8th. World Congress on Computational Mechanics (WCCM8)
5th European Congress on Computational Methods in Applied Sciences and Engineeering (ECCOMAS 2008)
June 30 –July 5, 2008
Venice, Italy

A POSTERIORI INITIAL IMPERFECTION IDENTIFICATION IN SHELL BUCKLING PROBLEMS

Christopher J. Stull[1], Wilkins Aquino[2] and *Christopher J. Earls[3]

[1]Doctoral Student
Sch. of Civil and Env. Eng.
Cornell University
220 Hollister Hall
Ithaca, NY, 14853, USA

[2]Assistant Professor
Sch. of Civil and Env. Eng.
Cornell University
220 Hollister Hall
Ithaca, NY, 14853, USA

[3]Associate Professor
Sch. of Civil and Env. Eng.
Cornell University
220 Hollister Hall
Ithaca, NY, 14853, USA
cje23@cornell.edu

Key Words: *Shell Buckling, Initial Imperfections, Inverse Problems, Genetic Algorithms.*

ABSTRACT

Since the publication of Koiter's seminal dissertation in 1945, it has become well known that initial imperfections in shell structures may lead to dramatic erosions in ultimate strength [1] [2] [3]. However, the jump from this notional understanding, to the realization of a practically useful means for predicting the actual strength of in-service imperfect shell structures, is formidable. It is virtually impossible to rationally guess the precise imperfection field that may be manifest in a given structure; and thus it is problematic to know the buckling strength of this same structure.

The current research aims to address this issue through the development of a method that leverages techniques from machine learning and nonlinear finite element analysis in order that sensor telemetry, related to structural response measures (*e.g.* displacement and load intensity), may be used in the solution of an inverse problem that characterizes the initial imperfection field. This *a posteriori* determination of the shell initial imperfection field is made under the safe condition of service loading, but it enables a reliable assessment of the ultimate strength for a given shell structure.

As a demonstration case, the buckling of an edge loaded barrel vault shell structure is considered (see Figure 1). This shell structure is made to possess an initial imperfection that is consistent with a single dent (see Figure 2, left). An inverse problem, aimed at inferring the existence and nature of the dent, is posed using a nonlinear shell finite element based forward model; applied in conjunction with a genetic algorithm (GA) tool. The form of the chromosome used to characterize individuals within the GA are comprised of genes that parameterize the initial imperfection field in the shell problem. These genes correspond to the salient quantities in a given radial basis function (RBF); given as follows for a representative Gaussian RBF:

$$\Psi_i(\bar{x}) = e^{-\left(\frac{\|\bar{x}-\bar{c}_i\|}{\sqrt{2}\sigma_i}\right)^2} \quad (1)$$

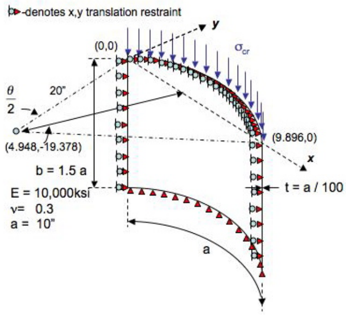

Figure 1: Edge loaded barrel vault shell example structure

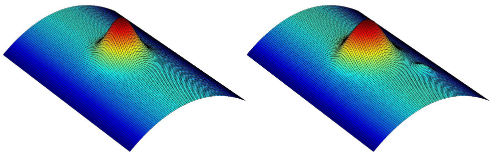

Figure 2: Representative (magnified ≈ x3000) results for *a posteriori* estimation (right) of initial imperfection (left)

where c_i are the coordinates of the radial basis center, ω_i are the magnitudes of the individual RBFs, and σ_i are their standard deviations. The GA guides a search through the parameter space associated with the ranges of genes assumed; in order that a solution to the inverse problem yields the initial imperfection field, $u(\bar{x})$, approximated as:

$$u(\bar{x}) \approx \sum_{i=1}^{N=1,4,8} \omega_i \Psi_i(\bar{x}) \tag{2}$$

The GA fitness function considers only normal displacements to the shell surface at a finite number of locations, as well as the peak load acting along the barrel vault edge.

Figure 2 presents representative results, for the case of a single dent located at the middle of the shell structure as an initial imperfection (left), wherein four radial basis functions are considered in arriving at the best approximation (right) to the initial imperfection present in the shell structure. In addition to centrally located dents, dents in the corners are also considered. The inverse problem solution space is alternately spanned by 1, 4, and 8 RBFs, and the solutions compared. Reasonable accuracy and repeatability are observed.

REFERENCES

[1] Z. P. Bazant and L. Cedolin. *Stability of Structures.* Oxford University Press, 1991.

[2] C. A. Featherston. "Imperfection sensitivity of curved panels under combined compression and shear." *International Journal of Non-Linear Mechanics*, 38:225-238, 2003.

[3] J. Singer, J. Arbocz, and T. Weller. *Buckling Experiments, Volume 2.* John Wiley and Sons, Inc. 2002.