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

An Intelligent Flaw Monitoring System: From Flaw Size Uncertainty to Fatigue Life Prediction with Confidence Bounds in 24 Hours

***Jeffrey T. Fong[1], James J. Filliben[2], Alan Heckert[3], and Pedro V. Marcal[4]**

[1] U. S. National Institute of Standards & Technology
Math & Computat'l Sciences
100 Bureau Dr, M.S. 8910
Gaithersburg, MD 20899 USA
fong@nist.gov

[2, 3] U. S. National Institute of Standards & Technology
Statistical Engineering
100 Bureau Dr, M.S. 8980
Gaithersburg, MD 20899 USA
filliben@nist.gov
alan.heckert@nist.gov

[4] MPave Corp.
3606 Calico Ranch Gate
Julian, CA 92036
USA
marcalpv@cox.net

Key Words: *Intelligent systems, Flaw size uncertainty, Fatigue life modeling, Multi-tasking, Design of experiments, Finite element method uncertainty, statistical analysis.*

ABSTRACT

To assist owners and operators in real-time on-site monitoring and damage assessment of aging structures, we propose a novel “structural soundness” monitoring system consisting of two distinct phases:

1.0 The Inspection Phase.

A carefully-designed and implemented field inspection program that yields a stream of nondestructive evaluation (NDE) data [1] such as ultrasonics, radiography, or other direct measurement techniques [2], for a specific component under surveillance.

2.0 The Analysis and Modeling Phase

A web-based, intelligent, and multi-tasking algorithm involving analysis, modeling, and field-office-field data transmission technology that converts, with access to an associated customized material property database, the flaw size data first into a new set with uncertainty, and then into an estimated remaining life to be delivered online to the field not as a single prediction but with a 95% confidence bounds.

More specifically, the algorithm in Phase 2 consists of four distinct parts, namely,

2.1. A Customized Material Property Database

The office computer has a customized database that stores not only relevant geometric and material property data with variability information, but also a history of prior loadings, cumulated strain (plastic) measurements, and flaw detection, location, and sizing data of similar NDE technique and comparable structural components. Such

database is constantly being updated with new field data of comparable components and similar NDE technique subsequent to an event of periodic inspection on a scheduled or unscheduled basis.

2.2. A Design-of-Experiment (DEX)-based Flaw Size Uncertainty Algorithm

Using a public-domain statististical analysis software package named DATAPLOT [3], we adopt a design-of-experiment approach [4] in constructing a flaw size uncertainty algorithm that converts, with access to part 2.1, the flaw size data set of Phase 1 into a new one with 95% confidence bounds.

2.3. A Finite-Element-Method (FEM)-based Damage Modeling Algorithm

Using a minimum of four commercially-available FEM packages, e.g., ABAQUS, ANSYS, LS-DYNA, MPAVE-MPACT, and a pre-processor such as TRUEGRID, we perform a series of numerical simulation experiments based on data set of Part 2.2 and a fracture mechanics/fatigue damage theory-based computational model for predicting remaining life for a selected class of future loading scenarios. This last has been implemented in the MPAVE-Python post-processing environment.

2.4. A DEX-based FEM Uncertainty Algorithm

The results of Part 2.3 are verified via a web-based statistically designed experiment, again using DATAPLOT [3], where an uncertainty-bounded estimate of the remaining life of the structure is delivered in real time to the field for decision making.

Examples drawn from potential applications in bridge inspection, life extension of aging piping systems, and high temperature low-cycle fatigue monitoring of pressure vessels, are presented. Significance of the prototype web-based system is discussed.

REFERENCES

[1] J. T. Fong, L. Mordfin, O. F. Hedden, and S. H. Bush, eds., *NDE Reliability Through Round Robin Testing*, Proc. International Symp on NDE Reliability via Analysis of PVRC/PISC/JPVRC Round Robin Testing Results, 4th National Congress on Pressure Vessels & Piping Technology, Portland, Oregon, June 19-24, 1983, *ASME Spec. Pub. NDE-1*. New York, NY: American Society of Mechanical Engineers (1983).

[2] W. F. Ranson, and R. I. Vachon, "Optical Strain Measurement of Accumulated Damage Ar ound Geometrical Discontinuities such as in Pipes and Pressure Vessels," Paper *PVP2006-ICPVT-11-93766*, ASME Pressure Vessel and Piping Conf., Vancourver, BC, Canada, July 2006. New York, NY: ASME (2006).

[3] J. J. Filliben, and N. A. Heckert, *DATAPLOT: A Statistical Data Analysis Software System*, a public domain software released by NIST, Gaithersburg, MD 20899, http://www.itl.nist.gov/div898/software/dataplot.html, (2002).

[4] G. E. P. Box, W. G. Hunter, and J. S. Hunter, *Statistics for Experimenters: An Introduction to Design, Data Analysis, and Model Building.* Wiley (1978).