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Book Reviews

Development of ideas in physics by Nils Ryde, AWI International AB, P.O. Box 4627, Alsnogatan 7, S-11691 Stockholm, Sweden, 1994, pp. 196, SEK 207.

In *Development of ideas in physics*, comprising 11 chapters totalling just about 200 pages, the author has tried to trace, at times too quickly perhaps, the course of the main line of ideas and events from the turn of the century 1800/1900 onwards that have led to the highly successful physics of today. In doing so he has provided a historical perspective on the rise of physicists' conception of Nature which is quite insightful. It recounts not only the textbook-finessed success stories of the great past masters, but also their mistakes, the many a false move and the road not taken. Thus, it is heartening to learn in Chapter VII on the *Neutrinos* that Niels Bohr, when faced with the problem of missing energy in the then known beta-decay, was prepared to give up on the law of conservation of energy at short nuclear distances! It comes not a little as pleasant surprise when we are told in Chapter I on *The atoms* that while Plank originated the idea of discontinuous emission of energy quanta from the oscillators, he did *not* envisage these quanta propagating through space as such. Similarly, in Chapter XI on *Matter and antimatter* we learn that the particle–antiparticle symmetry wasn't, after all, all that clear even to Dirac whose equation subsumed it. It is also amusing to read in Chapter X on the *Origin of the elements* of the great astrophysicist Eddington who in his exasperation *vis-a-vis* the white dwarfs (with their high densities and weak radiation) declared that *A star will need energy to cool*! The book contains several case studies of great discoveries, *e.g.*, of *The neutron, the neutrinos and the spinning particles* that reveal the continual interplay of theory and experiment, or conjectures and refutations.

The choice of the material covered in this book is quite apt—quantum mechanics; atomic, nuclear and sub-nuclear particle physics; high-energy astrophysics and cosmology. A discernible omission, however, is perhaps that of black holes.

Much of the book is written in a matter-of-fact style, without anecdotes that distract. It is really addressed to students and practitioners of physics who would like to have a sense of their historical bearing, but do not have the patience, or the time, to go through the available exhaustive volumes on the history of modern physics. Recommended for libraries.

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Applications of random vibrations by N. C. Nigam and S. Narayanan, Narosa Publishing House, 6, Community Centre, Panchsheel Park, New Delhi 110 017, 1994, Rs 495.

This book is a welcome addition to the growing literature on random vibrations. It is a befitting successor to the previous book *Introduction to random vibrations* by N. C. Nigam (MIT Press, 1983). The present book under review concentrates on explaining how the theoretical developments described in the previous book are applicable to a wide variety of practical problems arising in civil, mechanical and aerospace engineering. The chapter titles better explain the content and reach of the book very well. There are ten chapters entitled 1. Introduction, 2. Modelling and simulation of random processes, 3. Fatigue and creep under random vibration, 4. Design of structural/mechanical systems in random vibration environment, 5. Response of aerospace vehicles to gust, boundary layer turbulence and jet noise, 6. Response of vehicles to guideway unevenness, 7. Response of structures to earthquakes, 8. Response of structures to wind, 9. Response of offshore structures to wave loading, and 10. Statistical analysis.

The authors have kept in mind not only those who may like to apply the principles of random vibration but also the student community. Thus several worked examples have been included to understand the details. The book has an excellent collection of references for further reading followed by author and subject indices. The weakness of the book, if at all one has to point out any, is in the thin spread of the subject. At places the matter is presented rather cursorily with a list of references or statements. For example, on p. 231 there is statement regarding hunting instability and wheel hopping in railway systems. However, this is not followed up later to explain what they are and how they can be handled through principles of random vibration. Another unusual feature the present reviewer found was in the usage of/in the title of Chapter 4. It is not clear whether this is 'and' or 'or'. The usage of the outdated FPS system of units in Chapter 4 also affects the otherwise lucid presentation. In Chapter 7, a large body of information on earthquakes has been presented. However, the views of the authors on issues like spectrum-compatible PSD functions for different damping values and uniqueness of the solutions would have been very valuable. However, these comments in no way lessen the usefulness of the book.

The book is a must for everyone who wants to either study or apply modern developments in the area of vibrations.

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History of liquid rocket engine development in the United States 1955–1980 edited by Stephen E. Doyle, 1992, pp. 176, $ 50, Published for the American Astronautical Society by Univelt, Inc., P. O. Box 28130, San Diego, California 92198, USA.

An important part of the growth of technology in any progressive society is the preservation of the history of technology, to enable successive generations to create the necessary recipe for contemporary technology development. The eastern societies, particularly in the Indian subcontinent, are not exactly famous, to put it mildly, for the preservation of the essentials of the historical development.

One of the hallmarks of western technology and culture revolves around the preservation of history. A case in point is the American Astronautical Society History Series of which the above book is a part. Edited by Doyle, the 155-page book is a collection of five leading articles and a very interesting set of summary and conclusions forming the quintessence of the recipe for new technology creation, the entire material written for a colloquium on the history of liquid propulsion technology.

The early sections on 'The introduction to liquid rocket booster propulsion systems' and 'Remarks on liquid rocket propulsion development' are reasonable but are not sufficiently attractive, considering the profound material covered in these sections. Tsialkowsky, Goddard and Oberth, the Russian, American and German seers and originators of liquid rocket propulsion systems as a means of access to space are brought in but not with the necessary anecdotes which always make the study of history interesting.

The hard stuff on history begins supposedly on storable systems but in fact starts with semi-cryogenics (LOX/RP1) for Titan I and moves on to nitrogen tetroxide/aerozine-50 (Titan II) system. The chapter has many details which have been documented in earlier works and the background stories on personalities are missing. One brief para on life of materials on page 30 is useful information from experience.

The next two chapters on LOX/RP1 engines are informative, but not much more than available in the literature of the sixties and the seventies. Perceptive readers won't benefit and others will find them too dull. The rich information base in the original documents has not been captured in these chapters.

Readers can feel compensated by the next two chapters which are the most delightful, insightful and gripping in terms of technical information as well as the backdrop on personalities. The style of writing in these two chapters also reveals a sense of deep involvement of the authors. SSME is a state-of-the-art reusable throttleble (full) cryogenic engine with a staged cycle and a chamber pressure of 200 bars. It is appropriate to state that such a large, high-performance (a specific impulse of 4500 N s/kg) engine has not been surpassed in its special features and reliability. Several segments of development have appeared in magazines like *Aviation Week* and *Space Technology* over the last two decades. But the material in this article is well arranged to provide a continuity of thought. Eight major development problems and the methods to overcome them have been highlighted. The 'special terms' and five O'clock daily meetings that were convened with great regularity to discuss the progress and resolve questions have been highlighted indicating the dedication and pace at which the development was made. Several interesting development truths have been brought out in the description. One of the usual features in the development process is to test individual components, qualify them before integration. In the staged cycle design of SSME, it was found that if the pumps were to be tested separately, "the test stand needed 2000 valves of which 24 were servo operated. Preburner propellants were supplied from a 14000 psi system with the valves weighing as much as 5 tonnes." It was felt that if the original test programme was gone through, valuable financial resources would have been drained and so Dr R. Frosch, the then NASA administrator testified to the Senate Subcommittee that "... the best and the truest test bed for all major components, and especially the turbo pumps, is the engine itself." The reason for such a conclusion is that the coupling between the various elements is so strong that component tests would reveal little of the major problems arising out of coupling.

In the development of this complex engine, it appears that safe engine start and shut down were the major steps to master. These needed transient behaviour of the components to a degree that is not demanded in most other systems. It required 19 tests, nearly six months, eight turbo pump hardwares to reach 2 s into an eventual 5 s startup sequence. An additional 18 tests over three months with 5 turbo pump replacements were needed to achieve the steady pressure. Ultimately, an engine-mounted computer was needed to do a safe start and shut down sequence. The high power with low inertia was responsible for unstable operation, something which was to be controlled by split-second timing and appropriate sequencing. It was during these tests that the need for purging by ultra dry gaseous nitrogen was learnt to avoid moisture and air in the hydrogen line.

The description of the resolution of the vibration on the high-pressure turbo pump on the fuel side in a subsynchronous manner is very fascinating. The power generated in the turbo pump, approximately 400 kW per blade of the turbine with uncooled blades operating at 1360 K, was and is the most stressed element amongst turbines of contemporary design and needed directionally solidified castings based on nickel-based super alloy to meet the stringent requirements.

One of the other fascinating descriptions consists of the structural failure of a steel horn put along the intersection of the nozzle as a protective element. After the first systematic analysis and redesign had produced a better configuration and was subject to full-scale test where again it failed. This time structural analysis indicated no cause for failure. A careful metallurgical examination showed the material to be Inconel 62 with half the strength of Inconel 718 as envisaged. An electron microprobe X-ray analyser was developed and used to cause this detection. A special etching technique using electrolytic oxalic acid was developed to effect instant recognition of the material. Finally, it was tracked that the problem was due to a batch of bad filler material and then sufficient inspection procedures were put in place.

Speaking of the development history, 1975 saw 27 tests with each test at 2 s; 1976 saw 108 tests with test duration of 22 s; 1977 was 155 tests with test duration of 97 s; 1978 saw 144 tests of 148 s duration; 1979 saw 136 tests of 176 s duration; 1980 saw 152 tests of 284 s duration. The total test time accumulated was more than 65000 s by 1980. This describes the kind of effort needed to develop the state-of-the-art system.

The preliminary flight certification demonstration required two cycles of tests in which each cycle meant 13 tests and 5000 s of test including simulations of normal and abort-mode tests on two separate engines, all these requiring 100% success. If any test were shut down because of engine problem, the whole cycle was to be repeated. It is these rigorous tests that provide the basis of the high reliability expected of engines to support man-rated missions.

Consequent upon this, the results of the performance of the first flight showed complete correspondence with expectations expecting a small departure in the mixture ratio in the tail-off region. This was analysed as due to radiant transfer from the hot engine components to the pressure sensor drift something which did not come out in test stand simulations. Correction by providing a thermal stand off cleared the problem in subsequent flights.

Chapter 5 is on the development of RL 10 engine, the first engine to be developed based on full cryogenics–liquid oxygen (LOX) and liquid hydrogen (LH2) preceding the SSME engine described above. While the SSME staged combustion engine was developed between 1972 and 1980, RI 10 engine was developed between 1956 and 1967, with the major activity completed by the end of 1965. This development took place at a time when hydrogen was thought of as a dangerous explosive and should be handled most carefully. It was only subsequently that it was uncovered that it was one of the most benign fuels albeit quick reactivity with most oxidisers. This paper is a recollection of the most interesting period of history when not much was known about this fuel or the engine likely to use it. A fair portion of the technical material reported here is also available in other published literature. As such only the important points will be highlighted. The combustion chamber of the engine is made of large number of shaped tubes which are set around a periphery and brazed together in a vacuum brazing furnace. This technique developed over a period of time used the tubes made by a company which specialised in the manufacture of golf club shafts and meat hooks! Apparently, they had the tapering technology to accurately produce tubes with precision diameters, smaller in the middle than at the ends. Further, since the solid metal injector face plates suffered severe warping during combustion, the face plate was constructed of what is known as rigimesh which is essentially a porous material of layers of stainless steel mesh made coherent through a carefully controlled sintering process. About 5% of the hydrogen is permitted to seep through this mesh to enable reduction in thermal stresses.

In the turbo pumps and other rotating surfaces, ideas of using hydrogen itself as a lubricant and venting the leaked lubricant into a low-pressure zone using a sequence of seals so that the small leaked material does not support combustion.

An interesting problem connected with ignition seems to have arisen because of the change in the test scheme from horizontal to vertical testing mode. System design arranged for horizontal arrangement and electrical ignition worked satisfactorily. However, in the vertical mode, it turned out that the correct mixture ratio for ignition could not be obtained and this led to delayed ignition implying much harder pressure rise and explosion. Apparently, one of the scientists had made the observation that ignition was not a sure phenomenon as he observed in the ignition test rig. However, in an environment where the whole programme was struggling to keep the hardware going and rest of the systems ticking, this observation appeared like a 'joke'. Ignoring it meant loss of two sets of engines and an initiation into the programme from the ignition end. Another effort to overcome the thrust overshoot in the initial transient led to the development of a bypass valve that routed part of the hydrogen into the thrust chamber around the turbine. The RL10 engine underwent, then onwards, several tests and its use on missions led to 100% success. Even as on January 1988, the engines had clocked successful performance totalling 1,641,425 s. It has been rated as one of the very reliable rocket engines in the inventory of rocket engines. The article goes on to describe the other variants that were developed for several missions.

In a final section on summary and conclusions, the authors reflect and set down the principles of rocket engine development. Some of these are "keep it simple in design", "build flexibility into the design when you can", "learn to work with failures", "take calculated risks" and "try to do things right the first time, if you can". They indicate with regard to "taking calculated risks" "now-a-days, we dont take calculated risks like we used to in the fifties and sixties, when we got a lot done for a relatively small amount of money". These thoughts are very reminiscent of what happens in India.

The reading of the last two chapters and the summary to those interested in rocket engines is so enthralling and educative that this book is strongly recommended as an essential reading material for all liquid rocket engine designers of modern era.

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