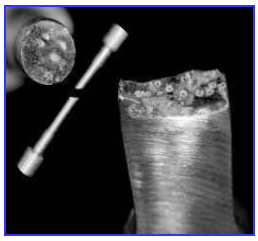
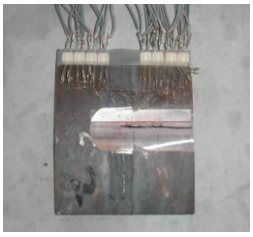
Introduction to Instrumented Indentation Technique (IIT)

□ Introduction

The instrumented indentation technique (IIT) is a powerful way to assess such mechanical properties of materials as strength, residual stress and the like. This technique is also a promising alternative to conventional residual-stress-measurement methods, particularly for welds with rapid microstructural gradients, because of its high spatial resolution and nondestructive experimental procedure. The technique is based on the key concepts that the deviatoric-stress part of the residual stress affects the indentation load-depth curve, and that by analyzing the difference between the residual-stress-induced indentation curve and residual-stress-free curve, the quantitative residual stress of a target region can be evaluated. In determining the stress-free curve of the target region, we take into consideration microstructural changes accommodating the strength difference. Indentation tests and conventional tests were performed on the weld zone to verify the applicability of the suggested technique. In addition, we introduce novel methods to evaluate tensile properties using IIT. Tensile properties can be evaluated by defining a representative stress and strain from analysis of the deformation behavior beneath the rigid spherical indenter and the parameters obtained from IIT.

☐ **Instrumented Indentation Technique (IIT)**

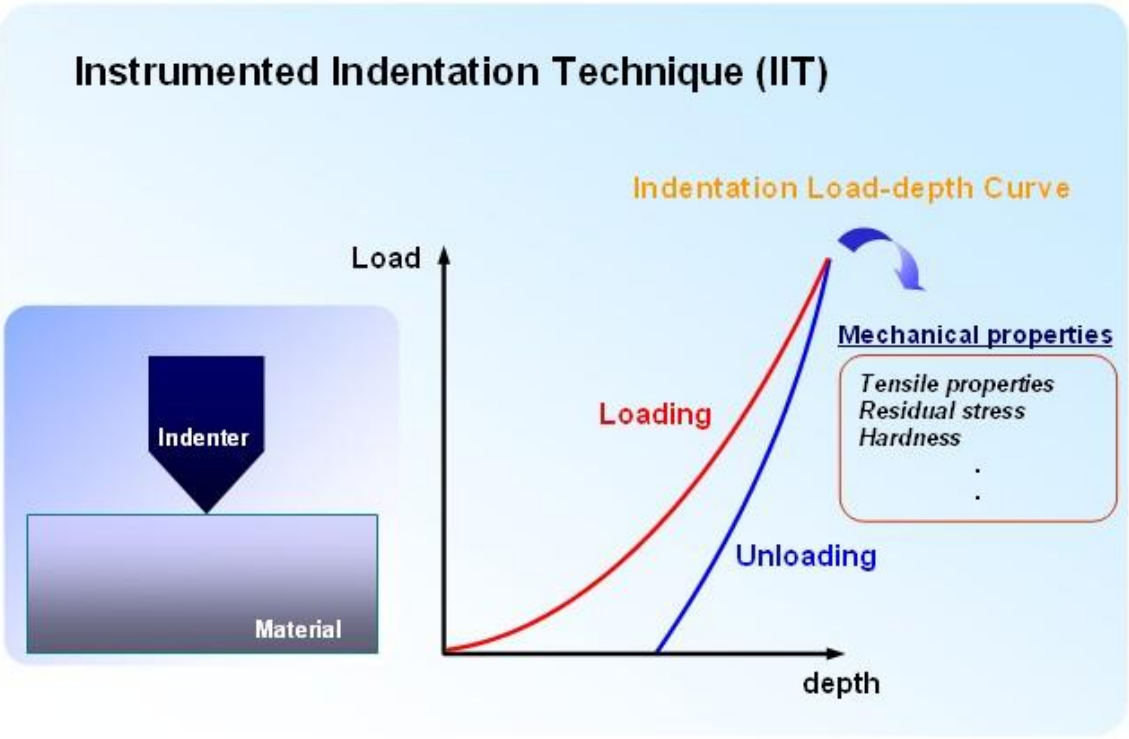
Conventional Tests	**Instrumented Indentation Technique**
  Tensile test Saw cutting	
Destructive method Difficult sample preparation Not applicable in-field	**Non-destructive method** **Easy and simple test** **In-situ & in-field application**

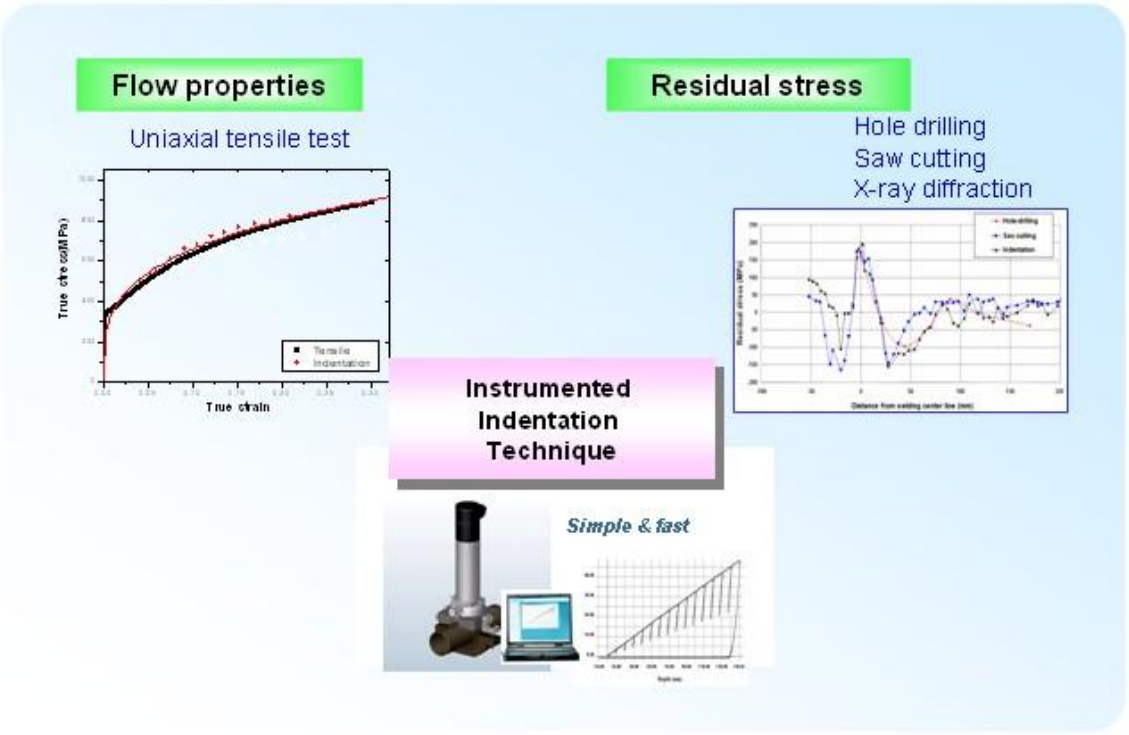
Measurement of the tensile properties of a material is most commonly performed using a uniaxial tensile testing machine. A material sample is clamped in the machine and strain is induced by application of an ever-increasing stress, stress and strain being measured by suitable means. The main mechanical parameters obtained by tensile testing are Young's modulus, yield strength, ultimate tensile strength and work-hardening exponent. The uniaxial tensile test has the benefit of making a measurement that is very similar to the final application in an easily understood way. However, it has a number of significant drawbacks:

- Test uncertainty due to misalignment in the instrument, the methods used to measure strain, and sample-to-sample inhomogeneity
- Difficulty of machining the materials to a controlled geometry without damaging them or changing their properties (in particular their work-hardened state)
- Destructive method
- Need for large enough volumes for testing

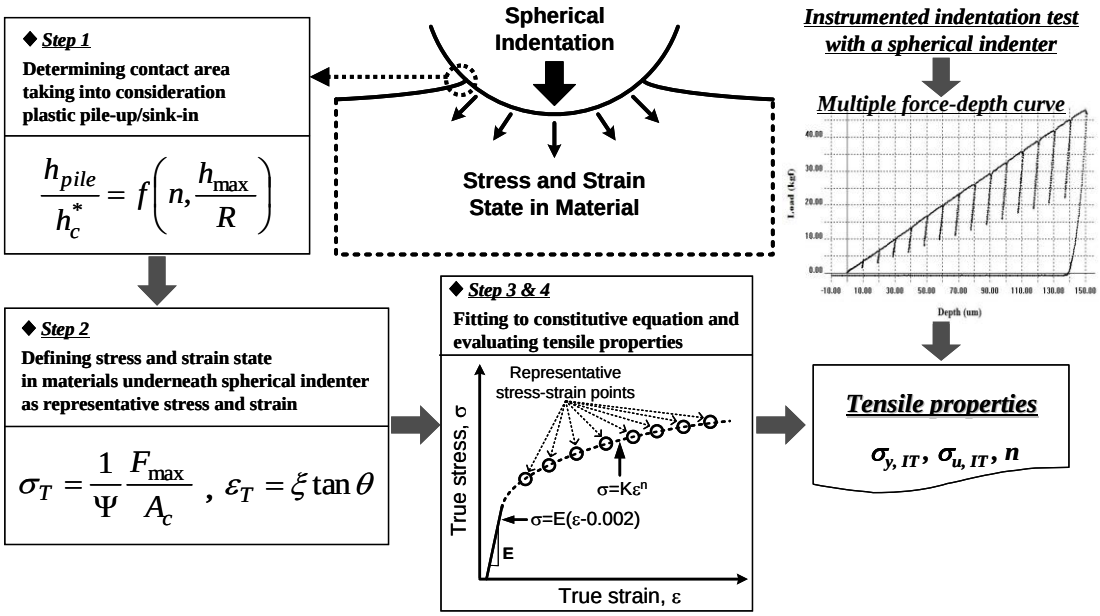
Use of the indentation method would remove many of the drawbacks of tensile testing and revolutionize the availability of tensile property information. Indentation testing can be made portable and thus nondestructive, in situ, on-site testing would become available, with relatively little (or no) sample preparation.

Instrumented Indentation Technique (IIT)

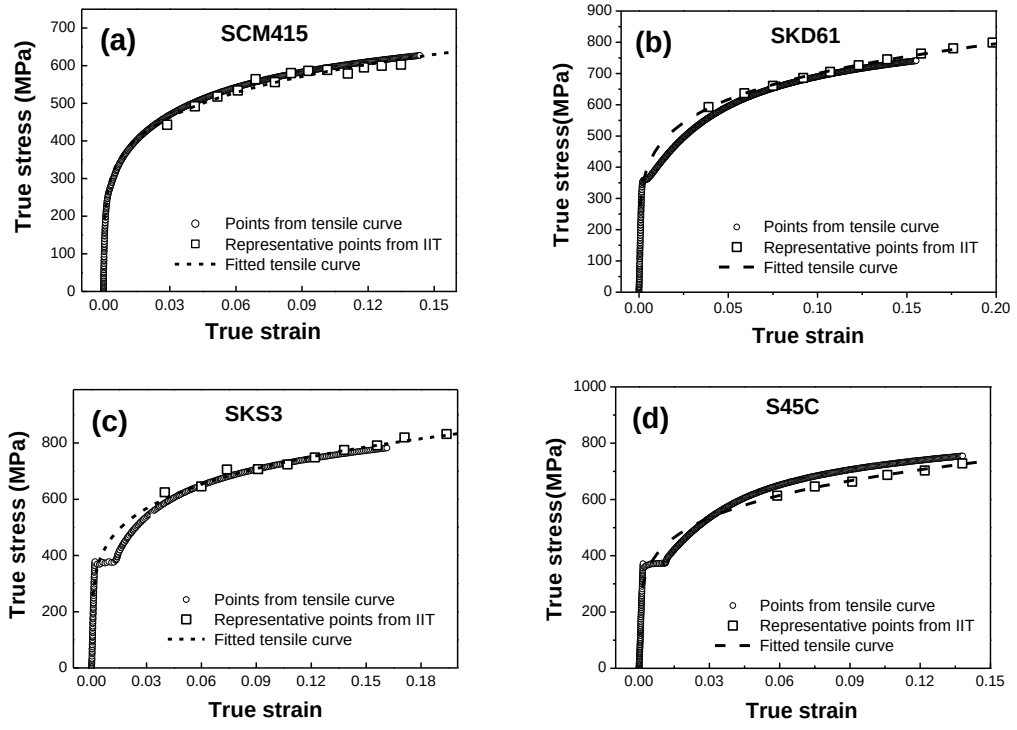




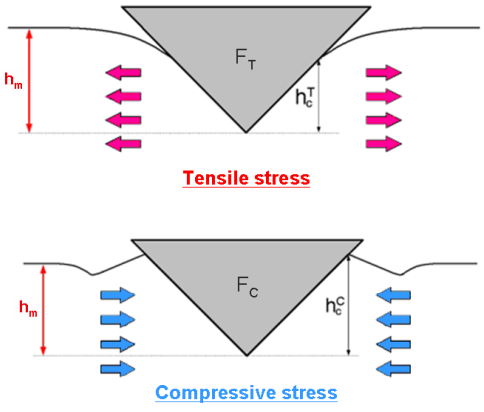
Tensile Properties

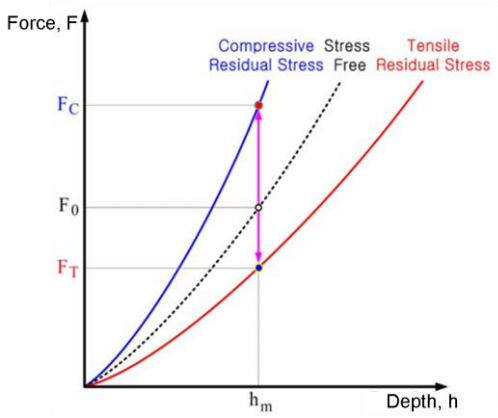


Comparisons between tensile curves from uniaxial tensile tests and instrumented indentation tests for (a) SCM415, (b) SKD61 (without Lüders strain), and (c) SKS3, (d) S45C (with Lüders strain)



Residual Stress

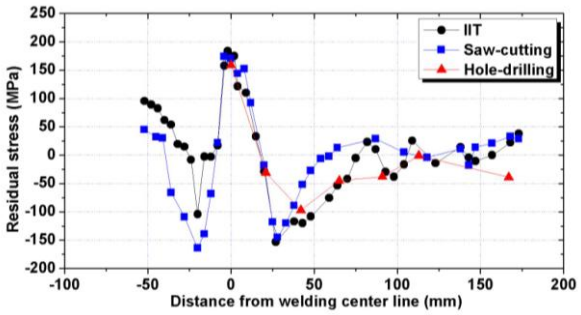




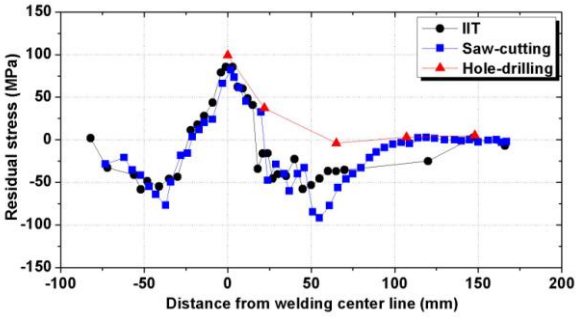
$$\sigma_{res} = \frac{3}{(1+p)} \frac{1}{\Psi} \frac{\Delta L}{A_S}$$

Comparison between instrumented indentation test and mechanical method (hole-drilling and saw-cutting)

[API X65]



[SS400]



Activity (Standardization)

ISO/TR 29831: Measurement of mechanical properties by instrumented indentation test: Indentation tensile properties

ISO/TR 29831 annex: Measurement of the residual stress by instrumented indentation test

KS (Korean Standards)

1) KSB0950 (Evaluation of Tensile Properties)

2) KSB0951 (Evaluation of Residual Stress)

1) KS B0950

- Title: "Metallic Materials -Instrumented Indentation Test for Indentation Tensile properties"
- Published in 2002

2) KSB0951

- Title: "Instrumented indentation tests on welds in steel -Measurement of residual stress on welded joints"
- Published in 2005

KEPIC: Korea Electric Power Industry Code

KEPIC MDF A370 (ASME B&PV Code, Section II, Part A, SA370: 2001 edition: IDT)

New Code by KEPIC: Revised 2006 edition (KEPIC MDF A370)

- Title: Measurement of the mechanical properties and residual stress by instrumented indentation test
- Revised in 2006