JOURNEY OF AN ENGINEER

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Preface

I had a dilemma about what to write, about self or about the engineer I am. I realized after reading “Krishnam Vande Jagatgurum”- a treatise by Late Ganashyam Das Birla- that writing about self is very difficult and an awkward job. His well wishers insisted he write his autobiography and rightly so that succeeding generations get benefit from his life stories, struggles and experiences. However, he could not decide and sought advice of late Pt Madan Mohan Malaviya who asked him to write about Lord Krishna's teachings on ‘Karma’ so that whole humanity can get benefit. Since the topic here is about the engineering community and to know about mind of an engineer, I decided to follow middle path by writing about my growth as an engineer in the hope that some of my experiences, knowledge and working strategies may provide guidance to the young readers.

Learning through Childhood

I belong to a farming family with the only exception of my father who was a teacher in a government school in a village of Durg District in the new state of Chhattisgarh. My first Guru was obviously my father who had a distinction in his career in a sense that he studied up to class 4, then did 4 years of farming due to family condition and then continued studies in school while maintaining top position in study. He used to solve all the questions in examination adding at the top of answer sheet, a note stating the required number of answers may be selected for evaluation. The first lesson I learnt from this is that one should be ready for any type of questions in examinations and problems in life. Nothing is more or less important; all problems are to be treated with equal importance. This always helped me succeed in getting first in rank in schools and district level till higher secondary where I was placed as a rank holder in MP HSSC Board.

I studied as a resident student since Class 6 onwards till my Doctoral studies. This has helped me a lot in terms of making me independent in thinking, planning and executing various tasks and projects in life and at work. I used to read all types of books, even unconnected with the class books. While I was in Class 5, I read Sanskrit language at home and appeared for Sanskrit examination Prathama (which was taught in class 6 onward) and scored highest mark. My love and speed for reading were very good. In class 8, I was given around 50 children classic novels to be distributed to the class section students. I read first all the novels in a day then distributed to colleagues. In my school classes 8 and 9 usually were part of middle school and high school. In high school one need to choose one stream out of 3 streams: mathematics, biology and arts streams. I came to know that one can complete 2 classes in one year. After self reading physics, chemistry and Mathematics of class 9 for few days, I approached the school Principal to allow me to appear for class 8 and 9 together. However, the principal persuaded me not to do so.

Memoirs of Higher Studies

During engineering graduate study, I had a typical habit of writing condensed notes for each subject, say 3 to 5 pages for each thick book of pages around 400 or more. The result was that I

needed to spend just 15 to 30 minutes for one revision during examination whereas my colleagues used to study throughout the night. Another habit I had was not to copy or seek any help for solving home assignments. I was of belief that if any student of my class solves the assignments, then I can also do. I used to love all the subjects in engineering such as engineering economics, refrigeration, automobiles etc. So, I applied for PG course on different subject to different institutes. I landed at IISc (Indian Institute of Science), Bangalore for Masters of Engineering since I was selected directly.

My postgraduate and doctoral studies were self driven with the help of library journals and reprints from abroad. My preferred subject during ME studies was turbo-machinery as taught by Prof S Soundarnayagam. I chose Aero-acoustics topic for PhD research. My guide, Professor M L Munjal was not directly involved in the field except for his wide experience on acoustics, but this helped me to expand my lateral and independent thinking. I learnt from my guide two things for the Fortran programming: first, the right-hand side, say b in a statement a=b must be defined before and second, one must check the program manually before punching the code; else the output from computer will be numbers but not the actual solution. The days at IISc shaped my future and made me independent, planner, task-oriented, and to a certain extent a work-alcoholic.

Initial Moulding at the Job

My first job which lasted till retirement was at Corporate R&D Division of BHEL where I joined as Senior Engineer in July 1978 and retired as Executive Director & Head of the unit in April 2009. This 31 years of service was very fruitful, challenging and rewarding too.

The first thing after joining, I decided was to align myself with Turbo-machinery field in fluid mechanics area (known now as Computational Fluid Dynamics) rather extending my PhD work. BHEL is primarily a turbo-machinery company dealing with steam, hydro and gas turbines, compressors, fans and blowers besides other power plant components like boilers, ESP, generators and motors. There are no machines or components designed here where fluid does not flow through.

Fluid mechanics computing has been a tough job for Mechanical engineers in those years and every mechanical engineer preferred working on Stress Analysis rather than Fluid Mechanics. So, for this reason I preferred turbo-machinery flow analysis as my career in spite of advice from well wishers. Fluid mechanics is the study of non-linear field with difficulty in convergence and stability during iterations. My strength was Fortran programming and knowledge of various numerical techniques which prepared me well for this field.

Finite Element Method (FEM) in the 1980s was the most popular and a developed technique for stress analysis and loss-less fluid flow (Laplace and Elliptical Flows). However, I preferred not to use the standard code of FEM since it made me feel enslaved to the code. I wasn't in favour of applying standard code for routine work hence decided to learn FEM from scratch and develop my own programming codes. Hence 6 months after joining, I took up a project based on FEM for analysis of pipe flow. I set a target for myself to complete FEM learning and code development and then apply and validate for flows through a pipe. Incidentally, BHEL R&D has been a great institution for giving engineers space and freedom to work independently on any topic related to BHEL products. During the course of my work I also picked up FEM through lectures of Prof G C Nayak (Univ. of Roorkee), who had worked under Prof O C Zienkowitcz, the main initiator of FEM. This interaction helped me to write FEM based codes. I have a good flair even now for writing fortran based computer programs. I wrote various FEM based codes such as CASFLO (for blade-to-blade cascade flow analysis, assuming Laplacian field) ,2D-FEM (FEM code for 2-dimensional Laplace Field), 3D-FEM (FEM code for 3-dimensional Laplace field such as 3d bend) for internal use.

I realized the need to extend finite element concept to finite difference method FDM so that surface curvature can be accounted. I wrote and applied 9-node Lagrangian element instead of usual differencing schemes. This way I developed a code GENFIND (Generalized Finite Difference Scheme) and applied to curved 2-dimensional field such as meridional space of hydro turbine impeller.

Blade Design as an Art

Blades are the most important components in power plants. It is like what a heart is in a human body. So, my interest expanded from duct passage to steam turbine blades. Flow through them is no more Laplacian. One needs to solve Navier Stokes equations which is very challenging thing for CFD engineers. One needd to know new technique FVM (Finite Volume Method) based on time marching method. I put a lot of struggle (say 1000 hrs continuously) to develop 2d-TMM (two-dimensional time marching method based code for flow through 2D blade-to-blade cascade assuming Eulerian field), ensuring stability of differencing scheme and convergence of solution. Many a time I lost hope. Around the same time, I was invited as a visiting fellow to Whittle Laboratory, University of Cambridge. There I worked with John Denton, Director of Whittle Laboratory and original writer of FVM for cascade flows. The visit and interaction benefited me a lot. My code finally worked to a good extent provided initial guess of field is good one.

Next logical step after cascade analysis was blade design which is kept confidential by turbine manufacturers worldwide and a company need to pay millions of dollars for collaboration. The blade profiles need to be purchased for case to case basis as they are all patented ones. I decided to work on design of indigenous blades for various conditions (such as Mach Number, inlet/exit angles, solidity and so on) for turbines covering both impulse and reaction ones and blades of various shapes such as cylindrical, tapered, twisted etc. This work spanned over one and half decades since it was enormous and needed to be tested theoretically and experimentally in both subsonic and transonic cascade tunnels. It finally needed to be patented to protect it.

I took as a first task to design LP (low pressure) bladings which are long, twisted and made of many 2-dimensional cascade profiles stacked over the blade height. I started to work from scratch, debugging available blade profiles, scanning through blade related literature. It involved working on drawing board then on autocad (which was just getting introduced) and at the end getting various profile shapes. Now each profile shape was needed to be smoothened (else losses due to profile surface unevenness would outgrow other kind of losses). This pushed me to write a code on Bezier Curve (Code BEZIER) to ensure continuity of surface co-ordinates and slope, through Bezier knots. The profile shapes are to be corrected by curve fitting through BEZIER program. Once Bezier fitted profile is designed it needed to be evaluated aerodynamically for loss estimation through standard time marching code or CFD (Computational Fluid Dynamics) code for number of times to cover a range of operation (such as flows and cascade solidity). The work was repeated to design a number of suitable profiles which can be stacked over the height to make one 3D twisted blade. After long and hard work I was successful in designing a suitable twisted blade and visualize on a computer screen. *The work was considered so important that it was chosen to be a front-page cover on special issue commemorating a decade of Corporate R&D activities.*

Aiming at Innovation

I realized that the recognition of self and Company occurs by international patents. So, I decided to design various kind of blade profiles and file for patents. A couple of years went into consolidating my work of a decade. In all I as a single innovator and BHEL as a company was granted five US patents on cylindrical subsonic and transonic blade profiles, LP blade and Francis hydro turbine.

The patenting activities gave me confidence and we further decided to design, manufacture and test 8 MW high speed impulse turbine with drum type rotor. I took this work as project leader with a team of more than 20 engineers. It took almost 30 man-years since work involved a range of technical activities such as blade design and analysis by a number of codes including CFD codes, stress analysis, rotor dynamics, bearing design, gear box selection, manufacturing of blade, casting of casing and exhaust hood, forging of rotor, testing of cascade at R&D and NAL in Bangalore. Finally, it became a success after getting the turbine manufactured by our sister unit at Ramchandrapuram, Hyderabad and successfully testing at compressor test rig. *This work led OEM (Original Equipment Manufacture) tag for our work and for BHEL as a whole.* It did not involve any collaboration even with existing foreign collaborators. The work was filed for an Indian Patent.

Toward Excellence

After attaining maturity and lot of experience through two decades at Corporate at R&D, I decided to put a proposal for creation of Centre of Excellence for Computational Fluid Dynamics (COE-CFD). Since all the power plant components at BHEL units need CFD modelling and study for performance upgradation I felt a necessity for a grand infrastructure involving a new building, procurement and establishing most of the reputed CFD software, computer hardware nodes to work and remote networking with units (Bhopal, Trichy, Hyderabad, Hardwar, Ranipet etc) so that each unit can log their jobs from own place. The dream came true in about 18 months and COE became functional. Initially a group of dozen engineers got trained in simulation of CFD through Boiler, ESP, Generator, Pump, hydro-turbines and Steam turbines among others. Later on, each unit was encouraged to get trained here and work for their units.

The importance of the centre was recognized by the publication of the building and CFD work on cover page of a special issue on Corporate R&D activities. To commemorate CFD activities, two national conferences were arranged where delegates from many industries, National Labs and Educational Institutions participated.

Time for Governance & Retirement

In Nov 2008, I was designated as unit head (Group General Manager, then Executive Director) to look after R&D unit. The unit had many disciplines such as Mechanical, Electrical, Electro-Magnetic & Chemical departments, Solar & Photo Voltaic groups, Cryogenic & Superconducting Generators department and Robotics cells among others. I advised the new engineering recruits to work and only work because it is not only good for the company but also for them to carry forward in life whether at R&D or outside. Publications and patents are real evaluators and should be the motto. I retired with satisfaction on 24 April 2009 after completing my tenure.

Ultimate Satisfaction

In the year 2009, a little known but smart and ambitious company MAXWATT Turbines Pvt Ltd at Bangalore was trying to expand its product range and acceptability as industrial turbine manufacturer in India and abroad. It had no collaboration for blade design which was its weak point. The management approached me to strengthen steam flow paths and blade design activities in the company. This work involved identifying, implementing and making user friendly software for steam flow design besides creating database of appropriate blade profiles and train their engineers. I joined as a consultant (designated as Vice-President, R&D) in Nov 2009 which I am continuing.

I found this company as high risk taking and challenging one since the turbine product range

they were handling were exhaustive. It was competing with reputed manufacturers in Condensing turbine with and without bleed and / or extraction, Back Pressure turbine with and without bleed and / or extraction for power generation and supply to industries. Each turbine is usually unique and designed as per order. The blades are critical to achieve efficiency and to fulfill customer order. Another aspect of this company is the delivery time mostly limited to 6 months. So, the design needed to be reliable and fast.

I took this as an opportunity to prove my knowledge in the field which was not possible at BHEL where only collaboration based designed blades were to be used. Here this company was willing to take commercial risk by using my yet to be fully proven blade knowledge as the other option available to them was to go for collaboration which was cost prohibitive.

At the end, both myself and the company got benefitted. Company became OEM on blades and my blades got manufactured and field tested which gave me tremendous satisfaction which I had not fully experienced in my earlier career at BHEL.

We designed steam flow paths and their bladings for more than seventy different turbines in 7 years; on the average 10 turbines in a year which was unimaginable till few years back. More than 60% of these turbines were supplied to countries like Korea, Kenya, Ukraine, Russia, Japan, Mexico and Bangladesh.

This phase of my life, perhaps was the test and recognition of my knowledge. It gave me ultimate satisfaction in the sense that turbines and blades designed and processed by me helped the mankind. My knowledge did not vanish without practical use which every engineer wishes at the end. I feel I lived my technical life with contentment and happiness because my work is physically visible in many sites in India and abroad, generating continuous power for industries for years to come.