One Man's Corner

Part 1.B Lessons Learned from My Early FEA Career

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Introduction

This article continues the discussion of the second of four aerospace structural analysis projects in my early career: (**Part 1.B**) Evaluation of NASA's public-domain *COSMIC/NASTRAN* general-purpose, finite-element, structural analysis program – sponsored by the Office of Naval Research, and work done by Swanson Service Corporation (Dr. J. William Jones, President). This article ends with a summary of the "Finite Element Standards" work done in the 1982-1985 period, under the sponsorship of AIAA/ASME.

1.B Evaluation of *COSMIC/NASTRAN* Program

This code evaluation work was conducted by Swanson Service Corporation (SSC), and funded by the Office of Naval Research (ONR), 1978-1980. The ONR program manager was Dr. Nick Perrone, and the project's technical monitor was Dr. Robert E. Nickell* (who later was elected President of the *American Society of Mechanical Engineers*).

* *Member, U.S. National Academy of Engineering*

1.B.1 Study Objectives – and ADINA Code Evaluation by Chang and Padovan (1978-1980)

In 1978-1980, ONR had sponsored a series of evaluations of large-scale, structural analysis computer programs, including two codes, *ADINA* and *COSMIC/NASTRAN.*

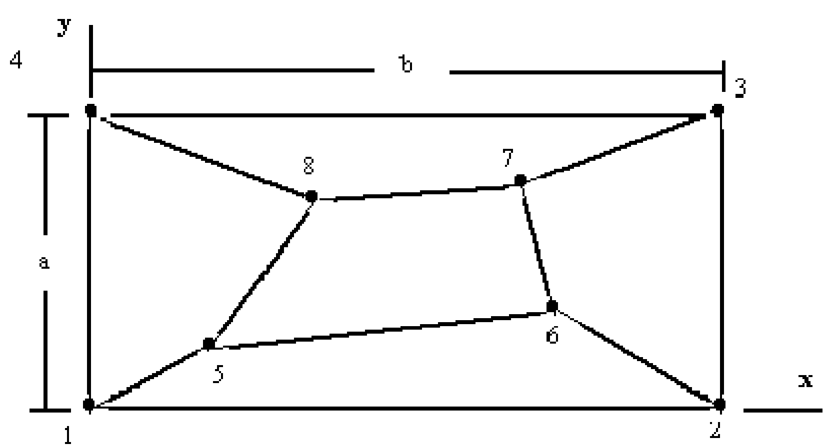
ADINA had its roots in the *NONSAP* nonlinear structural analysis code, developed at the University of California at Berkeley, by Professors Edward L. Wilson*, and his graduate students Klaus-Jürgen Bathe and Robert H. Iding. After Bathe received his PhD, he went to MIT and became a professor of mechanical engineering, where he enhanced the code and renamed it *ADINA* (and "commercialized" it). Bathe also started his own *ADINA* code development and consulting company, in Cambridge, Massachusetts, named ADINA Engineering. In 1978, ONR awarded its first FEA code evaluation project to Professors Paul T.Y. Chang and Joseph Padovan, at the University of Akron, Ohio. Their *ADINA* evaluation report was published in June 1980. [Chang and Padovan, 1980].

The objectives of the *COSMIC/NASTRAN* evaluation project were to study its programming and operating characteristics, assess its user-friendliness (documentation, etc.) and strengths and weaknesses, and evaluate its numerical accuracy (by doing benchmarks and comparing results against published solutions and other FEA codes).

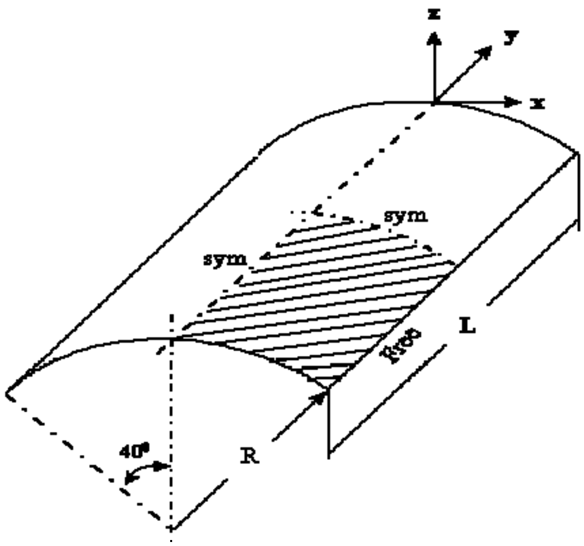
1.B.2 COSMIC/NASTRAN Evaluation

In 1978, I had just left McDonnell Douglas Astronautics Company, and was then working as a senior staff engineer at Hughes Aircraft Company's Electron Dynamics Division (Torrance, California), performing thermostructural analyses of traveling wave tubes (see my article, ***Part 1.D***). I "moonlighted" during my spare time for Dr. J. William ("Bill") Jones, Fellow ASME, and President, Swanson Service Corporation. At that time, SSC was the Southern California distributor of the *ANSYS* code. (Note: together with *MSC/NASTRAN*, *ANSYS* was considered in the 1970s as the two leading general-purpose, structural, dynamic, and thermal analysis FEA codes in the world.) Bill had just been awarded the *COSMIC/NASTRAN* code evaluation contract by the ONR, and needed some help. This began a two-year, enjoyable collaboration project, which led to the publication of SSC's final report in 1980 on our *COSMIC/NASTRAN* evaluation work to ONR, as well as to our jointly-authored paper published in John Robinson's book entitled, *Third World Congress on Finite Element Methods,* Beverly Hills, 1982.

Two sample benchmark problems (both considered *de-facto* standard benchmark problems to test finite element accuracy and convergence) we used to evaluate the performance of *COSMIC/NASTRAN*'s plate and shell elements are shown below:



This first figure shows the 2-D "picture window" *patch test* to test the accuracy of plate elements like *MSC/NASTRAN*'s *QUAD4* [originally attributed to FEM pioneer Bruce Irons, and later included in 1985 as one of the standard *MacNeal-Harder Problems* by Richard H. MacNeal and Robert L. Harder of The MacNeal-Schwendler Corporation (MSC)]. There is also, of course, an equivalent *3-D patch test* for solid hexahedral elements, i.e., a small cube inside another larger cube.



These two figures on the previous page show the well-known shell benchmark problem known widely amongst finite element researchers in the 1960s-1980s as the *Scordelis-Lo barrel roof* (originally solved in closed form and by finite differences, by UC Berkeley Professor Alexander

C. Scordelis and his graduate student Kam-Shing Lo, in 1969). The shell was loaded by gravity loads. Only one-fourth of the shell (because of symmetry considerations) was analyzed by finite element researchers, using various quadrilateral and triangular plate elements, and mesh refinement studies were conducted to test convergence.

ONR's Nick Perrone and Bob Nickell had special reasons to select the *COSMIC/NASTRAN* code for evaluation. It was inexpensive, easily accessible and "public-domain," versus the proprietary and much more expensive *MSC/NASTRAN* code – even though at that time, *MSC/NASTRAN* was generally regarded as having better capabilities, documentation, and support. They picked Swanson Service Corporation as the contractor to perform this code evaluation work, because they specifically wanted an experienced, professional engineer (in this case, Bill Jones) with large-scale FEA code applications experience in industry, and who preferably was also intimately familiar with a general-purpose FEA code (in this case, *ANSYS*) other than *NASTRAN*.

Awarding this *COSMIC/NASTRAN* evaluation contract to SSC caused some consternation and concern at MSC, especially with its President, Dr. Joseph Gloudeman. (But, MSC's Chairman and Co-founder, Dr. Richard H. MacNeal*, a long-time friend of mine who also knew Drs. Perrone and Nickell quite well, responded very professionally and took this matter in stride). Nevertheless, Perrone and Nickell stood firm on their choice of SSC to do the *COSMIC/NASTRAN* evaluation work, knowing that the study might be controversial (they already knew that Professor Bathe did not care either for the *ADINA* evaluation work done by Professors Chang and Padovan). Bob Nickell carefully guided our *COSMIC/NASTRAN* evaluation study to a successful conclusion. [I can still remember in 1981, when I presented our paper at John Robinson's *Third World Congress on Finite Element Methods* conference in Beverly Hills, the very nervous Dr. Gloudeman's pacing back and forth in the back of the hall during my entire half-hour talk – making sure that I gave a "professional" presentation, and that I did not make any disparaging remarks about *MSC/NASTRAN*, or about MSC.]

For further details on this *COSMIC/NASTRAN* evaluation work, see the four references at the end of Part 1.B [Jones and Fong, 1980, 1981, 1982; Fong, 1982]:

1.B.3 AIAA/ASME *Finite Element Standards* Activity (1982-1985)

As part of the AIAA/ASME/ASCE/AHS *Structures, Structural Dynamics and Materials Conference (SDM)*, a small group led by Dr. Kevin J. Forsberg of Lockheed (who was then manager of the Space Shuttle's "thermal protection system" carbon-carbon tiles program at Lockheed) met regularly to discuss the formation of a FEA standards working group in the U.S. Also on this "Finite Element Standards" working committee were Dr. Richard MacNeal of MSC (who volunteered to develop a standard set of finite element test problems to evaluate codes), myself (who examined the pros and cons of recommending documentation standards for FEA codes), and a few other interested individuals.

We then sponsored and organized a *Finite Element Standards* open forum, held at the 24th AIAA/ASME/ASCE/AHS *SDM* Conference in Palm Springs, California (1984) – which was attended by over 140 finite element engineers, researchers, code developers, and other interested people. Several well-known FEM researchers from academia participated in this forum, such as Professors Robert L. Taylor*, Ted H.H. Pian*, Ted B. Belytschko*, Klaus-Jürgen Bathe, and Thomas J.R. Hughes*, and presented their thoughts on "standard" finite element benchmark tests (linear elastic and static problems only). Leading commercial FEA code developers were all invited and many were present; they either made presentations (e.g., from *ABAQUS, MARC, MSC/NASTRAN, ANSYS, ADINA,* etc.) or participated in the discussions. A British representative (William Mair), from UK's nascent *NAFEMS* organization (National Agency for Finite Element Methods and Standards) based in Glasgow, also attended our forum and participated in our committee meeting.

Unfortunately, despite this excellent start of the "Finite Element Standards" activity in 1984, financial support was rather difficult to obtain from the U.S. engineering professional societies (AIAA, ASME, ASCE, etc.), or from U.S. Government organizations, and this effort eventually fizzled. The only notable work that resulted was Dr. MacNeal and Bob Harder's publication of their so-called *MacNeal-Harder Problems* to test finite element accuracy [MacNeal and Harder, 1985]. Meanwhile, the NAFEMS organization in UK took up the "Finite Element Standards" cause, and continues to this day as the only "international finite element standards" activity going on anywhere in the world (to the best of my knowledge).

Lesson #6: *A good idea is like a seed. Without the proper environment (sunlight, water, air, and fertile soil* – i.e., the interplay among our many socio-economic and political forces*) and nutrition (food and minerals* – i.e., funding*), the seed will not grow and blossom into a tall, fruit-bearing tree.*

Acknowledgments: The author would like to thank Dr. J. William Jones, Fellow ASME, for giving me the opportunity to assist him and his SSC colleagues in this interesting *COSMIC/NASTRAN* evaluation study (1978-1980) – and the unwavering support of ONR's Nick Perrone and Bob Nickell. And, for the friendship and encouragement of Drs. Richard H. MacNeal, Bob Nickell, and Kevin J. Forsberg.

Part 1.B References:

Chang, T.Y. and J. Padovan. *Evaluation of ADINA – Part I Theory and Programming Characteristics, Part II Operating Characteristics*, University of Akron, 8 June 1980. Defense Technical Information Center, accession numbers ADA 096678, 096681.

Jones, J.W. and H. H. Fong. *Evaluation of COSMIC/NASTRAN General-Purpose Computer Program*, Swanson Service Corporation, Report #81580, submitted to Office of Naval Research, August 1980.

Jones, J.W. and H. H. Fong. An Evaluation of COSMIC/NASTRAN, *Third World Congress on Finite Element Methods* (ed. J. Robinson), 1981, pp. 324-338.

Jones, J.W. and H. H. Fong. Evaluation of NASTRAN, *Structural Mechanical Software Series IV* (ed. W. C. Pilkey), University Press of Virginia, 1982, pp. 147-237.

Fong, H.H. "An Evaluation of Eight U.S. General-Purpose Finite Element Computer Programs," *Proc.23rd AIAA/ASME/ASCE/AHS Structures, Structural Dynamics and Materials Conference*, AIAA Paper 1982-699, New Orleans, Louisiana, May 10-12, 1982, pp. 145-160.

MacNeal, Richard H. and Robert L. Harder. "A Proposed Standard Set of Problems to Test Finite Element Accuracy." *Finite Elements in Analysis and Design*, vol. 1, 1985, pp. 3-20.

-End of Part 1.B-
