Book Reviews

Encyclopedia of Aerospace Engineering:

Vol. 1 – Fluid Dynamics and Aerothermodynamics

Vol. 2 – Propulsion and Power;

Vol. 3 – Structural Technology

Vol. 4 – Materials Technology

Vol. 5 – Dynamics and Control

Vol. 6 – Environmental Impact, Manufacturing and Operations

Vol. 7 – Vehicle Design

Vol. 8 – System Engineering

Vol. 9 – Index and Units

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Volume 3: Structural Technology

Structural Technology, Volume 3, comprises fifty chapters (121 – 171) arranged in five Parts (13 – 17). Part 13, structural mechanics, comprises 10 chapters of approximately 12 pages per chapter. The first two Chapters 121-122 are on linear elasticity and variational principles and are as one should expect, highly mathematical. Each chapter is supported by a couple of well publicised textbook examples. Regardless of their chosen discipline students will find Chapter 123 on torsion of bars and bending of beams far less demanding but arguably of more practical value. NB: those not well versed might consider reading Chapter 123 before attempting Chapters 121 and 122.

Chapter 124 on plates and shells also traces the content of a standard higher level undergraduate course. Stiffened plates and sandwich panels, but not the theory of stringer stiffened thin-walled skins get a mention, but 8 pages in total is not enough to satisfy the aerostructures engineer. Chapter 125 fatigue and fracture mechanics in aerospace systems covers: safe life, *S/N* curves, Goodman and Miner's rule, but only in scant detail, the sections on fracture fechanics being somewhat better. The finite element methods of structural analysis, Chapter 126, is also sketchy, insofar as only the briefest lessons in axial and beam elements are on offer – NB: FEA is developed further in Part 15.

'Structural Stability', Chapter 127, explains many of the basic concepts needed but without reference to the stringer stiffening of thin-walled skins, an omission which the authors of Chapter 124 and/or Chapter 127 should have covered in detail. The best it would seem has been left till last. Chapters 128, 129 and 130 on element of structural dynamics, damping in structural dynamics and dynamics response computations are excellent and provide a smooth seamless way into the aerodynamic disciplines which follow.

Part 14 aeroelasticity and aeroservoelasticity begins at Chapter 131 by tracing the evolution of analytic and computational

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methods. All readers who have a soft spot for the historical will enjoy advancing through revelations recorded in Chapter 131. It is, for example, instructive to read how Bairstow and Lanchester were able to explain and to some extent cure flutter problems encountered during World War I; while subsequent work by Theodorsen *et al* and the development of the equivalent beam wing, using 2D aeroelastic theory makes interesting reading and sets the tone for much else to come. Be it through differential equations, weighted residuals, Galerkin, Rayleigh-Ritz or NASTRAN codes 1982 and 2000, the pursuit of flutter is ongoing. Piston theory, panel methods and CFD based computational modelling takes the subject to an even higher level.

'Static and Dynamic Aeroelasticity', Chapter 132, is less mathematical but no less worthy of attention. The text reads well and the diagrams with informative captions combine to make a first rate undergraduate lecture. Topics range from: wing lift distribution from a rigid wing compared to that of a flexible wing, dynamic response, stability and flutter, Mach number compressibility, control effectiveness and swept wing aeroelastic tailoring, divergence and flutter. More specialised branches of transonic nonlinear aeroelasticity, hypersonic aeroelasticity and aerothermoelasticity and panel flutter (appropriate to a Masters course) are covered in detail from Chapter 133 to Chapter 135.

On the aeroservoelastic front issues include: the aeroelastic redistribution of lift and the active and passive alleviation of load. The working principle of the 1901 Wright Brothers Wing Warping Kite is explained, as is the aeroelastic tailoring of swept composite wings. The DARPA X-29 and X-53 are included as examples. Chapter 136 contains numerous control circuit diagrams and covers much electronic nitty gritty.

Chapter 137 on the aeroelastic behaviour of turbomachinery in general and flutter in particular, is expertly covered and will be of great interest to the aero/mechanical engineer. Subsonic flutter, supersonic flutter, stall flutter, LPT (low pressure turbine) flutter and transonic bending flutter form the basis of discussion. There is also much about blade tuning and blade mistuning. One interesting point is that blades are nominally identical, but rotors may be mistuned, leading to a random variation in natural frequency of order one or so percent. The full story takes time to tell but is well worth reading.

Part 15 'Computational Solid Mechanics and Fluid-Structure Interaction' is by far the longest part of the volume. Given that an introduction to FEA appears in Part 13, Part 15 is pitched at a higher level and the fourteen additional chapters add much theoretical and practical grist to the mill. Discretisation, multi-scale modelling, nonlinear extensions, shell formations and interface elements are topics clearly explained and developed. Occasional numerical embellishments add to the applicability of the text. Other areas of practical application include chapters on: fracture mechanics, delamination of composites, computational dynamics and aeroelastic shape optimisation. Revelations about the NASA Aeroelastic Research Wing Project 2 (ARW2) are included. The authors of the final Chapter 153 on fundamentals of fluid-structure Interactions sign off with panache.

Part 16 'Experimental Techniques for Structural Mechanics' balances the books and in part guides the reader towards what many see as a less glamorous pursuit, one far removed from the 'glam' of stem cell research in the medical field. In an age when FEA/CFD is so powerful and so widely used, by quite junior 21st century students, often to the point of obsession, it is welcome and refreshing to find and read eleven full chapters on materials and structural testing, all of which serve to proclaim and demonstrate the worth of the empirical method. Static fracture, including traditional photoelastic fringes and the more recent method of digital imaging are well documented. See Chapter 163 on Non-destructive evaluation of structures for other equally important techniques.

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Areas which are covered on a whole chapter basis include: buckling, dynamics, vibration and the certification of aerospace systems, metal, composite sandwich structures and structural joints, under static and cyclic loading. Dynamic response, damage tolerance, structural integrity and non-destructive testing are other topics considered.

All who enjoy reading case histories will find sections on the de Havilland Comet (pages 1845-1847 and pages 1848-1850) on the Space Shuttles *Challenger* and *Columbia* of interest – as also the description relating to the 'Mamooth' mechanical crusher used to investigate shell bucking at NASA Marshall Space Flight Center. The final chapter 163 on digital image correlation may be a technique known only to those who habitually wear lab coats and is a fitting point to end.

Part 17 'Structural Health Monitoring (SHM)' is a damage detection technology strategy, not new but an area said to warrant further research and development to ensure wider use in the near future. To paraphrase one author the motivation lies in: there being a rational need to detect damage (in a structure) at the earliest possible stage. The known fact that the cost of maintaining an aircraft far exceeds its purchase price is cited along with safety issues and long term economic benefit as reason enough. Another author refers to 'power by the hour', an emerging business model, whereby aircraft products are leased rather than sold, with responsibility for lifetime maintenance remaining with the manufacturer. Although formal fixed time or set cycle maintenance of aircraft has long been the norm, the argument is that the monitoring of damage has for the most part been of a 'passive' nature, whereas SHM is seen to be an 'active' process which monitors damage, ideally in real time. Measured, recorded and acted on landing (if need be) or, if not the perceived damage is critical, entered into an updated data base and statistically assessed. So what of the strategy already in place? Given that SHM is itself the philosophy there are four (not five) closely related disciplines which have (in this Volume) been identified. These are: (1) Conditional Monitoring (CM), (2) Non-Destructive Evaluation (NDE), (3) Statistical Process Control (SPC) and (4) Damage Prognosis (DP).

It is reported on page 1965 that the most refined form of SHM is the use of HUMS (Health Usage Monitoring Systems), one example of which is their use on helicopter rotors and gear boxes. Dating from the use of strain gauges c1954, the reader is told that HUMS were first certified in the UK in 1991 and subsequently developed into relatively sophisticated integrated systems. One example cited is the Space Shuttle Model Inspection System (SMIS). MEMS, meaning Micro Electronic Mechanical Systems, is a collective buzzword used in the trade, which does not feature within the text. Nevertheless the Part includes the widest coverage of such devices, ranging from theory, use and suggested applications.

The Rayleigh Lamé equations exemplify the theory, while insight and experience explains the uses to which guided waves, ultrasonics, SMART piezoelectric wafer (thin) sensors, C scans, model vibration techniques, impedance methods and pulse echo systems may be put. All the chapters are well illustrated and contain interesting results, supported by graphic displays and tabulated data.

Every chapter is authoritative and fully supported by a long list of references. The downside is that although an ordered Contents Page gives chapter headings, the itemised Index for Volumes 1-8 is locked away in Volume 9 – a misguided editorial decision in the reviewer's opinion.

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