INDIAN INSTITUTE OF TECHNOLOGY MANDI

भारतीय प्रौद्योगिकी संस्थान मंडी

Institute Colloquium

“On Higher-Order Theories of Elastic Beams, Plates and Shells”

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Auditorium, North Campus

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“On Higher-Order Theories of Elastic Beams, Plates and Shells”

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Abstract: -

Before the mechanics of laminated composites was established in the early nineteen hundred sixties, the simplest form of sandwich construction with a thick material layer of low strength and density sandwiched between two thin sheets of high strength material was in use in aircraft industry. This was indeed the situation around Second World War. The three-dimensional (3D) modeling of laminated composites with a large number of orthotropic/isotropic layers was intractable. Researchers, therefore, focused their attention on two dimensional (2D) analytical models coupled with effective, general and robust computational tools. As a rule, 2D smeared single-layer theories have dominated the literature. The classical lamination theory (CLT) was the first candidate for application. CLT for beams, plates and shells is an extension of the Euler-Bernoulli beam, Poisson-Kirchhoff plate and Love shell theories and neglects the effects of transverse strains and assumes each lamina to be in a state of plane stress. CLT fails to predict accurately the static and dynamic response in case of laminated composites which are rather thick and/or exhibit high anisotropy ratios. It was soon realized that such theories are unsuitable for laminated composites including sandwiches in which transverse shear and transverse normal deformation energies were significant. A search led the displacement based Mindlin plate theory which did include transverse shear energy in a simplistic manner. Here, the normality condition of the transverse normal was relaxed to include transverse shear strains. This application, no doubt, became very popular, but was found to be deficient in many ways. The approach of Hildebrand, Reissner and Thomas which could include both transverse shear and normal strains in a realistic manner in the laminated composites gave a new hope to the researchers and this development gave rise to what is known as higher order theories. This approach did predict accurate deformations and in-plane stresses. However, reliable computation of transverse stresses was still a distant dream.

Developments in the last decade, by Kant and his co-workers, of a novel partial discretization methodology for reliable computation of transverse stresses has given rise to some expectation.

It is first of its kind of a mixed model which is based on solution of two-point boundary value problem (BVP) governed by coupled first-order ordinary differential equations (ODEs) through thickness of laminated composite. Good agreement of the present results with the elasticity solution is observed. The most significant advantage of the present development lies in the fact that both displacements and transverse stresses are evaluated simultaneously at the lamina spatial nodes with the same degree of accuracy through a numerical integration process. There is a need to popularize this first of the kind semi-discretization methodology for equilibrium problems in general.

Chronological developments of two-dimensional models of laminated composites including sandwiches and functionally graded materials along with recent innovations in evaluation of transverse stresses will be highlighted in this presentation.

Bio-Sketch: -

Prof. Tarun Kant was born on 1 July 1946 in Ballia district of eastern Uttar Pradesh, India. Passed his High School (10^{th} standard) in 1958 from Queens' College, Varanasi and his Intermediate (12^{th} standard) in 1960 from King Edward Government Inter College, Deoria. He received his BSc degree with Physics, Chemistry and Mathematics from the University of Allahabad in 1962, his BTech (Hons) in civil engineering from IIT Bombay in 1967 and MTech in civil engineering with specialization in structural engineering from IIT Kanpur) in 1969. He spent about one and a half year in a consulting engineering firm in Mumbai before joining IIT Bombay on 20 January1971 as a *Lecturer*. He earned his PhD degree from IIT Bombay in 1977. He was selected as an *Assistant Professor* in 1978 and a *Professor* in 1986.

He has held the positions of the Department Head (2000-2002), the Dean (Planning) of the Institute (2001-2003), the Chairman of JEE-1998 and the Chairman of the Central Library (1993-1998). The Institute appointed him as an *Institute Chair Professor* from 31^{st} December 2009. He was re-employed by the Ministry of Human Resource Development (MHRD), presently Ministry of Education of Government of India (GOI) for five years until 30 June 2016 though he formally retired (superannuated) from service on 30 June 2011. He was also an Emeritus Fellow of the Institute (2016), an INSA Senior Scientist (2016-2022), a Visiting

Distinguished Professor at IIT Mandi (2019-2022), an Adjunct Professor at IIT Indore (2019-2022), a Honorary Professor at IIT Hyderabad (2019-2021), an Adjunct Professor at IIT Hyderabad (2021-2024) and an Adjunct Professor at IIT Patna (2025-2026).**The Institute honoured him with the title of *Professor Emeritus* for life, an honour bestowed on a select few of the retired faculty**, on 27 September 2017. Through an endowment of Rs. 1.15 crore created by his own donation, his students and well-wishers in the industry, a *Prof. Tarun Kant Endowed Chair* was established in his honour in the department of civil engineering of IIT Bombay on 19th March 2020.

Prof. Kant was elected a *Fellow of the Indian National Academy of Engineering* (INAE) in 1999, a *Fellow of the Indian Academy of Sciences* (IASc) in 2004, a *Fellow of the Indian National Science Academy* (INSA) in 2007 and a *Fellow of the National Academy of Sciences, India* (NASI) in 2011. **He is the first civil engineering academic in the country to get elected to all the four national academies** – one engineering (INAE) and three science (INSA, IASc and NASI)**.**

Prof. Kant was a *visiting scholar* at University of Wales, Swansea (1979-'82) and a *visiting professor* at University of Cambridge (1993) and University of California, Los Angeles (2005).

He is a recipient of the *Burmah-Shell Best Paper Prize*. He was the first engineer selected by a committee after personal interview whose chairperson was no less a person than the Prime Minister of India (Late Mr. Morarji Desai) and was awarded the *1979 Jawaharlal Nehru Memorial Trust (U.K) Scholarship* to carryout research in Finite Element Methods in the United Kingdom; he was also selected for the *1992-'93 European Commission (EC) Senior Faculty Exchange Fellowship*, both by the Government of India. He was awarded the *2006 Professor H.H. Mathur Award for Excellence in Research in Applied Sciences* in recognition of his outstanding work in the area of Mechanics of Composite Materials and Structures by IIT Bombay on 13th March 2007. He also received the *2009 Khosla National Award for his lifetime achievement* in the field of engineering. He is also a recipient of the *2010 IIT Bombay Research Paper Award*. **He was conferred with the *2011 Lifetime Achievement Award* of IIT Bombay on 4th April 2012**. ICCS17 (17th International Conference on Composite Structures, Porto,

Portugal, 17-21 June 2013) honoured Professors Romesh Batra, JN Reddy and Kant with the title "***legends and pioneers in mechanics of composites***". Of course, being included in the same category as Professors Batra and Reddy was in itself a great honour for Prof. Kant. He received the *APACM Senior Scientist Award* of the Asia Pacific Association of Computational Mechanics (APACM) on 12th December 2013 during APCOM2013 in Singapore. Received the *ICCES* (International Conference on Computational and Experimental Engineering and Sciences) *Lifetime Achievement Award - 2015* Medal in Reno, Nevada, USA on 23rd July 2015 for making seminal contributions to composite materials and to the education of generations of students in India. Birla Institute of Technology & Science (BITS) Pilani also honoured him with *Lifetime Achievement Award* on 26th February 2018. He is also honoured with 2019 INSA's Prof Brahm Prakash Memorial Medal and 2020 Vasvik Award for Mechanical & Structural Science & Technology.

He has published 167 research papers in refereed journals, 7 chapters in edited books, about 185 papers in conference proceedings, edited 5 books and currently serves on the editorial boards of 5 international journals in diverse areas of computational structural mechanics. He has supervised 27 PhD and over 77 MTech and over 90 BTech students in their theses/ dissertations/ projects. He has also been a referee for over 100 external PhD theses. He has *Research & Citation Standing in terms of* h-index of 52 and citations of 10550 ***on Google Scholar* He is in the top 0.3659% in the list of *Top 2% Global Scientists* published by Stanford University in November 2020 *and in subsequent years***.

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