Introduction to Aerospace Materials

A. P. Mouritz

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This comprehensive undergraduate text is descriptive, mathematical and factual in equal measure. That much of it is being drawn from authentic and highly regarded sources is acknowledged.

Professor P. Mouritz points out that: "*Materials affect virtually every aspect of the aircraft"* and rightly regards Materials Science as a core subject, no less important than *"Design, Aerodynamics, Flight Control Systems and Propulsion Technology*", plus Structures and Materials which are one and the same in practice.

Following an easygoing Introduction, 'Aerospace Materials:, Past, Present and Future' are reviewed in Chapter 2. Materials and material requirements are then considered in greater detail in Chapter 3, where the structural design of all major aircraft parts (fuselage, wing, empennage, control surfaces and landing gear) are discussed, at the appropriate level.

Chapter 4 'Strengthening of Metal Alloys' provides a sound grounding in metallurgical defects and strengthening procedures, while Chapter 5 'Mechanical and Durability Testing of Aerospace Materials' covers all well-known testing techniques available to the aeronautical engineer. Section 5.11.2 on Material Allowables (A Basis and B Basis) derived from a normal statistical distribution shows that neither the highest nor the lowest test strength is used for calculations.

The full range of metal casting and machining processes likely to be encountered by an aeronautical apprentice are fully covered in Chapters 6 and 7. The processes considered range from: die/sand/investment casting to the transformation of a single crystal into a turbine blade (in Chapter 6). A case study report on a 150kg cast titanium fan disc that broke free on United Airlines Flight 232 in 1989 focuses the mind on just how catastrophic a manufacturing flaw and an uncontained engine failure may be. Chapter 7 covers a wide range of processes from drilling/deburring to superplastic forming.

The International Alloy Designation System (based on chemical composition) is used to identify some of the more widely used aluminium alloys/2000, 6000, 7000, 8000 series in Chapter 8; series 8000 being a relatively new series which includes the slightly lighter aluminium/lithium alloys.

The reader should learn from the text that relatively few different alloys are actually used; while the precise properties of those that are may be significantly altered by heat treatment processes, by solution/quenching/tempering heat treatments and some by age hardening. Suffice to add that specific alloys and tempers are chosen for specific parts of the aircraft. All is clearly explained in the text.

The chemical and crystal structure of alpha, beta and gamma titanium alloys is well illustrated and fully discussed in Chapter 9. The author explains that the excellent strength, fatigue-and corrosion-resistant properties make certain alloys ideal for airframes, while their high temperature resistance promotes use in jet engines (but see Chapter 12 'Superalloys for Gas Turbine Engines'). Shape memory properties are also discussed.

Magnesium alloys are described in Chapter 10 as the lightest of all metals used in aircraft – only carbon fibre composites are lighter. The reader is informed that although their resistance to corrosion is poor, magnesium alloys were widely used pre-1970 but are now largely restricted to engine parts/gearboxes in helicopters.

Chapter 11 covers all types of steel (carbon, alloy, stainless) which together make up 90% of all metal used worldwide and yet less than 8% of the structural weight of an aircraft is composed of steel. All aspects of steels in general and steels used for slat tracks, wing root fittings/carry through boxes, landing gear and engine mounts in aircraft are covered. Types, phases, micro-structure, treatments, properties and uses, all are there.

Chapter 12 'Superalloys for Gas Turbine Engines' covers the nickel, iron-nickel and cobalt alloys used in aircraft turbine engines. These alloys are chosen for their exceptional heat resistant properties, high strength, long fatigue life, fracture toughness, creep resistance and stress rupture resistance at high temperature. A full appraisal of all alloys is given including a section on thermal barrier coatings. Section 12.2, 'A Simple Guide To Jet Engine Technology', is also well worth reading.

Chapters 13-17 cover more or less all the student needs to know about structural composites: how they are made, of what they consist, how structural and material properties are combined, how and where they are used, with several very good illustrations of current aircraft types. Case studies include: 1) Space Shuttle *Challenger*; 2) Nanotubes; 3) Ceramic matrix composites in Space Shuttle Orbiter; 4) WWII aircraft, *Spruce Goose*, designed by Howard Hughes (built mainly of birch not spruce).

Chapter 18 'Fracture Processes of Aerospace Materials' follows the now established fracture mechanics route and is well supported by authentic case studies, 1) Re-entry break-up of *Columbia* in 2003; 2) The fracture of a composite radome hit by a pelican bird in 2008. 'Fracture Toughness Properties of Aerospace Materials' follows in Chapter 19 with classical metal fatigue, crack growth and fatigue of polymer composites discussed in Chapter 20, including two case studies: 1) Fatigue failure on Japan Airlines Flight 123 in 1985; 2) de Havilland Comet aircraft disasters in 1954.

'Corrosion of aerospace metals' reportedly costs the industry 2·2 billion dollars (per year) we are told in Chapter 21 (design/manufacturing costs small – inspection/down time/maintenance costs large). NB: the reviewer believes this is a US cost and not a worldwide cost – the author does not say. Eight types of corrosion are identified and fully explained in the text, Section 21.4, methods of protecting vulnerable parts and bringing down cost being particularly important, while Section 21.8 provides another case study, this time the Aloha Airlines Flight 243 in 1988.

Chapter 22 on creep sets out to explain another slow/moderate time dependent form of deterioration, now reasonably well understood. Displacement limited creep and stress limited creep are two of the failure modes discussed. Also a fairly general overview of creep in polymer composites is included, but no case study this time.

Chapter 23 'Non-Destructive Inspection and Structural Health Monitoring of Aerospace Materials' spans the field of methods which are more widely used in aerospace than in other less demanding fields. Visual/tap, ultrasonics, c scan, radiography, thermography, eddy current, magnetic particle, liquid dye penetrant, acoustic emission, are procedures all clearly explained. 'Structural Health Monitoring (SHM)' Section 23.3 gives brief details of the Bragg grating sensor, piezoelectric transducers and vacuum monitoring.

The final chapter on 'Disposal and Recycling of Aerospace Materials' is also informative and will appeal to those who seek to save the planet.

This is a sound, well-written text that encourages one to read on – a text no undergraduate (worth his/her place) would ever call boring. At £55 per copy, the book is good value for money but maybe a touch expensive for many cash-strapped students who need to buy a book on more than one core subject.

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