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Gammalloy Materials–Processes–Application Technology

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Gamma TiAl alloys (herein called *gammalloys*) are becoming the first advanced engineering structural metallic materials with their substitution for superalloys in select civil, aero-engine, low-pressure turbine blades (LPTBs) and their potential use as moving components in select high-performance ground vehicle engines.

The applications of gammalloy materials (cast 4822-CDP/NL, cast 45XDL and wrought TNM-WNL) as LPTBs for intermediate service temperatures (up to 750°C) began to establish the foundations of their respective materials–processes–manufacturing technologies. The first commercial flights of the 4822 LPTBs took place in 2012, which was nearly 40 years after the first gamma TiAl alloy exploration program was initiated by the US. Air Force and conducted by Pratt and Whitney. As implementation of the LPTBs becomes widespread, higher temperature, capable gammalloy material has become a crucial need for lower stage LPTBs, which will significantly enhance engine performance. Despite the developments and demands, the low-temperature capability of gammalloys for LPTBs has remained unchanged for the last 10 to 30 years. This continued lack of progress is a result of the inability to produce engineering fully lamellar (FL) material forms having high-anisotropy lath structures and required γ-rich phase distributions and appropriate utilization/integration of incoherent strengthening particles such as carbides. In ground vehicle engine applications, the requirements for property balance are less stringent, allowing their use temperatures to be 800°C (wrought valves) and up to 1000°C (cast FL turbocharger wheels). Widespread adoption, however, awaits lower production cost and improved reliability, in addition to somewhat higher use temperatures. Cast gammalloys (Ti-46/47Al-3/6Nb base) began to be used for automotive engine turbocharger wheels first at 850°C (2000) and then at gradually increased gas temperatures up to 1000°C (2011). This enhancement has been possible because of less stringent requirements in property balances. Adoption has been slow, however, as a result of reliability and cost issues.

The future of gamma alloy technology will depend on whether we can develop gammalloy materials–processes–microstructure combinations with greater service temperature (750°C to 920°C) capability for specific aero-engine applications and greater producibility-reliability for ground vehicle engine component applications.

The Gamma Alloys Technology 2017 (GAT-2017) symposium aimed to address these issues and discuss appropriate measures collectively by providing seven oral sessions and two discussion sessions for 74 presentations. The succeeding nine papers are based on select presentations that report on advances in important areas of gammalloy technology. These advances can provide useful tools for improving current technologies or developing advanced, higher temperature engineering gammalloys. Select presentations are introduced. Bünck et al. report their casting technology development effort made at Access through which they have recently been certified according to Aircraft Standards, aiming at qualifying parts such as LPT blades for production on TRL (Technology Readiness Level) 6.

Liang and Lin review their work in the fabrication and properties of γ-TiAl sheet materials with emphasis on sheet rolling methods, microstructural control and mechanical properties, along with future challenges and opportunities. Couret et al. discuss the development of a TiAl alloy by spark plasma sintering (SPS) and report the microstructure and mechanical properties of a high-temperature alloy IRIS developed using the process. Lin et al. report the effect of surface topography on RT plasticity of TiAl. They found the RT tensile

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ductility of an extruded gammalloy sensitively dependent on surface treatments. Hecht and Witusiewicz report significant refinement and texture mitigation in aluminum-lean alloys with low boron additions of 0.2 at.%. Also discussed are the effects of borides on the refining and cooling rate dependence of the formation of morphological anisotropy of grains.

Kan et al. discuss the microstructure degradation of a high Nb-TiAl alloy, Ti-45Al-8Nb, during electron beam melting (EBM). The lamellar structure formed in the bottom part of as-EBM samples degrade significantly and reduce tensile properties at both ambient temperature and high temperature. This deterioration is attributed to coarsening and to discontinuous dynamic recrystallization. Schütze reviews the development routes for increasing operation temperatures in gas turbines up to 800°C and higher, and in automotive applications for turbocharger rotors even up to 1050°C. Recent and future works are discussed for (I) metal consumption of the load-bearing cross section; (II) subsequent massive ambient temperature embrittlement; and (III) high-temperature abrasion resistance, thermal barrier coatings, and surface quality in additive manufacturing. Tang et al. discuss the superplastic deformation mechanism of a low-Al and high-Nb TiAl alloy under compression. The interrelation between DRX and intergranular versus intragranular deformation is assessed, and new deformation techniques are suggested. Haun introduces recent advances in melting equipment design by Retech to produce 5 cm and 10 cm diameter ingots up to 100 cm long. Equipment design for the economical production of gammalloy powder is also introduced.

The following papers are published under the topic "Gamma Alloys Technology 2017" in the December 2017 issue (vol. 69, no. 12) of *JOM* and can be accessed via the *JOM* page at http://link.springer.com/journal/11837/69/12/page/1:

- "Titanium Aluminide Casting Technology Development" by Matthias Bünck, Todor Stoyanov, Jan Schievenbusch, Heiner Michels, and Alexander Gußfeld
- "Fabrication and Properties of γ-TiAl Sheet Materials: A Review" by Yongfeng Liang and Junpin Lin
- "Development of a TiAl Alloy by Spark Plasma Sintering" by Alain Couret, Thomas Voisin, Marc Thomas, and Jean-Philippe Monchoux
- "Effect of Surface Topography on Room Temperature Tensile Ductility of TiAl" by Bochao Lin, Renci Liu, Qing Jia, Yuyou Cui, and Rui Yang
- "Grain Refinement and Texture Mitigation in Low Boron Containing TiAl Alloys" by Ulrike Hecht and Victor T. Witusiewicz
- "Microstructure Degradation of Ti-45Al-8Nb Alloy During the Fabrication Process by Electron Beam Melting" by Wenbin Kan, Yongfeng Liang, Hui Peng, Hongbo Guo, Bo Chen, and Junpin Lin
- "The Role of Surface Protection for High-Temperature Performance of TiAl Alloys" by Michael Schütze
- "Hot Workability and Superplasticity of Low-Al and High-Nb Containing TiAl Alloys" by Bin Tang, Fengtong Zhao, Yudong Chu, Hongchao Kou, and Jinshan Li
- "Advances in the Systems and Processes for the Production of Gamma Titanium Aluminide Bars and Powder" by Robert E. Haun