

Non-destructive inspection for magnetic visualization
of spot welding "process quality"



NUGGET PROFILER

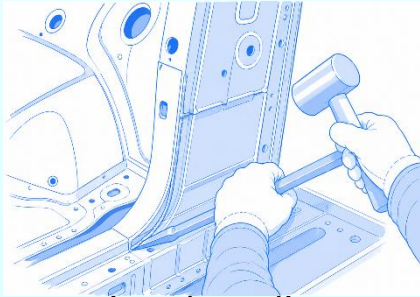


日本高圧電気株式会社

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Created on: Jun 10, 2010

1. Spot Weld Inspection: Challenges & Future

Current Challenges



Conventional quality control
(chisel testing)

Inconsistent Results

High-Tensile Limits

Hard to Quantify

Material Loss

Labor Shortage

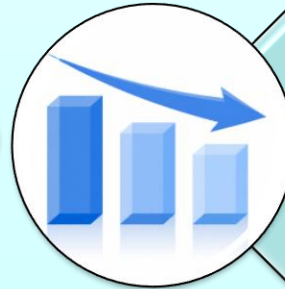
Future with NP*

*Nugget Profiler



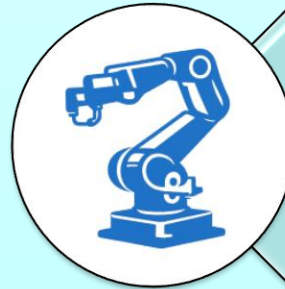
[QUALITY]

Zero Defect Escape



[COST]

Lower Testing Cost



[PRODUCTIVITY]

Automation

2.What is NP?

Magnetic NDT for spot welds.

Waveform &
Numerical
Analysis

No Gel
Required

Nugget /
Pressure Weld
Detection



4 sec / Spot

One-Touch
Data Saving

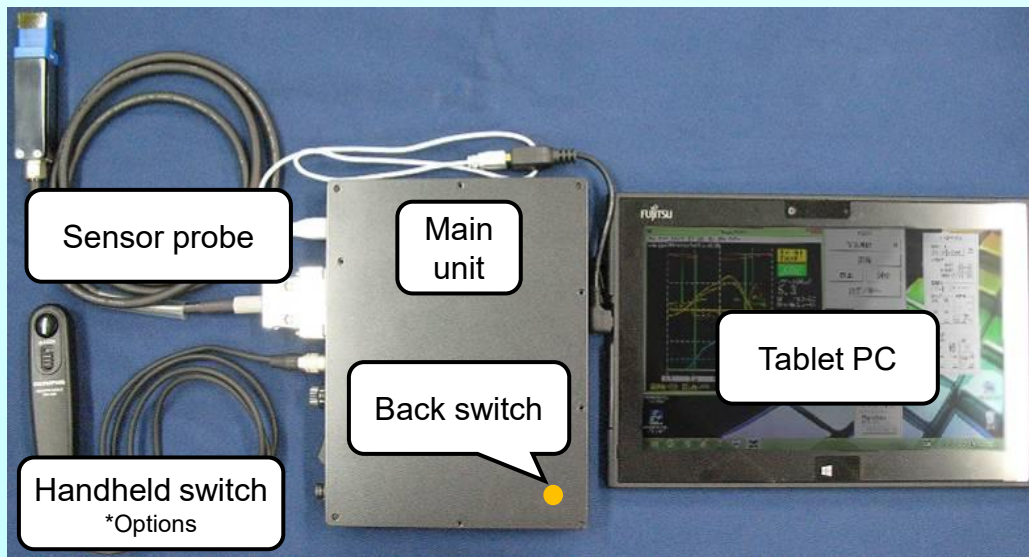
Simple Sensor
Placement

Portable to
Automated

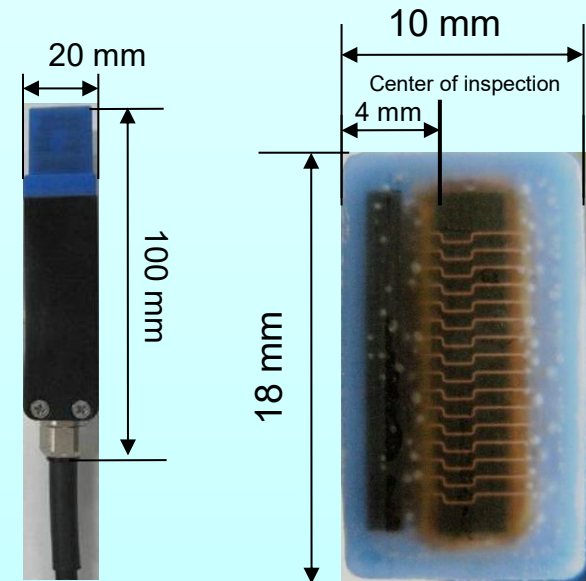
⇒ Inspection Equipment for Quality Variation at the Same Weld Spot.

3. NP Configuration

Components	Functions
Main unit	Hardware Control / Excitation Pattern
Tablet PC	Data Analysis / HMI
Sensor probe	Magnetic Flux / Data Acquisition
Switch	Data Recording Trigger



Standard Portable Unit



Sensor probe size

4. What NP Detects

Phase Changes in Steel by Temperature

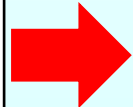
Ferrite phase



- Room temperature structure
- BCC lattice
- Soft
- Ferromagnetic
- ***Low magnetic resistance**

Ferrite and pearlite microstructure

Electric current

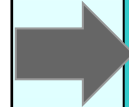


Temperature
increase

Martensite Phase (welding in progress)

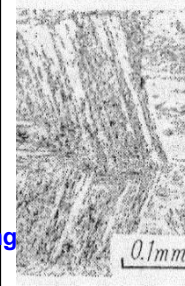
- High-temperature structure
- FCC lattice
- Ductility
- Non-magnetic

Water flow



Temperature
Rapid cooling

Martensite Phase (After Welding)



- Dense needle-like structure
- Hard but brittle
- Paramagnetic
- Higher magnetic resistance

***Slightly low magnetic resistance
(higher than ferrite phase)**

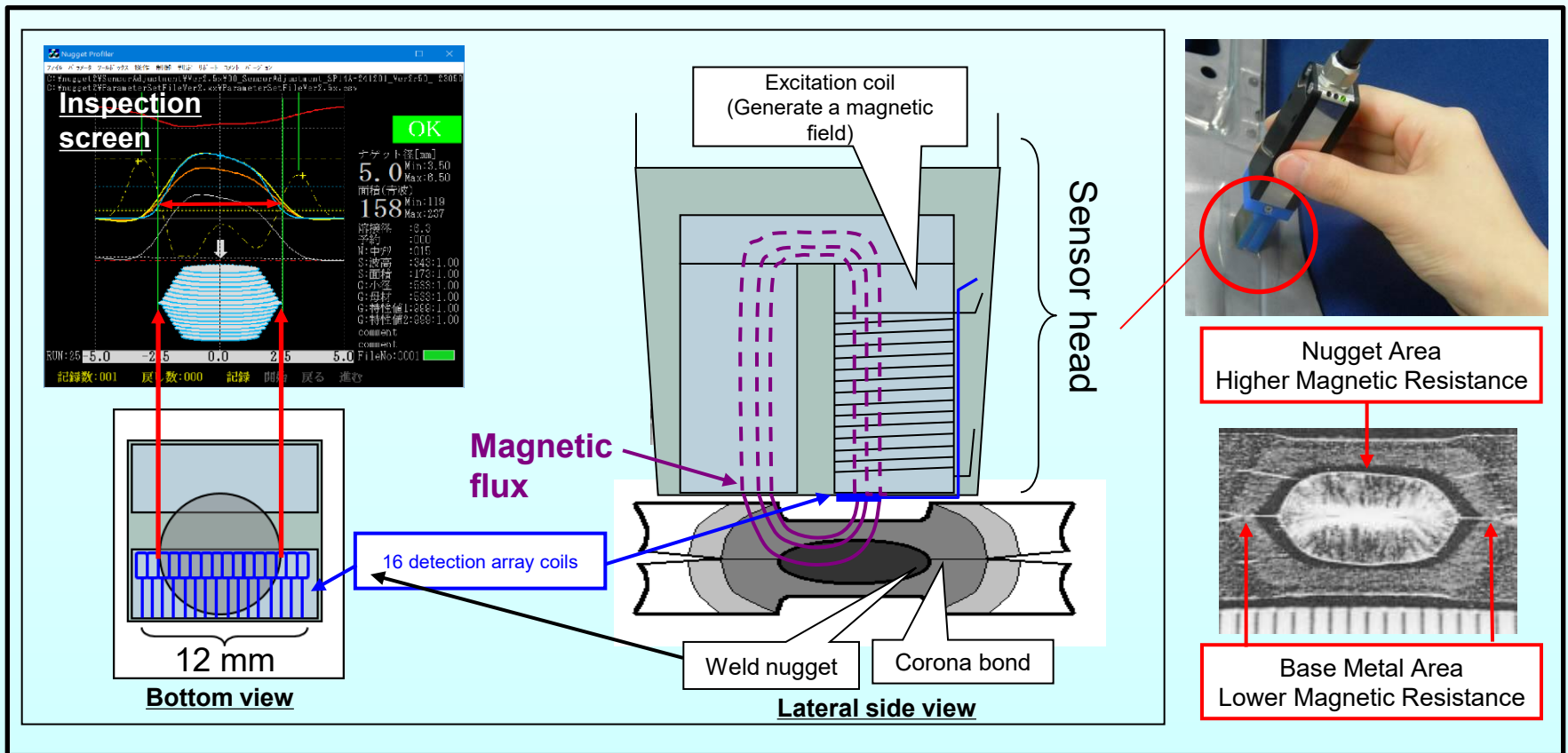


Cross-sectional photograph of weld

**NP detects microstructural changes
through magnetic resistance.**

5. How NP Detects It

6/20



Place the sensor so the 16 detection coils cover:

Base Metal + Nugget + Base Metal

→ he coils detect magnetic resistance differences and convert them into waveforms.

6. Weld Quality vs. Inspection Results (1)

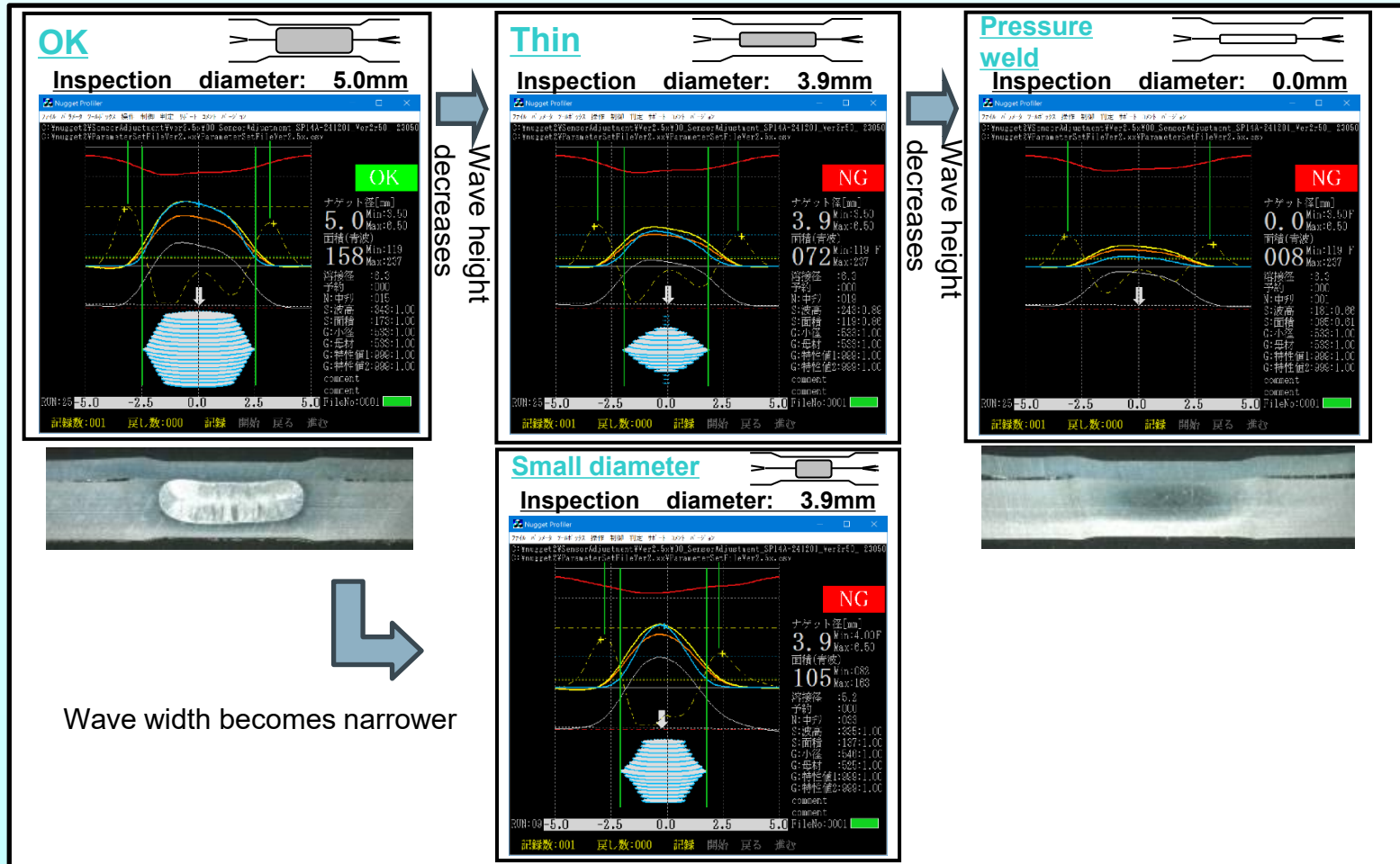
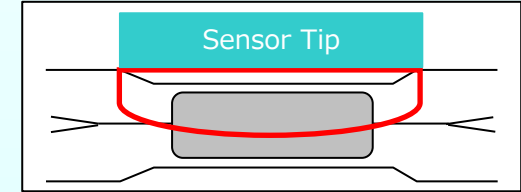
7/20

[Main Inspection Results]

Diameter: Nugget diameter across the sensor contact direction

Waveform Area: Nugget growth from the center toward the sensor contact direction

Sensor Measurement Area



6. Weld Quality vs. Inspection Results (2)

8/20

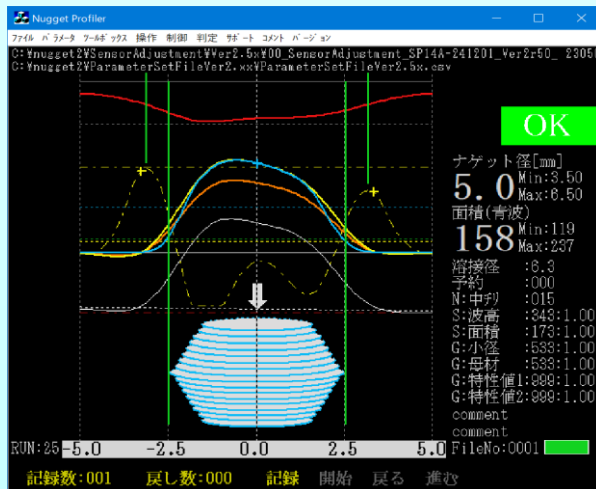
Waveform Analysis: Yellow – Orange → Reduced Noise

[Differential Waveform]

- **PASS:** High Peak
- **FAIL:** Flat / Low Peak

*Pass/Fail criteria are based on destructive test results.

Inspection screen (when inspection result = PASS)



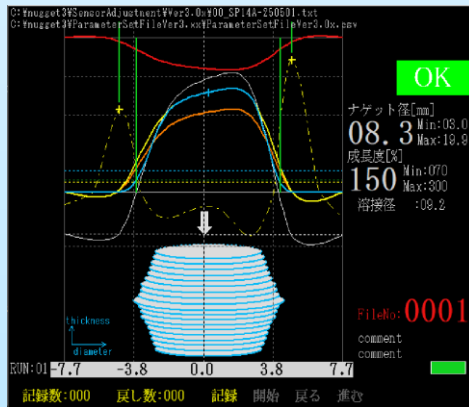
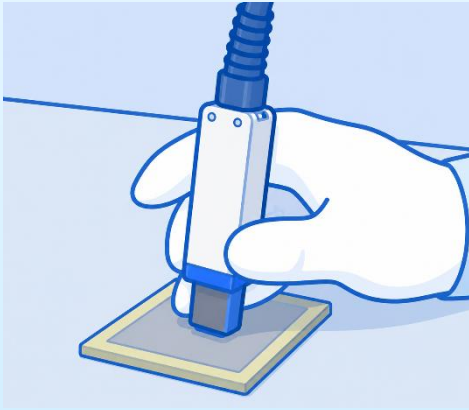
*Red lines indicate surface shape (surmised)

	PASS (weld nugget)	FAIL (weld nugget)
Macro photo (cut cross-section)		
Weak magnetic field Inspection screen: Orange wave (unnecessary information)	Base material Weld nugget Base material Coil array x 16	Base material Pressre weld Base material Coil array x 16
Strong magnetic field Inspection screen: Yellow wave (necessary + unnecessary information)		
Differential Inspection screen: blue wave *Analysis result (necessary information)		

7. nspection Setup Process

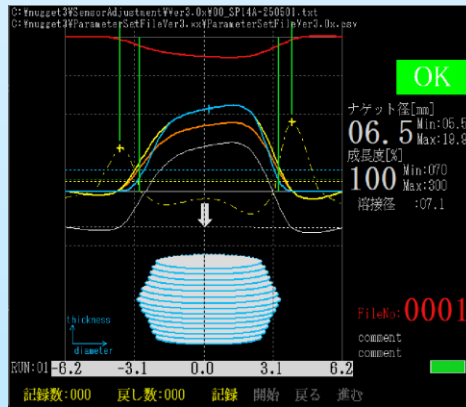
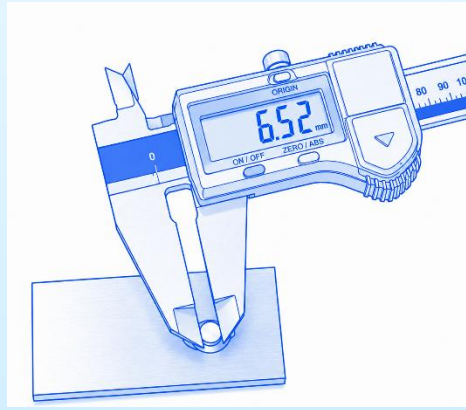
STEP1

Capture the Reference Waveform



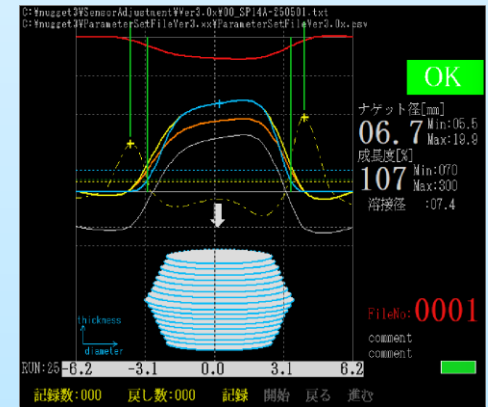
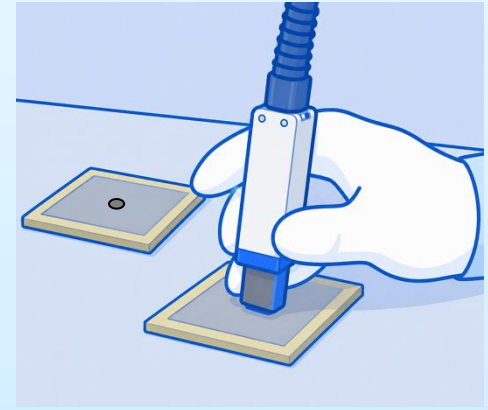
STEP2

Apply Destructive Test Results



STEP3

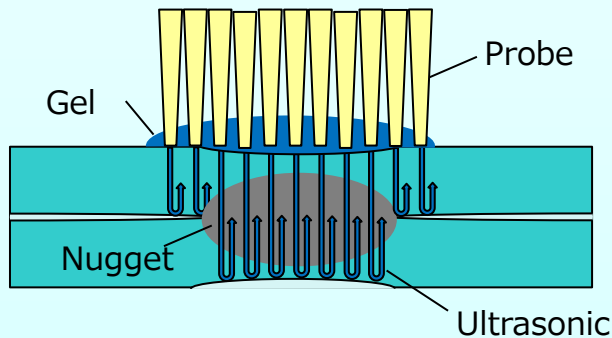
Repeat Comparative Inspection



5. Comparison with Other Inspection Methods(1)^{10/20}

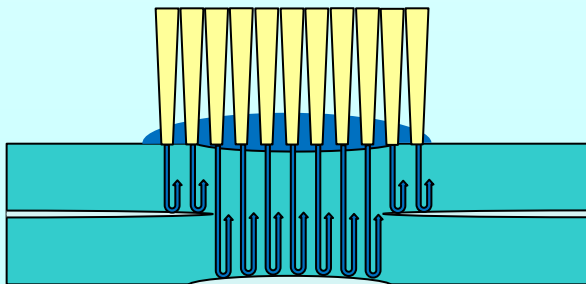
Ultrasonic Testing (Array Type)

【OK】



- Measures ultrasonic wave travel time
- Ultrasonic waves **reflect at air gaps**
→ Gel eliminates the surface air gap
- Multiple probes map the nugget in 2D
→ Nugget size can be quantified

【Pressure weld】



- Applicable to various sheet combinations and thicknesses
- No air gap in pressure welds
→ Ultrasound passes through
→ Difficult to distinguish from good welds

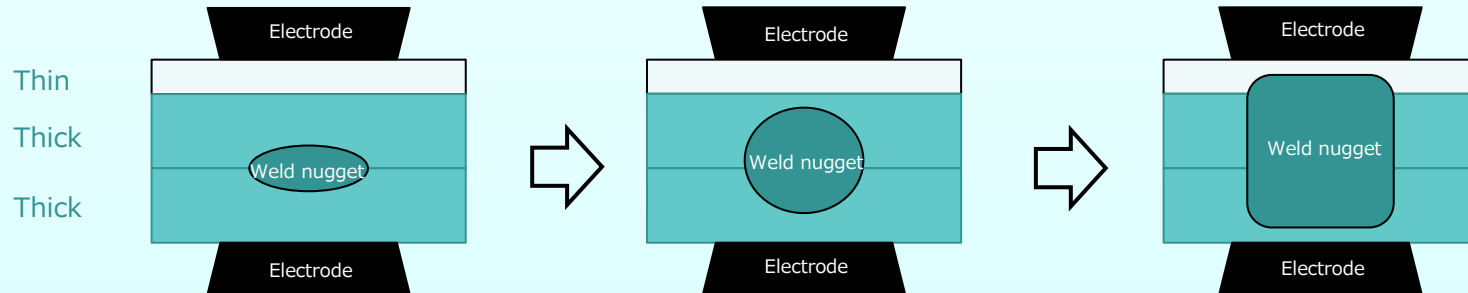
5. Comparison with Other Inspection Methods(2)^{11/20}

	NP	Ultrasoni	Chisel test
What It Detects	Microstructural Change	Acoustic Impedance	Mechanical Strength
Applicable Materials	Steel / Dissimilar Joints	Ferrous / Nonferrous Metals	Ferrous / Nonferrous Metals
Inspection Area	○ Non-convex areas	◎: Single ○: Array	△ Tool Access Required
Nugget Quantification	○	×: Single △: Array	×
Pressure Weld Detection	○ (Quantitative Comparison)	△	○
Damage to Workpiece	None	Water / Gel Required	Bending / Hammering
3-Layer Inspection	△ (Front & Back)	○	△ (Front & Back)
High-Tensile Steel	○	○	△ (Risk of Weld Cracks)
Inspection Time	○	△	◎
Traceability	○	○	×

9. Three-Layer Welding (1)

Nugget Formation in Three-Layer Welding

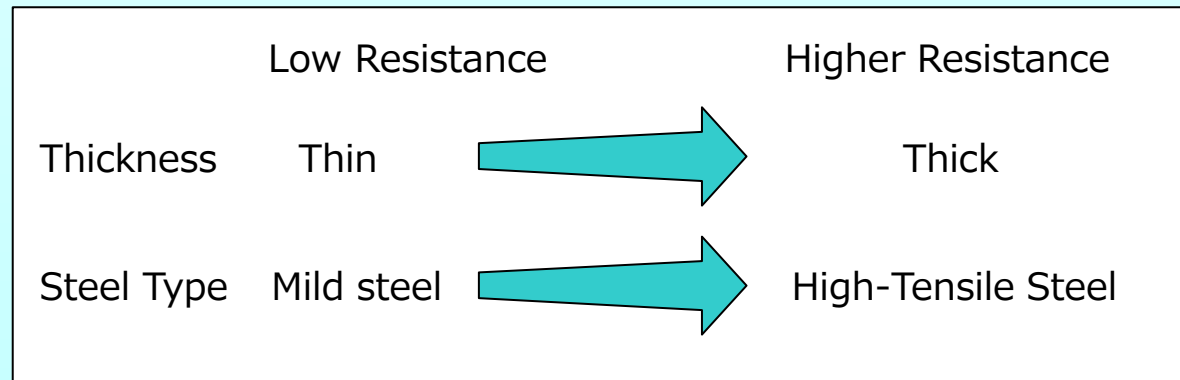
[Citation source]
Journal of the Japan Welding Society
Vol. 35 (2017), Issue No. 1, et al.



Nugget formation starts at higher-resistance areas.

⇒ One-sided inspection from the thin-sheet side is commonly used.

Electrical Resistance by Sheet Thickness & Steel Type

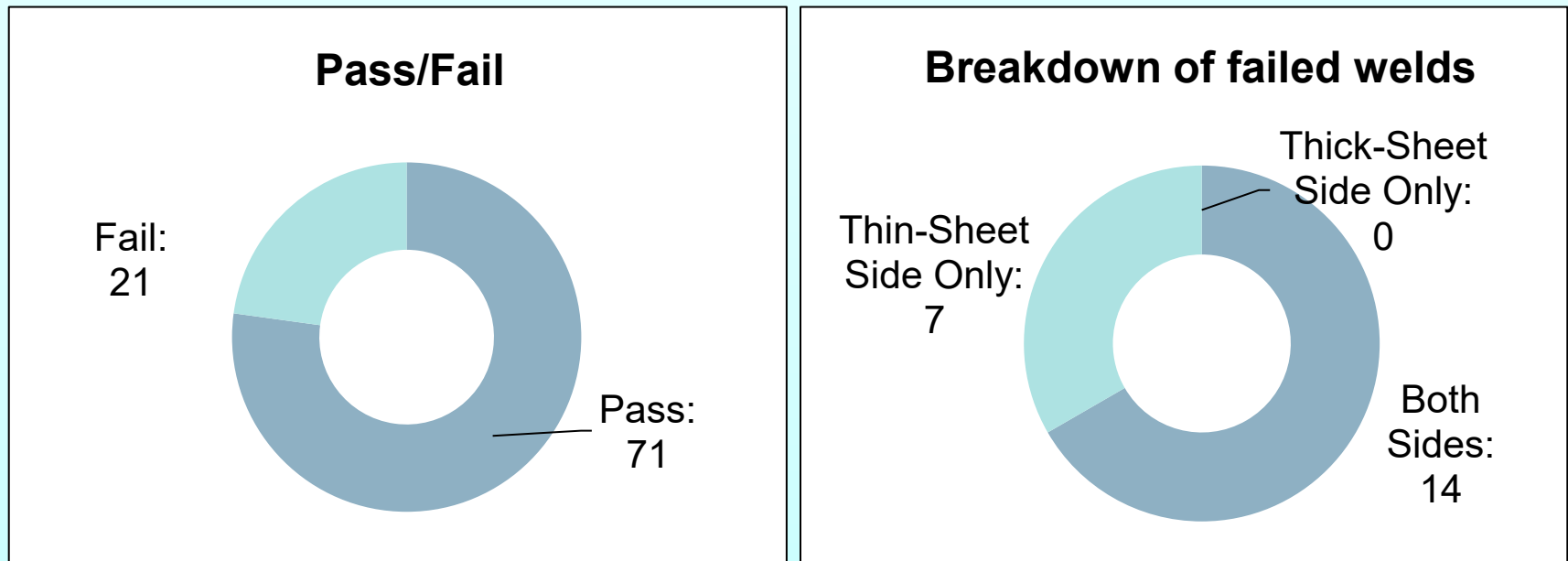


9. Three-Layer Welding (2)

Three-Layer Welding Verification 92 Welds Tested

⇒**[Conclusion]** No Failures on the Thick-Sheet Side Only

Cut-Check Results

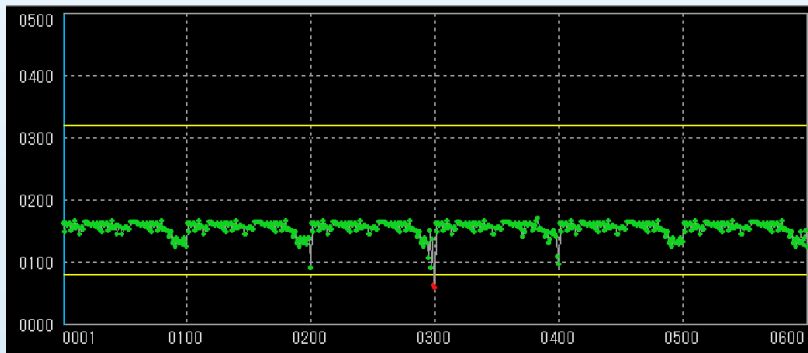


*Cut check:
Destructive testing to measure weld diameter.

10. NP Applications

Quality Control

Built-In Trend Monitoring



- Automatic Data Logging by Weld
- Visualize Quality Changes
- Support Process Improvement (See Section 11)
- Improve Quality Stability

Cost Reduction

Customer Case Study

【Before NP】

- Destructive Test Every 2 Hours

【After NP】

- Destructive Test at Start-Up Only
- NP Inspection Every 2 Hours

【Cost Savings】

- Reduced Scrap from Destructive Testing

Approx. ¥4 Million / Year

	Before NP	After NP
Start of Production	Destructive Test	Destructive Test
2 h		
After Break	Destructive Test	NP
2 h		
After Break	Destructive Test	NP
2 h		
After Break	Destructive Test	NP
2 h		
End of Production	Destructive Test	NP

11. NP Operation Flow

Conventional

Setup

- Welding Conditions
- Tip Replacement Interval
- Welding Gun Teaching

Production

- Welding

Shipping



Proposal

Build a **PDCA Cycle** to Stabilize and Improve Shipping Quality

Setup (P: Plan)

- Welding Conditions
- Tip Replacement Interval
- Welding Gun Teaching

Production (D: Do)

- Welding

Inspection (C: Check)

- Check Quality Stability

Identify Unstable Welds

Shipping

- Improve quality of shipments



Feedback (A: Act)

- (1) Optimize Tip Replacement Interval
- (2) Review Teaching Settings
- (3) Eliminate Gaps Between Sheets
- (4) Review Welding Conditions

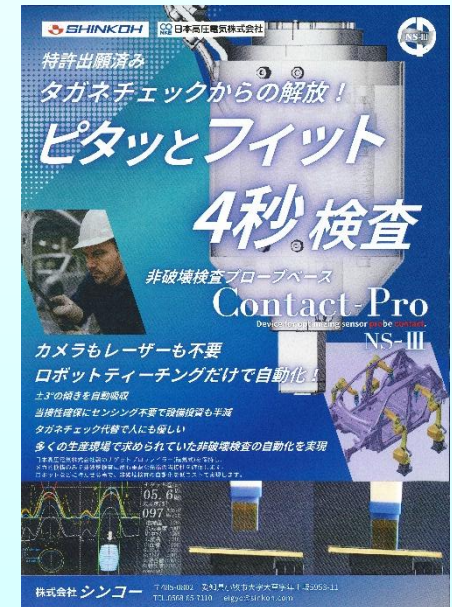
NP Inspection

Detect High-Variation Welds
→ **Stabilize the Process**

12. NP Automation(1)

CONTACT PRO NS-III

DEVICE FOR OPTIMIZING
SENSOR PROBE CONTACT.



- Positioning and sensor contact challenges resolved
- Under evaluation by multiple OEMs / Tier 1 suppliers
- Automation PoC Lab in Komaki, Aichi — Tours Available

12. NP Automation(2)

Two Challenges in NP Automation

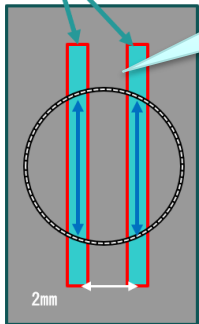
1. Tracking Weld Position

2. Ensuring Sensor Contact

Development I: New Sensor

Calculates weld diameter even when the sensor is off-center

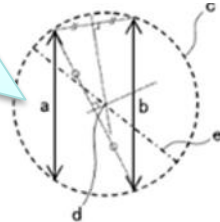
Detection Coil Array



Two-Line Weld Detection

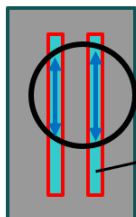
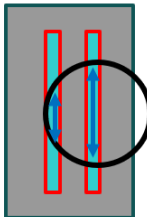
Diameter calculated from 3 contact points

Diameter Calculation



Short-Axis Offset

Long-Axis Offset



16 Coils per Row



Development II: Floating Mechanism

No Air or Electric Power Required
Handles $\pm 2^\circ$

Contact Pro
機構動作

※自動化用懸架装置は株式会社シンコーとの共同開発です

10. Device Specifications

Device Type		Portable	Stationary
Model		NPH03B	NPF02
Outer dimensions of the main unit		285(W) × 205(D) × 70(H)mm (excluding protrusions)	350(W) × 255(D) × 100(H)mm (excluding protrusions)
Weight		2.32kg	3.36kg (main unit only)
Screen display unit		TOUGHBOOK 10inch	Any compatible option
Welding inspection unit	Inspection weld diameter (standard sensor)	3–7mm [Indentation diameter: 8mm or less] (It may be able to accommodate inspections outside the above range, but please first inquire)	
	Thickness of the plate under inspection (thickness of a single inspection surface)	0.7mm to 2.3mm ((It may be able to accommodate inspections outside the above range, but please first inquire)	
	Materials	Ultra-high-tensile steel, high-tensile steel, mild steel plate (can also accommodate arrangements of multiple thin mild steel plates individually) Heterogeneous material bonding (can also accommodate arrangements of aluminum × carbon steel plate, etc. individually)	
	Surface treatment of inspected plates	Untreated, electrogalvanized, hot-dip galvanized (aluminum plating available upon request)	
	Number of inspected plates	Compatible with 2 plates or 3 plates (we recommend performing the inspection from both sides)	
	Sensor end material	FR	
PC unit	Data storage format	csv format	
	Inspection condition settings	Configure settings on the inspection screen (settings can be saved to a file)	
	Result determination method	Pass/Fail determination, estimated nugget diameter, nugget growth rate	
	Optional	Navigation mode, inspection record management	
	OS	Windows11 (Languages other than Japanese are supported via language packs) *Software supports Japanese, English, and Chinese.	
Operational temperature range		5-40℃	
Operational humidity range		Up to 80%RH (without condensation)	
Power source		The device can switch between the following power sources: 1. AC85V-240V, 0.5A 2. Battery (AA Ni-MH rechargeable batteries: 8 ct)	AC85V-240V, 0.5A

Product specifications are subject to change without notice for improvement purposes.

13. Implementation Process

Step-by-Step Support from Evaluation to Implementation

1. Product Introduction & Demo	On-site or Online
2. Sample Evaluation & Report	Prepare OK / NG Samples *See separate guide for details
3. Operation Trial	Trial with a Rental Unit in Your Production Environment
4. Implementation Decision	Review Feasibility and Operation Based on Evaluation Results
5. Delivery & Setup Support	Initial Setup Support Lead Time: Approx. 1.5 Months after Order

13. Importance of Regular Inspection

Frequency: Once a Year

Service: Sensor Performance Check & Calibration

Purpose: Maintain Inspection Accuracy and Operability

Risks Without Regular Inspection

Impact on Inspection



Harder to Achieve PASS Results



Risk of Missed / Over-Detection



Results May Shift After Sensor Replacement

Impact on Operation



Longer Inspection Time



Increased Sensor Tip Load



Higher Risk of Head Failure