A Call-for-Papers

for

A Special Symposium

Entitled

Computational Mechanics and Finite Element Method : Impact of Accuracy and Uncertainty

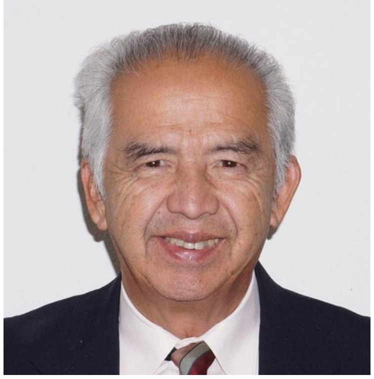
to be held during the

2016 International Conference on
Computational and Experimental Engineering & Sciences
ICCES'16 Madeira, Portugal, September 5 – 9, 2016

in honor of

Dr. Pedro V. Marcal

Lifetime Achievement Medalist, ICCES'16



1. Introducing **ICCES,** the **I**nternational **C**onference on **C**omputational & **E**xperimental Engineering and **S**ciences (www.icces.org)

ICCES is an organization of highly reputed international researchers, from academia, industry, and governments across the world. It was founded in 1986 by **Prof. Satya N. Atluri**, and has met 23 times with the most recent one at Reno, Nevada, USA (ICCES2015). Each ICCES conference brought together more than 500 of the world's most respected researchers in such disciplines as *Nanoscience and Technology; Nanostructured Materials; Engineering, Biology, and Medicine; Bio-MEMS/Bio-NEMS/Labs-on-Chips/Life-Chips, Complex Engineering Systems; Molecular and Cellular Biomechanics; Computers, Materials, and Continua; Computer Modeling in Engineering and Sciences; Sustainability, Environment, and Climate; Disaster Prevention and Control; Computational Biology, Biomechanics, and Bioengineering; Meshless and Novel Computational Methods; Soft Computing and Fuzzy Logic, etc.*

2. Introducing **Dr. Pedro V. Marcal**

Dr. Pedro V. Marcal was educated at the University of London (B.Sc. Mech. Eng., 1959), and the Imperial College London (Ph.D., Applied Mechanics, 1964). He began his teaching career in 1963 as a Lecturer at the Imperial College London, and later a Professor in the Division of Engineering, Brown University (1967-74). In 1971, he founded the MARC Analysis and Research Corp., a software company that developed and marketed the first general purpose nonlinear finite element analysis (FEA) program named MARC. This program was and continues to be used widely in industry for nonlinear analysis of complex structures such as nuclear reactors, car crashes, manufacturing processes, etc. In 1995, he founded PVM Corp. and embarked on the development of a general purpose FEA program for multi-physics named FEVA. In 2004, he founded the MPAVE Corp. to develop CAD-centric FEA software to foster more widespread adoption of the FEA technology.

Dr. Marcal is active in ASME and was awarded Fellow of ASME in 1975. In 1989, Dr. Marcal was awarded the ASME Pressure Vessel and Piping Medal for his pioneering contributions to nonlinear finite element analysis technology. Dr. Marcal was also a leader in ASME, having served as a Founder in 1966 and later Chairman of a major division in ASME named the Pressure Vessels and Piping Division.

Dr. Marcal has authored more than 100 scientific papers on finite element analysis, fatigue and fracture, risk analysis, and AI (expert systems). He has organized or co-organized numerous scientific meetings on Computational Structural Mechanics. More importantly, he was one of the early pioneers in FEA, and had many collaborators including **Prof. James Rice** of Harvard University, who stated in 1994 at his Timoshenko Medal award ceremony that "*. . . **Pedro Marcal opened my eyes to computational mechanics**,*" and **Dr. Poh-Sang Lam** of DOE Savannah River National Laboratory, who added, "*. . . **Pedro opened Jim Rice's eyes to computational mechanics; then Jim Rice opened his students' eyes like David Parks' and Bob McMeeking's; and then David and Bob opened my eyes; . . . so I guess I owe Pedro my eyes**.*"

3. A **General Call-for-Papers** and an *Option to write a Tribute* to Dr. Pedro Marcal

All interested in the topic, "Computational Mechanics and FEM: Impact of Accuracy and Uncertainty," are invited to attend or contribute a talk at this symposium. The organizers plan to publish a pre-symposium bulletin by Aug. 1, 2016 for distribution free to all who plan to attend, contribute a presentation, or wish to write a tribute to the honoree, Dr. Marcal. The bulletin containing all accepted and invited abstracts as well as tributes will be printed for distribution before the Sep. 5-9, 2016 conference. Please submit an abstract of a proposed talk, and/or a tribute (1/4-page to 2 pages maximum) to the undersigned by ***June 1, 2016:***

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4. Introducing the **Symposium Advisory Committee**

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Yamagata, Nobuki	Japan		***Consultant, Tokyo, Japan***
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(More to be announced.)

5. Why is **Accuracy in Stress or Strain Computing** *Important* ?

Finite element method (FEM) has been used by engineers to compute stresses and strains with confidence for decades. As an approximate method in numerical analysis, FEM results are known to depend on (a) element type, (b) mesh quality such as density, aspect ratio, and inhomogeneity, (c) model parameters such as material and physical properties, loads, and constraints, and (d) solution method as implemented by an individual or a commercial platform such as ABAQUS, ANSYS, COMSOL, LS-DYNA, or NASTRAN.

The development of fast and large-memory computers and the availability of a number of automatic mesh generator for tetrahedron element has greatly simplified the work of an FEM analyst to obtain “accurate” FEM solutions, because what’s left is to increase the mesh densities to as large a degree of freedom as one can compute in order to achieve convergence. Once convergence is achieved, the answer is accepted as “correct” according to the classical theory of truncation errors.

Unfortunately, this FEM practice is incorrect because of at least three reasons:

(i) The tetrahedron element is known to give poor accuracy as compared with other element types such as the 8-node, 20-node, or 27-node hexahedron elements. A convergent tetrahedron-based solution at very large degrees of freedom does not necessarily guarantee a “correct” solution.

(ii) The truncation error theory did not account for variation in mesh quality such as aspect ratio.

(iii) The truncation error theory is violated when an FEM analyst introduces one or more techniques to implement the solution algorithm such as the reduced integration method.

As shown in Fig. 1 and Table 1, a recent paper (Fong, et al., ICPVT-14, Sep. 2015, *Procedia Engineering*, **130** (2015), 135-149) gave an example of the above, where three element types with two FEM codes give solutions that differ by a factor of two.

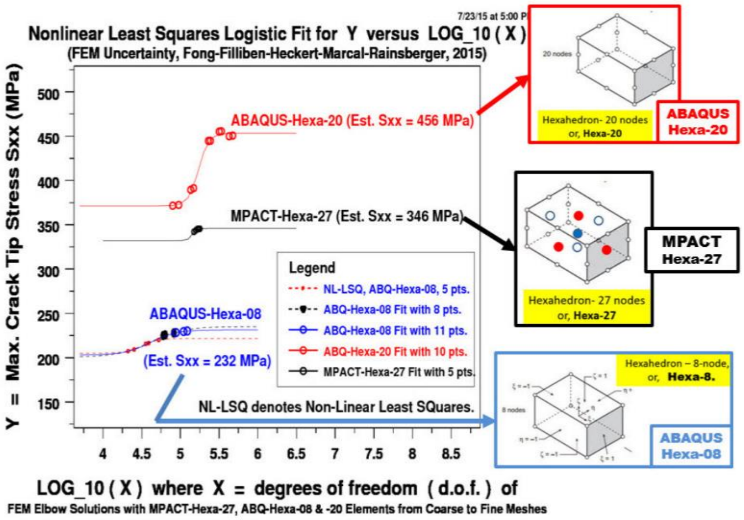
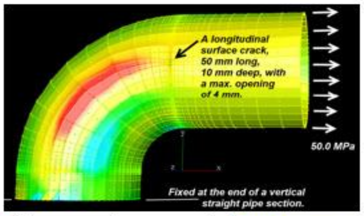


Fig. 1. FEM crack tip stresses using different element types.

Table 1. Ranking of FEM Solutions by Coefficient of Variation

A 900-mm (36-in) o.d. Pipe 90-deg. Elbow with a surface crack in one of its two welds

Est. Max. Crack Tip Stress ***Sxx (MPa)*** *at* ***1 billion*** *(10^9)* ***degrees of freedom*** *using a Nonlinear Least Squares Logistic Fit of 5 or more FEM solutions of the same mesh design at increasing mesh densities*



FEM Code-Element Type *No. of Runs* (Best Estimated Solution)	95 % Lower Limit at 10^9 d.o.f. (MPa)	Predicted Max. Crack Tip Stress at 10^9 d.o.f. (MPa)	95 % Upper Limit at 10^9 d.o.f. (MPa)	Stand. Dev. (S.D.) at 10^9 d.o.f. (MPa)	Coeff. of Variation (C.V.) at 10^9 d.o.f. (%)	Ranking of Solutions by C.V. (least being the best)
ABQ-Hex20 ***7 runs*** (455.20)	407.32	**457.96**	508.60	**19.70**	**4.30 %**	**6**
ABQ-Hex20 ***9 runs*** (455.50)	413.80	**454.23**	494.67	**17.10**	**3.76 %**	**5**
ABQ-Hex20 ***10 runs*** (455.50)	418.74	**453.17**	487.61	**14.93**	**3.29 %**	**4**
MPACT-Hex27 ***5 runs*** (345.48)	345.10	**345.47**	345.85	**0.12**	**0.03 %** ***(lowest)***	**1**
ABQ-Hex08 ***5 runs*** (220.00)	203.02	**246.05**	289.09	**13.52**	**5.49 %**	**7**
ABQ-Hex08 ***9 runs*** (228.30)	215.78	**233.37**	250.96	**7.44**	**3.19 %**	**3**
ABQ-Hex08 ***11 runs*** (230.10)	220.56	**231.69**	242.82	**4.92**	**2.12 %**	**2**

6. Why is **Verification of Finite Element Computing** *Critical* to **Computational & Experimental Engineering and Sciences ?**

Since FEM is the *de facto* method of computing stresses and strains in engineering and all branches of sciences from nano to macro, the lack of confidence in the accuracy of an FEM solution is unacceptable, because decisions of life or failures of a component or system can result from the application of an inaccurate stress or strain estimate. An example of this is recently documented in Figs. 2 and 3 (Ref.: Fong, et al., Paper PVP-2016-63350, to appear in *Proc. ASME PVP Conf.*, July 17-21, 2016, Vancouver, BC, Canada), where the creep rupture time of an API Grade 91 steel at 600 C at an applied stress of 101.4 MPa can drop by 70 % at its 95 % lower limit and a further 23 % due to an error of 2 % in stress estimate.

Traditionally speaking, all numerical solutions should be first "verified" to ensure that the solution is "mathematically" correct for a given physical model, and then "validated" by a physical experiment to check whether the model is correct.

Because of time and cost limitations, most FEM solutions can never be "validated" by a physical experiment. That means we need to do as much as we can to at least "verify" an FEM solution, and hope and pray that the model is correct.

Since verification of FEM solutions is critical to computational and experimental engineering and sciences, it is the purpose of this ICCES symposium to bring attention to this important task of FEM solution verification.

Even though the truncation error theory is less than adequate to deal with an inhomogeneous FEM mesh with different aspect ratio and element type, the theory still predicts that a 27-node hexahedron element should give the most accurate solution, as illustrated in Fig. 1 and Table 1. Since **Dr. Pedro Marcal** has not only been a pioneer in nonlinear FEM, but also contributed the FEM methodology using a 27-node hexahedron element, we choose to honor him with this symposium on the occasion of his being awarded an *ICCES Lifetime Achievement Medal.*

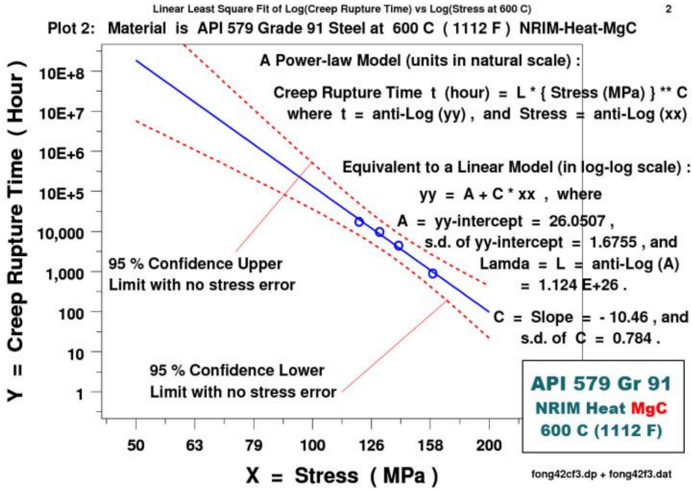


Fig. 2. Log-Log Plot of Linear Least Squares Fit of NRIM 1996 Creep Rupture Time vs. Stress Data with 95 % Confidence Limits.

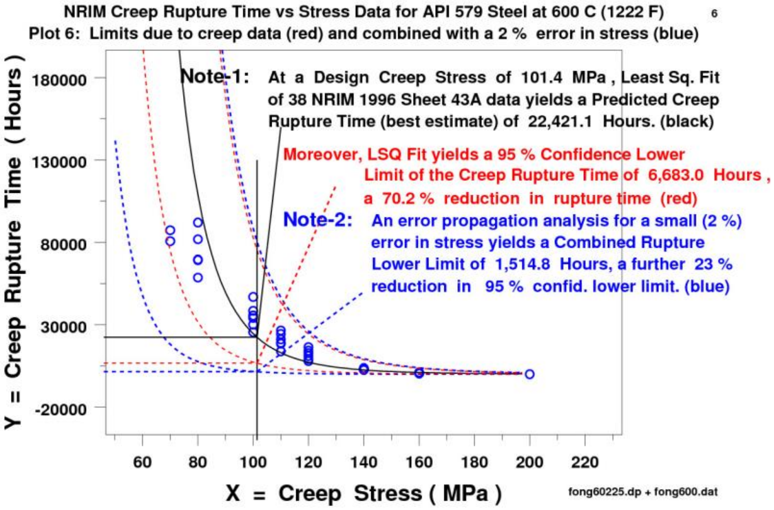


Fig. 3. Natural-Scale Plot of 3 heats of NRIM 1996 Creep Rupture Time vs. Stress with Predicted (**black line**), 95 % Confidence Limits (**red lines**), and 2 % stress error plus 95 % Confidence Limits (**blue lines**), based on a linear, first order model of the log-log plotted data.