

<Applications Cases> 1

Instrumented indentation testing is widely used across various industries and research institutions to measure the mechanical properties and residual stresses of materials, from large structures to thin films, at macro, micro, and nano scales.

This technology offers superior local property analysis compared to traditional testing methods, providing fast, convenient, and accurate measurements.

Frontics' instrumented indentation testing technology plays a crucial role in material inspection, quality assessment at various production stages, process improvement, and product quality control in a wide range of industries. It is also extensively used for equipment safety evaluation, material degradation life assessment, and damage analysis.

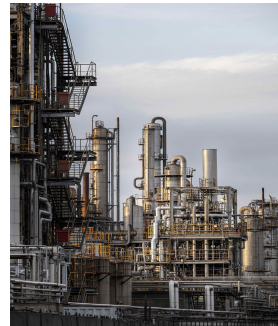
Steel Structures



In cases where deformation occurs due to fire or external stresses in bridges, buildings, steel structures, or where weld zone characteristics are required, IIT is used to non-destructively measure tensile properties and residual stress.

 case study attached 1

Petrochemical plants



For the safe operation of equipment, it is necessary to assess tensile properties and residual stress at vulnerable areas of various facilities, including pipes, storage tanks, reactors, reformers, and heat treatment furnaces.

 case study attached 2

<Applications Cases> 2

Energy transport pipeline



IIT is effective for new piping material inspections, long-term piping life assessments, integrity evaluations of operating pipes, residual stress analysis of pipes, and characterization of weld zones.

📄 case study attached 3

Power plants



IIT is ideal for new material inspections, weld zone analysis, residual stress evaluation, turbine rotor property assessment, and material property changes in long-term equipment.

📄 case study attached 4

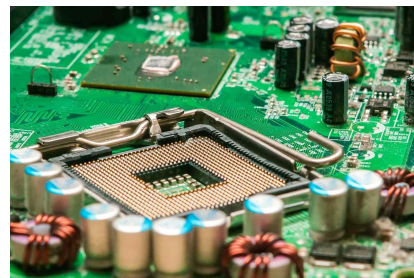
Aerospace, automotive and railway



IIT ensures transportation equipment safety by evaluating material properties, residual stress in automotive bodies, engine components, railway carriages, wheels, and aerospace materials.

📄 case study attached 5

Electronic components and batteries



IIT can be used to measure and analyze micro-strength, residual stress, adhesion, and other properties at the nano scale in electronic components, displays, coatings, batteries, etc., ensuring the reliability of the components.

📄 case study attached 6

<Applications Cases> 3

Renewable energy



In the wind turbines, solar panels, and hydrogen storage containers, IIT material testing aids in evaluating environmental resistance, optimizing energy efficiency, and enhancing durability.

📄 case study attached 1

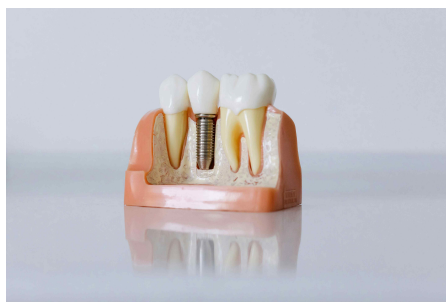
Hydrogen embrittlement



In the low-carbon hydrogen era, IIT should be used for real-time evaluation of hydrogen embrittlement in pipelines, storage containers, reformers, valves, and other equipment to ensure safety.

📄 case study attached 2

Biomaterials



Evaluating hardness, tensile properties, fracture toughness, and other characteristics of implants or prosthetics exposed to external loads is crucial for selecting materials with optimal durability and reliability.

📄 case study attached 3

University and Research Institutions



IIT can be used at the nanometer scale for mechanical property evaluation when specimen preparation is challenging or quick measurement is needed.

📄 case study attached 4

[Case Study 1] Steel Structures: Bridges, Buildings, Steel Structures, etc.

- Evaluation of residual stress and tensile properties in areas of concern for material degradation in bridge structures due to fire.
- Comparison of residual stress distribution after heat treatment of welded joints in cable anchoring pipes.
- Evaluation of residual stress in cast steel welded structures used in construction.
- Material property evaluation of steel structures involved in collapse accidents.
- Assessment of material property changes in H-beams after fire exposure.
- Residual stress analysis of high-strength H-beam welded joints.

[Case Study 2] Petrochemical Plants

- Residual stress measurement in elbow and welded joints of production equipment.
- Measurement of mechanical properties of materials inside hydrogen storage tanks.
- Material property analysis of tubes used in crude oil refining equipment.
- Verification of materials used in piping of operating crude oil refining facilities.
- Residual stress measurement for reactor integrity assessment.

[Case Study 3] Energy Transport Pipelines

- For various energy transport pipelines (crude oil, natural gas, hydrogen, CO₂, hazardous materials),
 - Detailed material property measurement of new pipes and welded joints.
 - Evaluation of material properties for the integrity assessment of operating pipes.
 - Compliance with regulations for obtaining material property data for pipeline materials.

○ Instrumented indentation testing equipment allows efficient and safe responses. The instrumented indentation testing equipment from Prontix has been evaluated as suitable for use in accordance with the US PHMSA Mega Rule.

○ Measurement of tensile properties at pipeline elbow sections.

○ Verification tests for tensile properties of pipeline materials.

○ Evaluation of tensile properties of pipelines.

○ Assessment of residual stress effects due to gas pipeline vibrations.

○ Tensile property measurement of water valve materials for water supply.

[Case Study 4] Power Plants

○ Residual stress analysis of boiler tube welds in thermal power plants.

○ Mechanical property evaluation of new materials delivered to thermal power plants.

○ Post-weld heat treatment property verification for welds in nuclear power

plant piping.

- Material property measurements for turbine rotor life assessments in thermal power plants.

- Characterization of new materials for nuclear power plants.

- Post-heat treatment property changes in elbows and nozzle sections of nuclear power plants.

[Case Study 5] Automotive, Rail, and Aerospace

- Instrumented indentation testing is widely used in the aerospace, automotive, railway, and shipping industries to evaluate mechanical properties of lightweight alloys and composites, and local properties of various welded joints.

- It helps verify part properties before and after manufacturing, assess coating layer properties, enhance durability, and improve product quality by deriving solutions for material improvement under different environmental conditions.

- Measurement of residual stress in engine cylinder blocks.

- Laser welding quality evaluation of vehicle inverter castings.

- Integrity evaluation of high-speed train bodies and residual stress measurement in wheels.

- Compression load stress comparison tests of long rails.

- Evaluation of properties of train wheel rims.

[Case Study 6] Electronic Components and Batteries

○ In the semiconductor industry, IIT helps improve the durability of circuits and devices by analyzing mechanical properties of thin films and coatings. It assesses material strength in fine patterns, evaluates properties after various processes, and ensures material integrity at the nanoscale, guaranteeing reliable device performance and product lifespan.

○ Residual stress measurement in PDP glass.

○ Residual stress evaluation in mobile phone cases.

○ Evaluation of plasma coating layer properties.

○ Residual stress evaluation of LCD TV frontal cases.

[Case Study 7] Renewable Energy

○ For renewable energy facilities, efficiency and durability are crucial, and accurately understanding and managing the properties of high-performance parts and materials is essential. Materials testing using instrumented indentation testing ensures the reliability of these facilities in harsh operating conditions.

○ Solar panels, wind turbines, and hydroelectric systems are exposed to extreme environmental conditions during operation, so durability is vital. To maximize the structural performance of wind turbine blades and solar panels, lightweight and high-strength materials are necessary. Using instrumented indentation testing during the production process ensures real-time quality control of parts and helps quickly detect non-compliant materials.

○ Wind turbine blades are subject to very high stresses, and analyzing the tensile properties and residual stresses of composite and metal materials used in blades ensures optimal quality during production and operation.

○ Instrumented indentation testing can help evaluate the mechanical properties of metals and composites used in the back panels and frames of solar panels, identifying minor defects and material property changes to develop reliable materials and equipment.

[Case Study 8] Hydrogen Embrittlement

○ Hydrogen embrittlement occurs when hydrogen infiltrates metals, decreasing ductility and increasing brittleness, which can be problematic, especially in high-strength metals.

○ Instrumented indentation testing allows precise evaluation of microstructural changes, deformation, and crack formation due to hydrogen embrittlement through load-displacement curves. Additionally, it enables real-time, non-destructive monitoring of material interactions with hydrogen in various gaseous and liquid environments.

○ The procedure begins by exposing materials to hydrogen gas or hydrogenated liquid in controlled temperature and pressure conditions to induce hydrogen penetration. Instrumented indentation testing then applies minute loads to the material's surface to obtain load-displacement curves. The difference between the curves for hydrogen-penetrated and non-penetrated materials is analyzed.

○ In the low-carbon hydrogen era, instrumented indentation testing should be used to assess hydrogen embrittlement in pipelines, storage containers, reformers, valves, and other equipment used in hydrogen production, supply, and utilization, ensuring the safety of hydrogen systems.

○ Evaluating hydrogen embrittlement sensitivity of automotive parts (e.g., high-strength steel bolts) using instrumented indentation testing allows precise measurement of crack initiation points and brittleness. Hydrogen embrittlement

evaluations in nuclear and wind power sectors (e.g., turbine blades, power plant piping) also help ensure component reliability.

[Case Study 9] Biomaterials

○ Biomaterials are used in artificial joints, dental implants, tissue engineering materials, etc. Understanding their mechanical properties, including elasticity, hardness, and fracture resistance, is essential for evaluating product durability and biocompatibility. Instrumented indentation testing accurately measures and analyzes the fine properties of biomaterials down to the nanoscale.

○ Biomaterials generally have small sizes and complex structures. Instrumented indentation testing provides accurate measurements even on small samples, minimizing deformation during evaluation and helping identify the relationship between the material's fine structure and its mechanical properties.

○ Hardness and tensile properties of artificial joint materials, such as titanium alloys, can be measured using instrumented indentation testing to evaluate long-term durability and wear resistance.

○ Biomaterials for dental implants and prosthetics must withstand various loading conditions within the oral cavity. Instrumented indentation testing can assess the elastic and deformation behavior of biomaterials under real load conditions, helping develop durable and optimal materials for use.

[Case Study 10] Universities and Research Institutions

○ Instrumented indentation testing is an essential tool in universities and research institutions for basic research in new material development, nano-technology, biomaterial analysis, and other fields.

○ When developing new materials such as metallic alloys, ceramics, and composites, instrumented indentation testing is used to evaluate properties

based on microstructural changes. It is especially useful for evaluating the properties of welded joints, microstructural strength distribution, and 3D printed materials at the nanoscale and microscale.

○ Coatings and thin films significantly affect materials' wear resistance, corrosion resistance, and electrical properties. Instrumented indentation testing is required to quantitatively evaluate these performances and establish characteristic standards for various industrial applications.

○ Biomaterials require precise evaluation of specific mechanical properties when interacting with the human body. Analyzing the surface characteristics of biomaterials, such as artificial joints and dental implants, is essential for developing materials with suitable physical properties for human compatibility.

○ Nanotechnology applications need instrumented indentation testing for precise measurement of mechanical properties down to the nanometer scale. It is used to analyze the strength and deformation properties of small mechanical and electronic components, such as semiconductors and MEMS (Microelectromechanical Systems).