Aerospace Materials: Microstructure, Fracture and Fatigue

Overview

Microstructures of Aluminum and Aluminium-Lithium alloys and Superalloys are constantly being improved to optimize their properties for applications in aerospace and space technologies. For example, many of the aluminium alloys are routinely used in the aircraft industry and aluminium-lithium alloys have found niche-applications such as cryogenic tankage for space launch. For the later application, friction stir welding is used for joining massive and very large spherical domes, as the debit in mechanical properties is much less compared to fusion welding for example, VPPA welding. Similarly there is a constant research effort to improve the superalloy temperature capability, for oxidation and creep. The goal of these lectures is to introduce to the students' various microstructures that can be produced in structural metallics particularly in Aluminum, Titanium and in Nickel-base super alloys and how one can manipulate the microstructure to produce desirable properties. Microstructure, i.e. grain size and precipitates in this case, are usually controlled during heat treatment which is provided to an alloy after solution heat treatment. Unrecrystallized, and recrystallized grain structures and precipitate coherency will have a major influence on a number of properties which we will discuss.

Aluminum alloys are widely used in the aerospace industry, for the skin of the aircraft, wing sections, sloping longerons and bulk heads and many more. The product forms and heat treatment tempers needed for these applications will be discussed along with lessons learned from previous experiences. There is also an emphasis to use aluminum alloys in the automotive industry and ship building, and these alloys have a different set of aspects that we will discuss. Some class of aluminum alloys can be used up to 150°C for hundreds of hours. Recently the 5xxx alloys are being researched to assess their applicability to ship building, however there are some issues that need to be addressed.

The alpha-beta and beta titanium alloys have a low density (light) and also have an excellent specific strength and specific modulus that are useful for high temperature applications. The alphabeta alloys can go up to 500°C for short periods of time as oxidation will becomes an issue, beyond this temperature. These alloys are used as fan blades and in early stages of the compressor section of the gas turbine engine. Fatigue crack growth and its relationship to microstructure is a key as it provides guidelines for microstructures most suitable for a specific application.

The nickel base superalloys on the other hand are used as turbine blades and vanes for gas turbine engines. The gas turbine engine alloys, such as the Ni base alloys can safely be used at 600°C and beyond for several hours as rotating components and under severe centrifugal loads. Both class of alloys are primarily face-center cubic structure but the precipitates and second phases that form upon heat treatment can be crystallographically complex and provide some fascinating mechanical behavior.

Properties important for application of aluminum alloys are fatigue, fatigue crack growth, fracture toughness and stress corrosion cracking and corrosion. Similarly, for Ti alloys there is a strong relationship between microstructure and properties. Also, there is a need to find coatings for

Ti alloys which can act as a barrier for oxidation which will be explored. For Nickel-base superalloys high temperature-fatigue, -fatigue crack growth and -creep are important parameters. To get a good grasp of the subject, students will be exposed to thermomechanical processing, heat treatments, elementary elastic fracture mechanics and Ashby-Raj creep maps. By understanding this material, the student will be able to apply the knowledge in real life applications.

Modules	• Classification of Al, Ti and Ni base super alloys, composition of most commonly used alloys, significance of alloying elements, strengthening mechanisms, work hardening and fracture under tensile loads • Thermomechanical processing, solutions heat treatments and post heat treatments to produce precipitate microstructures. General identification of microstructures using optical and electron microscopy techniques. • Low cycle and high cycle fatigue, ASTM E606 for low cycle fatigue testing, Coffin-Manson Law, notch effects on fatigue and industrial applications. Application of fatigue test results to automotive industry. • Elementary fracture mechanics, ASTM E399 standard for fracture toughness and ASTM E647 for fatigue crack growth test. How are crack growth rates used for damage tolerance methodology? • Microstructure relationships to fatigue, fracture toughness and fatigue crack growth in Al alloys. • Microstructure relationships to fatigue, fracture toughness and fatigue crack growth in Ti alloys. • Microstructure relationships to fatigue, fracture toughness and fatigue crack growth in Ni base super alloys. • Fracture modes and empirical relationship and models existing in the literature for crack growth. • Raj-Ashby map for creep, High temperature creep crack growth in Titanium and Ni Base superalloys. • High temperature Al alloys, prospects for increasing temperature of operation for Ti alloys and efforts to replace Ni base superalloys with other alloys such as Co base alloys gamma Titanium aluminides. **Dates: 11-22 June, 2018. Venue: IIT Gandhinagar** **Deadline for registration: 25 May 2018.** **Limited number of seats are available for the workshop.**
You Should Attend If…	▪ You are student (BTech/MTech/PhD) or faculty member from Materials Science/Metallurgy/Mechanical/Production Engineering. ▪ You are executive, engineer or researcher from manufacturing, service and government organizations including R&D laboratories.

Fees and Registration	The participation fees for the course is as follows: Participants from abroad : US $500 From SAARC: US$300 Industry: Rs. 30,000/- Research Organizations: Rs. 15,000/- Faculty/Academic Institutions: Rs. 7,500/- Student : 3,000/- The above fees include all instructional materials, computer use for tutorials and internet facility at the host institute during the course. The participants will have to take care of their travel. Accommodation can be arranged for participants on first-cum-first-serve basis for nominal payment. For any queries regarding registration or other practical information, please contact the course coordinator. Participants can register for the course on the link below:

The Faculty

Dr. Kumar V. Jata is CEO, Jata Materials Solutions LLC, Palm Desert, CA USA. Dr. Jata is an Air Force Research Labs Fellow (2006), and Fellow, ASM International (1998). Dr. Jata has more than 30 years of experience in the areas of Microstructure and Mechanical Behavior of Metal and alloys; Fatigue and Fracture, Processing and Manufacturing of
Components Performance and Life Prediction of Corroding Components; Technology Transition of Corrosion Control and Prevention. Dr. Jata worked with US Air Force Research Laboratory for more than 25 years and now conducts various technical training programs in the area of Microstructure-Property correlation, Corrosion science, Fatigue and Fracture.

Dr. Amit Arora is Assistant Professor of Materials Science and Engineering at IIT Gandhinagar. Dr. Arora is B. Tech. and M. Tech. (Dual Degree) in Metallurgical and Materials Engineering from IIT Kharagpur. He received Ph.D. in Materials Science and Engineering from The Pennsylvania State University in August 2011. His research focus is physical understanding of the joining processes, heat transfer and material flow modeling, and recently he has started working on Friction Stir Processing and Friction Stir Channeling.

Course Co-ordinator

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