Designation: E2862 – 12

Standard Practice for Probability of Detection Analysis for Hit/Miss Data[1]

This standard is issued under the fixed designation E2862; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice defines the procedure for performing a statistical analysis on nondestructive testing hit/miss data to determine the demonstrated probability of detection (POD) for a specific set of examination parameters. Topics covered include the standard hit/miss POD curve formulation, validation techniques, and correct interpretation of results.

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E1316 Terminology for Nondestructive Examinations

2.2 *Department of Defense Handbook:*

MIL-HDBK-1823A Nondestructive Evaluation System Reliability Assessment[3]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *analyst, n*—the person responsible for performing a POD analysis on hit/miss data resulting from a POD examination.

3.1.2 *demonstrated probability of detection, n*—the calculated POD value resulting from the statistical analysis on the hit miss data.

3.1.3 *false call, n*—the perceived detection of a discontinuity that is identified as a find during a POD examination when no discontinuity actually exists at the inspection site.

3.1.4 *hit, n*—an existing discontinuity that is identified as a find during a POD demonstration examination.

3.1.5 *miss, n*—an existing discontinuity that is missed during a POD examination.

3.1.6 *probability of detection, n*—the fraction of nominal discontinuity sizes expected to be found given their existence.

3.2 *Symbols:*

3.2.1 a—discontinuity size.

3.2.2 a_p—the discontinuity size that can be detected with probability p.

3.2.2.1 *Discussion*—Each discontinuity size has an independent probability of being detected and corresponding probability of being missed. For example, being able to detect a specific discontinuity size with probability p does not guarantee that a larger size discontinuity will be found.

3.2.3 $a_{p/c}$—the discontinuity size that can be detected with probability p with a statistical confidence level of c.

3.2.3.1 *Discussion*—$a_{p/c}$ is calculated by applying a statistical uncertainty bound to a_p. The uncertainty bound is a function the amount of data, the scatter in the data, and the specified level of statistical confidence. The resulting value represents how large the discontinuity with POD equal to p could be when uncertainty associated with estimating a_p is accounted for. Hence $a_{p/c} > a_p$. Note that POD is equal to p for both $a_{p/c}$ and a_p. a_p is based solely on the hit/miss data resulting from the examination and represents a snapshot in time, whereas $a_{p/c}$ accounts for the uncertainty associated with limited sample data.

4. Summary of Practice

4.1 This practice describes step-by-step the process for analyzing nondestructive testing hit/miss data resulting from a POD examination, including minimum requirements for validating the resulting POD curve.

4.2 This practice also includes definitions and discussions for results of interest (for example, $a_{90/95}$) to provide for correct interpretation of results.

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[1] This practice is under the jurisdiction of ASTM Committee E07 on Nondestructive Testing and is the direct responsibility of Subcommittee E07.10 on Specialized NDT Methods.

Current edition approved Jan. 15, 2012. Published February 2012. DOI:10.1520/E2862-12.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098, http://dodssp.daps.dla.mil.

5. Significance and Use

5.1 The POD analysis method described herein is based on a well-known and well established statistical method. It shall be used to quantify the demonstrated POD for a specific set of examination parameters and known range of discontinuity sizes when the initial response from a nondestructive evaluation inspection system is ultimately binary in nature (that is, hit or miss). This method requires that a relationship between discontinuity size and POD exists and is best described by a generalized linear model with the appropriate link function for binary outcomes.

5.2 Prior to performing the analysis it is assumed that the discontinuity of interest is clearly defined; the number and distribution of induced discontinuity sizes in the POD specimen set is known and well-documented; discontinuities in the POD specimen set are unobstructed; the POD examination administration procedure (including data collection method) is well-defined, under control, and unbiased; and the initial response is ultimately binary in nature (that is, hit or miss). The analysis results are only valid if convergence is achieved and the model adequately represents the data.

5.3 The POD analysis method described herein is consistent with the analysis method for binary data described in MIL-HDBK-1823A, which is included in several widely utilized POD software packages to perform a POD analysis on hit/miss data. It is also found in statistical software packages that have generalized linear modeling capability. This practice requires that the analyst has access to either POD software or other software with generalized linear modeling capability.

6. Procedure

6.1 The POD analysis objective shall be clearly defined by the responsible engineer or by the customer.

6.1.1 The analyst shall obtain the hit/miss data resulting from the POD examination, which shall include at a minimum the documented known induced discontinuity sizes, whether or not the discontinuity was found, and any false calls.

6.2 The analyst shall also obtain specific information about the POD examination, which shall include at a minimum the specimen standard geometry (for example, flat panels), specimen standard material (for example, Nickel), examination date, number of inspectors, type of inspection method (for example, line-of-site Level 3 Fluorescent Penetrant Inspection), and pertinent comments from the inspector(s) and test administrator.

6.3 Prior to performing the analysis, the analyst shall conduct a preliminary review of the POD examination procedure and resulting hit/miss data to identify any examination administration or data issues. The analyst shall resolve any issues prior to conducting the POD analysis. Examples of examination administration or data issues and possible resolutions are:

6.3.1 If problems or interruptions occurred during the POD examination that may bias the results, the POD examination should be re-administered. If this occurs, it shall be documented in the report.

6.3.2 If a discontinuity was missed because it was obstructed (such as a clogged discontinuity), the discontinuity shall be removed from the POD analysis since there was not an opportunity for the discontinuity to be found. If a discontinuity is removed from the analysis, the specific discontinuity and rationale for removal shall be documented in the final report.

6.3.3 POD cannot be modeled as a continuous function of discontinuity size if there is a complete separation of misses and hits as crack size increases. If a complete separation of misses and hits is present in the data, the POD examination may be re-administered. If this occurs, it shall be documented in the report. If a complete separation of misses and hits occurs on a regular basis, the specimen set should be examined for suitability as a POD examination specimen set.

6.3.4 POD cannot be modeled as a continuous function of discontinuity size if all the discontinuities are found or if all the discontinuities are missed. If this occurs, the specimen set is inadequate for the POD examination.

6.4 The analyst shall use a generalized linear model with the appropriate link function to establish the relationship between POD and discontinuity size. For application to POD, the generalized linear model with discontinuity size as the single predictor variable is typically expressed as $g(y) = b_0 + b_1 \bullet a$ or $g(y) = b_0 + b_1 \bullet ln(a)$, where a or $ln(a)$ is the continuous predictor variable, b_0 is the intercept, b_1 is the slope, y is the binary response variable, and $g(\bullet)$ is the function that "links" the binary response with the predictor variable. If predictor variables other than discontinuity size are quantifiable factors, a generalized linear model with more than one predictor may be used.

6.5 The analyst shall choose the appropriate link function based on how well the model fits the observed data. MIL-HDBK-1823A discusses four different link functions (Logit, Probit, Log-Log, Complementary-LogLog) and describes methods for selecting the appropriate one. In general, the logit and probit link functions have worked well in practice for modeling hit/miss data.

6.6 Only hit/miss data for induced discontinuities shall be used in the development of the generalized linear model. False call data shall not be included in the development of the generalized linear model.

6.7 The analyst shall conduct the analysis using software that has generalized linear modeling capabilities.

6.8 After running the analysis, the analyst shall verify that convergence has been achieved. The resulting POD curve shall not be used if convergence has not been achieved.

6.9 After verifying convergence, the analyst shall use at a minimum the informal model diagnostic methods listed below to assess the reliability of the model and verify that the model adequately fits the data.

6.9.1 If included in the analysis output, the analyst shall check the number of iterations it took to meet the convergence criterion. If more than twenty iterations were needed to reach convergence, the model may not be reliable. A statement indicating that convergence was achieved and the number of iterations needed to achieve convergence shall be included in the report.