Patrika

July 1994 No. 31 Newsletter of the Indian Academy of Sciences

Diamond Jubilee of the Academy

1994 marks the sixtieth year of the founding of the Academy and this landmark event will be celebrated by mainly scientific activities. Special issues will be published by some of the Academy journals. There will also be a larger number of Discussion Meetings during the year.

The Diamond Jubilee Annual Meeting will be held in Bangalore from 30 November to 2 December 1994. The first two days will be devoted to symposia, special lectures and lectures by Fellows and Associates and is expected to be held at the Faculty Hall of the Indian Institute of Science. The main public function of the Diamond Jubilee will be on 2 December 1994 at the J N Tata Auditorium in the campus of the Indian Institute of Science.

A Reception Committee and a Local Organizing Committee are being formed to look after the arrangements.

Fellows and Associates who are unable to obtain travel support from other sources will be paid first class train fare from their places of residence to Bangalore and back to enable them to attend the Diamond Jubilee Meeting.

Fellows and Associates who have not yet informed the Academy Office of their intention to attend the meeting may do so as early as possible.

Mid-Year Meeting

At the invitation of the Central Food Technological Research Institute (CFTRI), Mysore, the fifth Mid-Year meeting of the Academy will be held on Sunday, 31 July 1994 and Monday, 1 August 1994 at CFTRI, Mysore.

There will be fifteen lectures by new Fellows and Associates and three special lectures. The special lectures are by: A V Rama Rao, Indian Institute of Chemical Technology, Hyderabad on "Synthesis of biologically active molecules with a difference"; Chandralekha, Madras on "Tradition and modernity" and Madhav Gadgil, Indian Institute of Science, Bangalore on "Biodiversity: Chance or necessity?".

The lectures by Fellows and Associates are:

R L Karandikar, ISI, New Delhi, "Semi-groups, Markov processes and Martingale problems"

R Amritkar, University of Poona, Pune, "Dissipative chaotic systems"

K A Padmanabhan, IIT, Madras, "Optimal structural superplasticity"

M Ramakrishnan, Geological Survey of India, Hyderabad, "The oldest rocks of South India and the early history of the earth"

K R Anantharamaiah, RRI, Bangalore, "Transitions between high Rydberg states of atoms in the interstellar medium"

N Periasamy, TIFR, Bombay, "Dynamics of fluorescent probes near surfaces"

K L Sebastian, Cochin University of Science & Technology, Cochin, "Dynamical effects in scanning tunnelling microscopy"

N Balakrishnan, IISc, Bangalore, "Applications of computational electromagnetics"

Amit J Basu, NAL, Bangalore, "Vortex breakdown"

R Raju Viswanathan, Centre for Artificial Intelligence & Robotics, Bangalore, "Fault tolerance in neural networks"

N Kochupillai, AIIMS, New Delhi, "Relevance of indigenous technology development in the study and management of health problems in developing countries"

A S Balasubramanian, Christian Medical College Hospital, Vellore, "Non-cholinergic activities of cholinesterase"

R V Hosur, TIFR, Bombay, "Multidimensional NMR studies on the Myb-DNA system"

D Chatterji, CCMB, Hyderabad, "DNA-dependent RNA polymerase: A key metabolic sensor"

Alok Kumar, Institute of Physics, Bhubaneswar, "Noncompact symmetries in string theory"

Binary Pulsars

Summary of an Academy Lecture given by Prof. J H Taylor, Princeton University, New Jersey, USA on 17 March 1994 at Bangalore.

The work of Prof. Joseph Taylor on pulsars, particularly on the timing of the famous Hulse–Taylor binary pulsar leading to precision tests of general relativity, is widely known. Taylor and Hulse shared the 1993 Nobel Prize for Physics for their work on pulsars.

The lecturer began by characterizing their work as a clock comparison experiment leading to the first experimental detection of gravitational radiation — a prediction of general relativity made by Einstein as early as 1916. In principle, a rotating dumb bell in the laboratory would lose energy by this mechanism, but at an undetectably small rate. The system of two neutron stars orbiting around each other, known to astronomers as 1913 + 16, provided the large masses moving at high velocities needed to make the effect detectable. The brief introduction to pulsars which followed acquired a dramatic quality when the speaker played an audio tape of the signals from three pulsars — the first a slow beat, the second a speedy rhythm and the fastest, more than 600 rotations per second, heard only as a continuous hum. The subsequent account of their discovery of the first binary pulsar using the giant 300-meter Arecibo radio telescope brought out many interesting sidelights — in 1974 a computer with 16 K of memory could be regarded as frontline automation, and even exciting discoveries were communicated by ordinary (paper) mail! The strange variations seen in the pulsar period were soon attributed to its motion around a companion star in a highly eccentric orbit. It soon became clear that this was an ideal laboratory for testing relativity. The precession of the perihelion of Mercury, to take one example of a classic solar system test was surpassed by a factor of approximately thirty thousand in this system. The strength of relativistic effects such as this one (or time dilation, for example) is measured by the ratio of the velocity of the motion to that of light — (v/c), about one part in five hundred for this object. The usually tested effects are proportional to the square of this ratio, while gravitational radiation is a higher order effect proportional to the fifth power. An orbit of the size of the Sun, nearly a million kilometres, shrinks by only three millimetres each revolution (roughly every eight hours) due to the radiation of energy in the form of gravitational waves. Nevertheless, over twenty years, the effect has been measured and agrees with the prediction of general relativity with no free parameters.

In his final summary, Prof. Taylor pointed out that many relativistic effects are present in the system, so that the equations determining the properties of the binary (masses, geometrical parameters, etc.) are three more in number than the unknowns, permitting an unprecedented test of internal consistency. Recently, another pulsar in a binary system has been discovered and preliminary results, of lower accuracy of course, indicate similar agreement with general relativity.

It is rare indeed that a quantitative high precision test of a fundamental physical theory can be carried out in an astrophysical situation. It was just as rare an opportunity to hear the test described with such force, clarity and humour, by one of the people who made it possible and carried it out.

Turbulence Problem

Summary of an Academy Lecture entitled "What is the turbulence problem?" given by Prof. Anatol Roshko at Bangalore on 19 January 1994.

In a masterly exposition that was extraordinary for its clarity and fresh approach to the long-standing and as-yet unresolved problem of turbulence, the lecture began with a reminder to the audience of Leonardo da Vinci's centuries old yet strikingly accurate view of turbulence as consisting of curls and waves, and his urging that in studying turbulence it is better to 'induce first experience and then reason'. He went on to show the striking similarities between the oil spill pattern from the wreck of the Argo Merchant and the oscillating wake behind an inclined flat plate. Turbulence was then introduced as consisting of disorder, unsteadiness, three dimensionality, enhancement of mixing and vorticality, the latter two being its most important characteristics.

Using examples from Van Dyke's 'Album of fluid motion', the onset of turbulence was illustrated through a series of pictures of the wake behind an airfoil and a cylinder, starting from the steady bifurcation observed at a Reynolds number (Re) of 28 based on the cylinder diameter, to two-dimensional periodic oscillations that occur at $50 \lesssim \mathrm{Re} \lesssim 200$, and, finally, to vortex shedding and the presence of 'turbulence' at $\mathrm{Re} \sim 10^4$.

The Navier–Stokes equations for a velocity field were introduced (with a mention that though the equations were known since 1850 and scientific observations of turbulence may be said to date back to 1500 AD, the 'problem' of turbulence remains!), along with the 'Reynolds averaged' equations which result when the velocity vector is split into a mean and fluctuating components. The latter lead to the introduction of the Reynolds stresses and the consequent problem of closure of these equations and the necessity for modelling. ('Even the direct numerical simulation of turbulence does not solve the problem, but gives us more extensive data sets'!) The $K-\varepsilon$ closure scheme was introduced and an elegant discussion of what produces the Reynolds stress in a free shear layer revealed that the turbulent shear and stress terms occurring together display a bias for the Reynolds stress to be positive when the shear is also positive. A more complete answer, it was noted, would have to take care of the presence of instability waves and coherent structures.

The discovery of ordered structures in fully developed turbulence, in large part by Roshko himself, was illustrated, using the photographs of Bernal, Brown and Roshko, again published in Van Dyke's album.

A study of instability in shear layer flows (jets, wakes, etc.) introduced the concept of the velocity being 'equivalent' to a distribution of vorticity (the curl of the velocity) and thus to an array of vortices. This leads to the possibility of modelling a flow as a collection of vortices and reproduces a lot of the richness and variety that turbulent flows exhibit — all the way from the existence of primary instabilities and transition to the characteristics of coherent structures.

The turbulence model of Morris, Giridharan and Lilley (*Proc. Roy. Soc.* 1990), which combines the Reynolds averaged equations with linear stability theory for a developing shear layer, was introduced as a significant departure from conventional modelling; its success was indicative of the fact that some of the turbulence 'folk' have been too preoccupied with the high wave number range of the broad-band turbulence spectra. Perhaps the time has come, Roshko suggested, for serious rethinking. This discussion set the stage for some comments on the classical and new approaches to turbulence, viz. why the statistical theory of turbulence may have unnecessarily emphasized *dissipation* of turbulence while instability/coherent structure models indicate the benefits of studying the *production* of turbulence. This discussion best illustrated the deep and significant ideas and conclusions that have come out from the remarkable scientific effort of one who has spent the greater part of his scientific life studying turbulence.

The lecture touched briefly on other new ideas (dynamical systems, fractals, complexity theory, self-organized criticality and the renormalization group). In conclusion Roshko stated what die-hard turbulence people have heard and believed for so long: the end of the problem of turbulence is not in sight. That, as Roshko said, should give us a good reason to meet again sometime.

Theories and Models in Biology

A discussion meeting-cum-workshop on "Theories and Models in Biology" was held at the North Eastern Hill University, Shillong, from 6 to 10 May 1994. It was jointly sponsored by the Academy, the S N Bose National Centre for Basic Sciences, Calcutta and the North Eastern Hill University, Shillong.

Including speakers, the total number of participants was 30. About one-half of them were post-graduate students and the rest were active researchers. The aim of the meeting was two-fold, to expose persons trained in the physical sciences, as also biologists, to concepts and issues in modern biology that might be amenable to theorizing or mathematical modelling, and to foster intense discussions on specific problems.

Formal presentations were made by J Das, Indian Institute of Chemical Biology, Calcutta; P Sinha, Bose Institute, Calcutta; S Sinha, Centre for Cellular and Molecular Biology, Hyderabad; M K Chandrashekaran, Madurai Kamaraj University, Madurai; D Roy and P Nongkynrih, North-Eastern Hill University, Shillong; A Elepfandt, Humboldt University, Berlin; and N Behera and V Nanjundiah, Indian Institute of Science, Bangalore. The relative degree of emphasis given to theories (or models) and experiments varied from speaker to speaker; however, all took pains to emphasize that there needed to be a close interplay between the two; the reality being, of course, that this is not widely acknowledged among biologists.

The meeting started with an introduction to the ideas of evolutionary theory by V Nanjundiah. The points he made were that (a) there is a meaningful distinction between genotype and phenotype; (b) selection acts on the phenotype; (c) genotypes change during the course of evolution because phenotypic variability — a prerequisite for selection to occur — is a consequence of random variations in the genotype. It was also pointed out that forces other than natural selection could result in evolution, for example, drift and catastrophes. However, unlike natural selection, in general, these do not lead to adaptation. At the end, the reasons behind the belief that mutations occurred randomly (in the sense that the probability of a particular mutational event was independent of whether its consequences for the organism were advantageous or not) were stated. The second talk by J Das was on the last point and he analysed the recent experimental results with microbial systems that question this belief and instead suggest that under certain circumstances, favourable mutations can occur with a higher probability than unfavourable ones. The speaker emphasized that judgement needed to be suspended until it was clear whether or not in each such situation of apparently directed mutagenesis, mutation rates at unselected loci remained unchanged. The third talk by P Sinha was a detailed exposition of the genetic circuitry involved in the switch between lysogeny and lysis in the bacteriophage lambda. This was followed with a discussion of the principles governing the regulation of gene activity in bacteria and of gene networking in eukaryotes.

The next presentation by J Das consisted of a description of techniques for designing stereospecific nucleic acids and polypeptides by making use of random variation and selection rather than by targeted design. Attention was drawn to the tremendous degree of specificity that could result from the use of these techniques, and the question was raised whether it might be possible to improve on the results achieved by natural selection.

The fifth talk by S Sinha, which was also the first one to have a substantial amount of mathematics, examined biochemical regulatory pathways with special reference to the tryptophan operon of *Escherichia coli*. A conclusion was that such analyses permit one to make predictions of the effects of parameter variations which, in terms of the organism, would be mutational changes. It was shown how one might go about improving yields by making use of the right combination of theory and experiment; in other words, by designing appropriate controls. The next topic to be covered by D Roy and A Elepfandt was acoustic communication and social behaviour in frogs. The Indian sub-continent, in particular the North-East, has a very large number of frog species that are ideally suited for behavioural studies. Illustrations of sound spectrograms were provided together with audio play-back of the appropriate calls. It was shown how acoustic

recording and behavioural observation can be a means of identifying species when morphological characters prove insufficient or misleading. It was stressed that an appropriate understanding of behaviour requires inputs from ethology, sociobiology and neurobiology. Continuing with behavioural biology, a review by M K Chandrashekaran and P Nongkynrih of the biology and mathematical analysis of circadian rhythms followed. After a presentation of data pertaining to the eclosion rhythm in *Drosophila pseudoobscura* and an illustration of phase-response curves based on the rhythm, a mathematical description of the underlying oscillator was attempted. The distinction between single oscillator and multiple oscillator models being difficult to make operationally, one could nevertheless hope to get a concise description of data from the qualitative aspects of a model. This of course left open the question of how 'good' the model was.

The final day started off with a discussion of optimality principles in population genetics. Beginning with the Lagrangian developed by Svirizhev, N Behera demonstrated that it was possible to derive a generalized extremum principle true for many non-interacting loci. The question left open was, would a similar exercise succeed with the inclusion of non-additive components of variance in fitness — for example, those caused by epistasis and dominance? The last talk by V Nanjundiah covered the possible role of phenotypic plasticity in evolution with specific reference to experiments on genetic assimilation. The conventional explanation of Waddington's observations was given, and it was pointed out that such explanations remain tentative and await examination with the help of the techniques of molecular biology.

An interesting part of the workshop was a round-table open discussion, held on the final afternoon, concerning the status of theoretical biology in the country and on possible ways of strengthening theoretical biology activity. A detailed paper on this topic, containing specific recommendations, is in preparation. There was unanimous agreement on the desirability of holding meetings, such as the present one, on a regular basis, say annually.

A very large number of areas that could have been covered could not even be touched upon. As a consequence, there was the inevitable differences of opinion between those who thought that it might have been better to have had a smaller number of topics and greater depth and those who thought that the present broad format was just right. Everyone felt, however, that the meeting was a success on many counts. Firstly, it led to intense discussions between persons who might otherwise have never met, 'theoretical biology' being as uncertainly defined as it is. Secondly, it introduced many to do-able problems that were new to them. And finally, it turned out that there was a real possibility of collaboration between different participants. The task for the immediate future is to chalk out concrete strategies for following up on the sense of well-being generated by this meeting. The prospect is an exciting one.

Special Issues of Journals

1. *Sādhanā — Academy Proceedings in Engineering Sciences*, Vol. 19(75), Part 1, February 1994, pages 1–188. Artificial Intelligence and Expert Systems.

Three decades of research in Artificial Intelligence (AI) and about fifteen years of experience with its first commercial products known variously as Expert Systems and Knowledge-Based Systems have led to wild speculations about the revolutionary nature of these technologies affecting a wide range of human activities from wars to businesses, and from medical diagnosis to legal applications etc. It appears that AI has matured from the days of solving puzzles and games, proving mathematical theorems or manipulation in the block world domain of robotics to the wider world of diverse science, engineering and business applications where artificial creatures (agents, actors etc.) attempt to solve problems in benign and hostile real worlds. This special issue of *Sādhanā* brings out a collection of papers emphasizing these trends in a predominantly Indian context.

AI research has evolved with the aim of making computing machines smarter by developing programs capable of simulating and mimicking facets of human intelligence. Traditionally, such systems are built using a

top-down design approach. Vast amounts of knowledge, from a few human experts, is acquired and stored to solve a narrow range of problems in a specific domain capturing competence along one dimension of a human being's intelligent behaviour. Simultaneously, psychologists and cognitive scientists are concerned with computer programs to provide models of human mental activities such as thinking, learning, perception, use of natural languages, speech and pattern recognition. It is not difficult to recognize the fact that intelligent action in a challenging environment cannot be obtained through the classical weak methods of AI involving heuristic search. Today, intelligent action is synonymous with adaptive behaviour of the agent and intelligent systems are built in a bottom-up manner.

The papers in this special issue deal with problem-solving in diverse disciplines incorporating some of the current trends in AI and expert system fields.

This special issue addresses issues and topics which are new and relevant to the Indian context. The eleven papers illustrate the range of possible applications of AI technology.

2. *Proceedings Mathematical Sciences* — Vol. 104, No. 1, February 1994, pages 1–304, K G Ramanathan Memorial Issue.

This special issue, dedicated to the memory of Prof. K G Ramanathan, who passed away on 10 May 1992 at the early age of 52, contains 24 papers by his friends and colleagues from all over the world. An obituary note by S G Dani, Editor, precedes the papers.

Obituaries

Bagepalli Ramachandrachar Seshachar passed away on January 24, at the age of 86. His death has removed from our midst an outstanding zoologist and a cell biologist, who left a deep imprint on the scientific and educational scene in this country. He had a profusion of qualities: penetrating intelligence, knowledge, ability, dynamism, energy, discipline, dutifulness and aesthetic sensibility. An intellectual aristocrat, he stood out in any group of scientists.

Born on 9 January 1908 at Bagepalli now in Karnataka, his scientific career started in 1926, when he joined the Central College, Bangalore (then part of University of Mysore) as Demonstrator in Zoology, soon after completing the Bachelor's degree. Even from early days he was deeply motivated and obsessed with excellence. A turning point in his life was his tutelage under Prof. C R Narayana Rao, an inspiring teacher who not only taught Zoology but also English. His initial research was on the cytology of Apoda, an ancient order of burrowing, limbless amphibians. This contribution has stood the test of time as a pioneering study. He had to give up working on these fascinating animals because of their restricted world-wide distribution and scantiness. In selecting the ciliate protozoans as subject of his research, Seshachar found an inexhaustible supply of microscopic organisms, occurring in aerated sewage. These organisms were characterized by the presence of two nuclei (the macronucleus and micronucleus). To understand the basis of the origin and development of nuclear dimorphism and the cell, he employed quantitative methods to estimate nucleic acid content, with optical techniques considered modern in his time. A steady stream of publications dealing with the ciliate macronucleus and conjugation, especially in *Spirostomum, Blepharisma, Vorticella* and *Frontonia* appeared in leading international journals and established the Bangalore School as a great centre for research. Although his personal interest was centred on the cytology and cell biology of protozoans, his students were encouraged to use insects, centipedes, millipedes, snakes and tunicates as materials.

The long service of 34 years at the Department of Zoology, Central College, Bangalore (which subsequently became the

Zoology Department of Bangalore University), which he also headed for many years, overlapped with the golden era of the University of Mysore, which had on its faculty many celebrated scientists and scholars.

He was an excellent teacher. He was admired for the breadth of his knowledge in general zoology, his deep understanding of cell biology, genetics and evolution, and above all for his mastery of exposition. He was also an impressive and forceful public speaker, who popularized the latest developments in biology with a sense of wonder and excitement. He was gifted with a clear, unforgettable voice.

After his retirement from the University of Bangalore he was invited to head the Department of Zoology of the University of Delhi in 1960. The responsibility of overhauling and transforming teaching and research in Zoology fell on his shoulders. Outmoded syllabi were changed, gifted faculty were selected, new laboratories were built and modern analytical instruments were acquired. Within a very short time the Department of Zoology rose in stature. Talented research scholars were trained in protozoology, cell biology, endocrinology, fishery biology, insect physiology, toxicology and taxonomy, biochemistry and developmental biology. In recognition of high quality research output, the University Grants Commission elevated the Department to a Centre of Advanced Study in Zoology, the first such centre in the subject to be started in India. The building of the Delhi Zoology Department is Seshachar's richest contribution to higher education. He was Dean of the Faculty of Science, and also Provost of Gwyer Hall.

He was elected a Fellow of the Indian National Science Academy (INSA) and served as Editor, Secretary, Vice-President and President. He was awarded the Sunder Lal Hora Medal by INSA (1965) in recognition of his work. He was elected a fellow of the Academy in 1953 and also served on its Council.

He formally retired from the University of Delhi in 1971 and was appointed Professor Emeritus and joined as Honorary Associate in the Centre for Theoretical Studies, Indian Institute of Science, Bangalore in 1973 and worked there till his death.

The 17 years spent in the Centre were devoted to study and discussions on various subjects: genetics, developmental biology, evolution, ethics, education and society. He wrote several articles on science policy and on the impact and limitations of science in the modern world.

Anantharaman Kalyana Sundaram was born on 10 May 1925 in Tanjore in Tamil Nadu. After graduating from Madras University in 1945, he obtained the Masters Degree in Science from Banaras Hindu University in 1948. He was awarded the Doctorate Degree in Chemistry by the University of Bombay in 1962.

He started his scientific career in 1949 in the Indian Institute of Sugar Technology, Kanpur where he pioneered work on Faradaic rectification and ac polarography, in association with Prof. K S G Doss. This work lead to later inventions of square-wave and pulse polarographic techniques. In 1951, he joined the Atomic Energy Commission (now the Bhabha Atomic Research Centre) where he served till his retirement in 1985 as Head, Electrochemistry Section. During his academic and research career, he built dedicated schools of research in electrochemistry, solvent extraction and thermal analysis.

The main areas of his interest were solvent extraction and kinetics of solid state reactions. He established methods of polarographic evaluation of irreversible processes and modified regular solution theory of solvent extraction. He was the first to extend the popular method of Borchardt and Daniels to the study of solid state reaction kinetics. Later, his interest was centred on the refinement of methods of analysis of thermoanalytical data and computer-aided modelling of decomposition reactions based on solid state reaction models.

He was a Fellow of the Royal Institute of Chemistry. A founder member of the Indian Thermal Analysis Society. He was its Vice President (1977–79) and later, its President (1979–85). He fostered and popularized ITAS and ensured a firm foundation for it. He was elected a Fellow of the Academy in 1965. His total integrity and sincerity to the task on hand was a hallmark of his personality. He passed away on 27 January 1994 leaving his wife, daughter and son and a large circle of colleagues and friends to mourn his loss.

Ramachandra Vaman Tamhankar was born on 28 July 1917. After his early schooling and graduation he took his M.Sc. degree in Physics from the Bombay University in 1943. He took a Technological Certificate in Electrical Engineering from the City and Guilds Institute in London in

1949 and obtained his D.Sc. degree in Metallurgy from the University of Paris in 1957.

He worked for a few months as Demonstrator in Physics in Elphinstone College, Bombay and for a year during 1946–47 in Sankey Electrical Stampings, Bombay. From 1947–49 he was Lecturer in Electrical Engineering in Victoria Jubilee Technical Institute, Bombay.

For the next six years he worked as a Research Metallurgist in the Tata Iron and Steel Co., Jamshedpur. In 1955 he left for France. On his return to India in 1963, after serving for six years as Research Engineer in the Institut de Recherches de la Sidérurgie Francaise from 1955 to 1963, he assumed charge as Director of the Defence Metallurgical Research Laboratory (DMRL), Hyderabad. Towards the end of 1963 DMRL was bifurcated into the Chief Inspectorate of Metals (CI Met) and DMRL and the latter was shifted to rented buildings in Hyderabad with practically no equipment. All the experienced metallurgists were retained at CI Met. at Ishapore and Dr Tamhankar had to start building DMRL with fresh inexperienced metallurgists.

Tamhankar's strength was not mainly in his metallurgical knowledge but in his inexhaustible energy and capacity for hard work. He succeeded in providing DMRL with modern buildings and specialized equipment. DMRL started work in advanced materials and processes such as super and heavy alloys, titanium, tungsten and magnesium alloys, precision casting, powder metallurgical processes and products, high conductivity copper, advanced ceramic products, atomized and HIPed materials etc.

After DMRL had been functioning at Hyderabad for about an year in 1965–66, the Mishra Dhatu Nigam Ltd. (MIDHANI) came into being with Tamhankar as Chairman and Managing Director. Using imported technology, manufacture of advanced materials such as superalloys, magnesium, molybdenum and tungsten alloys and magnet materials etc were started to meet the requirements of aircraft, missiles, space technology, electronic industry etc.

He was the founder President of the Powder Metallurgy Association of India and the Magnetics Society of India. After the formation of these societies there was a spurt in the growth of industries in these fields. Some of the results of the powder metallurgy work initiated by Tamhankar are the 'HAPP' project which has become an ordnance factory and the 'Brakepad Project' which has resulted in the installation of two HAL production plants to manufacture different types of friction materials.

He was also the founder President of the Marathi Vigyan Parishad, Hyderabad Chapter. He was elected a Fellow of the Academy in 1976 and was the recipient of the 1977 Award of the Federation of Indian Chambers of Commerce and Industry.

He was a Visiting Professor at the Indian Institute of Science, Bangalore for 3 years after his retirement from MIDHANI in 1979, and Technical Director of Kamani Metals and Alloys Ltd. for a year in 1982.

He passed away on 16 June 1993 leaving a host of friends, admirers and colleagues to mourn his loss.

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