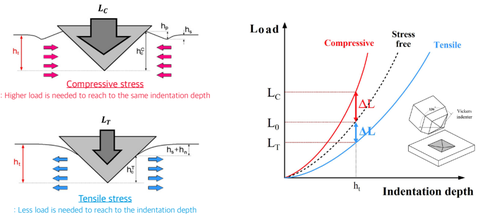
Residual stress evaluation using IIT (ISO TS 19096)

Residual stress refers to the internal stress that remains within a material even in the absence of external forces. Such internal stress responds when a new external force is applied, and in fact, when a localized indentation load is applied to the material, the ease or difficulty of indentation depends on the existing internal stress state. As a result, depending on whether the material is already in a tensile, compressive, or other stress state, the indentation load-depth curve will differ from that of a material without residual stress.

The Instrumented Indentation Test (IIT) technique can directly measure the nature and magnitude of residual stress by analyzing the differences in indentation load depending on the presence or absence of internal stress within the material.



The principle of residual stress measurement using IIT

Key Features of IIT

Direct Stress Measurement
Surface stress can be directly measured from the indentation load-depth curve; no strain gauge is needed.

Non-Destructive Nature
Stress can be measured without damaging the material; the material structure remains intact after testing.

Consistent and Accurate Results
Minimal influence from microstructure and environmental factors; a simple procedure delivers consistent and accurate results.

Broad Material Applicability
Applicable to various materials such as metals and amorphous materials.

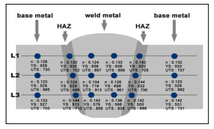
Efficient Comparison of Stress States
No stress-free reference needed; easy evaluation by comparing indentation load-depth curves for different stress states.

Multi-Scale Measurement Capability
Stress distribution can be measured across macro, micro, and nano scales.

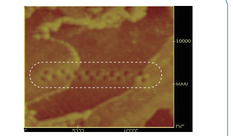
Common Evaluation Methods

Hole-drilling	X-ray diffraction	Instrumented Indentation Test (IIT)
		
• Destructive	• Non-destructive	• Semi-destructive
–	–	• Fast test (3 min/point)
• Requires installation of a strain gauge	• Surface stress (below 50 μm)	• Macro~Nano range
• Require skills of high proficiency	• Sensitive to microstructures	• High in-field applicability
• Low accuracy near the surface	• Limited to crystalline materials	• Measures both hardness and tensile properties simultaneously

Local Mapping Test (measurement range: macro to nano scale.)



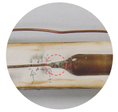
Macro (Weld zone)

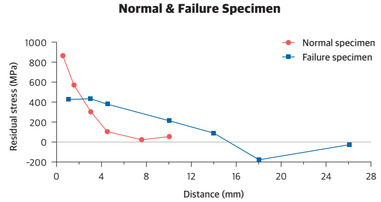


Nano (Intragranular)

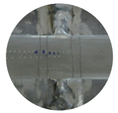
Instrumented Indentation Test(IIT) Data

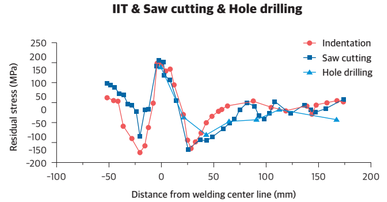
Pressure vessel
Brazed joint



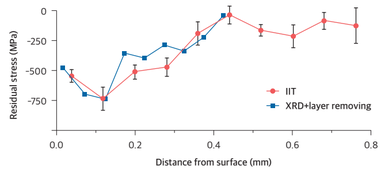


Gas pipeline
Weldment





Shot peening
Block coupon



FRONTICS

STRESS MAPPER SERIES

Frontics Inc
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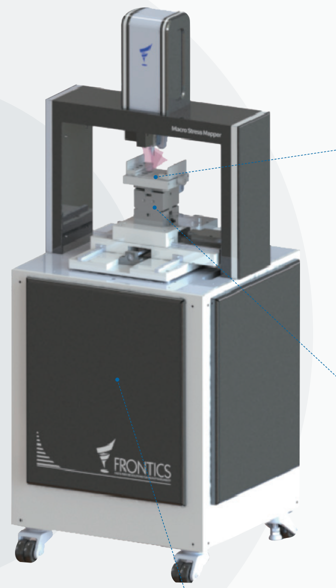
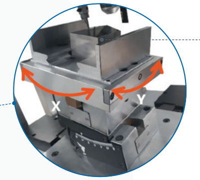
Macro Stress Mapper

· Evaluated properties

- Residual Stress
- Vickers Hardness
- Strength (optional)
- Fracture Toughness (optional)



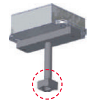
Jig



X-Y

· ±15˚angle adjustment

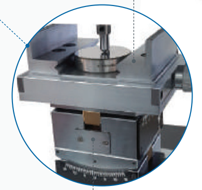
Automatic level control



Permanent magnet(Nd) installed

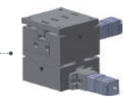
Wireless automated normal control jig

· Applicable to flat and curved surfaces
· Wireless transmission of x-y angle information



VISE JIG

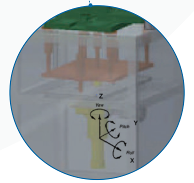
Size	180x130x43mm
Weight	4kg
Features	· Permissible specimen size * Bar: ø17~ø54×130mm * Plate: 82x55x130mm · Interchangable with the Tilting jig



TILTING JIG

Size	100x190x60mm
Weight	5kg
Features	· Motorization via Worm & Worm wheel gear

Apparatus



▸ Stage is designed to only move in the Z-axis (No wobbling)

▸ Jack Screw: Configured to withstand any backlash phenomena from the specimen or applied load

Main features and specifications

Features

· Large working space eliminates need of specimen processing
· Capable of testing at different angles and positions

Microscope

· Max. magnification of 180x for determining indentation size

Laser pointer

· Determines the indentation location of the specimen

Auto Stage

· X-axis: 150mm, Y-axis: 250mm, Z-axis: 95mm

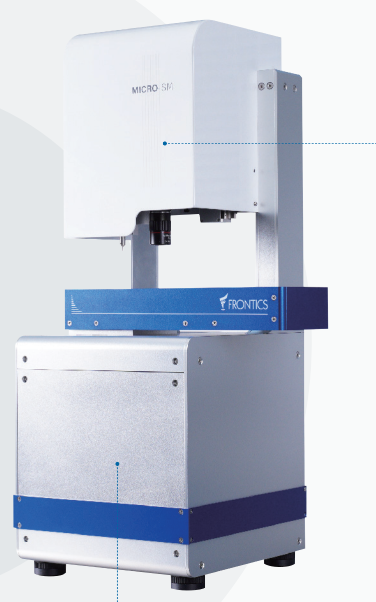
Specifications

· **Size:** 715x640x1610mm
· **Resolution:** 2.0gf/0.1μm
· **Weight:** 230kg
· **Max.stroke:** 25mm
· **Max. loading force:** 100kgf
· **Loading rate:** 0.05~20mm/min

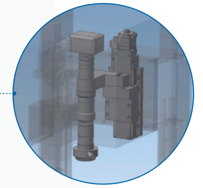
Micro Stress Mapper

· Evaluated properties

- Residual Stress
- Vickers Hardness
- Strength (optional)
- Fracture Toughness (optional)

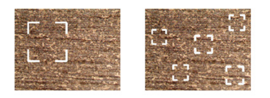


Microscope

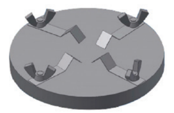


Function

· Selected area can be tested in grid form
· Any arbitrary location may be selected for testing



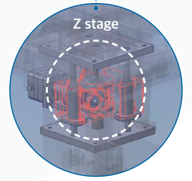
Jig



TRIPOD JIG

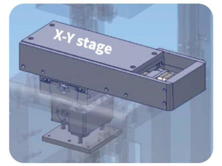
Size	ø100x11mm
Weight	700g
Features	· Permissible specimen size: Recommended below ø50X10 mm · Tripod for even leveling

Apparatus



▸ Minimized pitching and rolling through parts clearance

▸ Worm & Worm wheel gear minimizes backlash phenomena



▸ Stage can be custom-made and produced

Main features and specifications

Features

· Suitable for testing specimens too small for macro-scale testing
· Hardness and tensile properties can be obtained

Microscope

· Max. 1500x magnification to determine the location of the indentation

Auto Stage

· X-axis: 155mm, Y-axis: 45mm, Z-axis: 40mm

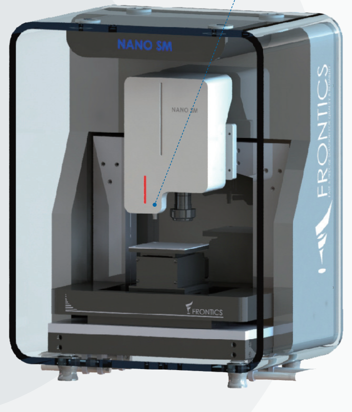
Specifications

· **Size:** 416x339x875mm
· **Resolution:** 0.01gf/10nm
· **Weight:** 82kg
· **Max.stroke:** 20mm
· **Max. loading force:** 2kgf
· **Loading rate:** 0.1~20mm/min

Nano Stress Mapper

· Evaluated properties

- Residual Stress
- Vickers Hardness
- Strength (optional)
- Fracture Toughness (optional)



Jig

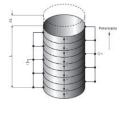
PUCK & TRAY (~Ø35)

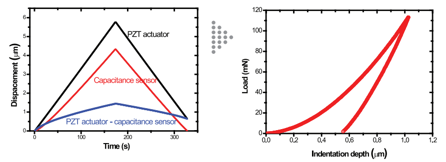
Size	55×50×35mm
Weight	660g
Features	· Permissible specimen size: recommended below ~ø35mm · Tripod for even leveling

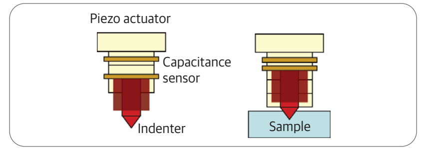
System concept

Piezo system is used to determine load and depth

- Lead Zirconium Titanate(PZT) actuator
- Electrical input ▶ Mechanical output
- Quick response (microseconds)







Specifications

Standard Size [mm]	Top plate: 610(W) x 730(L) / Chamber inner height: 895(H)
Top Plate Type	Stone surface plate (standard) / M6-tapped Optical Breadboard (optional)
Control Frequency & DOF	0.5 Hz ~ 1000 Hz / 3 axes, 6 degrees of freedom (Full active system)
Support Frame	Pneumatic spring
Required Air Pressure	0.5 MPa
Height Adjustment	Automatic height adjustment using mechanical leveling bolts

Accessories

Technical Advantages

▸ Active vibration isolation system with pneumatic support

· Excellent vibration isolation and strong resistance to impact vibrations

▸ Multi-layer soundproof chamber

· Completely eliminates noise and airflow

Main features and specifications

Features

· Useful when testing semiconductors and other small electronic devices
· Measures the stress distribution in thin films
· Measures interfacial adhesive force

Microscope

· Max. magnification of 2000x to determine the location of indentation

Obtains the stable indentation load-penetration depth curve (l-h curve) of nano-regions

Auto Stage

· X-axis: 120mm, Y-axis: 50mm, Z-axis: 12mm

Specifications

· **Size:** 548x680x360mm
· **Resolution:** 100kg
· **Weight:** 200mN
· **Max.stroke:** 10nN/0.04nm
· **Max. loading force:** 10um
· **Loading rate:** 1~12,000nm/sec

Instrumented Indentation Technique Standards

· **KS B 0950 (2002)**
: Metallic Materials - Instrumented Indentation test for Indentation Tensile Properties

· **KS B 0951 (2005)**
: Instrumented Indentation tests on welds in Steel - Measurement of residual stress on welded joints

· **KEPIC MDF A370 (2006)**
: Measurement of the mechanical properties and residual stress by instrumented indentation test

· **ISO/TR 29381 (2008)**
: Measurement of mechanical properties by instrumented indentation test - Indentation tensile properties

· **ISO/TR 29381 annex (2008)**
: Measurement of the residual stress by instrumented indentation test

· **ISO TS 19096(2023)**
: Metallic materials-Instrumented indentation test for hardness and materials parameters-Evaluation of stress change using indentation force differences

· **ASME Code case 2703 (2011)**
: Instrumented Indentation Testing as Alternative Hardness Test for QW-290 Temper Bead Welding

· **ASME Code case N-881 (2017)**
: Exempting SA-508 Grade 1A From PWHT Based on Measurement of Residual Stress in Class 1 applications

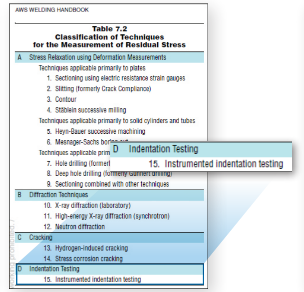
· **Guobiao Standard (2020)**
: Measurement of the tensile properties and residual stress by instrumented indentation test

· **AWS Handbook (2019)**
: Measurement of Residual Stress in Weldment (Measurement by Indentation)

· **ASM Handbook (2025)**
: Residual Stress (Instrumented Indentation Method)

International Handbook Standards: Residual Stress Measurement

AWS Handbook,10th edition (2019)



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