Book Reviews

An Introduction to Aircraft Structural Analysis

T. H. G. Megson

Elsevier Butterworth-Heinemann, The Boulevard, Langford Lane, Oxford, OX5 1GB, UK. 2010. 638pp. Illustrated. £48.99. ISBN 978-1-85617-932-4 .

Megson's *Aircraft Structures for Engineering Students*, first published by Edward Arnold in 1971 and reissued as a fourth edition in 2007, has long been the definitive text for undergraduates studying the subject in Britain. The publishers have now produced an abridged version of Megson's 'big' book, under a different title. Vibration, aeroelasticity and to a lesser degree airworthiness and structural loading have been axed and prospective buyers should understand that this abridged edition is a two part as opposed to a three part book. Part A (Chapters 1-9) covers the fundamentals of structural analysis, while Part B (Chapters 10-23) is more specialised and addresses the analysis of aircraft structures in considerable mathematical detail.

The new book carries with it only a few trivial changes, typified by: two altered sub-headings and a deleted reference in Chapter 1; two new problems in Chapter 2 and one new figure in Chapter 3. Much else in the book remains: word, sentence, paragraph, diagram, equation, problem – as originally set. Virtual Work, Chapter 4, is an exception, insofar as it has been elevated from a section in early editions to full chapter status. Virtual Work, Chapter 4, Energy Methods, Chapter 5 and Matrix Methods, Chapter 6, are shown to be united and form a powerful tool. Chapter 7 on the Bending of Thin Plates is presented unaltered. Structural instability, originally a single chapter covering all forms of buckling, has been split into Columns, Chapter 8, and Thin Plates, Chapter 9 – the combined content being little changed.

Part B, headed the Analysis of Aircraft Structures, begins with a short descriptive account of six generic aircraft materials, Chapter 10. Aluminium alloys, two pages; steels, less than a page; titanium, half a page; plastics and glasses, six lines each; composites, two pages. Sections within the chapter on mechanical testing and material behaviour are also brief. Structural Components of Aircraft, Chapter 11, contains a table listing 214 different component parts relating to the Harrier aircraft. A typical wing pressure distribution is sketched and used to show how lift, drag and pitching moments arise. The difference between the centre of pressure and the aerodynamic centre is also explained. Function, form and fabrication also features at a fairly basic level within the chapter.

The flight envelope, load factors and what amounts to a historical review of metal fatigue are topics discussed in the five pages allotted to Airworthiness, Chapter 12. Chapter 13 on Airframe Loads is 'good' on inertia loadings, normal accelerations and includes sections on: the manoeuvre and gust envelopes, sharp edged gusts and the graded gust, all sections being directly applicable.

Next up is Fatigue, Chapter 14 (metal fatigue that is), in which safe life and fail-safe philosophies are briefly discussed – along with mathematical details ranging from: 'Goodman', the ground air ground (GAG) cycle; statistical aspects and crack propagation. By Chapter 15 on the Bending of Open and Closed, Thin-Walled Beams, vintage Megson is back on track.

The structures considered in Chapters 15-19 and in Chapters 20-23 are representative of lightweight subsonic aircraft; aircraft designed around stressed skin principles which have wing sections of high thickness to chord ratios, deep spars and thin skins stabilised by longitudinal stiffeners. Such structures are in theory infinitely redundant, in the mathematical sense and are most easily analysed using the structural idealisations, outlined in Chapter 19.

Chapters 20, 21, 22 and 23 are filled with examples which show how the methods outlined in Chapters 15-19 can be applied using no more than a handheld calculator. Every chapter is supported by a host of highly taxing problems, with answers where appropriate.

Two pages on fibre-reinforced composites are, however, nowhere near enough and this is a serious omission that needs to be addressed. The pursuit of minimum weight has long been recognised as a driving force in the design of aircraft structures and space needs to be found in which to express this relevance. Even students who are just doing the course will look in vain for material specifications and data – which could have been tabulated and so easily included.

One final point important to educationalists, if not those concerned with copyright law, concerns the inclusion of approximately 90 London University BSc eng. exam questions, set between 1957 and 1967, for which (unlike the first edition) no acknowledgement is given. This is a matter for Megson and the publishers to reflect on.

The reviewer has long admired the work of Megson and still occasionally refers to a first edition, owned for 40 years. What better recommendation could there be.

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Advances in Aeroacoustics: in honor of Professor Geoffrey M. Lilley

P. J. Morris *et al*

Multi-Science Publishing Co., 5 Wates Way, Brentwood, Essex, CM15 9TB, UK. 2010. 331pp. Illustrated. £75. ISBN 978-1-907132-18-6.

The University of Southampton, in November 2009, held a symposium to honour the life and work of Professor Geoffrey Lilley, a titan in the discipline of aeroacoustics. The book under review contains papers from this symposium, each by distinguished researchers. The subjects covered are aerodynamic noise theory, combustion noise, jet noise, airframe noise and flow control. The volume opens with a warm and affectionate biography of Professor Lilley by Philip Morris followed by a tribute from Robert Westley to this 'father of aeroacoustics'. These are followed by ten contributions, each summarised below.

Goldstein considers Professor Lilley's reformation of Lighthill's equation and demonstrates how it can be considered as a special case of the generalised acoustic analogy. Tester and Morfey review methods for solving the Lilley equation and conclude that even though direct numeric solutions are the preferred route for jet mixing noise prediction (because of lower computational effort), analytic solutions offer important physical insights and can validate numeric results. The derivation of inhomogeneous wave equations for analyzing combustion noise from reacting flows is dealt with by Bailly, Bogey and Candel.

Khavaran, Kenzakowski and Mielke-Fagan present a method for predicting aerodynamic noise radiated from high-speed, hot jets. The method is based on the generalised acoustic analogy and therefore, unlike empirical methods, is not bound by the range of the database. A semi-empirical wave-packet source model for jet mixing noise from large-scale turbulent structures is presented by Reba, Narayanan and Colonius. The model, though lacking in first principles predictive capability, provides very encouraging agreement between the measured acoustic field and that calculated.

A detailed study of noise spectra measured on 'university rigs' and on industrial rigs is described by Harper-Bourne. The study shows that higher peak noise levels are measured on university rigs but this is not due to rig noise as sometimes thought. Professor Lilley's comparisons of full-scale and model-scale jets suggest free transition in the shear layer of university jets as the most probably cause. Viswanathan also deals with jet noise measurements. He offers guidance on minimum distances for far-field noise measurements. He also concludes that noise source distributions are not dependent on jet temperature.

The next paper by McLaughlin, Bridges and Kuo reports on a study aiming to characterise the acoustic field produced by supersonic jets from converging-diverging nozzles of military aircraft. An equally important objective of the study is validation of methodology to predict components of full scale engine noise from model scale experimental data. The last two papers deal with airframe noise. Khorrami and Lockard consider the generation and propagation of leading-edge slat noise. They use computational simulations in conjunction with a Ffowcs Williams-Hawkings solver to investigate the relevance of the geometric details of slats. Finally, Huang and Zhang discuss the novel approach of using plasma actuators to control flow-induced aircraft noise. Plasma actuators are shown to reduce noise by modifying the flow field. Most recent designs are reviewed and applications and limitations are discussed.

In summary, this volume shows the tremendous strides that have been made in our understanding of aeroacoustics and anybody or any institution with an interest in the current state of research in aerodynamic noise should consider obtaining this book.

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Multiple Scales Theory for Aerospace Applications

R. V. Ramnath

American Institute of Aeronautics and Astronautics, 1801 Alexander Bell Drive, Suite 500, Reston, VA 20191-4344, USA. 2010. 587pp. Illustrated. $74.95 (AIAA Members); $99.95 (Non-Members). ISBN 978-1-60086-762-0.

Mathematical modelling is the art of sorting out the whole spectrum of effects that play a role in a problem and then including what is relevant and excluding what is too small. Normally, when the problem is rich enough, this spectrum does not consist of two classes, 'big' and 'small', but has a smooth distribution such that there are always effects that are small but not small enough to be excluded. We can utilise their smallness by simplifying the problem without losing the effects in question altogether.

Perturbation methods do this in a systematic manner by using the sharp fillet knife of mathematics in general and asymptotic analysis in particular. From this perspective, perturbation methods are ways of modelling with other means and are therefore much more important for the understanding and analysis of practical problems than they're usually credited with. David Crighton called "Asymptotics – *an indispensable complement to thought, computation and experiment in applied mathematical modelling*".

Therefore, I am always happy with any publication that tries to propagate this message, including the present book, which is on the multiple scales technique for a number of aerospace applications. It covers a quite wide range of problems: from flight control and stability analysis of sub-, super- and hypersonic aircraft, to space flight orbit prediction and attitude control of satellites and deformable reflectors. Prior to these applications an attempt is made to review asymptotic analysis and multiple scales methods in a more general fashion.

The book is ordered in five parts plus some appendices with useful background information. Part I is on General Theory, 83 pages; Part II is on System Applications, 90 pages; Part III is on Vehicle Mathematical Models, 17 p; Part IV is on Atmospheric Flight, 174 p; Part V is on Space Flight, 170 p. Although the aerospace applications look very interesting and clearly the work of an expert (I have found a few nice exercises for my course), my expertise in these is, unfortunately, next to nothing, so I can't give any comments on the Parts III, IV and V, other than that many (not all) pictures are of poor quality and details are barely readable. They seem to have been scanned at very low resolution.

For the rest I will concentrate on the theoretical parts I and II. These parts are, regretfully, not very good. I am not expecting proofs or theorems, but at least the definitions as they are known (for very good reasons) in the literature and no vague words which have at best a meaning to the very experienced reader only. No definition of asymptotic expansion or asymptotic approximation is given. At least, I can't see a 'definition' in (Eq. 2.16):

$$f(\varepsilon) \sim g(\varepsilon) = O[g(\varepsilon)] + o[g(\varepsilon)].$$

Even elementary and basic notions (in a chapter on asymptotic analysis!) as the big O and small o are defined incorrectly. *Uniform validity* receives a separate section, but in spite of the fact that it is mentioned as something important, it is not defined and only vaguely indicated what it means. The very fundamental concept of Poincaré expansion ($\Sigma\mu_n(\varepsilon)\phi_n(x)$), in order to be able to equate groups of terms of equal order, is implicitly used everywhere but never mentioned. A turning point is (incorrectly) introduced as a point where the solution diverges. The simple fact that a turning point is called this way because the incident wave changes from propagating into cut-off and hence has to reflect because of energy conservation is not mentioned.

The author refers (too) often to himself in the third person, apparently in order to imply that some notion is generally accepted (for example 'Principle of sub-minimal simplification' and variants-thereon) while this is not the case at all. The author also refers often to an article of his own from 1969, his PhD dissertation from 1968 and unpublished lecture notes, sometimes with the remark that here more can be found on the subject considered. This is really inappropriate. After more than 40 years one may expect that the better and more mature version will be found in the book if this is from the same author.

Most of these theoretical chapters are based on this 1969 article: 'A Generalised Multiple Scales Approach to a Class of Linear Differential Equations', R.V. Ramnath and G. Sandri, *Journal of Mathematical Analysis and Applications,* 28, pp 339-364 (1969). Here a generalisation of the multiple scales method, in particular the WKB method, is proposed, which is by most asymptoticists not considered as a genuine extension. This proposed generalisation is in essence already included in the accepted interpretation of the WKB method. At least, I don't recall to have ever seen any reference to this so-called Generalised Multiple Scales Method (GMS) in the literature.

Since this GMS method is used throughout the book, I want to explain why it was better if it had not been introduced as something new. Suppose, a regular asymptotic expansion (i.e. a uniform Poincaré expansion) is not possible on the whole domain of interest, because two time scales are together important. Think about a pendulum with small damping, or relatively short waves in a slowly varying medium. Then a suitable approach is to take the short (fast) and long (slow) time scales apart and consider them temporarily as independent coordinates, say $t_1 = t$ and $t_2 = \varepsilon t$. The obtained extra degrees of freedom can now be used to construct an asymptotic approximation (now in two dimensions) that is regular everywhere (at least near the line $t_2 = \varepsilon t_1$). Having this approximation, we can re-couple the two time scales by expressing them both in t to obtain the regular approximation that we were looking for. This is an example of the simplest version of the multiple scales method. In general it will work only if the slow and fast time scales are an intrinsic property of the system and do not change during the process. Think of a weakly damped pendulum where the differential equation is autonomous (no t-dependent coefficients), and the frequency of the pendulum and time constant of the damping are constant. Of course, this is in many problems not the case. If by external effects the fast time constant (the high frequency, say) slowly drifts away (a pendulum with a slowly varying length, waves in a varying medium), then the accumulation of a phase error (and usually also an amplitude error) produces on the long time scale a large error. In its simplest version, for strictly periodic phenomena, this problem was already solved in the 19th century by the Lindstedt-Poincaré technique. Here the time (the fast time, there is no slow time) is scaled on the exact inherent (but unknown) frequency, such that now a regular expansion becomes possible. The unknown frequency is found by the very condition that the expansion should be regular (no secular terms). In the early years of the 20th century, the name-givers of the WKBJ method generalised this insight for non-strictly periodic phenomena by allowing the fast time scale to vary slowly as follows:-

$$t_1 = \int^t \phi(\varepsilon\tau)\, d\tau$$

where the as yet unknown phase function ϕ is chosen such that the approximation of the full solution becomes regular.

This is identical to the 'generalisation' proposed by Ramnath en Sandri. The suggestion that there is a difference with the WKB method is probably due to the fact that WKB is mostly employed in wave problems where as a matter of course the solution obtains the form of a complex exponential with a slowly varying amplitude and phase. In order to avoid extensive algebra the solution is usually directly assumed to have this form. It is, however, a simple exercise to show that a slowly varying fast time scale applied within the multiple scales technique is sufficient to produce this form.

In conclusion I think the breadth of the considered problems is admirable and shows clearly the potential of the WKB and other multiple scales-types of methods. The attempt on a generalisation has failed, as far as I'm concerned, in particular with respect to elementary mathematical precision. Also the way the author tries to put forward his own work is not very subtle.

Dr Sjoerd W. Rienstra

Operation of a Cryogenic Rocket Engine: an Outline with Down-to-Earth and Up-to-Space Remarks

W. Kitsche

Springer-Verlag, Tiergartenstrasse 17, D-69121 Heidelberg, Germany. 2011. 142pp. Illustrated. £90. ISBN 978-3-642-10564-7.

This is a very personal book where the meaning of the subtitle is made clear: "*The greatest honour is due to God who gave us all the ability and the opportunity to do this thrilling work without any serious incident*"(page ix). The 'opportunity' was to have worked for 20 years at one of the two largest test facilities for cryogenic rockets in Europe, or 'a prototype of some gigawatts is handed over to a test engineer with a value of umpteen millions of Euros and the focus of the whole space program is on the result of his work' (page vii). The proud tone is tempered with a sadness, as if the present official orientation towards solid propulsion is corrupting the past work. As always politics will tell the future.

After a very short introduction retelling the history of aviation and astronautics the reader is presented with the aim of the book: 'an outline of how to operate a test facility, how to maintain it and keep it available and how to modify it over the decades to meet the needs of rocket propulsion technology' (page 2). Is the book providing all this? In a general way the answer is yes, especially with the details provided in fourteen Appendices covering aspects such as valve characteristics and flow schemes. Further, the text is sometimes interspersed with 'Remarks' that significantly add to the outline. One very interesting such 'Remark' relates to the time when Ariane 5 was to be used for humans: 'therefore, originally 500 development tests were planned on the two facilities, PF 50 in Vernon and P5 in Lampoldhausen...11 Vulcain engines were tested in 135 development tests on P5' (page 11). The figure for PF 50 is not provided and that fact illustrates the very personal focus.

The central theme is the complicated operation of the cryogenic rocket engine. The modification from Vulcain to Vulcain 2 involved 80 tests on four engines but even so the engine failed during its first flight. So after decades of efforts going into setting up procedures and training matrix systems tests can not predict flights with total confidence. The 'Last Remark' is more personal: 'Instructions, procedures, rules and documents are indispensable on the test facility but the execution is always up to a team which consists of human beings. The most genuine instruction on how to operate in a team is given in the Bible' (page 93).

It is perhaps understandable that when being responsible for verification of something as complex as a liquid rocket a connection to a non-human power helps, but it is rare that such sentiments form part of a technical text. If the reader can accept such a view, this book (and even more so the tables and Appendices) does provide a good outline.

The real question is what will be the future of such 'extraordinary workplaces'?

Anders Hansson