Basic Control Volume Finite Element Methods for Fluids and Solids.

The emergence of the digital computer has provided impetus for the rapid development of computational methods for solving field problems. In the early days, the two popular methods were Finite Difference Method (FDM) and Finite Element Method. An important development of FDM led to the Control Volume Finite Difference Method in which a set of discrete equations is arrived at by appropriate balancing of the control volume boundary fluxes. This has a direct connection to physics of the system. Control volumes can also be constructed around the nodal points on an unstructured finite element mesh that conforms to an arbitrarily shaped domain. The fluxes around control volume faces can be approximated by using finite element interpolation. Balancing of these fluxes leads to a physically based representation of the governing equations as a discrete set of equations in terms of mesh nodal values. The original application was in the solution of electromagnetic field problems. It was then extended to heat transfer and fluid flow problems and finally to solid mechanics problems.

The author has consolidated his lectures on Control Volume Finite Element Method (CVFEM) delivered at the Indian Institute of Science during the Centenary celebrations. He gives a brief introduction to the historical development of the method and also the control volume method itself. Then, he proceeds to derive the governing equations for solid and fluid mechanics problems, both in point and integral forms, to provide a background for solving multi-physics problems. Then, the essential ingredients of a numerical solution in general and a CVFEM solution in particular are presented. A data structure that codifies the critical geometric relationships in an unstructured mesh is developed. Then, a brief outline is provided to show how this data structure can be used to make an automated link between the physics underlying the governing equation and the discrete CVFEM equations. The key information required for fully constructing working solutions of basic fluid flow and solid mechanics problems are clearly explained for two-dimensional problems using linear elements and upwinding. The example problems considered are based on (i) advection–diffusion equations for scalar transport; (ii) plane stress and plane strain problem for linear elasticity and (iii) the stream-function–vorticity form of two-dimensional Navier–Stokes equations for incompressible Newtonian fluid.

The results from CVFEM are compared with available analytical solutions. The comparison is good. The methods of extending the work to nonlinear problems as well as 3D problems are also given.

In order to help the reader to start the work in CVFEM, a mesh generator and a CVFEM code are provided based on MATLAB in the appendices A and B. The objective of the monograph to introduce a single common framework for CVFEM solution of both fluid and solid mechanics problems has been achieved in this book. The book deserves a place in libraries of many engineering institutions where numerical solutions are sought for engineering problems.

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Ramamurthy Balasubramaniam (1961–2009)

Ramamurthy Balasubramaniam (fondly known as Bala) was born on 15 April 1961 in Salem, Tamil Nadu to R. S. Ramamurthy and R. Savithri. He did his schooling at Holy Cross Matriculation School at Salem. He obtained his Bachelor of Technology from the renowned Metallurgical Engineering department in the Institute of Technology, Banaras Hindu University (BHU), Varanasi in 1984. He won the N. P. Gandhi Gold Medal from the Department of Metallurgical Engineering, BHU and the Vidyarthi Bharathi Award from the Indian Institute of Metals. He received his Ph.D from Rensselaer Polytechnic Institute (RPI), Troy, USA in 1990 for his dissertation on ‘The role of hydrogen in the stress corrosion cracking of a binary aluminum-lithium and a ternary aluminum-lithium-copper alloy’. He joined the faculty of Materials and Metallurgical Engineering at Indian Institute of Technology (IIT), Kanpur in 1990 as Assistant Professor and became a full Professor in 2001. Balasubramaniam’s illustrious career was cut short by his untimely demise on 9 December 2009. He had every right except one of long life.

Bala’s research interests included material–hydrogen systems, environmental degradation of materials, structure–property correlation in advanced materials and Indian archaeometallurgy. He established a state-of-the-art laboratory to facilitate corrosion research at IIT Kanpur. He was successful in developing ceramic reinforced metallic coatings and such coatings exhibited superior tribological properties. His recent research has also large national relevance in terms of safety concern for millions of citizens travelling on Indian Railways. One of his most recent research projects was on Corrosion Prevention of Rails and was funded by Indian railways under their Technology Mission on Railway Safety. Lately, his research interest was in the area of nanostructured coatings on metallic substrates.

In the area of Indian archaeometallurgy, he had in a very short span of time established himself as India’s leading archaeometallurgist. His first and perhaps best known major study was on the Delhi Iron Pillar. Despite extensive research on the pillar over the last century, many questions remained unanswered. His pioneering research on the corrosion resistance of Delhi iron pillar attracted worldwide attention. Using multiple characterization tools, his research answered a long-standing question as to why iron pillar at Delhi has the unique corrosion resistance property. In his book The Story of the Delhi Iron Pillar, Bala used his experience in corrosion science and metallography to formulate the first convincing mechanism by which a corrosion-resistant surface could have developed in the open atmosphere. He proposed the formation of a protective passive film on the pillar surface and the chemistry of this film was consistent with high phosphorus content of the iron that was used several centuries ago to build the iron pillar. Not only that but Bala gave a full account of the construction of the pillar and the complex wrought top. He also gave a detailed account of the likely original location and history of the pillar, thereby displaying a deep knowledge and understanding of India’s history, culture and philosophy. He drew on epigraphy, astronomy, metrology and several other disciplines to bring fresh insights into this ancient and impressive object.

A second major area, where he made magnificent contribution, is related to cannons. This resulted in The Saga of Indian Cannons. From an archeometallurgical point of view, the book, for the first time, presented the massive and wonderful forge welded iron cannons and cast bronze cannons of medieval India. Indian innovations in cannon technology like shatrunjal (cannons fired from back of camels), composite cannons (of inner wrought iron bore and outer bronze casting) and bans (battlefield rockets) offer sufficient proof of Indian ingenuity in science and technology, thereby providing rare glimpses into the country’s rich military and metallurgical heritage. His paper on sajt peter manufacturing in medieval India is a notable contribution.

A third area was wootz steel, where his attention turned to several facets of this legendary material. These included the gift to Alexander, the etymology of wootz, Hinduwani and pulat, detailed recording of the locations of smelting sites in the Deccan including Konasamudram, the ethnography of the smelting communities, the metallographic examination of the steels that they made. Here again he brought out the influence of phosphorus.

In recent years the history of Indian metrology attracted his attention. He came about with the bold hypothesis that Angulam was the probable measure used from the days of Mohenjodaro to the Taj of the Mughals. His ability to come out with new insights into ancient technology is unparalleled. He coupled this with an intensive study of Indian and Persian literature and offered significant evidence for this startling possibility that India used a single measure of length over millennia. It was clear that this is path-breaking work and he had embarked on a new journey of discovery tragically cut short.

Most inspiring aspect of his career is that despite his busy schedule related to research activities, he never compromised on his teaching and research at IIT Kanpur. He had adapted the famous text book by Callister on Materials Science. He kept a meticulous record of his courses and has taught more than two thousand students. He was bestowed with the inaugural Distinguished Educator Award (2009) from Indian Institute of Metals (IIM) in November 2009. An even more befitting acknowledgement of this commitment to teaching and his exemplary teaching skills is there in the tributes paid by his students on the IIT Kanpur obituary pages. In their outpouring of grief, the facts stands out that they were inspired by his teaching and the lucid and incandescent style he brought to his lectures.

Bala was a prolific researcher and has published about 275 research papers in various refereed journals. He has autho-