In-Line ERW Tube and Pipe Inspection Using EMAT-Generated Guided Waves
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- Innerspec Technologies, Inc.
ERW Pipe Manufacturing and Inspection Needs
ERW pipe is a high-quality product with growing markets

- First produced in the 1920’s
- Switch from low to high-frequency in the 1960’s improves quality and mechanical performance
- Today ERW tubes and pipes are a valid choice for the most demanding applications including Oil Country Tubular Goods (OCTG), and structural pipes
- ERW tubes need to be inspected to meet API and ASTM standards required for these applications
ERW tubes are formed and welded into tube form from flat strip

- A flat strip (skelp) is pulled through a series of rollers to form the circular shape
- High frequency welders are used to close the edges and create the tube
- A piece of ferrite (impeder) is used to concentrate the induction current and produce the heat required for welding
- The impeder needs to be cooled with fluid flowing through it
- The ID flash is normally removed used a tool attached to the impeder. Outside (OD) flash is removed by an external cutting tool as the tube leaves the weld zone
ERW pipe undergo many processes after welding

- **Entry**
- **Shear**
- **Looper**
- **Roll Forming**
- **ERW Seam Welding**
- **Scarf**
- **Cooling trough**
- **Sizing**
- **UT Inspection**
- **Cut-Off**
- **ID Scarf removal**
- **Preliminary Inspection**
- **Straightening**
- **End Facing**
- **Hydro Test**
- **Repairs**
- **Hydro Test**
- **Final UT**
- **Coating**
- **Marking**
- **Packaging**
Weld inspection normally occurs after cooling and sizing

- Weld Inspection on weld line is essential to eliminate value added processes prior to final product inspection
- Weld must be cooled prior to inspection
- Cooling and Sizing accounts for up to 100’ of pipe length prior to inspection
- After sizing, the weld typically experiences significant drifting from normal 12:00O’clock Position
- Inspecting further upstream (near welder) would detect defects earlier potentially saving tons of valuable product

Cooling Trough
Traditional Solution with Piezoelectric Transducers
ERW welds are inspected on the weld line for process control

**History:**

- Standard ERW tube weld inspection is ultrasonic testing using piezoelectric transducers.
- Method has two important shortcomings:
  - It requires very precise positioning of sensors to address the weld
  - It uses a liquid couplant to transmit the sound from the transducer into the material
- ERW is often referred to as “Straight Seam” pipe, but all ERW lines suffer significant weld drift
- Weld line inspection near to the welder is preferred but not possible
Piezoelectric Ultrasonics inspection is the industry standard method of inspection for ERW pipes

Method and shortcomings:

- Piezoelectric Ultrasonic inspection sends ultrasound at an angle for weld inspection.
- Weld position must be maintained for sound to inspect the weld line.
- Sensitivity focuses on ID and OD reference notches.
- Mid wall sensitivity is often compromised.

“Half skip” / “Full Skip” Method of PZT
Ultrasonic Testing (PZT) requires precise positioning of sensors

- Calibration uses ID and OD reference notches
- Weld position must be maintained or Sensors must follow weld line
- Effort to “see” notches neglects Mid-wall
- ID and OD are both effected by weld drift
- Weld drift and couplant quality are primary shortcomings
- “fixes” are very cumbersome an costly
Typical Piezoelectric Ultrasonic Fixture On Weld Line

Weld following devices are costly, cumbersome and typically not effective
The EMAT Guided Wave Solution
While Piezoelectric UT uses a crystal to generate the ultrasound, an Electro Magnetic Acoustic Transducer (EMAT) generates the sound in the part inspected.
EMAT enjoys all the benefits of UT plus other particular advantages

Ultrasound is Generated in the Part Inspected

**Dry Inspection** (no couplant)
- Easy to Automate and Integrate in Production
- No Couplant Induced Errors
- High Inspection Speeds (up to 60 m/s)
- Capable of High and Sub-Zero Temperatures

**Insensitive to Surface Conditions**
- Capable of Inspecting Rough, Dirty (Oily/Wet), Oxidized or Uneven Surfaces

**Easier Probe Deployment**
- No Signal Variations from Probe to Probe
- Small Changes in Probe Angle do not Affect Results (e.g. part curvature)

**Unique Wave Modes**
- Capable of Generating Horizontally Polarized Shear Wave Energy
- Guided Waves (Especially Advantageous for Weld Inspection)

**Self-Calibration**
- Sample to Sample Self-Calibration of Signals on Guided Waves
- Accurate and Repeatable Inspections
- No need for Operator Interpretation

Ultrasonic Technique
- Volumetric Inspection
- Easy One-Side Access to Difficult to Reach Areas
- Meets UT Standards
- Safe
Waves that propagate constrained by boundaries are usually referred to as Guided Waves.

Guided Waves:

- What can be a waveguide?
  - A surface
  - A plate,
  - A rod, tube, pipe
  - rail or other structure

- In ultrasound, the practical range of guided waves can vary from centimeters to tens of meters
Guided waves have a lot of advantages for ERW weld inspection

- Guided waves fill the volume of the material enabling inspection of the entire weld in one shot
- Detects hook cracks, zipper welds, lack of fusion, and mismatch with greater reliability than angled beams
- Less sensitive to probe positioning, making it easier to automate and integrate into production
- Root and Crown reflections from poor flash removal can be selectively ignored (in some cases, permits inspection of unscarfed welds)
- Normalization of the signal for self-calibration
- Permits up to 55° of weld drift
EMAT-generated guided waves eliminate the shortcomings of piezoelectric methods

- Easier probe deployment and integration
- Ability to choose different modes to optimize sensitivity based on requirements (with or without scarfing)
- Dry inspection
  - Easier to install in production
  - No couplant management required
  - Permits installation near the welder at higher temperatures which results in less material loss, more mill uptime and elimination of drift issues
In-line installations are cost-effective, easy to operate and maintain

- Transmitter and Receiver positioned as shown (180 degrees apart) with weld between T/R
- Permits installation before or after the cooling trough
- Adjusts to a variety of diameters
- Diameter and thickness information can be collected automatically from line plc for automatic set-up
- Reduced number of sensors/channels and ancillary hardware provide a very cost-competitive solution
Inspection Results
Computer simulation (FEM) was used for technique development and to determine the sensitivity to defects

- At 220 micro seconds
Laboratory experiments corroborate the theoretical results

* Multiple reflections enhance the signals after several round
The results are presented in a simple format that is easy to interpret and to program for automatic operation.
Other EMAT Solutions for Tube and Pipe
EMAT is already used for a variety of inspection needs

Applications:
- Conventional Plate/Skelp inspection
- Thin (up to 12mm) strip inspection
- Thickness measurement at high temperatures
- Ductile iron pipes
- Seamless tubes
The temate® Pi-NB is used to inspect plates/skelp ranging from 0.25” (6mm) to 4” (100mm)

Characteristics:

- Up to 350 sensors perform simultaneous inspection of a plate moving at 100fpm using normal beam techniques

- Designed to detect 5mm flat bottom holes anywhere within 1.5mm from the top and bottom (Meets ASTM 578/A578M-96 and A435A and EN10160)

- Independent edge inspection to detect (2mm from edge) defects that would be in the weld material
The temate® Pi-GW is designed for full volumetric inspection of thin strip (up to 12mm) using Guided Waves

Characteristics:

- In-line or off-line installation
- 100% full volumetric non-traditional inspection
- Multi-channel system for different gage materials
- Detects internal defects at production speeds (over 400m/min)
- Custom designed for the each customer’s specific requirements
The temate® TG-IL is designed for measuring thickness in production environments

Characteristics:

- Ambient and high-temperature probes for continuous measurement of materials up to 1200°F (650°C)
- Integrated temperature correction for maximum accuracy
- Resolution down to 0.0005" (0.013mm)
- Capable of covering large areas using sensor arrays
- Other solutions available for ultra-high temperatures (1000°C)
The temate® Ti-DP is designed for inspection of Ductile Iron Pipes

Characteristics:

- Longitudinal crack detection without rotating the pipe or the sensor
- Exclusive flexible sensor technology that conforms to the surface of the material
- Completely automated operation. Easy to program and to interpret results
- Thickness and Nodularity measurement options
The temate® Ti-M is designed for volumetric inspection of tubes and pipes

Characteristics:

- Uses conventional techniques (half-skip, full-skip), adapted to EMAT
- Detects transversal and circumferential defects
- Different configurations available (rotating sensors, rotating and translating tube, rotating tube-translating sensors)
- Completely automated operation. Easy to program and to interpret results
- Thickness measurement options
Our Company

- US company located in Lynchburg, VA with offices in Europe and representatives and distributors throughout the world
- Focus exclusively on state-of-the-art Non Destructive Testing applications
- First EMAT (NASA) in 1989. First commercial EMAT in 1994
- World leader in commercial applications of EMAT with over 150 inline systems installed in 20 countries
- temate® and Rollmate product lines
Why Innerspec Technologies?

- World leader in design and manufacture of EMAT with our own, proprietary technology
- Off-line and in-line systems installed in industrial environments with millions of hours of inspection. Most (95%) are currently in operation 24/7
- R&D resources to tailor the technology to each particular application
- Experience in complete turnkey solutions for full automation or use by low-skilled operators
- Top references from world-class manufacturers
Thank You

Questions?