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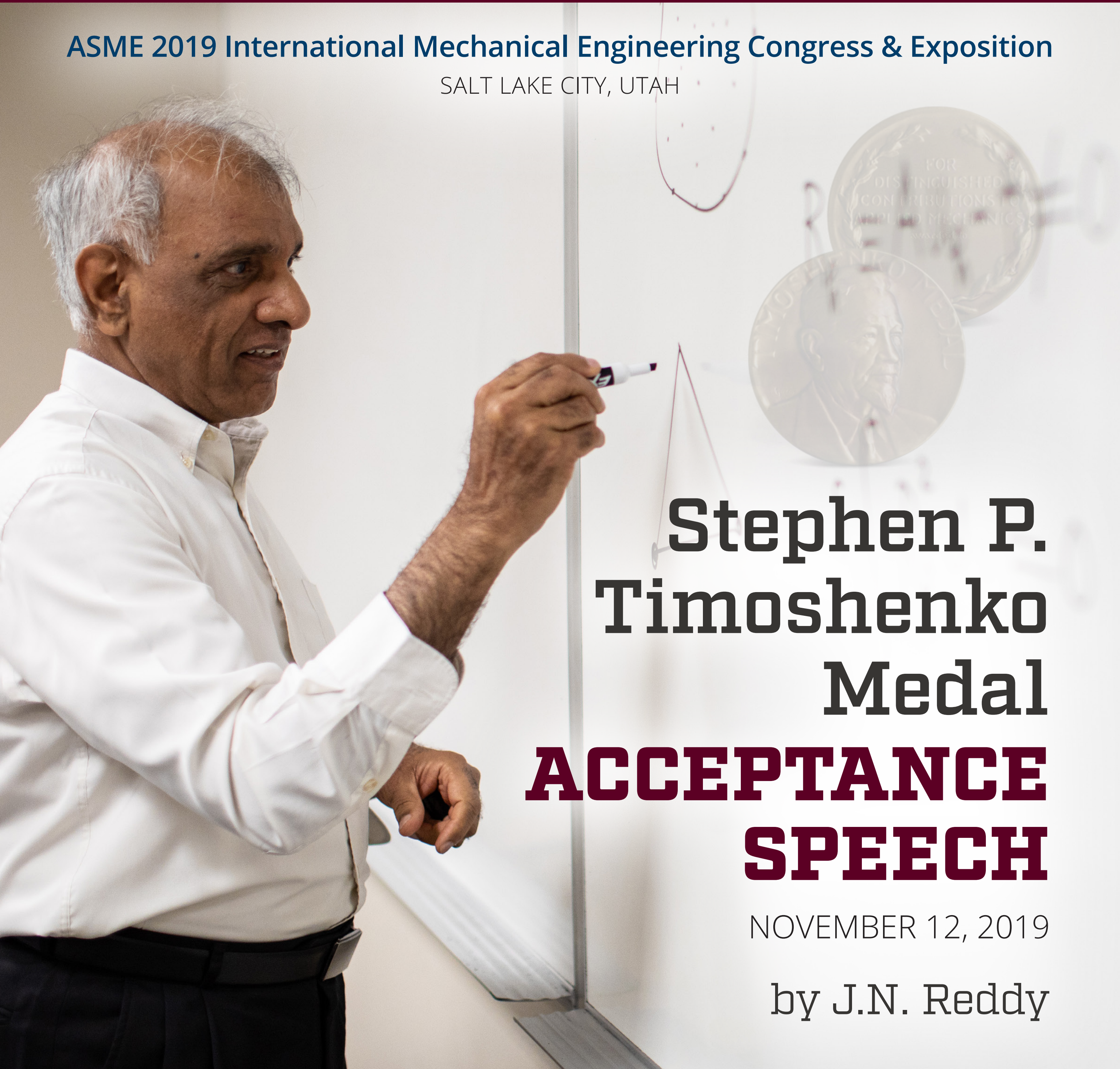

Stephen P. Timoshenko Medal

ACCEPTANCE SPEECH

NOVEMBER 12, 2019

by J.N. Reddy

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By J.N. Reddy
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The Timoshenko Medal was established by ASME in 1957 to recognize the enormous and distinguished works and legacy of Stephen P. Timoshenko as a researcher, teacher, and mentor in the field of applied mechanics. The first recipient was Timoshenko himself, an individual who is considered to be the father of modern mechanics in the United States of America, one who has contributed enormously to the prestige and strength of mechanics as a discipline in this country, and a legend whom I tried to emulate very closely. I want to express my sincere appreciation and gratitude to the Applied Mechanics Division and ASME for bestowing this honor, which has a very special meaning for me, as I will explain shortly. I consider it to be the most significant professional honor of my life, even more than the membership in the National Academy of Engineering and one for which I will be eternally grateful. I will do my best to continue to uphold the legacy of S.P. Timoshenko and live up to the high standard exemplified by the past recipients of the Timoshenko Medal – many of whom are present here tonight. My sincere and deepest respects to them; I feel deeply honored to be included among them. I have been fortunate over the years to have met and be inspired by the works of several previous recipients of the Timoshenko Medal.

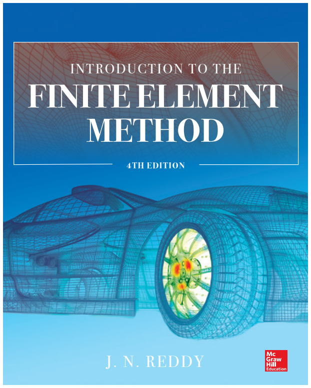
My presentation starts with a short background of my arrival to the United States of America, my journey through mechanics, and some observations and thoughts about the role and responsibilities of the mechanics community in improving the quality of life and enabling us to build a sustainable society for all its citizens through education and research and development.

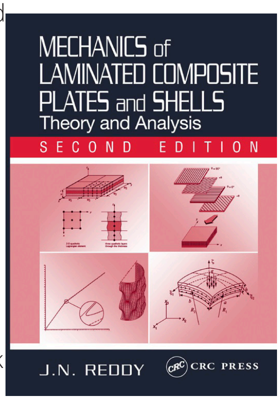
As for my personal background, I come from a lower middle-income farming family in rural South India. As the youngest of five children, I was the first in my family to go beyond high school. During summer holidays, I used to help my father on the farm, which prepared me to be a hard worker, diligent, and thorough. I went through a five-year integrated Bachelor of Engineering degree that prepared me with a broader engineering background and helped me in the later years to work not only in solid mechanics but also in heat transfer, fluid mechanics, and applied mathematics.

When I arrived at Oklahoma State University in the spring of 1969, the first thing that caught my attention was the IBM 360 computer on the campus. While doing assignments in a course on vibrations, I would solve the problems by hand and then write Fortran programs to solve them using the computer. The teacher of the course was very impressed by my interest in the use of computers and suggested that I should work with Professor J.T. Oden, who was at the University of Alabama, Huntsville, at that time. I was fortunate to be accepted by Professor Oden, who has been my teacher, mentor, and friend to this day. That was the beginning of my journey in mechanics. Professor Oden was one of the top researchers in the world and the only engineer who was beginning to work on mathematical foundations of the finite element method. My dissertation topic was on the existence and uniqueness of mixed finite element approximations of boundary value problems as well as the unification of variational principles of theoretical mechanics. Both of the topics led, in addition to several journal papers, to two books with Dr. Oden, who was very kind to let me be a co-author. I learned a lot as a student of Professor Oden. Most importantly, I learned the subjects of applied functional analysis, variational methods, the finite element method, and the ability to explain complicated concepts in simple terms. In later years, the knowledge and writing style made me an effective and passionate teacher as well as a textbook writer who cares about teaching and imparting knowledge to the readers. These topics led me to write books in later years on functional analysis, variational methods, and the finite element method - all as a sole author.

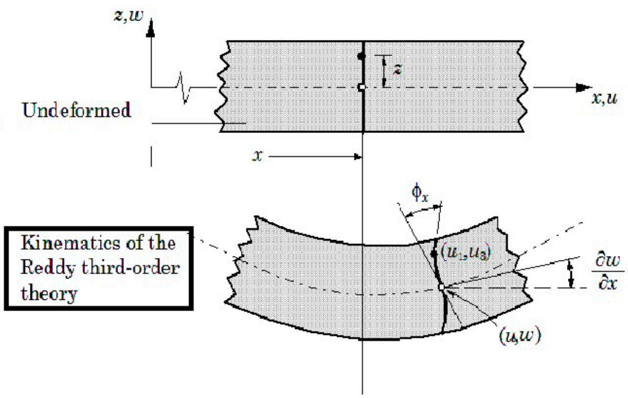
After a short period of employment with Lockheed Missiles and Space Company, where I worked on a NASA (Glenn) research project to develop a 3D finite element code to study hypervelocity impact, I joined the University of Oklahoma, Norman, in January 1975. It was there where I was introduced to the subject of composite materials and structures, by Professor Charles Bert, that would change the course of my professional career and follow the legacy of Timoshenko. Knowing the limitations of classical thin plate and shell theories in capturing inter-laminar stresses, I started working on shear deformation theories for composite laminates. My background in mathematics, mechanics, and the finite element method enabled me not only to conceive novel and improved mathematical models of beam, plate, and shell theories, but also to develop locking-free and robust finite element models – an activity that continues to the present day. These works on shear deformation theories have resulted in both scientific advancement as well as technological utility that have helped researchers and practicing engineers in the field of laminated composite structures to extend and apply to real-world problems.

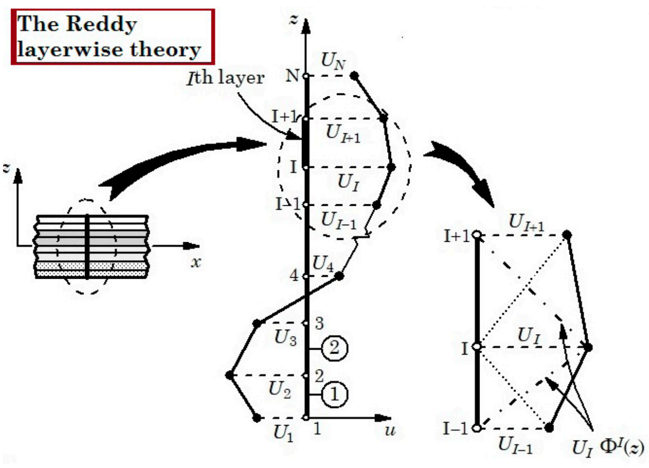
When I moved to Virginia Tech in 1980, I was already recognized as a leading researcher in refined theories of composite laminates, plates, and shells, as well as the finite element method applied to a variety of interdisciplinary problems, including: structural geology, geophysical fluid dynamics, and coupled fluid flow and heat transfer. The Department of Engineering Science and Mechanics was as good as any mechanics department in the country with well-known researchers like Professors Ali Nayfeh, Leonard Meirovitch, John Junkins (now at TAMU), William Saric (now at TAMU), Kenneth Reifsnider, Hal Brinson, Carl Herakovich, Dean Mook, Liviu Librescu, Robert Jones, among several others. My teaching of a course on the FEM at Oklahoma and Virginia Tech motivated me to write a textbook due to the lack of a general and self-contained introductory book on the subject. Today, it is one of the most popular books on the subject. The book is also one of the first engineering textbooks to present the finite element method as a numerical technique of solving differential equations, independent of the field of application. As a result, people with no structural mechanics background were able to learn how the method could be used to solve equations arising in other fields. I wrote a very comprehensive book on laminated composite plates and shells that covers anisotropic elasticity, plate and shell theories, analytical solutions, and linear and nonlinear finite element analysis. Art Leissa, former editor-in-chief of *Applied Mechanics Reviews*, commented in his review of my book that it is the best textbook that he has seen for understanding the most important aspects of plate and shell theories, and containing modern, important aspects which Timoshenko hardly could touch upon at all. I





also wrote a book on applied functional analysis and another one on energy principles and variational methods in applied mechanics. The latter replaced the classic book by Langhaar. All of these books are now in at least their second edition.





After I moved to Texas A&M University in the summer of 1992, I started working on layerwise theories for composite laminates. I showed how inexpensively the approach could be used to predict 3D stress fields accurately in the edge regions of composite laminates. I have collaborated with Professor C.M. Wang of the National University of Singapore (now he is at the University of Queensland, Australia) to develop algebraic relations between the bending, frequency, and buckling solutions of shear deformation theories in terms of the corresponding solutions of the classical theories.

I was one of the first to work on penalty finite element models for fluid flows, including Newtonian and generalized non-Newtonian fluids. These works have been implemented into commercial software NISA (marketed by Engineering Mechanics Corporation) and HyperXtrude (marketed by Altair). During the last 25 years at Texas A&M, I have authored and co-authored many other books, including one on the finite element method in heat transfer and fluid mechanics, another one on nonlinear finite element analysis, two books on continuum mechanics, and two books on finite elements for boundary- and initial-value problems.

Another topic that I worked on, in collaboration with Professor Karan Surana of the University of Kansas, was a new paradigm in computational mechanics. Namely, the least-squares finite elements. This paradigm shift from the conventional c0-finite elements based on weak-form Galerkin formulations of the Navier-Stokes equations has proven to be far superior to the weak-form Galerkin formulations that employ ad hoc approaches like upwinding, artificial viscosity, reduced integration, stabilization, and other techniques. The weak-form Galerkin finite element formulations are not well-suited for the solution of the Navier-Stokes equations because they do not represent any physical principle. We have shown that the least-squares formulations provide a much more robust computational framework for the solutions of flows of Newtonian and non-Newtonian fluids.

During the last decade, I have been working on two major fronts: (1) development of 7-, 8-, and 12-parameter shell theories and their finite elements with my students and Dr. Marco Amabili of McGill University and (2) nonlocal and non-classical continuum mechanics with my colleague Arun Srinivasa and Professors Karan Surana of University of Kansas and Debasish Roy of the Indian Institute of Science. The first one is a continuation of many years of my work on shear deformation theories of plates and shells to develop locking-free shell elements for large deformation analysis of laminated composite and functionally graded structures. The second is a rejuvenation of ideas originated and advanced by Cosserat bothers, Green, Naghdi, Mindlin, Eringen, Hutchinson, and likes, and their implementation into structural theories. These include: couple stress theories, strain and stress gradient theories, and micromorphic theories. The nonlocal and non-classical continuum ideas can be used to study architected and meta materials and efficient modelling of large or mega structures, by bringing material as well as structural length scales into structural theories. One of the highlights of my research with my colleague Professor Srinivasa on nonlocal models is GraFEA. It is capable of studying fracture, based on edge breakage within a classical FEA scheme, which combines the best features of FEA and bond-breakage methods in a single framework, without the user input in creating finite element meshes and, at the same time, eliminating mesh dependency.

Finally, coming to my observations and thoughts on roles and responsibilities as members of the mechanics community, I will begin with some observations. Mathematical models of all physical phenomena have been developed using laws of physics, experimental observations, and assumptions. There is no such thing as an “exact” mathematical model of anything we model, and we can only improve upon the existing models. Mechanics and its offspring, computational mechanics, no matter how incomplete they are, have served humanity in predicting the response of a variety of complex phenomena to a satisfactory degree. Of course, the degree of sophistication of mathematical models can change as we understand more about the process being modelled. Computational mechanics has emerged as the “third scientific methodology,” in addition to the traditional two pillars of scientific inquiry, namely, mathematical and experimentation studies. The computational mechanics has also contributed to unifying ideas and bringing together diverse fields. The advances in computational mechanics also have paved ways to help both analysts and experimentalists to evaluate mathematical models and help design experiments, especially at lower spatial as well as temporal scales. Thus, mechanics of materials and computational mechanics provide an important link between materials, design, and manufacturing. Therefore, funding agencies must see this important mechanics link in going from the creation of novel materials to design and manufacturing and support the mechanics research that evaluates and certifies materials selection in the design.

There is some mistrust of computational methods by some of the engineering community. This is because some users are less knowledgeable of the underlying mathematical models, associated computational models, and their limitations, and develop blind faith in accepting the outcome without questioning. Many people, both researchers as well as managers (in companies or funding agencies), think that the subject of mechanics has nothing more to contribute and is taken care of by ANSYS and ABAQUS like programs. This unfortunate viewpoint has led to increased importance given to materials at the expense of mechanics and resulted in not supporting mechanics ideas by funding agencies. Consequently, many young faculty members at most research universities, aided by the undue pressure put on them to bring dollars, have resorted to areas that they consider fundable topics. Consequently, there is an erosion of “mechanics” or “science” content in some published works.

Now I share my thoughts on engineering education. Education is the fundamental block of the foundation to improve the quality of life. To achieve educational excellence, we must look beyond academic achievements and build a curriculum that requires a strong footing in one of the three pillars (theoretical, experimental, and computational mechanics) and adequate knowledge in the remaining two. Our engineering graduates should also have an adequate understanding of our complex technological problems. This, in turn, requires us to determine what kind of learning models should be developed. To remedy the erosion of the importance of mechanics education, our curriculum, especially at the graduate level, should not overlook the fundamental subjects like continuum mechanics and elasticity and include only more specialized subjects like multiscale modelling, nanomechanics, multifunctional materials, and so on. I believe that computational mechanics has challenged and enabled a much more basic and fundamental view of mechanics by incorporating effects that were considered impractical from a solution or analysis point of view. It has helped the mechanics community to enlarge and extend the mathematical models to include effects that are important but precluded their solution by the classical method of analysis. In the words of Professor Oden in his Timoshenko Medal acceptance speech, “A successful engineering mechanician, these days, must have a more fundamental knowledge of basic mechanics than did his (or her) predecessors.” To be able to formulate a suitable mathematical model, we must take advantage of the powerful computational tools to predict realistic response, and make an informed decision to help design and manufacture goods. Thus, computational mechanics has increased rather than decreased the need for rigorous mathematical studies and more fundamental mechanics understanding. Therefore computational mechanics (i.e., mechanics-based computations) should be brought early on into the curriculum.

Lastly, I wish to share a concern I have with what is happening at some of Tier I (research) universities. They are preoccupied with increasing their rankings in the *U.S. News & World Report* and likes, and instituted policies that contribute to the ranking criteria. These universities have increased pressure on faculty to bring research dollars and publish. Tenure and promotions at these universities are tied to dollar amounts and number of publications, although they include teaching as one of the criteria. Young researchers faced with this pressure tend to do the minimum to get adequate student teaching evaluations (to meet the teaching part of the tenure and promotion criteria). This has a significant effect on the quality of education provided, and ultimately on the quality of the workforce for industry and academia. I believe that no one should be a faculty member unless she or he is as passionate about teaching as they are about research. There is no other profession that has the same influence on young people in building their professional future and molding their character as the teaching profession. Therefore, faculty members should take interest as well as pride in teaching, without the expectation of any rewards. The pressure to publish (especially when one counts the numbers) also has a negative impact: it encourages publishing incremental contributions and/or contributions that have no impact (as measured by citations and inventions and patents that are used). Many young people tend to “check boxes” to get tenure or the next promotion. In the process, they are not known for any particular topic area. The only way to remedy this is when some of us get to the decision-making table, insist on criteria that encourages excellence in teaching and research without using the number of dollars, which are only a means to an end.

I never met Professor Timoshenko in my life. Still, he lived in my works, and I promoted his legacy as a mechanician who is known for shear deformation theories of structural elements as well as a textbook writer. It is not an exaggeration if I say that his name appeared in my writings more than anyone else’s, living or dead – including Timoshenko himself. Timoshenko’s works bring out the importance of mathematics in explaining mechanics concepts. I enjoyed studying his books and papers, which helped me learn and contribute to the mechanics subjects he is well known for. I extended his theories to higher order and into the computational arena.

Although I never could fully emulate S.P. Timoshenko, I feel that I have carried his legacy forward as a researcher and textbook writer. To date, I have written 21 upper-level undergraduate and first-year and advanced graduate textbooks on a variety of topics from mechanics of materials, continuum mechanics, energy and variational methods, linear and nonlinear finite elements, composite plates and shells, to computational fluid dynamics and heat transfer. Many of them are well-received by the mechanics community and have seen 2nd, 3rd, and even the 4th editions. I consider this as important a contribution as my research works.

A professional contribution that is often overlooked, or not given much recognition, is the time and effort put into mentoring young people, providing them the opportunity to learn through workshops and short courses, and research collaborations – whether they are in big or small institutions in nooks and corners of the world. I have travelled for this purpose to places where ABC (Argyris and Achenbach; Batchelor, Biot, and Budiansky; Carrier and Crandall), NBC (Needleman; Bazant; and Clifton), IRS (Irvin; Rivlin and Rice; and Southwell and Stoker), and HBO (Hutchinson and Hughes; Belytschko; and Oden) did not and could not go. I feel that this too is an important professional contribution I made.

Once again, I thank the Applied Mechanics Division for this prestigious award. No matter how much one deserves, it is not possible for someone to receive an award without the thoughtful consideration of the colleagues on the award committee and those who provide the support letters. I give my most sincere thanks to these unnamed colleagues. I also want to take this moment to thank my teacher and mentor, Professor Oden, and all my students and collaborators all over the world who have contributed to my professional success that enabled me to receive the Timoshenko Medal. I thank my wife for her love, support, and sacrifice throughout our married life. Finally, I thank you all for your presence tonight, and I wish you and your families the best in life.

Brief Vitae of J.N. Reddy

mechanics.tamu.edu

Dr. Reddy, an ISI highly-cited researcher and author of 21 textbooks, is known for his pioneering works on the development of shear deformation theories that bear his name in the literature as the Reddy third-order plate theory and the Reddy layerwise theory, which have had a major impact and have led to new research developments and applications. In recent years, Reddy's research has focused on the development of locking-free shell finite elements and nonlocal and non-classical continuum mechanics problems involving couple stresses and surface stress effects. In addition to the 2019 Timoshenko Medal, his most recent honors and awards include: 2018 Theodore von Karman Medal from the Engineering Mechanics Institute of the American Society of Civil Engineers, the 2017 John von Neumann Medal from the U.S. Association of Computational Mechanics, the 2016 Prager Medal from the Society of Engineering Science, and 2016 ASME Medal from the American Society of Mechanical Engineers. He is a member U.S. National Academy of Engineering and a foreign fellow/corresponding member of the Indian National Academy of Engineering, the Canadian Academy of Engineering, the Brazilian National Academy of Engineering, the Chinese Academy of Engineering, and the Royal Academy of Engineering of Spain (RAI: Real Academia de Ingeniería). In a recent world ranking of researchers in engineering by Stanford University, he is listed as #13 in all fields of engineering and #5 in mechanical engineering.