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Standard Practice for Crack Detection Using Vibroacoustic Thermography[1]

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1. Scope

1.1 *Purpose*—This practice covers procedures required to conduct an examination of components using vibroacoustic thermography.

1.2 *Application*—The vibroacoustic thermography process has been used for component inspections in the aircraft, power generation, automotive, and other industries for testing new and serviced components, both coated and uncoated. Current applications are mostly targeting metallic components, but composite and ceramic component applications are under development (**1**).[2]

1.3 *Background*—Vibroacoustic thermography is an active thermography technique that falls under the category of Infrared Thermography Testing (IRT). The technique was first published by Henneke, et al. in 1979 (**2**) and has been expanded on and popularized by Favro, et al. (**3**). During the test, a defect thermal response resulting from a short burst of ultrasonic energy typically in the range of 15 kHz to 40 kHz is detected by an infrared camera. The ultrasound coupled into the component being tested can activate a thermal response in defects with contact areas that can move against each other, that is, cracks and delamination. There are different energizing and coupling techniques that are commonly used depending on the needs and capabilities. These variations and the down selection process are not included in the procedure and should be developed/optimized by experimentation for each new component application.

NOTE 1—Vibroacoustic thermography is typically sensitive to tight planar defects (**4**). Volumetric defects such as porosity, inclusions, open ruptures, or cracks in wide-open areas, will not typically result in an indication. Therefore, an augmenting method should be conducted to detect volumetric defects. (See Terminology E1316.)

NOTE 2—Vibroacoustic thermography is a surface examination but has demonstrated detection sensitivity for subsurface defects including back wall defects for thin components (**5**), (**6**). Care should be taken when developing vibroacoustic thermography for the detection of subsurface defects.

1.4 *Warnings:*

1.4.1 **Warning—**Vibroacoustic thermography requires the energization of the test article with vibrational energy. During energization, the complete component may be excited with vibroacoustic (vibration) energy for as long as several seconds. The development of this test for a new application requires special measurements, precautions, and attention to component response. The component design engineer and the NDE engineering specialist knowledgeable of this technique should be satisfied that the test will not cause damage or reduction of service life.

1.4.2 **Warning—**Vibroacoustic thermography, like any other NDT technology, requires thorough development and testing for each application, including clear definition of the inspection objective, as well as development of objective means to distinguish between rejectable indications and conditions that should not be cause for rejection. Incomplete development and application will result in high incidence of improper rejections and high incidence of defect "misses."

1.5 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*

E168 Practices for General Techniques of Infrared Quantitative Analysis
E1213 Practice for Minimum Resolvable Temperature Difference for Thermal Imaging Systems
E1252 Practice for General Techniques for Obtaining Infrared Spectra for Qualitative Analysis
E1311 Practice for Minimum Detectable Temperature Difference for Thermal Imaging Systems
E1316 Terminology for Nondestructive Examinations
E1933 Practice for Measuring and Compensating for Emissivity Using Infrared Imaging Radiometers

[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.

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[2] The boldface numbers in parentheses refer to the list of references at the end of this standard.

E2585 Practice for Thermal Diffusivity by the Flash Method

2.2 *ASNT Standards:*[3]

SNT-TC-1A Recommended Practice, Personnel Qualification and Certification in Nondestructive Testing

ANSI/ASNT CP-189-2001 Standard for Qualification and Certification of Nondestructive Testing Personnel

2.3 *ATA Standard:*[4]

ATA-105 Guidelines for Training and Qualifying Personnel in Nondestructive Testing

2.4 *U.S. Publication:*[5]

MIL-HDBK-1823A Department of Defense Handbook: Nondestructive Evaluation System Reliability Assessment

3. Terminology

3.1 *Abbreviations:*

3.1.1 *ANSI*—American National Standards Institute

3.1.2 *ASNT*—American Society for Nondestructive Testing

3.1.3 *ATA*—Air Transport Association

3.1.4 *CCD*—Charge Couple Device

3.1.5 *FOV*—Field of View

3.1.6 *IR*—Infrared

3.1.7 *IRT*—Infrared Thermography Testing

3.1.8 *LWIR*—Long-Wave Infrared

3.1.9 *MWIR*—Mid-Wave Infrared

3.1.10 *NDE*—Non-destructive Examination

3.1.11 *NETD*—Noise Equivalent Temperature Difference

3.1.12 *POD*—Probability of Detection

3.1.13 *ROI*—Region of Interest

3.1.14 *SDS*—Safety Data Sheets

3.1.15 *SPDS*—Safe Practice Data Sheets

3.1.16 *TBC*—Thermal Barrier Coating

4. Summary of Practice

4.1 *Personnel Qualification/Certification*—Vibroacoustic thermography is a new active thermography technique within the method of infrared and thermal testing (see Practices E168). As the technique develops, it is expected that several sub-techniques for energizing will be developed, refined, and documented. The current energizing variations require competence in areas of materials, mechanics, and heat transfer. Therefore, early users are expected to be well versed in these areas to ensure conservative applications. Because there is no existing single NDE method that matches all of the necessary skills, this first procedure requires the responsible control of a certified Level III in the method of infrared and thermal testing in accordance with ANSI/ASNT CP-189 or ASNT, SNTTC-1A. It is recommended that the Level III, under consultation with the responsible component engineer, develop the necessary supplemental training requirements for Level I and Level II personnel. Inspections shall be conducted by NDE Level I or Level II inspection personnel certified in accordance with ANSI/ASNT CP-189 or ASNT, SNTTC-1A. The NDE Level I should be qualified to properly perform specific calibrations, specific NDE, specific evaluations and record results according to written instructions. The NDE Level II should be qualified to set up and calibrate equipment, to interpret and evaluate results with respect to applicable codes, standards and specifications and to organize and report the results of NDE.

4.2 *Vibroacoustic Thermography Test System*—The system consists of an ultrasonic exciter, an infrared camera, and operating software to sequence the test and capture the result. The exciter is an ultrasonic piezoelectric transducer stack that may commonly be used for ultrasonic welding (plastics industry) or vibrations testing. Depending on the specific method of energization, a booster (amplifier) or a horn may also be used to augment, phase, couple, or focus the ultrasonic energy. Energization occurs for the first 0 - 8 seconds of test again depending on the energization method. During this time, the IR camera is triggered to capture resulting active heating of the component defects. The images are labeled and stored for slow motion play back of the simple vibroacoustic thermography movie, or for further analysis.

4.2.1 *Ultrasonic System*—Includes power supply and component fixture. Examples of these systems include a piezoeletric shaker, or ultrasonic welder system. Specific power ratings (watts) and frequency (kHz) for the power supply and the converter are essential to the vibroacoustic thermography inspection process and shall not be changed or modified without contacting system manufacturer. Typical power ratings for a piezoeletric shaker system range from 800W - 4000W with typical frequencies ranging from 14 000 Hz - 100 000 Hz. For ultrasonic welder systems, booster gain ratio, horn shape and horn material also are essential to the vibroacoustic thermography inspection process and shall not be changed or modified without contacting system manufacturer.

4.2.2 *Infrared Thermal Camera*—Thermal camera must have the sensitivity to achieve the required defect Probability of Detection (POD) (**7**, **8**, **9**). Cooled MWIR (InSb) thermal cameras usually provide the best sensitivity (around 20 mK or better), whereas LWIR microbolometer are generally less sensitive but may be adequate in many applications. Frame rates ≥30 Hz are generally sufficient for vibroacoustic thermography measurements. Any resolution is adequate so long as the camera is close enough to the specimen to resolve defect indications as in Practice E2585, subsection 6.1. This can be determined prior to test by use of a setup specimen having a defect in it of similar thermal signal to that of the defects of interest in the inspected parts. (See Practice E1252.)

4.2.3 *Minimum Software Requirements*—The software should provide a method for triggering the excitation of the part and recording the part response. The software should also provide a method for reviewing and analyzing the results.

4.3 *System Calibration:*

4.3.1 If detection of certain critical defects is an engineering requirement, then a rigorous evaluation of capability and reliability is required, including a proper POD study. Such an evaluation would consider process variability due to excitation,

[3] Available from American Society for Nondestructive Testing (ASNT), P.O. Box 28518, 1711 Arlingate Ln., Columbus, OH 43228-0518, http://www.asnt.org.

[4] Available from Air Transport Association (ATA), 1301 Pennsylvania Avenue, Suite 1100, Washington, DC 20004–1707.

[5] Available from IHS Markit, https://global.ihs.com/.