HANDBOOK OF NONDESTRUCTIVE EVALUATION (NDE)

CAPABILITY AND RELIABILITY*

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INTRODUCTION

Nondestructive inspection (NDI) is often the primary basis for establishing the initial flaw size that is used as the basis safe life analysis of components, structures and systems. It is often desirable to use a small initial flaw size for purposes of fatigue and fracture analysis, thus the capability of applied the nondestructive inspection procedure often becomes a primary design constraint. The introduction of fracture mechanics analysis in design applications has established requirements to quantify the capabilities of applied nondestructive inspection procedures for purposes of determining the "largest flaw that might be missed". That flaw size, in turn, becomes the starting point for fracture mechanics analysis and for crack growth in fatigue life analyses. It is clearly desirable to start with a very small flaw size. In recent years, considerable effort has been expended in both meeting "attainable" flaw requirements and in improving NDI procedures capabilities to detect smaller flaws. Such efforts have identified uncertainties in fracture mechanics analysis procedures in predicting the behavior of small flaws and have greatly increased the complexity and sophistication of NDI procedures being applied.

A large gap exists between the expectations of the capabilities of many NDI procedures and the demonstrated / validated capabilities. One hallmark of maturity of an engineering technology is the ability to quantify the capabilities and reliability of application of the tools that are used in that technology. While methods have been developed and much work has been completed to quantify and document NDE procedure

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capabilities, no single baseline reference has been available to integrate this work with user requirements or to provide a baseline reference for NDE engineers and implementers.

Questions of primary engineering interest in the application of NDE are:

- What inspection?
- How small a flaw can it detect?
- What are the relative costs of inspection?
- What special equipment and/or facilities are required?
- What are the special personnel training and skill development requirements?
- What objective evidence of the inspection (out put) is provided?

The answers to those questions are scattered in different reference sources and are not specifically available for many NDE procedures and applications. To this end, the task of documenting demonstrated NDE capabilities in a single reference source is underway and will be published in the form of a handbook.

PURPOSE AND SCOPE

The purpose and goal of the handbook is to provide an initial, single baseline reference source for documented NDE process capabilities and for development, quantification, validation and use of new NDE procedures; more succinctly to provide a common engineering / application knowledge baseline. It is intended to be a general reference and guideline for communicating, documenting and using quantitative nondestructive evaluation capabilities (performance levels) as applied to various material, geometric configurations and systems under various operating / application conditions. Data and reference documentation have been gathered from currently available sources and are being included in the Appendix Volumes to the handbook. Data additions to the Appendix Volumes are anticipated in future work.

HANDBOOK STRUCTURE

The mode of documentation in the handbook is intended to answer many of the primary engineering questions on NDE applications and to present the information and answers in a form that will be most useful to the users of the technology. Primary anticipated use of the information / data provided are in:

- Hardware / system design
- Production / process acceptance
- Field maintenance and life-cycle management
- Hardware / system life extension
- System requalification and acceptance
- Hardware / system retirement for cause

Anticipated individual users of the information / data provided are:

- The designer
- The materials engineer
- The reliability and safety engineer
- The maintenance engineer
- The manufacturing / production process engineer
- The liaison (rework and repair) engineer
- The life-cycle maintenance manager
- The hardware / system operator and customer(s)
- The NDE engineer
- The NDE process manager
- The NDE engineering technology manger

The points of view of the diverse population of anticipated users have been kept in mind in organizing and classifying the information in terms of NDE questions most frequently posed and the applications of the technology. Handbook organization has therefore been approached as a compliance matrix with the intent of rapid access to answer questions of primary engineering interest. This approach combines ideas of a "HELP" module that is familiar to users of modern computer software programs with additional focus on "what I want to know" from the perspective of specific, anticipated users. The general structure of the handbook is shown schematically in FIGURE 1.

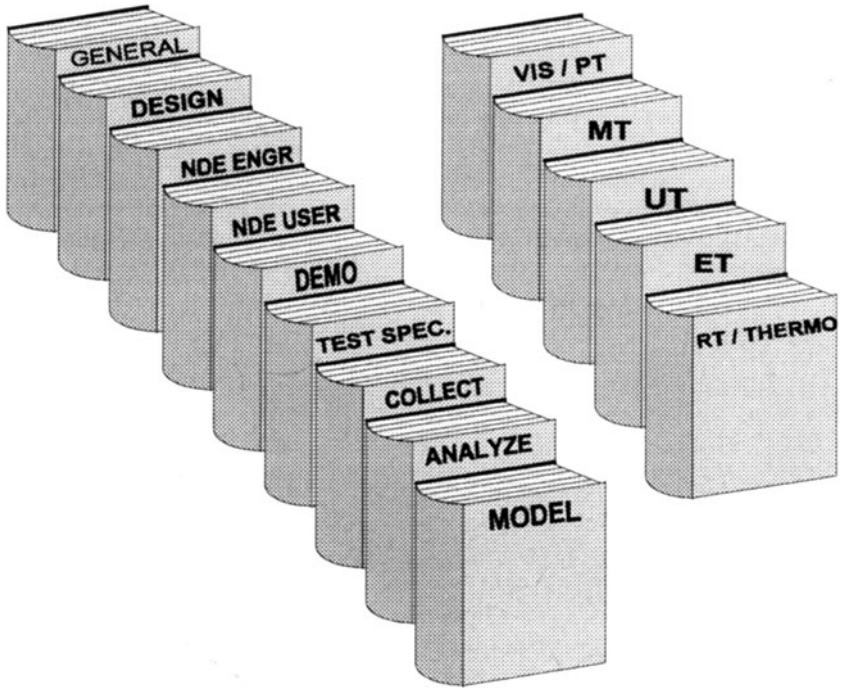

Figure 1. Handbook Structure.

HANDBOOK APPLICATIONS

AS A GENERAL DESIGN REFERENCE - To identify requirements for, and use of, a "minimum detectable flaw size" that may be used in fracture mechanics analyses as a basic design parameter; to identify boundary conditions and operating constraints that may vary the "minimum detectable flaw size" that can be used in design analysis; and to identify requirements and considerations in establishing a "minimum detectable flaw size" for use in life cycle management.

GENERAL NDE ENGINEERING DESIGN REFERENCE - To provide a general reference for selection of candidate NDE procedures; to establish requirements for determining and validating the capabilities of specific NDE procedures applications; and to identify requirements and process control methods for maintaining continuing NDE performance capabilities.

GENERAL REQUIREMENT FOR THE NDE USER - To provide a general reference for materials, equipment, procedure, calibration, and personnel qualification and validation for quantitative NDE processes.
GENERAL REQUIREMENTS FOR DEMONSTRATION OF NDE CAPABILITIES - To provide general requirements and consideration for demonstrating NDE capabilities for small flaws and / or special operating conditions.

GENERAL REQUIREMENTS FOR TEST SPECIMENS - To provide general guidelines for generation, validation, documentation, control and use of test specimens for quantitative NDE demonstration.

GENERAL REQUIREMENTS FOR DATA COLLECTION - To provide general guidelines for data collection in quantitative NDE capabilities demonstrations.

GENERAL REQUIREMENTS FOR DATA ANALYSIS - To provide general guidelines for data analysis and data presentation for purposes of quantitative NDE capabilities validation / demonstration.

PREDICTIVE METHODS FOR QNDE - To provide guidelines for predicting NDE procedure capabilities by experiment and modeling.

CONTENT

APPENDICES - Appendices will be added to provide documentation of demonstrated NDE capabilities as applied to different test objects and problems. These will be organized into separate sections to document the capabilities by NDE method.

RAW DATA - Raw data that supports the capabilities documented in the appendices will be archived in electronic form. Tentatively, the data will be stored in "Microsoft - Excel" spread sheet format. Alternate formats may also be used to assure continuing capabilities for access. It is anticipated that this will be initially in magnetic (floppy disk) media and will be later transferred to compact disk for storage and distribution. An on-line down load capability may be provided depending on demand and resources.

GUIDELINES FOR ADDING TO THE DATABASE - The quantitative NDE process capabilities database is anticipated to continue to grow and the baseline document will include provisions for adding to the database within the resources available.

SUMMARY AND CONCLUSIONS

The is great need for, and interest in, a baseline, general reference source for the generation, control and use of nondestructive evaluation data. Some of the difficulties in building such a reference are in the diverse sources of data and the diverse media on which it is stored. As might be anticipated, strong interest in the handbook has been expressed by the NDE community and useful suggestions have been made for both structure and content. Strong interest has been shown by the user communities in providing a basis for design assumptions and inclusion of initial flaw sizes in flaw growth analysis tools (NASA FLAWGRO*). We anticipate interest in linking this work to analytical tools necessary to build integrated engineering capabilities. It is expected that the handbook will meet a growing need and that continuing support and update will be necessary.

The nature of the work is such that caution in use of data provided must be made and understood by all users. Notably:

This document shall not be used as the primary basis for establishing acceptance criteria. Design acceptance criteria must be established analytically as part of the integrated design process ([i.e. system functional analyses, stress analysis, thermal analysis, fracture mechanics analysis (FAIL SAFE), life-cycle fatigue analysis (SAFE-LIFE), etc.] Users are cautioned that "The guidelines and data presented are specific to the applications and conditions that accompany the data description. Special conditions and/or applications of NDE in the production process must be included in the NDE requirements and process analyses; for example, etching may be required before penetrant inspection and penetrant inspection data on properly prepared test objects are not applicable to inspections performed without preparation".

INFORMATION AND DATA PRESENTED IN THIS HANDBOOK ARE INTENDED FOR TECHNICAL REFERENCE ONLY. THE RESPONSIBILITY FOR DEMONSTRATING NDE CAPABILITIES REMAINS WITH THE USER.

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