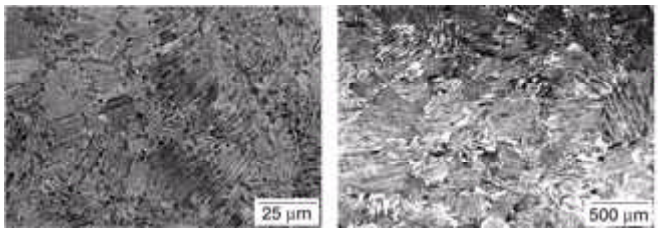
Third-Generation TiAl Alloy Tested--Exhibits Promising Properties for Rotating Components

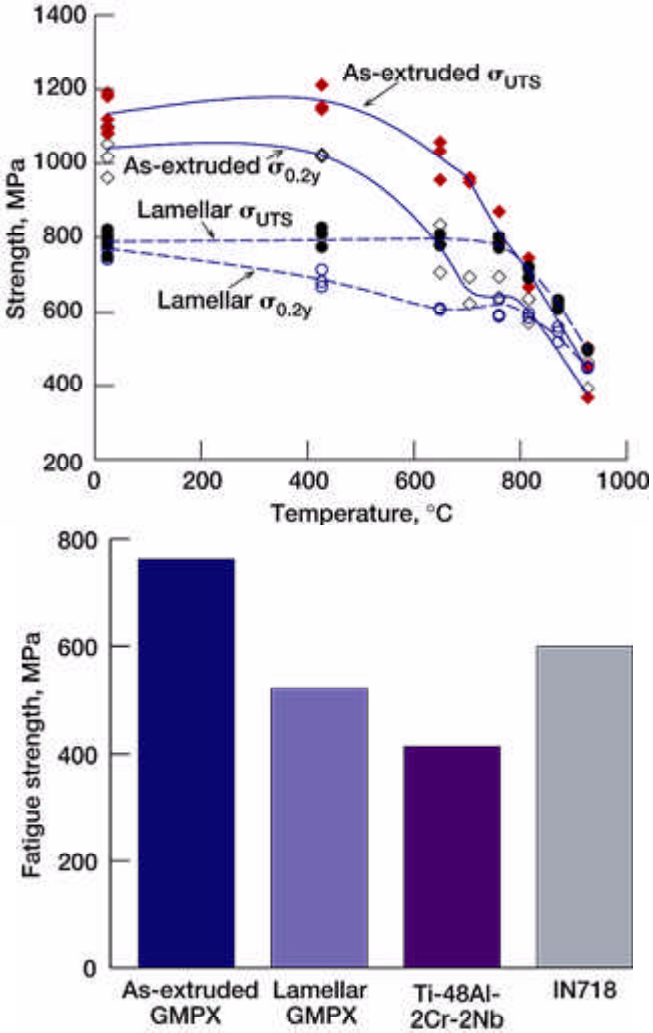
The Revolutionary Turbine Accelerator/Turbine-Based Combined Cycle (RTA/TBCC) Program for the next-generation launch vehicle has targeted gamma titanium aluminide as a potential compressor and structural material. Because of the high compressor inlet and exit temperatures, the TBCC engine requires higher temperature materials than conventional Ti alloys, and because of its stringent thrust-to-weight requirements, the engine requires low-density material to be utilized wherever possible. Third-generation gamma alloys offer higher temperature capability along with low density and high stiffness. A high-temperature, high-strength •-TiAl alloy with a high Nb-content (Gamma MET PX[1]) was selected for evaluation. The microstructure and mechanical properties of Gamma Met PX (GMPX) in both the as-extruded and a lamellar heat-treated condition and the influence of the microstructure on the tensile, creep, and fatigue properties were investigated in-house (ref. 1).



Microstructure of Gamma Met PX. Left: As-extruded condition. Right: After a lamellar heat treatment of 1340 °C for 40 min in vacuum.

Triple vacuum arc-remelted Ti-45Al-X(Nb,B,C) (at.%) gamma TiAl ingots were extruded in two steps to a final extrusion ratio of 100:1. The as-extruded bars had a fine-grained, nearly lamellar microstructure. Heat treating at 1340 °C for 40 min in vacuum produced a fully lamellar microstructure with equiaxed lamellar colonies. The mechanical properties of GMPX depend on the microstructure. The tensile strength of the as-extruded microstructure was exceptionally high for a •-TiAl alloy at all test temperatures. The as-extruded microstructure achieved room temperature total elongations slightly higher than 2 percent, traditionally considered the lower limit for component design. The tensile strength of the as-extruded material is on the order of forged superalloys. On a density-corrected basis, however, the specific strength would be double that of superalloys. Although still stronger than traditional •-TiAl alloys, the lamellar heat-treated material had lower strengths than the as-extruded material from room temperature to 760 °C and also lower room-temperature ductility, typical for TiAl alloys. High-cycle-fatigue specimens, with both as-extruded and lamellar microstructures, were step fatigue tested at 650 °C with a load ratio of 0.05. The bar chart compares the fatigue strength of GMPX to a baseline TiAl alloy, Ti-48Al-2Cr, 2Nb and also a Ni-base superalloy, IN718 (ref. 2). Similar to the tensile strength, the fatigue strength of as-extruded GMPX was equivalent

to a Ni-base superalloy even without correcting for density. The lamellar microstructure resulted in significantly lower fatigue strength because a lamellar microstructure is conducive to easy crack initiation (ref. 3). As-extruded and lamellar heat-treated GMPX samples were tested in both compression and tension to determine the creep behavior between 727 and 1027 °C. Creep strengths reached superalloy levels at fast strain rates and lower temperatures but deformation at slower strain rates and/or higher temperature indicated significant weakening for the as-extruded condition. At high temperatures and low stresses, the lamellar microstructure had improved creep properties. The microstructure can, thus, be altered to match the requirements for a particular application.



Left: Tensile strength of Gamma Met PX (GMPX), both as-extruded and after a lamellar heat treatment (• $_{UTS}$, ultimate tensile strength; • $_{0.2\%y}$, 0.2-percent yield strength). Right: As-extruded GMPX had a higher fatigue strength than a Ni-base superalloy, IN718 (ref. 2), even without correcting for density. The fatigue strength of both as-extruded and lamellar GMPX was significantly improved over that of a second-generation TiAl alloy, Ti-48Al-2Cr-2Nb.

References

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2. Metallic Materials and Elements for Aerospace Vehicle Structures, MIL-HDBK 5G. 1994.

3. Lerch, B.A., et al.: Durability Assessment of Various Gamma TiAl Alloys. Gamma Titanium Aluminides 2003, Y.-W. Kim, H. Clemens, and A.H. Rosenberger, eds., TMS, 2004, pp. 477-483. To be published.

[1]Gamma MET PX is a trademark of PLANSEE AG, Austria. Alloy composition is based on TNB alloys developed by GKSS Research Center, Germany.

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