; Hans Fredriksson[2]; Saied Azadian[3]; Richard Warren[4]; [1]Volvo Aero Corporation; [2]Royal Institute of Technology; [3]Luleå University of Technology; [4]Malmö Högskola

2:50 PM
High Temperature Hold Time Effects on Fine Grain Processed 718 Fatigue Properties: *Dan Greving*[1]; Harry Kington[1]; Derek Rice[1]; Brian Hann[1]; [1]Honeywell Engines, Systems & Services

3:10 PM Break

3:30 PM
Influence of Thermal Exposure on the Microstructure of Delta Processed Billet and Bar for Alloy 718: *Jeffrey Russell*[1]; [1]ATI Allvac

3:50 PM
Modelling Microstructural Transformations of Nickel Base Superalloy IN718 during Hot Deformation: *Robert Paul Guest*[1]; Sammy Tin[2]; [1]Firth Rixson Ltd; [2]Cambridge University

4:10 PM
Dynamic and Metadynamic Recrystallisation of IN718: *Robert Paul Guest*[1]; Sammy Tin[2]; [1]Firth Rixson Ltd; [2]Cambridge University

4:30 PM
Influence of P on Creep Performance of DA IN718: *Joe Heaney*[1]; Jeff Russell[2]; Pawel Mrowczynski[3]; [1]GE/MPED; [2]ATI Allvac; [3]Wyman Gordon Forgings

4:50 PM
Influence of Phosphorus on the Deformation Mechanism and Mechanical Properties of IN718 Alloy: *Wenru Sun*[1]; L. F. Huang[1]; S. L. Yang[1]; S. R. Guo[1]; Z. Q. Hu[1]; [1]Chinese Academy of Sciences

5:10 PM
Alloy 625 and 725 Trends in Properties and Applications: *Lewis Edward Shoemaker*[1]; [1]Special Metals Corporation

Tuesday Evening, October 4, 2005
Design, Processing, Properties

Session Chairs: John F. Radavich, Micro-Met Laboratories Inc; Edward A. Loria, Consultant

7:30 PM
Modeling Microstructure Evolution in 718 Ingot to Billet Conversion: *William Carden*[1]; [1]Vista Engineering, Inc.

7:45 PM
Design Optimization of Alloying Elements and Their Concentrations for Specified Strength, Temperature, Time-to-Rupture, Cost and Weight: *George S. Dulikravich*[1]; Igor N. Egorov[2]; [1]Florida International University; [2]IOSO Technology Center

8:00 PM
Spray Forming and Post Processing of Superalloy Rings: *Michael Walter*[1]; Johann Tockner[2]; Martin Stockinger[2]; Nils Ellendt[3]; Volker Uhlenwinkel[3]; [1]Bohler Edelstahl GmbH; [2]Bohler Schmiedetechnik GmbH & Co KG; [3]University Bremen

8:15 PM
A Unified Computer Model of the Spray Forming Process of Inconel 718 Billets and Rings: *Iñaki Garmendia*[1]; Aitor Landaberea[1]; Udo Fristching[2]; Omar Belkessam[2]; Patrick S. Grant[3]; Jiawei Mi[3]; [1]INASMET; [2]University Bremen; [3]University of Oxford

8:30 PM
Sprayforming Optimization of Superalloy Aeroengine Components: *Oscar Caballero*[1]; [1]ITP

8:45 PM
Thermophysical Properties of IN738LC, MM247LC and CMSX-4 in the Liquid and High Temperature Solid Phase: *Rainer K. Wunderlich*[1]; H. J. Fecht[1]; L. Battezzati[2]; R. Brooks[3]; P. N. Quested[3]; I. Egry[4]; J. Etay[5]; J. P. Garandet[6]; B. Vinet[6]; K. C. Mills[7]; A. Passerone[8]; E. Ricci[8]; S. Seetharaman[9]; R. Aune[9]; [1]University of Ulm; [2]Universita di Torino; [3]National Physical Laboratory; [4]DLR-Köln; [5]Centre National de la Recherche Scientifique EMP; [6]Commissariat à l'Energie Atomique/CEREM; [7]Imperial College; [8]IENI-CNR; [9]Royal Institute of Technology

9:00 PM
Microstructural Investigations of Electron Beam Welded Alloy 718: *Mahadevan Sundararaman*[1]; Padmakar Potdar[1]; [1]Bhabha Atomic Research Centre

9:15 PM
A Comparison of the Precipitation Kinetics of γ' Particles in Virgin and Re-Solutioned Alloy 625: *Mahadevan Sundararaman*[1]; Hrishikesh Chidanand Pai[1]; [1]Bhabha Atomic Research Centre

9:30 PM
Notched Low Cycle Fatigue of Alloy 718: *A. Sridhar*[1]; Vikas Kumar[2]; A. K. Gogia[1]; [1]Project Office (Materials); [2]Defence Metallurgical Research Laboratory

9:45 PM
Properties of Bulk and Sheet Micro-, Submicro-, and Nanocrystalline Alloy 718: *Shamil Khamzaevich Mukhtarov*[1]; Vener Anvarovich Valitov[1]; Nadya Ruzavilevna Dudova[1]; [1]Institute for Metals Superplasticity Problems RAS

Wednesday AM, October 5, 2005
Processing Effects and Properties

Session Chairs: Joe Lemsky, Ladish Company, Inc.; Kevin E. Kloske, Pratt & Whitney

8:30 AM
Characterization of Residual Stresses in Turbine Discs by Neutron and High-Energy X-Ray Diffraction: Ulrike Cihak[1]; Helmut Clemens[1]; Peter Staron[2]; *Martin Stockinger*[3]; Johann Tockner[3]; Jens Homeyer[4]; [1]University Leoben; [2]GKSS Research Center; [3]Bohler Schmiedetechnik GmbH&Company KG; [4]HASYLAB at DESY

8:50 AM
Residual Stresses in IN718 Turbine Disks: *Christian Krempaszky*[1]; Ewald Werner[1]; Martin Stockinger[2]; [1]TU-Munich; [2]Böhler Schmiedetechnik GmbH & Company KG

9:10 AM
Effect of Grain Size/Tensile Strength on the Low Cycle Fatigue at Elevated Temperature of Alloy 718 Cogged by Open Die Forging Press: *Y. S. Song*[1]; M. R. Lee[1]; J. T. Kim[1]; [1]Doosan Heavy Industry Company

9:30 AM
Effect of Portevin-Le Châtelier Instabilities on the Sensitivity of Alloy 718 to Oxidation Assisted Intergranular Cracking at High Temperatures: *Eric Andrieu*[1]; Jean Marc Cloue[2]; Bernard Viguier[1]; Veronique Garat[2]; [1]CIRIMAT-ENSIACET; [2]Framatome-ANP

9:50 AM
High Temperature Intergranular Oxidation of Alloy 718: *Eric Andrieu*[1]; Julien Deleume[2]; Veronique Garat[2]; Jean Marc Cloue[2]; [1]CIRIMAT-ENSIACET; [2]Framatome-ANP

10:10 AM
Modelling the Material Properties and Behaviour of Ni and Ni-Fe Based Superalloys: *Nigel John Saunders*[1]; Zhanli Guo[2]; Alfred Peter Miodownik[1]; Jean-Philippe Schille[2]; [1]Thermotech Ltd; [2]Sente Software Ltd.

10:30 AM Break

10:50 AM
Effects of Cyclic Solution Treatment on the Microstructures and Mechanical Properties of Alloy 718: *Jaekeun Hong*[1]; Jihong Park[1]; Nhokwang Park[1]; Seongjun Kim[2]; Chungyun Kang[2]; [1]Korea Institute of Machinary and Materials; [2]Pusan National University

11:10 AM
The Role of Oxygen Grain-Boundary Diffusion during Intercrystalline Oxidation and Intergranular Fatigue Crack Propagation in Alloy 718: *Ulrich Krupp*[1]; Philip E.-G. Wagenhuber[1]; Vicente Braz da Trindade Filho[1]; William M. Kane[2]; Charles J. McMahon Jr.[2]; [1]University of Siegen; [2]University of Pennsylvania

11:30 AM
Thermal Fatigue Resistance of 718 Derivatives for Aluminum Die Casting Dies: *Michael Antony*[1]; John W. Smythe[1]; [1]ATI Allvac

11:50 AM
A New Alloy Designed for Superheater Tubing in Coal-Fired Ultra Supercritical Boilers: *Brian A. Baker*[1]; [1]Special Metals Corporation

12:10 PM
Metallurgical Effects on Machinability of Wrought Inconel 718: *Maria Johansson*[1]; Viktor Recina[2]; Birger Karlsson[1]; [1]Chalmers University of Technology; [2]Volvo Aero Corporation

Wednesday PM, October 5, 2005
Weldability and Applications

Session Chairs: Xishan Xie, University of Science and Technology Beijing; Edward A. Loria, Consultant

1:30 PM
Transient Liquid Phase Joining of Single Crystal Superalloy Blades to Polycrystalline Superalloy Disk Material: *Gopal Das*[1]; [1]Pratt & Whitney

1:50 PM
Design and Manufacture of a Very Large Hot-Gas Expander Impeller in Alloy 718 for Highly Corrosive Off-Gas: Volker Schulte[1]; *Sharad Chandra*[1]; Klaus Mohr[1]; Dieter Bokelmann[2]; Karl-Heinz Schoenfeld[2]; Joerg Poppenhaeger[2]; [1]MAN Turbo AG; [2]Saarschmiede Freiformschmiede GmbH

2:10 PM
Heat Affected Zone Microfissuring in Electron Beam Welded Allvac 718 Plus™ Alloys: Krutika R. Vishwakarma[1]; Norman L. Richards[1]; *Mahesh C. Chaturvedi*[1]; [1]University of Manitoba

2:30 PM
Mixed INCONEL® Alloy 718 Inertia Welds for Rotating Applications — Microstructures and Mechanical Properties: *Olaf Roder*[1]; Dietmar Helm[1]; Stephanie Neft[1]; Joachim Albrecht[2]; Gerd Luetjering[2]; [1]MTU Aero Engines GmbH; [2]Technical University Hamburg-Harburg

2:50 PM
Mechanical Properties of 718 Inertia Weld and Its Comparison with EBW: *P. V. Neminathan*[1]; T. Mohandas[2]; [1]Kaveri Engine Programme; [2]Defence Metallurgical Research Laboratory

3:10 PM Break

3:30 PM
Single Point Turning Process Optimization of Fine Grain Processed 718: *Brian Hann*[1]; Dan Greving[1]; Harry Kington[1]; Derek Rice[1]; [1]Honeywell Engines, Systems & Services

3:50 PM
Development of Forgeable Ni-Base Alloys for USC Steam Turbine Applications by Microstructure Simulation and Formability Tests: *X. Li*[1]; R. Kopp[1]; M. Wolske[2]; [1]RWTH Aachen University; [2]Hydro Aluminium Deutschland GmbH

4:10 PM
A Method of Optimizing Chemical Composition to Obtain Both Higher Strength and Higher Plasticity for Alloy IN718C: *Ping Yan*[1]; [1]Central Iron & Steel Research Institute

4:30 PM
A Precipitation-Hardened, Corrosion-Resistant Nickel-Chromium-Molybdenum-Niobium Alloy for Service in Marine and Oilfield Applications: *Lewis Edward Shoemaker*[1]; [1]Special Metals Corporation

4:50 PM
Creep-Testing Foils and Sheets of Alloy 625 for Microturbine Recuperators: *Neal D. Evans*[1]; Philip J. Maziasz[1]; John P. Shingledecker[1]; [1]Oak Ridge National Laboratory

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