

## 100 word

The paper is an overview of work by the author in measuring and monitoring loads in bolts using an ultrasonic extensometer. A number of cases of bolted joints are covered. These include, a clamped joint with clearance fit between the bolt and hole, a clamped joint with the bolt in an interference fit with the hole, a flanged joint which allows the flange and bolt to bend; and a shear joint in a clevis and tang configuration. These applications were initially developed for measuring and monitoring preload in the NASA Space Shuttle Orbiter critical joints.

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## Simulating the X-ray image contrast to set-up techniques with desired flaw detectability

## Abstract

100 words

The paper builds on the previous work by the author in developing a model for estimating detectability of crack-like flaws in radiography. This paper focuses on the simulation runs using the model. Results of various simulation runs in calculating crack flaw size parameter and image contrast for varying input parameters such as crack depth, crack width, part thickness, X-ray angle, part-to-detector distance, part-to-source distance, source sizes, and detector sensitivity and resolution are given as 3D surfaces. These simulations demonstrate utility of the simulation and the flaw size parameter in setting up X-ray techniques that provide desired flaw detectability in radiography.

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The paper builds on the previous work by the author in developing a model for estimating detectability of crack-like flaws in radiography. The methodology is developed to help in implementation of NASA Special X-ray radiography qualification, but is generically applicable to radiography. While previous work provided the model, this paper focuses on the simulation runs using the model. Resolution of the detector used in these simulation runs uses the definition given in ASTM E 2737–10 standard practice for digital detector array performance evaluation and long-term stability. The paper describes a model for simulating the detector resolution. A computer calculator application, discussed here, also performs ASTM contrast and noise calculations. Results of various simulation runs in calculating crack flaw size parameter and image contrast for varying input parameters such as crack depth, crack width, part thickness, X-ray angle, part-to-detector distance, part-to-source distance, source sizes, and detector sensitivity and resolution are given as 3D surfaces. These results demonstrate effect of the input parameters on the flaw size parameter and the simulated image contrast of the crack. These simulations demonstrate utility of the simulation and the flaw size parameter in setting up X-ray techniques that provide desired flaw detectability in radiography. The method is applicable to film radiography, computed radiography, and digital radiography.

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The paper provides information on a new infrared (IR) image contrast data post-processing method that involves extracting normalized contrast versus time evolutions from the flash infrared thermography inspection video data. In this method, thermal measurement features such as peak contrast, peak contrast time, persistence time, and persistence energy are calculated from the contrast evolutions. In addition, simulation of the contrast evolution is achieved through calibration on measured contrast evolutions from many flat bottom holes in a test plate of the subject material. The measurement features are used to monitor growth of anomalies and to characterize the void-like anomalies.

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The paper provides information on a new infrared (IR) image contrast data post-processing method that involves extracting normalized contrast versus time evolutions from the flash infrared thermography inspection video data. Thermal measurement features such as peak contrast, peak contrast time, persistence time, and persistence energy are calculated from the contrast evolutions. In addition, simulation of the contrast evolution is achieved through calibration on measured contrast evolutions from many flat bottom holes in a test plate of the subject material. The measurement features are used to monitor growth of anomalies and to characterize the void-like anomalies. The method was developed to monitor and analyze void-like anomalies in reinforced carbon-carbon (RCC) materials used on the wing leading edge of the NASA Space Shuttle Orbiters, but the method is equally applicable to other materials. The thermal measurement features relate to the anomaly characteristics such as depth and size. The contrast calibration is used to provide an assessment of the anomaly depth and width which correspond to the depth and diameter of the equivalent flat bottom hole from the calibration data. An edge detection technique called the half-max is used to measure width and length of the anomaly. Results of the half-max width and the equivalent flat bottom hole (EFBH) diameter are compared with actual widths to evaluate utility of the IR contrast method. Results of IR contrast method on RCC hardware are provided. An example is provided to demonstrate use of the normalized contrast as the signal response in probability of detection analysis.

## Abstract

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The paper addresses some on-orbit NDE needs of NASA for International Space Station (ISS). The presentation gives NDE requirements for inspecting suspect damage due to micro-meteoroids and orbital debris (MMOD) impact on the pressure wall of the ISS. This inspection is meant to be conducted from inside of the ISS module. Results of the ultrasonic and eddy current demonstration scans on test samples are provided. The ultrasonic technique uses shear wave scans to interrogate the localized damage area from the surrounding undamaged area.

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The paper addresses some on-orbit NDE needs of NASA for International Space Station (ISS). The presentation gives NDE requirements for inspecting suspect damage due to micro-meteoroids and orbital debris (MMOD) impact on the pressure wall of the ISS. This inspection is meant to be conducted from inside of the ISS module. The metallic wall of the module has a fixed wall thickness but also has integral orthogrid ribs for reinforcement. Typically, a single MMOD hit causes localized damage in a small area causing loss of material similar to pitting corrosion but cracks may be present too. The impact may cause bulging of the wall. Results of the ultrasonic and eddy current demonstration scans on test samples are provided. The ultrasonic technique uses shear wave scans to interrogate the localized damage area from the surrounding undamaged area. The scanning protocol results in multiple scans, each with multiple "vee" paths. A superimposition and mosaic of the three dimensional ultrasonic data from individual scans is desired to create C-scan images of the damage. This is a new data reduction process which is not currently implemented in the state-of-art ultrasonic instruments. Results of ultrasonic scans on the simulated MMOD damage test plates are provided. The individual C- scans are superimposed manually creating mosaic of the inspection. The resulting image is compared with visibly detected damage boundaries, X-ray images, and localized ultrasonic and eddy current scans for locating crack tips to assess effectiveness of the ultrasonic scanning. The paper also discusses developments needed in improving ergonomics of the ultrasonic testing for on-orbit applications.