DESIGN INSPIRES RESEARCH

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INSPIRATION

To cover the achievements and aspirations of a professional career of over 3 decades within four pages is not easy, but we will make an attempt.

Design is synthesis, it is the creation of new systems and new artifacts to meet man's desires and needs. Naturally, it is the basis of all human development and is the inspiration for most research. Thus, research directions inspired by design tend to be purposeful, economical, exciting and satisfying. The design objective also helps to give a feed back and keep research in check from its natural run-away tendency, while yet preserving an imaginative approach and a comprehensive far-sighted outlook. This philosophy was evolved in the first decade of working and studying with Dr. V.M.Ghatage in Hindustan Aeronautics, Dr. P. Nilakantan in the Civil Aviation Department, Prof. J.H.Argyris at the Imperial College (London), W.E.W. Petter in Folland Aircraft and Prof. S. Dhawan at IISc. It has formed the basis for my research aspirations and strategy. It was implemented with the exciting and devoted participation of a large number of students, colleagues and collaborators in India and abroad. It has resulted in a large body of research workers and design engineers, many research theses (well over 25 for Ph.D.), a number of scientific publications and presentations (over 200) and some industrial applications. The achievements have been highly satisfying. The prospects appear exciting.

THE CHOICE

1959 was an year of hope in Indian aeronautics. Soon after came the inspiration of the space programme. I was given the task of planning teaching and research in Aerostructures and Design in IISc, to assist and respond to the concurrent developments in R&D and industry. The first step we, Profs. C.V.Joga Rao, P.N.Murthy, S.Durvasula and I, took was to reorient the teaching & research in Aerostructures from applied mechanics to engineering and design. We took a decision to leave full scale structural testing to NAL and HAL, and to concentrate on analytical and experimental investigations into fundamental aspects of practical problems of design, manufacture and operation. Thus, my research here was initiated in the areas of Finite element methods, Structural joints, Mechanics of structural elements, Design against fatigue, Fibre-reinforced composites and Experimental stress analysis. The dual objectives of local need and international recognition for the school were kept in view. The fields and

methods were continuously reviewed and updated. My colleagues Profs.A.V.Krishnamurty, K.P.Rao, K.Vijayakumar and K.Rajaiah actively participated in this process. In time, we moved on to Systems engineering, Fracture mechanics and Structural integrity, System optimisation, Fleet operation and maintenance, Safety and Reliability and the promising fields of Acoustic emission for monitoring of structural integrity, and Computer techniques for analysis and design. The theme has been comprehensive approach and simple methodology.

Aeronautics and Aerospace are demanding technologies drawing upon many disciplines and capable of spin-off benefits for science and industry at large. We have taken active interest in consciously bringing about this mutually beneficial interaction between Aerospace and other technologies like Railways, Power engineering, Nuclear engineering, Transportation etc. The systems engineering concepts evolved in aerospace engineering have spurred me on to applying them to such areas as Industry-academic interaction (eg. evolving structural models for STEP:Science, Technology and Entrepreneurial Parks), Educational technology and Socio-economic problems.

IMPLEMENTATION

Today scientific research in engineering, is a matter of team work. When drafted from design to teaching, I set my objective as one of training the next generation and creating teams. On the job, I realised that in the Indian ethos, viable teams should be relatively small and small teams can interact across institutional barriers. I also realised that scarcity of facilities is not an unmixed curse; it can spur one to greater creativity and simpler solutions, which once found are valued even in affluent societies.

Fundamental Studies: Typical of our fundamental studies, were the analytical investigations into torsion and analogous problems with rectilinear boundaries (S.A.Hussainy, Ph.D.,1966, S.G.Sampath, M.Sc.(Engg), 1966), which gave us deep insight into handling boundary value problems to achieve convergence, accuracy and close bounds and the three-dimensional elasticity analysis of plates and laminates (S.Srinivas, Ph.D., 1970) which has become seminal work against which people compare the results of alternative formulations and approximations in plate theory. These brought very clear understanding of certain anomalies in thin plate flexure like the circle-polygon paradox (significant to finite element formulations) and the concept of simple support (K.Rajaiah, Ph.D., 1972). My serious research studies having started with load diffusion and stress concentration (A.K.Rao, Ph.D., London, 1958), these form an underlying current in my work and have resulted in some fine theses (B.Dattaguru, Ph.D., 1972, H.M.Aruna, M.Sc.(Engg.), 1972, M.V.V.Murthy, Ph.D., 1975).

Techniques: We initiated research in finite element methods in India when computers were yet unavailable (S.P.Govindaraju, M.Sc.(Engg.),1966) and

moved on to initiate a reverse process in finite element methods by proposing a single large special element in place of large number of small elements to model stress concentrations and singularities (I.S.Raju, Ph.D., 1972). We also made fundamental studies of closed-form and finite element methods for vibration and stability (G.Venkateswara Rao, Ph.D., 1972, K.S.R.K.Prasad, Ph.D., 1974, S.Suryanarayanan, Ph.D., 1974).

Structural Integrity In the broad field of structural integrity we made notable inroads in more than one direction.(1) Structural Joints: By developing a few conceptual tricks we are achieving deep insight and extensive data on problems of bolted joints (N.S.Venkataraman, Ph.D., 1966, Wg.Cdr. V.A.Eshwar, Ph.D., 1977, P.D.Mangalgiri, Ph.D., 1980 and A.K.Rao 'Elastic Analysis of Pin Joints', Invited paper for the Argyris 65th Birthday Special Issue of the International Journal of Computers and Structures, Vol.8, No.4, 1978). Currently we are moving towards three-dimensional aspects and fracture mechanics of bolted joints (A.C.B.Naidu and N.Sundarraj). Recognising the increasing importance of bonded and welded joints, we have made fundamental studies on effects of nonlinearity and methods of optimal shaping of such joints (T.S.Ramamurthy, Ph.D., 1979). (2) Fatigue and Fracture: Due to my earlier studies in India on airframe fatigue, I was given the privelege in UK, to develop a total procedure starting with design to ensure guaranteed fatigue performance of new aircraft. This method was used for the Gnat and subsequently for the Harrier. This interest has continued (K.N.Raju,Ph.D.,1981, Col. V.J.Sundaram, Ph.D., 1984). (3) Non-destructive Evaluation and Acoustic Emission (AE): The most important aspect of structural integrity today is NDE. Its economic implications are tremendous. New techniques have to be developed and available techniques have to be combined. We have made basic postulations and research in AE highlighting the need for moving from simple time domain analysis to pattern recognition concepts (C.R.L.Murthy, Ph.D., 1983, Col.V.J.Sundaram, Ph.D., 1984, Baldev Raj and G.E.Giridhara). Another aspect of fracture mechanics we are looking at is efficient repair technology (Rameshchandra).

Systems Concepts: We have applied systems concepts to important problems of fleet operation such as logistics economics and resource allocation (Wg.Cdr.Ramchand, Ph.D., 1977 and V.Mani).

Composites: We saw the age of fibre reinforced composites coming and initiated work on thick laminates (S.Srinivas, Ph.D.,1970), defects and discontinuities in composites (S.S.Patil, Ph.D.,1973), joints in composites (T.S.Ramamurthy, Ph.D., 1979, P.D.Mangalgiri, Ph.D., 1980) and repair systems (Rameshchandra).

Experimental Methods: Often, experiment is essential to understand or examine a phenomenon, to validate a model, or to complement and analytical study; so all my research students are trained in both analytical and experimental techniques and some fine experimental work has been done mainly in the fields of fatigue and fracture, photomechanics and acoustic emission. The emphasis is on simplicity and accuracy.

Flight Mechanics: The love of aircraft occassionally drags me into

investigating problems like aircraft runway interaction and under carriage design (Krishnadevarayalu, M.Sc.(Engg.), 1974 and C.Venkatesan, Ph.D.,1980).

Sponsored Research and Consultation: The success of our programme is borne out by the large number of substantial research and consultation projects we have received and the wide range of topics they cover. The sponsors include Public Sector, Private Sector and Overseas Institutions. We have also had the privelege of close collaboration with many competent colleagues from within the Institute and sister organisations like HAL, NAL, ISRO,DRDO, RDSO and DAE.

ASPIRATIONS

The years to come are bound to be increasingly demanding. We in our school are well poised to meet the challenges and to make significant professional contributions to research and application in science, technology and education.

Science: I will continue to strive for conceptual research and simple solutions that will advance productivity and sophistication in Engineering and technology. The fields of structural integrity, structural joints, fibre reinforced composites, non-destructive evaluation and acoustic emission will receive special attention. Elsewhere in this volume my colleagues Prof.B.Dattaguru, Dr. T.S.Ramamurthy and Dr. C.R.L.Murthy will be spelling out in more detail our achievements and aspirations in these areas.

Technology: Some small strategic inputs to our industry can create quantum jumps in productivity with existing resources. In this context, we identify Design technology, Systems concepts, Computer aided design and analysis (particularly with mini computers), Maintenance engineering, Resource allocation studies and, last but probably the most important, NDE as fruitful areas for scientific research.

Education: Creative urge is inherent in all individuals and this can be brought out by an education that emphasises decision making and design methodology. (A.K.Rao, 'Technical Education in Developing Countries - Prospect and Retrospect', Keynote address, at COSTED - UNESCO Conf. on Tech. Education for Development, Bangkok, 1978). I propose to step up my interest in developing teaching programmes aimed at students at various levels and at mature individuals seeking continuing education. The video and the computer will be exploited for this purpose.

Ours is an Institution of international reputation. **It is well poised to become an International Institute.** I like to continue my efforts to contribute to this transformation.