7th International Small Scale Testing Techniques Conference

SSTT 2025

September 16-18, 2025

TU Bergakademie, Freiberg, Germany

Book of Abstracts

7th International Small Sample Testing Techniques Conference

SSTT 2025

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September 16-18, 2025, TU Bergakademie Freiberg, Germany

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Fracture Toughness Evaluation from Small Punch Tests on Notched Specimens Optimized via FEM

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Abstract:

Fracture toughness provides the resistance to fracture of a given material in the presence of a crack-like defect and is essential for assessing the structural integrity of engineering components. The J-R curve is a useful tool for evaluating materials with pre-existing flaws. According to ASTM E1820, the J_{IC} value indicates the toughness at the onset of crack extension from a preexisting crack. However, standard tests require large specimens and significant material volume. The Small Punch Test (SPT), which uses disc-shaped specimens only 0.5 mm thick, offers a promising alternative with minimal material requirements. In this work, finite element simulation was used to optimize the geometry of notched specimens for fracture toughness determination. Subsequently, SPTs were performed on the optimized notched specimens using the multiple specimen method from the standard to obtain the J-R curve. Two high-strength low-alloy (HSLA) steels were tested. The $J_{0.2}$ values obtained from the SPT were found to be in close agreement with those from conventional fracture toughness tests, demonstrating the potential of the SPT method as a viable alternative for evaluating fracture properties when limited material is available.

Application of the Small Punch Test to support the development of Hydrogen-compatible steels

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Abstract:

Hydrogen is a promising alternative as an energy vector in the context of decarbonization. However, its use poses significant technical challenges, including the embrittlement of steels, which demands a rigorous evaluation of the materials used in storage and transport equipment. The Small Punch Test (SPT) is an effective technique for studying hydrogen-induced mechanical degradation, particularly through in-situ electrochemical charging. Nevertheless, in real service conditions, components are often exposed to high-pressure gaseous hydrogen, making it necessary to perform tests under such conditions. This work presents SPT experiments conducted on various steels exposed to high-pressure hydrogen gas, analyzing the influence of factors such as the materials microstructure and testing conditions.

The materials exhibiting higher performance in hydrogen environments have been selected for further analysis, with the aim of identifying their operational limits and proposing possible improvements. This methodology seeks to support the development of steels with enhanced resistance to hydrogen embrittlement and to define more robust selection criteria for critical applications where only small amounts of material are available.

Assessment of Material Degradation in a Boiler Component Deformed Under Service Conditions Based on Small Punch Test and Acoustic Emission results

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Abstract:

Methods for evaluating material degradation play a crucial role in predicting the service life of components operating under demanding conditions, such as elevated temperature and high pressure. An essential aspect of effective diagnostics is the ability to apply non-destructive or minimally invasive testing techniques, especially when examining components still in service or available in limited quantity. The Small Punch Test (SPT) performed on miniature specimens enables the assessment of, among others, mechanical properties of material of in-service equipment, and acoustic emission method (AE) is one of NDT method which is used for test of large structure in e.g. energetic plants.

This paper will presents an evaluation of material degradation in different areas of component that experienced permanent deformation during operation. The investigation of material was carried out using the SPT method with acquisition of acoustic emission signals during loading. The use of AE method aimed to broaden the scope of material diagnostics by recording signals associated with the damage development process.

The laboratory research was further complemented by fracture surface analysis and microstructural observations conducted using scanning electron microscopy (SEM).

Small punch testing of the newly developed ODS nanocomposite

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Abstract:

Small specimen testing of two batches of newly developed Fe-10Al-4Cr-4Y_2O_3 nanocomposite by SPT and additionally also by mini-tensile specimens at a wide range of temperatures was performed. The study shows that the EN 10371 standard formulas for the determination of the ultimate tensile strength and yield strength can be applied well at high temperatures over 500°C when the nanocomposite demonstrates ductile behavior, but not precisely at elevated temperatures and room temperature (RT) when the nanocomposite becomes less ductile or brittle. The ductile to brittle transition temperature was estimated using SPT between 170-275°C, depending on the batch. The observation of the SPT fracture surfaces shows typical facets for brittle fracture at RT, with mixed fracture at 200°C, and fully ductile fracture at 450°C, with again decreasing ductility and signs of grain decohesion at 800°C.

Multiaxial Creep Experiments using Miniature Cruciform Specimens

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Abstract:

Creep experimental investigations are essential for the safety design and remaining life evaluation of structural materials for high-temperature equipment, such as turbine blades and boiler piping for power generation. A multiaxial creep experimental investigation is required because actual structures are subjected to multiaxial stresses. Furthermore, because experimental investigations using samples taken from actual structures have many advantages, this study conducted multiaxial creep tests using a miniature cruciform specimen of a commonly used austenitic stainless steel. Specifically, the optimal shape and dimensions of 50 mm × 50 mm and 20 mm × 20 mm cruciform specimens were obtained, and an in-situ observation technique in an electric furnace was developed. The creep rupture life of Type 304 stainless steel was significantly reduced at 650°C under non-equibiaxial stress conditions that simulated the stress state of a thin-walled pipe subjected to internal pressure. The maximum principal stress parameter is an effective parameter for creep rupture life evaluation.

Verification of Creep Constants in Norton's Law for High Chromium Steel by Indentation Creep Testing

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Abstract:

In this study, the creep property obtained by using an indentation creep testing was compared with that obtained from the conventional uniaxial tensile creep testing for high Cr steel (equivalent to modified 9Cr-1Mo steel, Grade 91), to evaluate their compatibility. Indentation creep tests were conducted using a small cylindrical specimen of the steel (10 mm in diameter and 10 mm in length), and the creep constants in Norton's law were obtained. These constants were compared with those obtained from tensile creep tests to assess the applicability of the proposed conversion equation between the two testing.

Creep Properties of High Temperature Materials in Miniature Creep Testing

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Abstract:

Miniature creep tests are performed on several types of heat-resistant metal materials, and their creep characteristics are shown. The test apparatus used is a miniature creep testing machine with a uniaxial tensile load using specimens with a diameter of 1~2 mm and a gauge length of 5 mm, a maximum test load of 1 kN and a maximum test temperature of 1073 K. In the testing machine, argon (Ar) gas is flown around the specimen to reduce oxidation during creep testing and the elongation of the specimen is measured by two LVDTs. In this study, the creep properties obtained by the miniature creep test are shown, and their compatibility is mentioned as well as their comparison with those of the conventional creep testing machine using standard sized specimens. In addition, the effect of oxidation on the creep properties of miniature tests is also discussed.

Progress of Small Punch Test and Standardization in China

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Abstract:

The small punch test (SPT) has advantages in obtaining mechanical properties of irradiated reactor material, due to the limited spaced of irradiation channel, the reduction of material consumption and lowering experimental costs. SPT is considered non-destructive, has a minimal impact on structural integrity, and requires much less material than conventional testing methods. This paper summarizes the progress of SPT in creep, tensile and fracture toughness properties and shows the phased achievements of d SPT technology research and development at home. Moreover, the process of standardization of SPT in China is also introduced, which improved the scientificity and reliability of material performance evaluation. Empirical correlation approach and formulae are recommended in the strength and fracture toughness in the standards. Combined structure with a penetrated slot and a U-groove was proposed on small punch sample to obtain fracture toughness. It can be expected that its application to assess the mechanical behavior for in-service equipment will increase.

Comparison of small-scale mechanical test techniques for the examination of irradiated material

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Abstract:

Small-scale testing is of great interest to the nuclear industry, given the obstacles involved with testing irradiated material and/or materials in development for the next generation of reactors. There is often a limited amount of material available, as well as a requirement to minimise operator dose. However, correlating mechanical data obtained from sub-sized specimens to those from conventional uniaxial tests is crucial if they are to be used directly in engineering design and/or evaluation. In this work two small-scale mechanical test techniques have been investigated; shear punch testing and micro-tensile testing. Both were carried out on three reduced activation ferritic martensitic (RAFM) steels, at room temperature, and correlations were generated between their shear and tensile properties. Earlier work by the authors investigated the suitability of using small scale testing to estimate tensile properties of precipitation-hardened martensitic steel from shear punch testing; when plotted alongside literature data from a range of different strength materials, single correlations linking shear and tensile properties were produced. The applicability of using these single correlations to evaluate the uniaxial tensile properties of RAFM steels has been investigated.

Fatigue Strength and Crack Propagation Assessment by Small Bulge Fatigue Test

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Abstract:

We have recently developed a novel hydraulic bulging fatigue test, which is termed the small bulge fatigue (SBF) test. In this test, a cyclic oil pressure is alternatively applied to both surfaces of a miniaturized disk-type specimen (8 mm in diameter) with flat and concave surfaces. The SBF test results (S-N curve) of Type 316 steel were in good agreement with those of conventional fatigue tests by defining fatigue life as the number of cycles to the sudden drop in oil pressure due to fracture. The experimental results showed that the SBF life of the pre-damaged specimen, in which a number of small fatigue cracks had been already generated before the SBF test, was only one tenth as long as that of the undamaged specimen. It seemed that Miner's rule (linear cumulative damage rule) held true in this case. It was also found that the experimentally measured SBF crack propagation rate, da/dN, was relatively well correlated with the maximum stress intensity factor, K_{max} obtained from the finite element analysis.

Experimental Approach to Material Model Calibration Using Miniature Specimens under Complex Stress States

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Abstract:

This work presents a methodology for calibrating material models in FEM software such as Abaqus and LS-Dyna using miniature test specimens. To enable robust calibration, various specimen geometries and test types are employed to capture a wide range of stress states, expressed in terms of stress triaxiality and the Lode parameter. These include, for example, uniaxial and plane strain conditions, shear, notched miniature tensile tests, small punch tests (biaxial), and bending tests. In most cases, the testing methodology allows for non-contact strain measurement using camera-based systems, with subsequent evaluation via Digital Image Correlation (DIC), enhancing the reliability of fracture and damage characterization. Furthermore, the study proposes a solution for the calibration of kinematic hardening behavior and introduces modifications to miniature testing procedures suitable for elevated temperatures and higher strain rates. This comprehensive approach is particularly applicable to cases where only limited amounts of material are available and advanced material card generation is required for complex FEM simulations.

Keywords:

miniature specimens; material model calibration; FEM; stress triaxiality; Lode parameter; digital image correlation; fracture locus; kinematic hardening; high-temperature testing; strain rate sensitivity

Influence of Chromium Content on the Mechanical Properties of a High-Entropy Alloy

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Abstract:

High-entropy alloys (HEAs) represent a relatively new class of materials distinguished by their unique properties. Unlike conventional alloys, which are typically based on one primary element with minor additions of others, HEAs consist of five or more principal elements in near-equiatomic proportions. This multi-principal element design introduces significant compositional complexity, which plays a key role in shaping their exceptional characteristics.

This study examines how varying chromium content influences the microstructure and mechanical behavior of $Cr_xCoFeMnNi$ HEAs, as derived from shear punch testing. Results revealed a strong correlation between increased Cr content and enhanced mechanical strength. Unlike traditional alloys, where grain size and secondary dendrite arm spacing are dominant factors, these parameters had limited effect in this context. Instead, properties were primarily influenced by chemical composition, lattice distortion, and elemental segregation. The composition containing the highest Cr content (30at.%) exhibited the highest hardness and shear strength, attributed to pronounced lattice distortion, Cr-promoted dendritic structures, and the formation of the sigma phase.

These findings highlight the pivotal role of chromium in tailoring the mechanical performance of FCC-based HEAs, emphasising the importance of precise compositional control to achieve a balance between strength and ductility for advanced applications.

Research on Platform Impact Energy Method of Small Sample Associated with Standard Sample Based on Machine Learning

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Abstract:

In the study of toughness of neutron irradiation-resistant structural materials, due to the constraints of small irradiation space and high irradiation cost, standard-sized Charpy impact specimens cannot be used anymore. Therefore, it is of great significance to study the correlation method between the upper platform impact energy of standard specimens and small specimens. In this paper, the Johnson-cook constitutive model and its fracture criterion were used to simulate the Charpy impact test, and a new calibration method for strain hardening parameters was proposed. Then, through data collection, the model parameters of 207 groups of materials and their corresponding KLST small specimens and standard specimens Charpy impact energy data sets were obtained. Finally, using the established data set, the impact energy of the KLST small specimen and the standard specimen on the platform was correlated through machine learning. The error between the correlation result and the actual value is about 8.39%.

The Ball-on-Three-Balls test and its variants: challenges and new developments in biaxial strength testing of ceramics

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Abstract:

For over twenty years, the Ball-on-Three-Balls (B3B) test has been successfully used for measuring the biaxial strength of ceramics. It is characterized by a robustness against inaccuracies in the specimen geometry, a particularly simple test execution and the possibility of miniaturization. The relationship between the applied load and the specimen's maximum tensile stress is based on a large number of finite-element analyses (FEA), enabling a wide variety of specimen geometries and materials to be evaluated. Experimental results show that it measures strengths comparable to those of other test methods within the framework of Weibull theory. The test can also be used to test square plates. An accurate determination of the maximum tensile stress is achieved through representing the plates as equivalent discs.

However, new challenges arise when testing particularly strong and/or thin specimens. To accurately assess the strength of these specimens, extensions and variants of the test were developed. These allow for a reduction of the specimen's edge stress and account for the impact of increased specimen deflection on the maximum tensile stress into account. For these cases, FEA-results were verified through experimental work. The relevance of these findings is demonstrated using current testing requirements.

Advanced Small-Scale Testing Methods for Enhancing the Safety of Power Plant Components

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Abstract:

Ensuring the safety and long-term reliability of power plant components is essential for the efficient operation of thermal and nuclear power facilities. Modern small-scale testing methods—such as the Small Punch Test (SPT), Instrumented Indentation Test (IIT), and Scoop Sampling—enable the evaluation of mechanical properties with minimal material removal. These techniques are particularly valuable for assessing material degradation under service conditions where conventional sampling is impractical or invasive.

This paper presents the principles and practical applications of these methods in evaluating material aging and damage. A comparative analysis highlights their advantages over traditional mechanical testing approaches. Practical case studies from power plant environments will be presented to illustrate the real-world applicability and benefits of these innovative techniques. Their implementation supports improved operational safety, optimized maintenance strategies, and extended service life of critical structural components in power plants.

Hydrogen embrittlement of structural steels by SPT: Comparison between hydrogen gas and electrochemical environment

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Abstract:

The use of hydrogen as a clean energy source requires the development of safe storage and transport infrastructures. However, hydrogen embrittlement in steels and their welded joints represent a major challenge. In this context, the miniature punch test (SPT) has become a valuable tool for assesing the mechanical behaviour of these materials in the presence of hydrogen, particularly when small quantity of material is available, as is often the case with welded zones.

This study uses the SPT to analyse the mechanical behaviour of various structural steels and welded joint zones operating in a hydrogen environment. To this end two sources of hydrogen were employed: pressurised gas and electrochemical medium. The aim was to determine the most suitable electrochemical parameters for a given hydrogen pressure.

The results obtained allow us to evaluate the feasibility of using the SPT test to study hydrogen embrittlement in a wide variety of steels with different microstructures and properties. The impact of various methodological parameters, such as current density, pressure, or test speed on the response of the material to hydrogen is also analysed. The identification of equivalent test conditions between different hydrogen charging methods is essential in order to select the most appropriate experimental methodology.

Characterisation of Transition Welds Manufactured using Laser Powder Bed Fusion (LPBF)

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Abstract:

Within several industrial sectors, there is a demand for dissimilar metals that are welded together, sometimes within a single component, as different regions require tailored material properties. This research explores the potential use of Laser Powder Bed Fusion (LPBF) for joining different alloys, aiming to expand the application of additive manufacturing in multi-material components. This study focuses on the feasibility of building one alloy directly onto another using LPBF across two variations of dissimilar metal combinations. The first variation examines the same alloy grade manufactured using a different technique. The second investigates depositing a LPBF alloy onto a dissimilar alloy grade through a different manufacturing process. This project will look to identify the optimal material combinations to enhance design flexibility while reducing the need of stress raising joints, complex welding, or brazing. Characterisation will include mechanical testing such as hardness mapping, tensile testing and three-point fatigue bend analysis. These assessments are complemented by microstructural investigations and chemistry analysis of the components before and after testing, with comparisons to traditionally welded samples.

A modular UEL framework for hydrogen-enhanced, ductile damage modeling

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Abstract:

The shift from fossil fuels to sustainable energy sources across different sectors increases the risk of hydrogen embrittlement in ductile materials, such as steel, used for hydrogen storage and transportation. **Hydrogen easily diffuses into the metal lattice due to its small size when exposed to various environments, inducing a ductile-to-brittle transition** [1, 2]. Ductile damage in steel is characterized by the nucleation, growth, and coalescence of microvoids—a process that is further accelerated in the presence of hydrogen. Theories explaining the hydrogen-induced reduction of strength in steels include hydrogen-enhanced decohesion (HEDE), hydrogen-enhanced localized plasticity (HELP), and hydrogen-enhanced strain-induced vacancies (HESIV) [3]. The HEDE mechanism results in a principal stress-controlled brittle failure mode, while the HELP and HESIV mechanisms are driven by plastic deformation, accelerating void growth and coalescence. To address the latter aspect of this complex stress-diffusion process, we propose a mesh-independent finite element framework by combining coupled chemo-mechanics and the well-known non-local Gurson-Tvergaard-Needleman (GTN) damage model [4, 5]. This fully-coupled framework is motivated by Fick's law for standard diffusion and the mixed rate-type potential approach introduced in [6], which accounts for the influence of hydrogen concentration on the material's mechanical response. Moreover, the effects of hydrogen on damage are incorporated by extending the original non-local GTN model to account for hydrogen-promoted void growth and nucleation, as suggested in [1, 3, 7]. The stress-diffusion coupled system of equations is solved using a monolithic approach. The mutual interactions are explored using the small punch test to assess the impact of hydrogen on material degradation and the stress state on diffusion.

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Charpy Transition Curve Analysis and Sub-Size Specimen Correlation for Steel Wires in Flexible Pipes

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Abstract:

Flexible pipes used in the oil and gas industry contain built-in steel wires that are responsible to withstand tensile loads. The mechanical properties of these wires can vary depending on their material and manufacturing process. This study presents the results of Charpy V-notch (CVN) impact tests conducted on sub-sized specimens extracted from wires made of different materials. Due to the typical wire thickness being under 10 mm, standard full-sized CVN specimens could not be used, but only 5 mm and 2.5 mm thick specimens. To enable comparison between different specimen sizes, a correlation method was applied to convert the results obtained from 2.5 mm thick specimens to an equivalent 5 mm thickness. The original and converted values of ductile-to-brittle transition temperature (DBTT), as well as lower and upper shelf energies, were compared using the 5 mm thickness as reference. Although the errors of the converted values were mostly smaller for DBTT and lower shelf, they were still significant. On the other hand, the converted values of the upper shelf were all underestimated. Therefore, a new conversion method for sub-sized CVN test should be proposed to obtain results with lower errors for flexible pipe wires materials.

Static and fatigue property assessment of SS316L cold spray coating on SS316L substrate through ball indentation testing.

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Abstract:

Automated ball indentation technique is a small specimen test technique that is used to assess the tensile properties of several engineering materials. The technique was further enhanced with capability of assessing the fatigue performance of metallic materials by the first author. While the focus was on conventional materials, materials with predefined levels of damage, recently the focus has been on additively manufactured materials such as Wire-Arc Additive Manufactures steel. To further expand the applicability, this paper will present the results of static and cyclic ball indentation studies carried out on a cold spray SS316L coating on SS316L substrate (similar material Cold spray coating). The cold spray coating of approx. 3 mm thickness was done at a temperature of 1000 C and a pressure of 45 bar using custom cold spray equipment at the second author's facility. About 15 layers of coating were carried out to build a 3 mm spray coating on the substrate. Conventional material characterization was carried out using optical microscopy and hardness tests. Static and cyclic ABI tests were carried out on the coating surfaces as well as on the substrate material to assess the mechanical behavior. Improved mechanical behavior was observed post cold spray coating.

Directed Energy deposition repair of traditionally forged gas turbine engine components with Alloy 718Plus additive material

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Abstract:

The repair of high-value gas turbine engine components using additive manufacturing (AM) has gained interest due to its potential to restore serviceable parts, reduce material waste, and extend component lifespan. This study investigates the viability of Directed Energy Deposition (DED) of Alloy 718Plus as a repair material for traditionally forged Alloy 718 and Alloy 718Plus components by evaluating mechanical properties and microstructural evolution. Three material conditions were examined: (i) conventionally forged Alloy 718 and Alloy 718Plus, (ii) fully additive DED-built specimens, and (iii) 50-50 repaired specimens containing an equal fraction of forged and AM material in their respective heat treatments.

Mechanical testing included room temperature and elevated temperature tensile evaluations to assess the strength and ductility retention of the repaired material. Additionally, high-temperature fatigue testing was conducted to determine the durability of the repaired components under cyclic loading conditions. Heat treatments were systematically explored, comparing a short aging cycle with a conventional full-age treatment to understand their impact on the microstructure and mechanical behaviour of the DED 718Plus material.

Microstructural analysis, including phase characterisation, porosity assessment, and dendritic arm spacing measurements were recorded to explore the effects of the additive repair process and subsequent heat treatments on the microstructural behaviour of the material. Particular emphasis was placed on the formation and distribution of Laves phase, a detrimental intermetallic compound known to influence mechanical performance. Furthermore, microhardness and nano hardness measurements were performed to evaluate localised variations in hardness between the forged and repaired regions, as well as between phases in the additive material, providing additional insight into the mechanical behaviour of the repaired components.

A novel creep law tailored for extrapolation and its application to 2.4856

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Abstract:

The time-dependent creep behavior of metallic materials is primarily influenced by their microstructure, ambient temperature, and the applied stress state. Classical approaches, such as Norton's law and its variants, are widely used to describe the resulting deformation behavior of arbitrary structures at temperatures above 40% of the melting temperature; however, their applicability diminishes with the increasing complexity of modern materials. To address this limitation, the Larson-Miller-Parameter (LMP) concept is revisited and extended. Based on fundamental experimental investigations of the heat-resistant steel 1.4849, a novel function describing the stress dependence of the LMP is proposed and reformulated into a creep law applicable to the secondary creep stage. To test the derived material model, miniaturized creep experiments are conducted on the nickel-based superalloy 2.4856 using the small punch test technique, which is employed for thermo-mechanical material characterization up to 1000 °C. The parameters of the newly proposed creep law are determined using an inverse parameter identification strategy, featuring nonlinear least squares optimization techniques. The identified parameters are subsequently verified against results from miniaturized uniaxial tensile creep tests, confirming the reliability and predictive capability of the proposed approach for advanced creep assessment in high-temperature applications.

Evaluating Hydrogen Embrittlement in Austenitic Stainless Steels from Cryogenic to Elevated Temperatures Using the Small Punch Test

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Abstract:

Currently, austenitic stainless steels are widely used in hydrogen applications due to their excellent corrosion resistance, mechanical stability, and weldability. This makes them ideal for hydrogen storage, transport pipelines, pressure vessels, fuel cells, and turbines that require resistance to both cryogenic and high-temperature conditions in high-pressure hydrogen environments. However, at room and low temperatures, particularly from -40 to 50°C, plastic deformation can induce martensitic transformation, potentially creating a hydrogen diffusion channel along stress concentrations, which can lead to hydrogen embrittlement (HE) and result in sudden failure. Therefore, to ensure reliable performance across a wide temperature range, it is essential to understand the temperature-dependent HE behavior of austenitic stainless steels at various strain rates. This study rigorously employs two simplified test methods to evaluate HE behaviors in 304L and 316L stainless steels at cryogenic and elevated temperatures in a high-pressure hydrogen (H_2) environment: small punch testing (SPT), using the Relative Reduction of Thickness (RRT) as the HE index, and hollow specimen slow strain rate testing (SSRT), employing the Relative Reduction of Area (RRA). Two different H_2 pressure conditions were applied based on temperature: 10 MPa from -196°C to room temperature (RT) and 3 MPa from RT to 200°C. The ferrite content was measured using a FERITSCOPE (FMP30) to assess the extent of martensite transformation induced during each test. The results show that SPT effectively assesses the HE susceptibility of STS304L steel over a wide temperature range, indicating that it retains strong HE resistance even at cryogenic temperatures below -130°C and at elevated temperatures up to 200°C, making it suitable for various hydrogen applications.

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(This talk was cancelled by the authors)

Gaseous hydrogen embrittlement behavior of API-X70 pipeline steel investigated using in-situ small punch test

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Abstract:

Pipelines are a reliable and cost-effective means of transporting gases and fuels over long distances. With the global shift towards hydrogen as the next-generation fuel, there is growing interest in repurposing existing pipeline infrastructure for hydrogen transport. However, hydrogen embrittlement of metallic materials presents a significant challenge that must be addressed. Assessing the suitability of these materials under operating conditions requires systematic evaluation of mechanical performance and thorough understanding of failure mechanisms. In this study, we investigated the gaseous hydrogen embrittlement behavior of X70 pipeline steel using in-situ small punch tensile test (SPT). Tests were conducted at 100 bar hydrogen pressure with a displacement rate of 0.005 mm/min, and reference tests were performed under identical conditions in nitrogen. The experiments were interrupted at three predetermined displacements (20%, 50%, and 80% of the failure displacement) and cross-sections of the samples were examined using advanced characterization techniques, including scanning electron microscopy (SEM) and electron backscatter diffraction (EBSD), to analyze and compare the difference deformation and fracture behavior. The study revealed various susceptible microstructural regions and conditions for embrittlement thereby providing detailed insight into failure mechanisms governing this alloy.

Determination of Johnson-Cook Parameters Using Neural Networks Trained with Small Punch Test (SPT) and Impulse Excitation Technique (IET) Data for Stress-Strain Modeling of AISI 4140 Steel

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Abstract:

In this study, an intelligent system based on backpropagation neural networks is developed to identify the Johnson-Cook model parameters and to simulate the stress-strain behavior of AISI 4140 steel, a material widely used for its high strength and excellent response to heat treatments. The methodology combines two complementary experimental techniques: the Impulse Excitation Technique (IET) for characterizing the elastic region, and the Small Punch Test (SPT) for the plastic region. A correlation between the load-displacement data obtained from SPT and the Johnson-Cook constitutive model parameters is established using the Inverse Finite Element Method (IFEM). The IET results are incorporated as bias values within the neural network architecture, contributing to the adjustment of weights during training and thereby improving the prediction accuracy of the model. This approach allows for the estimation of material parameters that are not directly accessible from SPT data alone. The results demonstrate the effectiveness of integrating small sample testing techniques, artificial intelligence, and inverse modeling for accurate material characterization with minimal material requirements.

Numerical Investigation of a Novel Notch Configuration for Fracture Toughness Evaluation Using Small Punch Test Specimens

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Abstract:

The Small Punch (SP) test is a well-established miniature testing method for assessing the mechanical and fracture properties of materials, particularly when only a limited amount of material is available. Among these properties, fracture toughness is of particular importance for structural design and safety assessments. To extend the application of the SP test to fracture toughness evaluation, various notched specimen geometries have been explored in the literature—circular notched, side-through-thickness notched, and diametrically notched specimens. In the present study, a new notch configuration is proposed: a central through-the-thickness slot introduced along the longitudinal axis of a diametrically notched SP specimen. This hybrid geometry combines aspects of existing configurations and is designed to generate a localized stress concentration. Three-dimensional numerical simulations are conducted to evaluate the stress intensity factor (SIF) for a range of slot lengths. The study also investigates the role of material anisotropy in influencing the crack driving force under the proposed configuration. Anisotropic plasticity is modeled using Hill's 1948 yield criterion, with notch orientations aligned along the rolling direction, transverse direction, and through-thickness direction to capture the directional dependence of material deformation during loading.

A modified Weibull stress model for prediction of cleavage fracture in small punch test specimens

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Abstract:

The prediction of existing Weibull stress models on cleavage fracture probability of SPT specimens was discussed in this study, as well as a modified model was proposed to enhance the accuracy of predictions. It was found that the modified model provides a more accurate prediction than that of existing Weibull stress models. The simulation results further indicate that the element region where the instability and propagation of micro crack cannot occur should be excluded from the fracture process zone, and a concept of double threshold criteria was proposed to redefine the fracture process zone. It was worth noting that considering the mutual effects of plastic strain and stress triaxiality on the nucleation and instability of micro defects is also very important. This study provides a fundamental study for using SPT to predict the cleavage fracture behavior of ferritic steels.

Keywords:

Small punch test; Weibull stress; Cleavage fracture; Stress triaxiality