SEAM SEEKER

An Introduction to the Seam Seeker

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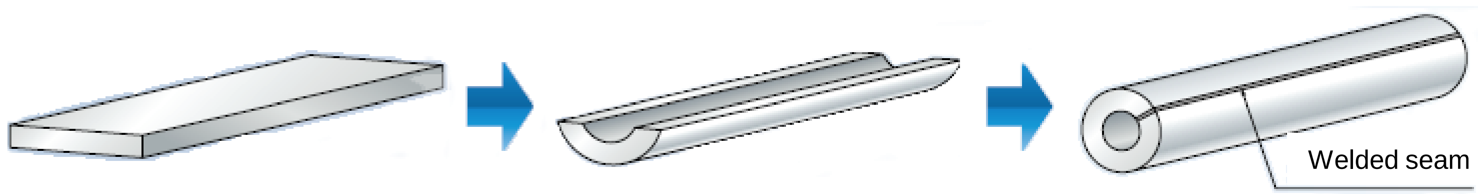
1. Background

The following figure shows a process for fabricating a pipe.

In this process, a steel pipe is produced by forming a steel sheet into a cylindrical shape and then welding the seam. Once the seam is welded, the weld (seam) hardens.

⇨ Since the weld could crack when the pipe is bent or otherwise worked, the seam needs to be located.



Conventionally, welded seams have been located by:

- Humans – visual inspection
- Using a device – camera inspection (optical inspection)

⇩

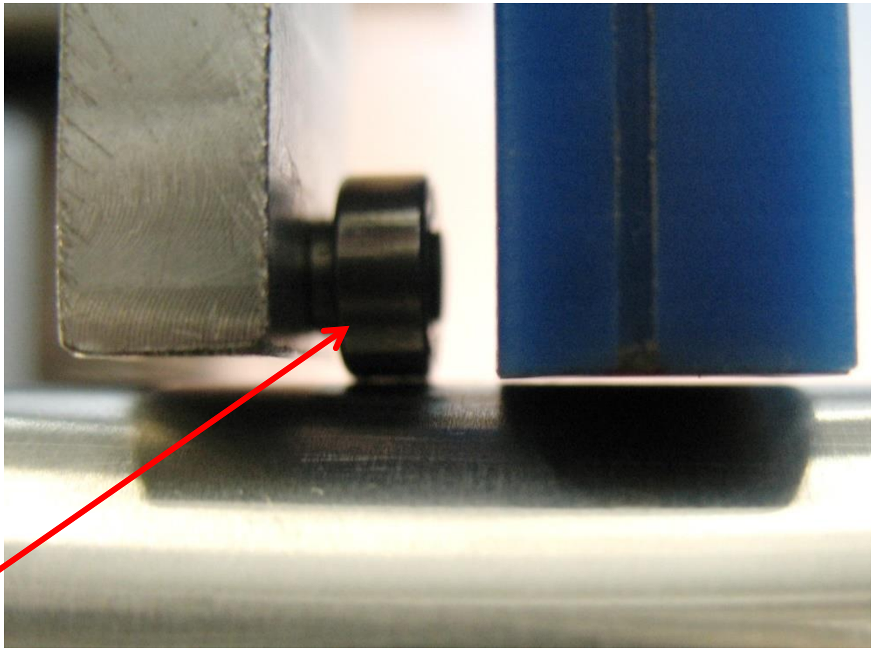
We will propose an alternative way to detect welded seams:

Non-destructive inspection utilizing magnetism

2. Benefits of the Seam Seeker

- Causes no damage to the pipe being inspected.
- Not affected by reflectance, color, or lighting. (Advantage over optical inspection)
- Not affected by oil or other substances on pipe surfaces. (Advantage over optical inspection)
- Ignores surface flaws.
- Capable of high-speed inspection (approx. 1.5 seconds or more).
- Includes a non-contact sensor.

  (A cam follower or other component is used to maintain the distance between the sensor and the pipe being inspected.)
- Allows settings to be configured automatically and manually.



3. Inspection Theories of the Seam Seeker – 1

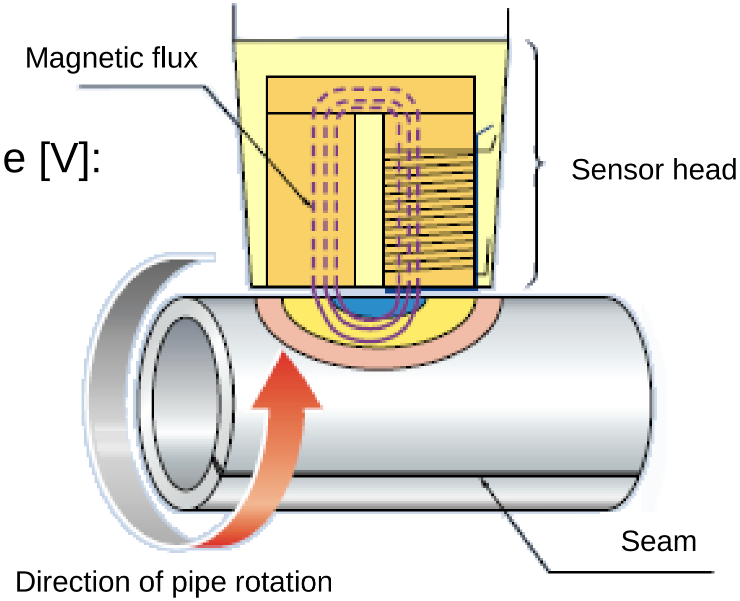
- Heat-treating steel (quenching = a welded seam) changes its structure and thus its mechanical properties. This, in turn, changes its magnetic properties (magnetic permeability and electrical conductivity) (see Inspection Theories 2, 3, and 4).
- The Seam Seeker obtains magnetic property data from a steel (according to Faraday's law of electromagnetic induction), and numerically represents the magnetic permeability and electrical conductivity (as **property values**).

Equation for Faraday's law of electromagnetic induction e [V]:

$\underline{e = -N \times d\Phi/dt}$

N: the number of turns in the sensing array coil

Φ: magnetic flux [Wb]



4. Inspection Theories of the Seam Seeker – 2

The magnetic sensor contains two types of coils:

(1) Exciting coil: Serves as an electromagnet, which produces magnetism.

(2) Sensing coil: Converts produced magnetic flux into electrical signals, which are then sent to the device.

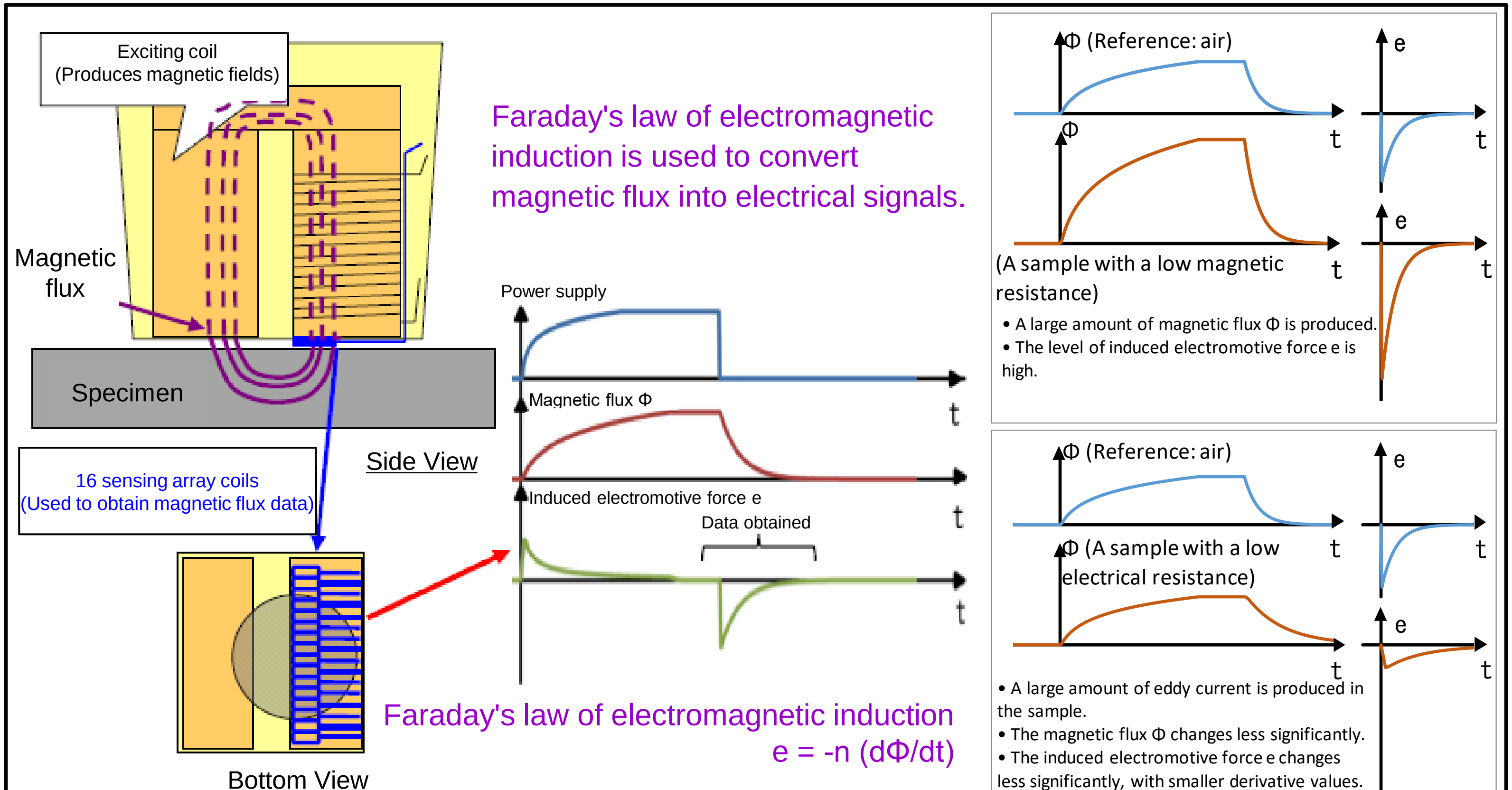


Figure 4.1: Sensor structure and data obtained

5. Inspection Theories of the Seam Seeker – 3

The magnetic sensor, which is the main component of Seam Seeker, is energized by direct current blocking (a patented Nippon Kouatsu proprietary technique).
This technique is capable of inducing a much larger electromotive force compared to the conventional alternating current (sine wave) method, providing the following advantages:

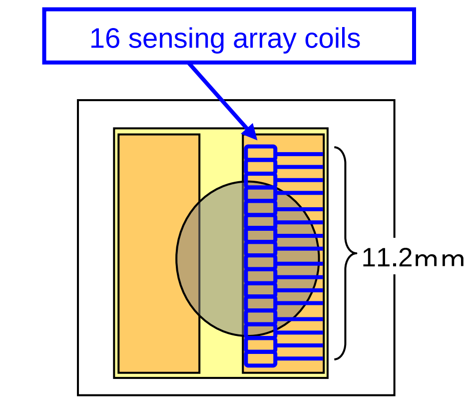


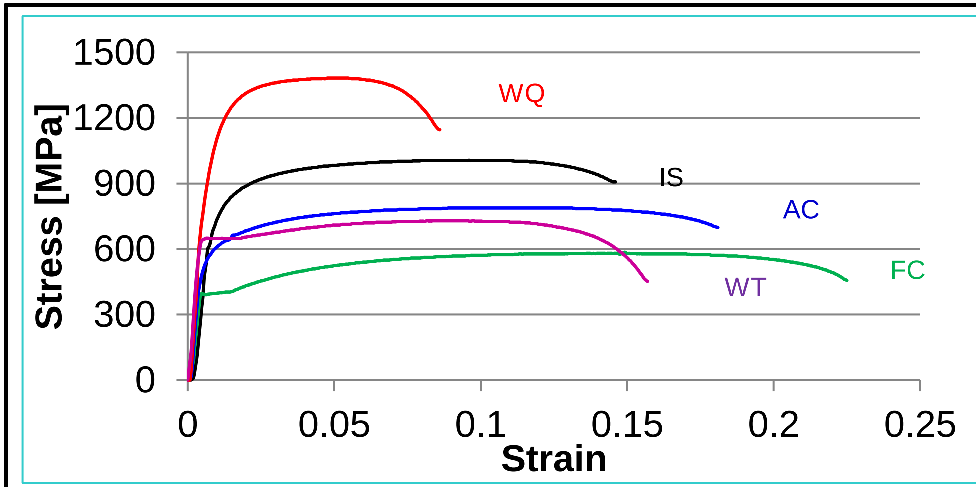
Figure 5.1: Sensor Bottom View

1. High performance: Changes in the steel microstructure characteristics (tensile strength, total elongation and hardness) can be detected.
2. Smaller size: 16 array sensors are provided within a space of approximately 11 mm.

6. Inspection Theories of the Seam Seeker – 4

Table 6.1: A list of heat-treated specimens

Name	Description of Process	Tensile Strength [MPa]	Total Elongation [%]	Hardness [HV]
FC	1000°C (5 minutes) + **furnace cooling**	585	22.5	155
AC	1000°C (5 minutes) + **air cooling**	788	18.1	176
WQ	1000°C (5 minutes) + **water cooling**	1383	8.6	354
WT	1000°C (5 minutes) + **water cooling + 600°C (15 minutes) + air cooling**	730	15.7	229
IS	**No treatment** (intact)	1006	14.6	295

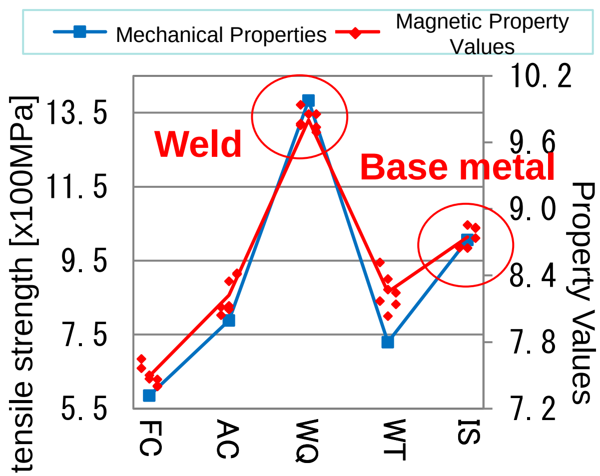


Mechanical Properties – Heat-Treated Specimens

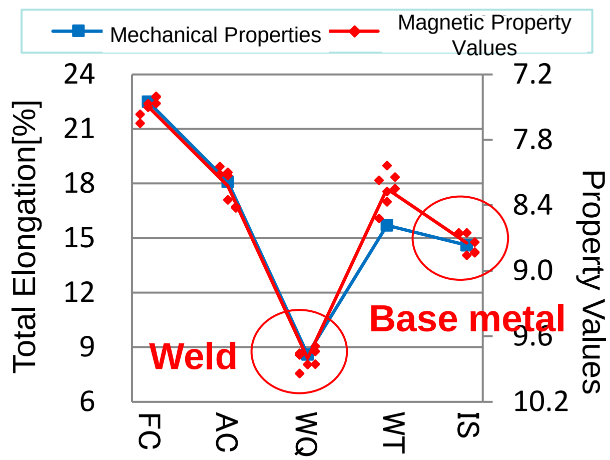
Material Specifications

- Steel material: JSC980Y
- Carbon content: 0.16 [mass%]
- Dimensions: W120 × D40 × t1.8 [mm]

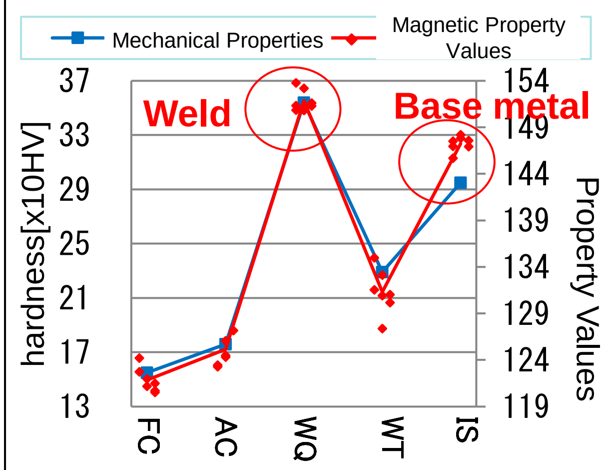
7. Inspection Theories of the Seam Seeker – 5



7.1: The relationship between tensile strength and property values



7.2: The relationship between total elongation and property values



7.3: The relationship between hardness and property values

This graph shows a strong correlation between the mechanical properties and property values.

8. Inspectable Materials

The following table shows the materials that can be inspected by the Seam Seeker.

Background: Quench hardening makes a welded seam more brittle, and thus more prone to cracking. This makes it necessary to locate the seam.

Table8.1 : A list of inspectable materials

Classification	Material	Inspection	Hardenability
Iron	Pure iron, SS	Not possible	No
	Carbon steel plates and sheets (steel)	Possible	Yes
Stainless steel	Austenitic (SUS304)	Not possible	No
	Ferritic (SUS430)	Not possible	No
	Martensitic (SUS440)	Possible	Yes

Supplementary information

- Austenitic stainless steel:

  With its typical steel grade being SUS304, it is a Cr-Ni steel that is non-magnetic and highly resistant to corrosion.

  It cannot be hardened by quenching, because it remains as stable austenite when heated to high temperatures.

- Ferritic stainless steel:

  With its typical steel grade being SUS430, which is commonly called 18Cr stainless steel, this type of steel is used as an anti-corrosion structural material that is less expensive than austenitic stainless steel. Ferritic stainless steel cannot be hardened by quenching either, because it remains ferritic when heated to high temperatures. It is magnetic.

- Martensitic stainless steel:

  With its typical steel grades being SUS440 and SUS420, which is made primarily of 13Cr stainless steel, this type of stainless steel contains a higher content of carbon than other types to enhance hardenability.

  The higher the carbon content, the lower the resistance to corrosion, so martensitic stainless steel is less resistant to corrosion than other stainless steels, although it can be hardened by quenching. It is magnetic.

9. Inspection Procedure

Step 1: Magnetic property data is obtained from the circumferential magnetic field as the pipe is rotated one turn.

Step 2: A distribution of property values is determined from the obtained data.

Step 3: The distribution shows a peak at the property value obtained from the weld.

Step 4: The motor positions the pipe according to the angle corresponding to the peak position.

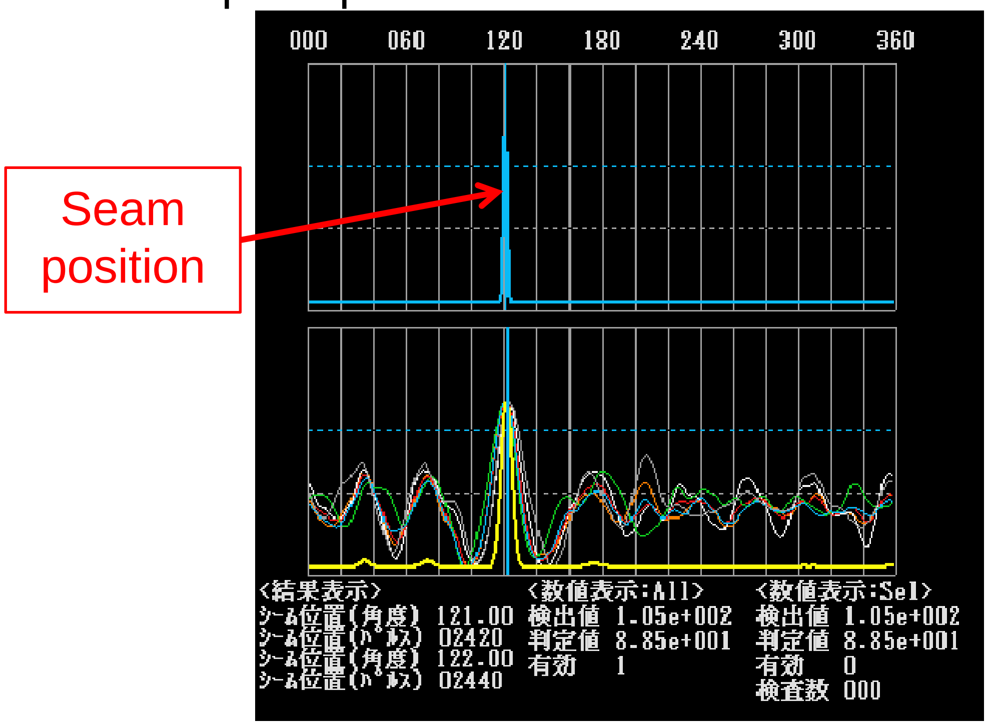


Figure 9.1: Inspection screen

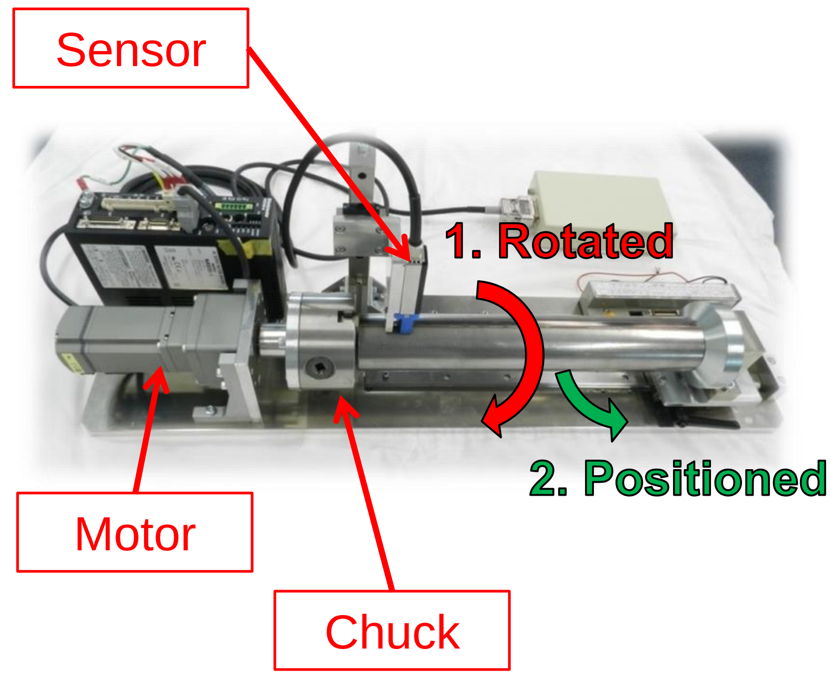


Figure 9.2: View of how the inspection is performed

10. Inspection Time

Inspection time (360 inspections = 1-degree inspection intervals)

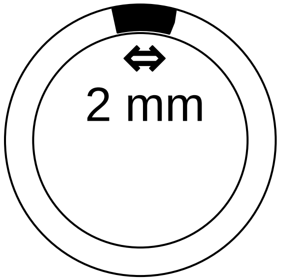
Rotation Angle	Number of Inspections	Time Required	Positioning*1	Total
360°	360	Approx. **1.50 s**	Approx. 0.20 s	Approx. **1.70 s**

Inspection time (180 inspections = 2-degree inspection intervals)

Rotation Angle	Number of Inspections	Time Required	Positioning	Total
360°	180	Approx. **1.10 s**	Approx. 0.20 s	Approx. **1.30 s**

*1) When the pipe rotates the maximum distance (180°)
*2) The above values depend on the performance of the motor.

How to determine the number of inspections



Pipe Specifications
Outside diameter: 20 mm
Seam width: 2 mm

Calculate the number of inspections to be performed on the seam from the circumference of the pipe.

- Circumference: 62.8 [mm] (Outside diameter: 20 [mm])
- One degree: 0.174 [mm]

→

- At 1-degree inspection intervals: 11.4 inspections
- At 2-degree inspection intervals: 5.73 inspections

Determine the inspection interval so that three to five inspections are performed on the seam.

11. Device Specifications

Model		SSF01
Inspection parameter settings		Can be configured on the inspection screen. (Settings can be saved to a file.)
Data saving		XLS format (CSV)
Material of sensor end		FR
Option		PLC communication settings
Product composition Dimensions and weight	Main unit	350 × 255 × 100 mm; weight: 5.4 kg
	Repeater	100 × 160 × 40 mm; cable length: 10 m Weight: approx. 350 g (excluding the cable)
	Sensor	100 × 20 × 20 mm; cable length: 1.5 m Weight: approx. 200 g (including the cable)
	Communication cables	Two cables (cable length: 10 m each) Note: For contact I/O and RS-422 communication
Operating temperature range		5°C to 40°C
Operating humidity range		80% RH max. (non-condensing)
Power supply		85 to 240 V AC, 0.5 A (only for the main unit)

Note: Due to product improvement, specifications are subject to change without notice.

12. Inspection of Samples

- We offer a service to inspect your samples in-house.
  The table below describes what samples we can inspect.
  (We use different jigs according to your samples.)

	For Small-Diameter Samples
Outside diameter [mm]	10 to 90
Inside diameter [mm]	80 or less
Longitudinal length [mm]	100 to 300
Weight [kg]	2.0 or less
Materials	Steel Martensitic stainless steel

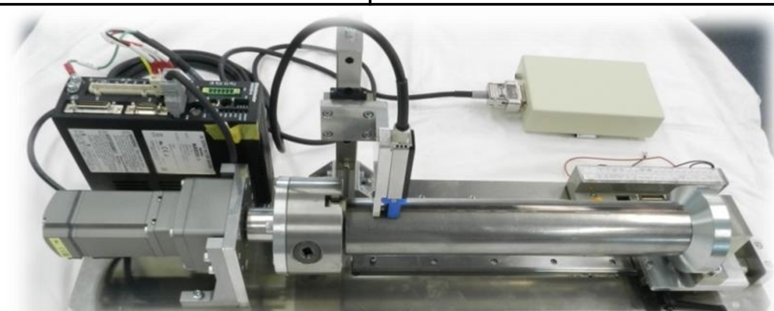


Figure 12.1: Jig for small-diameter samples

13. Fields of Application

Since the Seam Seeker can identify structural changes in steel, it is expected to have a wider range of applications than now, including:

Inspection of materials subjected to

- High-frequency quenching
- Carburizing and quenching
- Other heat treatments (such as annealing and tempering)

Examples of applications include inspection of bearings subjected to quenching.