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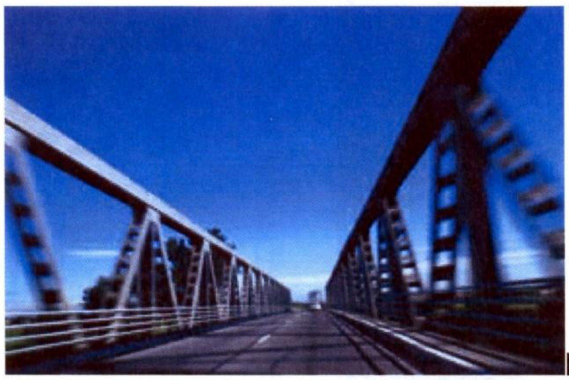

Mechanical Testing Task Group Works on Automated Ball Indentation Tests

Oil and gas pipelines, nuclear pressure vessels, and highway bridges are three examples of structures that must be tested for structural integrity and fitness for service, among other requirements, with results that must be submitted to the appropriate regulating body. A draft standard being developed by Task Group E28.06.14 on Automated Ball Indentation Test Methods, a part of ASTM Committee E28 on Mechanical Testing, includes nondestructive field procedures that would enable owners and operators to gather information about key mechanical properties of such structures for the U.S. Nuclear Regulatory Commission or the Department of Transportation Office of Pipeline Safety, or other agency.

The document, "Draft Standard Test Methods for Automated Ball Indentation Testing of Metallic Samples and Structures to Determine Stress-Strain Curves and Ductility at Various Test Temperatures," provides a field alternative to other procedures that require cutting tension and fracture toughness specimens and potentially interrupting service.

According to E28.06.14 task group chair Fahmy Haggag, president and chief engineer of Advanced Technology Corp. in Oak Ridge, Tenn., "There is a need for the unique capabilities of in-situ testing and small volume testing of small and irregular welds and their heat-affected -zones, and when small samples are the only option for failure analysis or new alloy development." This standard, which is based on methods that have been used for more than a decade, should address this need.

The standard, which has already been through an interlaboratory study and revised accordingly, is being developed by engineers, metallurgists, product manufacturers, test labs, academia, and research and development staff from the Department of Energy, Defense, and Transportation.

For technical information, contact Fahmy Haggag, Advanced Technology Corp., Oak Ridge, Tenn. (phone: 865/ 483-5756). Committee E28 meets May 17-19 during the May Committee Week in Salt Lake City, Utah. For membership or meeting details, contact Dan Schultz, manager, Technical Committee Operations, ASTM International (phone: 610/832-9716). //

Use of Automated Ball Indentation Testing to Measure Flow Properties and Estimate Fracture Toughness in Metallic Materials

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Source: STP1092-EB

Abstract

A field indentation microprobe (FIM) apparatus was developed (and patented) to evaluate, nondestructively *in situ*, the integrity of metallic structures. This study investigated the applicability of using a new automated ball indentation (ABI) test, which is a major part of the FIM, to measure the flow properties of metallic materials including those exhibiting Lüders or inhomogeneous strains (carbon steels, titanium alloys, aluminum alloys, etc.) and to estimate their fracture toughness. The ABI test is based on multiple indentations (at the same penetration location) of a polished metallic surface by a spherical indenter. Automation of the test, where a computer and test controller were used in innovative ways to control the test as well as to analyze test data, made it simple, rapid, accurate, economical, and reproducible. Results of ABI tests on different base metals, welds, and irradiated materials are presented and discussed in this paper. Excellent agreement was obtained between ABI-derived data and those from standard ASTM uniaxial tension and fracture toughness tests.

Keywords:
automated ball indentation, spherical indenter, cyclic loading, partial unloading, yield strength, flow properties, fracture toughness, in situ, testing, field apparatus, automation, nondestructive test, mechanical test, welds, heat affected zone, irradiated steels, fatigue testing, fracture testing

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In-Situ Measurements of Mechanical Properties Using Novel Automated Ball Indentation System

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Abstract

Determination of the integrity of any metallic structure is required either to ensure that failure will not occur

Effects Of Irradiation Temperature on Embrittlement of Nuclear Pressure Vessel Steels

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Abstract

The effects of neutron irradiation on the steel reactor vessel for the modular high-temperature gas-cooled reactor (MHTGR) are being investigated, primarily because the operating temperatures are low [121 to 288°C (250–550°F)] compared to those for commercial light-water reactors (LWRs) [~288°C (550°F)]. The need for design data on the reference temperature (RT^{NDT}) shift necessitated the irradiation at different temperatures of A 533 grade B class 1 plates, A 508 class 3 forging, and welds used for the vessel shell, vessel closure head, and vessel flange. This paper presents regular- and mini-tensile, Automated Ball Indentation (ABI), and Charpy V-notch (CVN) impact test results from five irradiation capsules of this program. The first four capsules were irradiated in the University of Buffalo Reactor (UBR) to an *effective* fast fluence of 1.1×10^{18} neutrons/cm^2 [0.7×10^{18} neutrons/cm^2 (>1 MeV)] at temperatures of 288, 204, 163, and 121°C (550, 400, 325, and 250°F), respectively. The fifth capsule (designated ORNL-7) was irradiated in the Ford Nuclear Reactor (FNR) of the University of Michigan at 60°C (140°F) to an effective fast fluence of 1.3×10^{18} neutrons/cm^2 [0.8×10^{18} neutrons/cm^2 (>1 MeV)]. The yield and ultimate strengths of both A 533 grade B class 1 plate materials of the MHTGR program increased with decreasing irradiation temperature. Similarly, the 41-J CVN transition temperature shift increased with decreasing irradiation temperature (in agreement with the increase in yield strength). The mini-tensile and Automated Ball Indentation (ABI) test results (yield strength and flow properties) were in good agreement with those from standard tensile specimens. The mini-tensile and ABI test results were also used in a model which utilizes the changes in yield strength to estimate the CVN ductile-to-brittle transition temperature shift due to irradiation. The model predictions were compared with CVN test results obtained here and in earlier work.

Keywords:
high-temperature gas-cooled reactor, Charpy impact specimens, transition temperature shift, nuclear pressure vessel, steel, welds, forging, irradiation temperature, tensile, automated ball indentation, fluence, embrittlement, drop-weight

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Comparison of Different Experimental and Analytical Measures of the Thermal Annealing Response of Neutron-Irradiated RPV Steels

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Source: STP1325-EB

Abstract

The thermal annealing response of several materials as indicated by Charpy transition temperature (TT) and upper-shelf energy (USE), crack initiation toughness, K^{Jc}, predictive models, and automated-ball indentation (ABI) testing are compared. The materials investigated are representative reactor pressure vessel (RPV) steels (several welds and a plate) that were irradiated for other tasks of the Heavy-Section Steel Irradiation (HSSI) Program and are relatively well characterized in the unirradiated and irradiated conditions. They have been annealed at two temperatures, 343 and 454°C (650 and 850°F) for varying lengths of time. The correlation of the Charpy response and the fracture toughness, ABI, and the response predicted by the annealing model of Eason et al. for these conditions and materials appears to be reasonable. The USE after annealing at the temperature of 454°C appears to recover at a faster rate than the TT, and even “over-recovers” (i.e., the recovered USE exceeds that of the unirradiated material).

Keywords:
annealing, fracture toughness, transition temperature, upper-shelf energy, reactor pressure vessel steels

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Committee/Subcommittee: E10.07
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Use of Portable/*in situ* Stress-Strain Microprobe System to Measure Stress-Strain Behavior and Damage in Metallic Materials and Structures

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Abstract

A novel portable/*in situ* Stress-Strain Microprobe (SSM) system was used to measure true-stress/true-plastic-strain (σ^t-ϵ^p) behavior of several metallic materials, welds, and their heat-affected-zones (HAZs) in various metallurgical and damage conditions. The SSM system utilized an automated ball indentation (ABI) technique to measure elastic modulus, yield strength, σ^t-ϵ^p curve, strength coefficient, strain-hardening-exponent (uniform ductility), and to estimate fracture toughness (from the ABI-measured flow properties) in carbon steels, stainless steels, nickel alloys, aluminum alloys, titanium alloys, zirconium alloys, etc. Numerous ABI tests were also conducted on several nuclear pressure vessel steels (NPVSs) in the unirradiated, neutron irradiated, and post-irradiated thermally-annealed conditions. For all these test materials and conditions, the ABI-derived results were in good agreement with those from conventional standard test methods. Furthermore, the nondestructive ABI test results rigorously indicated the various levels of neutron-embrittlement damage and the percentage of ductility recovery following thermal annealing of the NPVS specimens. *In situ*/nondestructive structural applications of the SSM system and its ABI technique have been demonstrated by testing a circumferentially welded stainless steel pipe and a full-thickness section of a nuclear pressure vessel (using 90° V-blocks and magnetic mounts for temporary attachment of the SSM testing head to the pipe and the steel section, respectively). All SSM localized tests were computer-controlled and conducted in less than 2 minutes per ABI test; depending on the desired strain rate. Example test results on metallic structural components and samples are presented in this paper.

Keywords:
nondestructive, in situ, structural integrity, ball indentation, partial unloading, welds, heat affected zone, yield strength, flow properties, metals

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