ABSTRACT

[0001] Nondestructive evaluation (NDE) testing is used to determine material properties, microstructural information, and defect location. Common NDE testing types include radiography, acoustic emission, ultrasound, resonant acoustic spectroscopy, x-ray computed tomography, and thermal imaging. The feasibility of using ultrasound NDE for various ceramic articles was evaluated.

DESCRIPTION OF THE STUDY

1. Experimental Setup and Objectives:

[0002] Silicon carbide (SiC) parts from Saint-Gobain Corporation were tested at Rutgers University Center for Ceramic Research (CCR). A pulse-echo, immersion-based, ultrasonic NDE scanning system was used and is generally shown in the schematic illustration of FIG. 1. The pulse-echo configuration used a single transducer that emitted and received the ultrasonic waves. A digital oscilloscope was connected and used to show peaks that corresponded to reflections off an interface in the ceramic material. The immersion-based testing used distilled or deionized water as the immersion medium. Three transducers were used in this study: (1) an Ultran 5MHz transducer, (2) Olympus 20MHz transducer, and an Olympus Omniscan MX handheld ultrasound phased array module having a transducer comprised of a linear array of 16 piezoelectric sensors operating at approximately 10MHz. The frequencies refer to the central frequency of the bandwidth emitted by the transducer without attenuation.

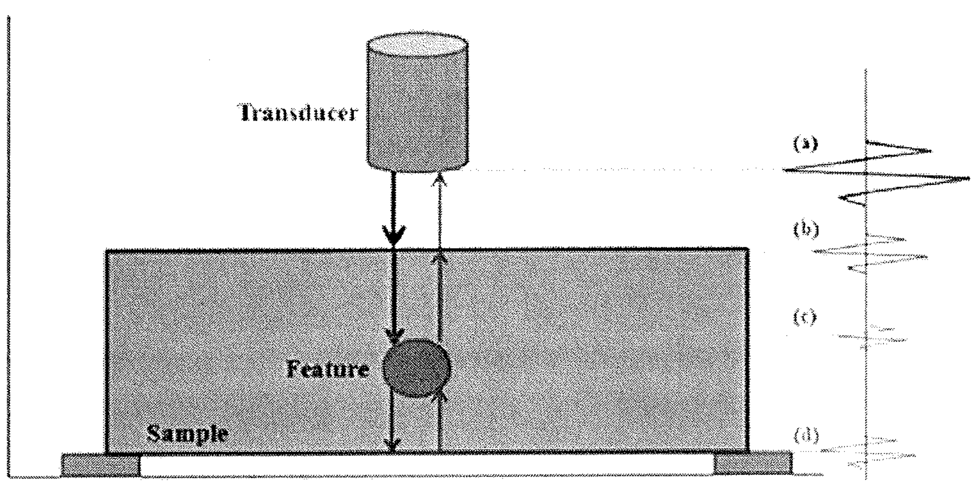

FIG. 1: Schematic illustration of the pulse-echo immersion-based, ultrasonic NDE scanning system.

Elise K. Johnson
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[0003] Referring again to FIG. 1, the signal on the right is an exemplary oscilloscope image, which represents the type of information generated by the experimental setup. Information generated by the oscilloscope is referred to as an A-scan. The A-scan can give the time and amplitude of each reflection generated at a single point in the sample. Compilation of the A-scan point measurements at each point in the material can be used to generate a C-scan property map. The time at which reflections occur can be transformed to give the sonic velocity and elastic properties of a material. Time-based measurements are strongly related to the density of the material. The amplitude of each reflection can be transformed to give the attenuation coefficient of a material. Attenuation coefficient measurements have been shown to be related to the material microstructure and its uniformity.

[0004] Two types of samples were used. Sample 1A, illustrated in FIG. 2, included a 1-inch hexagonal tile approximately 4 mm thick and having a density of approximately 3.2g/cm^3. Two other samples tiles were evaluated based on their forming process. While Sample 1A was formed with no applied load during sinter-bonding, Sample 1B was sinter-bonded under an applied load of 0.63kg, and Sample 1C was formed via sinter-bonding under an applied load of 4.30kg.

[0005] Sample 2, illustrated in FIG. 3, included a silicon carbide tube having an increase in the diameter at the collared region.

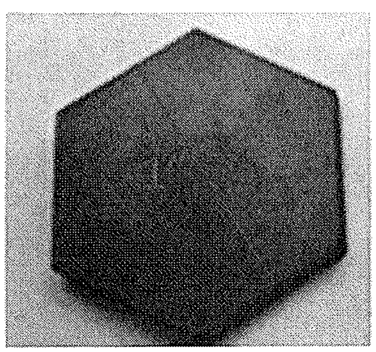

FIG. 2: Sample 1A

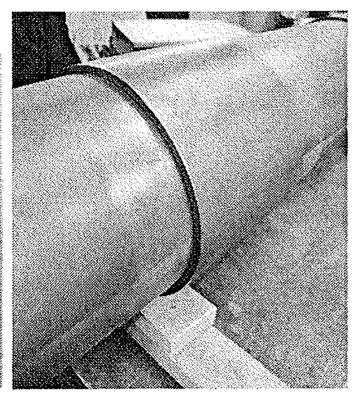

FIG. 3: Sample 2

[0006] FIG. 4 provides an exemplary oscilloscope output using the experimental set up for two SiC plates stacked on top of each other without having been bonded. FIG. 4 demonstrates three distinct peaks "a", "b" and "c" corresponding to the surfaces that generated the reflections. Due to the similar thickness and sonic velocities through each bonded SiC tile, the reflections subsequent to the bond layer are convolutions of multiple generations of peaks produced from all interfaces (i.e., top surface, joint, and bottom surface). The purpose of the testing was to determine whether an applied load during sinter-bonding would reduce the peak corresponding to the joint. The ability to detect boundaries (e.g., flaws, pores, boundaries between two different phases, etc.) is dependent on the ultrasonic wavelength compared to the feature to be detected and the acoustic impedance mismatch between two interfaces. A large acoustic impedance mismatch will create a large reflection seen on the oscilloscope. Thus, the relative amplitude of the peak corresponding to the joint can provide a measure of the quality of the sinter-bonding at that joint.

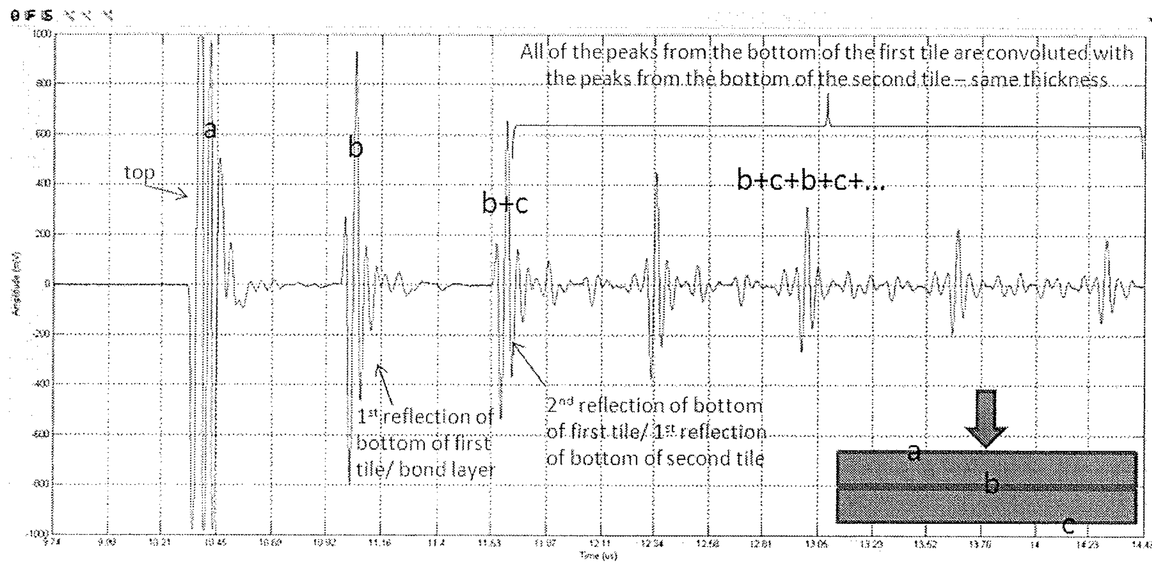

FIG. 4: Representative oscilloscope A-scan output for sample illustrated

2. Results:

[0007] FIGs. 5, 6, and 7 are A-scan measurements taken from Samples 1A, 1B, and 1C respectively. Samples 1A, 1B, and 1C were measured using the Olympus 20MHz. As illustrated, the testing confirms that greater applied load reduces the second peak associated with the sinter-bond joint. Thus FIGs. 5-7 demonstrate that increased applied load during sinter-bonding creates a more uniform microstructure and stronger bond at the sinter-bonded joint. This is further confirmed by the C-scan measurements created from the A-scan data.

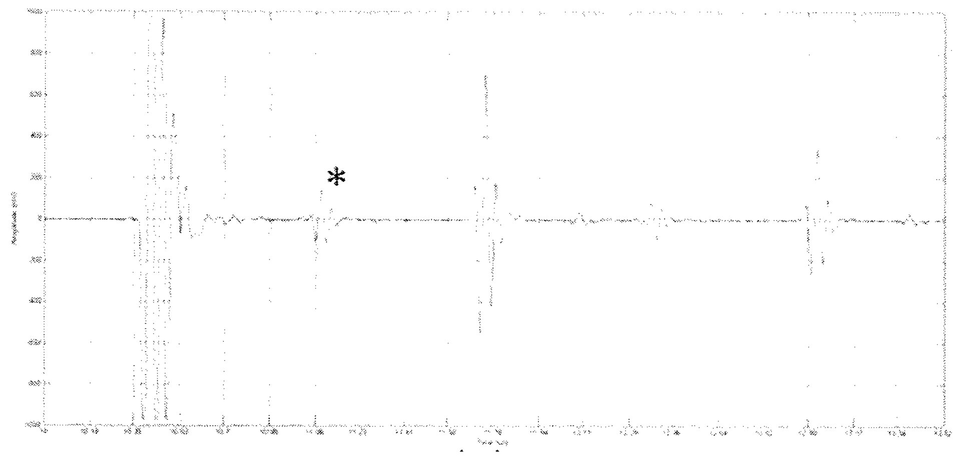

FIG. 5: A-scan of Sample 1A with * at second peak indicating relative sinter-bond uniformity.

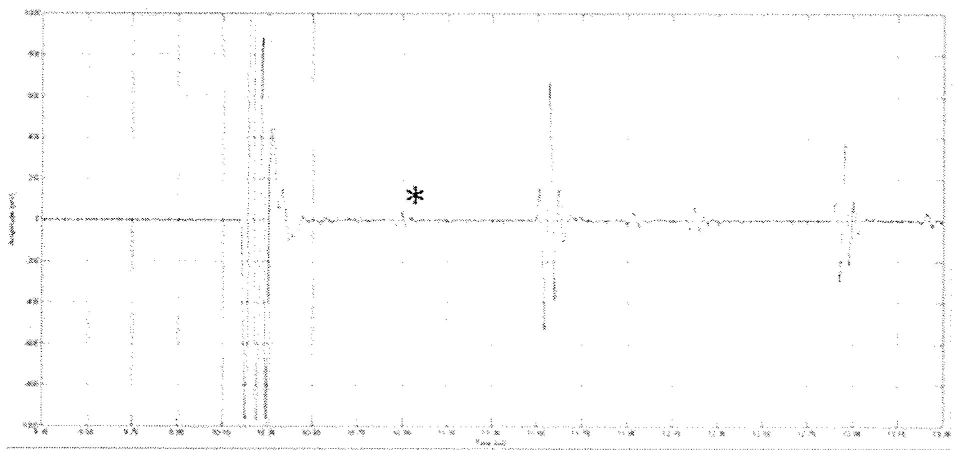

FIG. 6: A-scan of Sample 1B with * at second peak indicating relative sinter-bond uniformity.

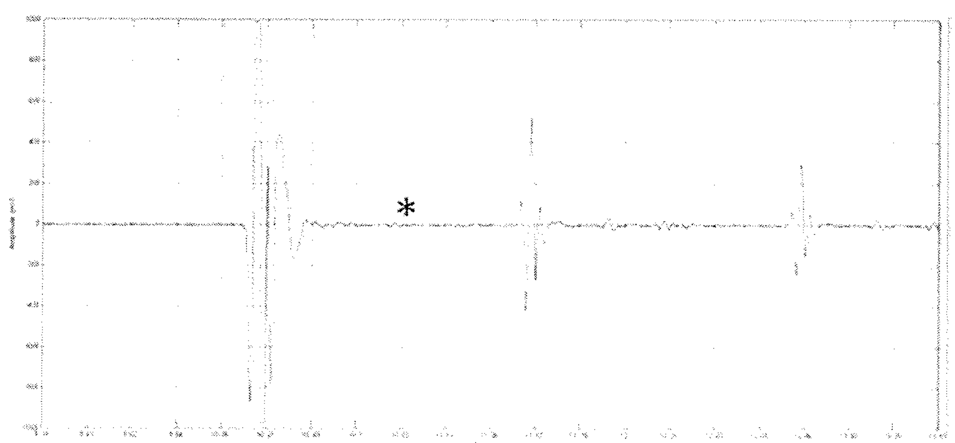

FIG. 7: A-scan of Sample 1C with * at second peak indicating relative sinter-bond uniformity.

[0008] FIGs. 8, 9 and 10 are C-scan images created from the A-scan measurements for Samples 1A, 1B, and 1C. As illustrated, FIG. 8 demonstrates a greater area of red correlating to a region of non-uniformity, wherein as Samples 1B and 1C in FIGs. 9 and 10 respectively, have notably less regions of red. Similar results were shown to be achieved using the Ultran 5MHz transducer.

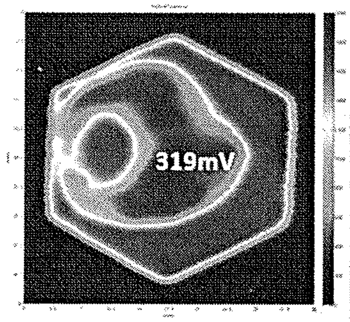

FIG. 8: C-scan of Sample 1A.

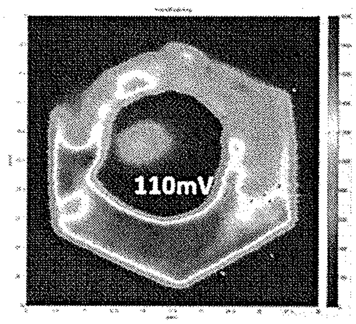

FIG. 9: C-scan of Sample 1B.

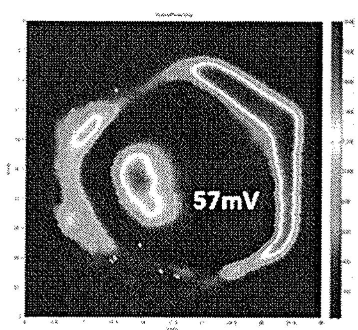

FIG. 10: C-scan of Sample 1C.

[0009] Sample 2 was evaluated by the handheld Omniscan transducer, but the results were not comparable, because the peak amplitude was a function of the pressure applied on the transducer. However, it is suggested that if the pressure applied to the transducer could be regulated and controlled, the system may be suitable for evaluating the quality of the sinter-bonded interface. The recommendation for testing such bonded tubes in manufacturing would be to purchase an ultrasonic flaw detector/ probe which is capable of saving and exporting oscilloscope data. A-scans can be saved at multiple points about the collar, from which a map could be constructed.

3. Conclusions:

[0010] Ultrasound NDE for determining bond integrity in sinter-bonded silicon carbide is effective and may be used to evaluate the relative quality of the sinter-bond joint. Processing constraints may urge the use of one type of system (e.g., handheld vs fixed) compared to another.