

Industrial X-Ray Inspection Futures

Swedish NDT Society (FOP) Webinar



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Agenda

Industrial X-Ray Inspection Futures

We will discuss 3 aspects for X-ray advances in field and bunker environments:

- NDT Challenges and Trends
- Usability advances in Flexible DDA, other next gen panel technology and industry standards implications
- Inspection speed brought about through automation and generative, robotic, and vision AI.
- Continuously improve NDT effectiveness
- Conclusion



Industry Situation



NDT Industry Challenges

• New Technology Features & Modalities

Acoustic Emission
Multiple sensors
Ultrasonic
Optical Sensing

X-ray/ CT image
 Spectroscopy
 Laser Excitation
 Piezoelectric

Visual Inspection
 Strain Sensor

- Resistivity
- New Materials & Applications
- People skilled workers
- Processes techniques, systems, reporting, standards
- Software more and better





Materials/Applications X-ray and beyond NDT

Traditional X-ray/CT NDT Topics

- Oil and Gas pipes, etc.
- Chemical
- Vessels
- Castings / Parts
- Road, Bridges
- Automotive
- Aviation
- Aerospace
- Art
- Electronics / BGAs

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Emerging NDT Applications

• Additive Parts





Body – hips, elbow, etc.

- Aviation turbine blades
- Pressure vessels
- Vehicles body, etc.

• Vehicle and other Batteries



• Hydrogen

Liquid Hydrogen Cooled Storage Tank



- Prismatic, Cylinder, etc.
- Liquid and Solid State
- Cars, Trucks, etc.
- Mobile, watch, etc.
- Storage/Transport Tanks
- H2 Pipelines
- H2 Power Stations
- Refinery, Chemical plant ..



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Flexibility / Usability



Usability & Advances in Software & Hardware

User Interfac of SW	of SW Form Factor/ of SW of HW		Casing	Technical of HW	Specs /
File Scanners	(CR	Port	able DDA	Flexible DDA
Stationary DDA	Large CT		UT/Pi	ezoelectric	Infrared
Visual / Cam	Ground Radar		Optic	cal & Lazer	Misc.

Flexible Use

- Multiple HW devices with a given category
- Simultaneous views of different studies, series
- Simultaneous views of multi-modality images





Flexibility / Usability – Case Study

Industrial X-ray Inspection Futures

Flexible DR

Sector

New Product Introduction planning for several industries
 Requirements

- $_{\odot}\,$ Fast, reliable, and good data sharing xray or gamma sources
- $_{\circ}$ 10 x 25 cm active area (up to 12 inch pipes)

Solution

- Flexible DR panel with wireless and wired connectivity to acquire SW
- \circ Applications
 - Pipe weld, erosion/corrosion (pitting), deposit in pipes
 - Other boilers, vessels, or tanks, etc. [back exposure]

	1		
H	1	205	
		the said	

System	Flexible DDA
Pixel pitch:	99 µm
Energy Range	50-450 KeV / gamma (SE/IR)
Integration time:	up to 180 seconds;multiframe

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Indicate	Indication Classify	Classification	Location	Dimension
1	Accept	Weld defect	1.2 meter, 17 ⁰	Small
2	Reject	Erosion	3.5 meter, 182 ⁰	Large
3	Reject	Pitting	4.7 meter, 232 ⁰	large
4	Accept	Deposits	5.2 meter, 47 ⁰	Small

ASTM DICONDE NDE Indication module planned Zero degree is marked with lead markers



X-ray Standards: ISO and ASTM Flexible and other DDA advances

Problem statement:

- ISO 17636-2 and ASTM standards are crucial for new technology adaption
- Standards have not set different norms for Flexible and some other emerging tech

Resolution :

- ISO 17636-s overview
- $\circ~$ ASTM overview
 - \circ SRB
 - o SNR
 - \circ Bad Pixels
 - o Other signal standards
- Pixel pitch and angles not an issue

	Designation: E2737 - 10	
	Standard Practice for Digital Detector Array Perform Term Stability ¹	ance Evaluation and Long-
	This standard is isometander the four despection E2777, the mortpeat adoption on it. Bu caused serialism, the year of tencomina separatelyst specific according an attention of damps sizes the term	nifter contentionally for lowering the designations and enter the year of Cast reapportal reviews or support of .
L Scope		2. Referenced Documents
1.2 This for industry evaluation	practice describes the evaluation of DDA systemial radiology. It is intended to ensure that the if image quality, as far as this is influenced by the	 ASTM Signifieds² EBDS Practice for Design, Manufacture, Grouping Classification of Hole Type Inc.

s process control and long term stability of the DDA	E1316 Terrarology for Nondestructive Examinations
s practice specifies the fundamental parameters of exector Array (DDA) systems to Se measured to hypeline performance, and to track the long term (the DDA system).	1990 Practice in Diarraphysics ("Additional") EWE Practice for Determining Total Image Undurgness in Radiology EA40 Practice for Performance Evaluation and Long-Term Stability of Computed Radiography Systems (2000) Provide of Neuropean Computer Systems (2000)
DDA system performance tests specified in this half be completed upon accuptance of the system configuration and intervals specified in this practical fore form withfilty of the oceans. The inner of these	E209 Practice for Statistication of Characterization of Digital E2008 Practice for Radiological Examination Using Digital Discourt Amyre
monitor the system performance for degradation and when an action needs to be taken when the system	A. Terminology
iy a comán krvel.	3.1 Defenitives-the definition of terms selating to gamma
use of the gages provided in this standard in for each test. In the event these tests or gages are ant, the user, in coordination with the cognizant	and X-radiology, which appear in Terreinology E1116, Practice E2997, Guide E2736, and Practice E2098 shall apply to the terms used in this practice.
g regarization (CEO) may deadop additional or-	3.2 Definitions of Territy Specific to This Standard:

Penetrated thickness w (a) in mm	Maximum BSR
w ≤ 1.0	50
1.0 < w ≤ 1.5	63
1,5 < w ≤ 2	80
2 <w≤5< td=""><td>100</td></w≤5<>	100
5 < _₩ ≤ 10	130
10 < w ≤25	160
25 < w ≤ 55	200
55 < _₩ ≤ 150	250
150 <w td="" ≤250<=""><td>320</td></w>	320
w > 250	400
(a) For double wall technique, sing	le image, the nominal thicknes
shall be used instead of	the penetrated thickness

Class B

6 inch SCH40 Se75 – DWSI – OD 168mm – wt 7.1mm



Se75
FS 3 mm
Source filter: no
SDD 174 mm
50Ci
4s int. time
10 frames

Example

- ISO 17636-2 requirements Class B: SRb Detector: 63 micron IQI detector side: w14 SNRn: 140
 - Class B achieved with CPII SRb Detector: 100 micron IQI visible: w16 SNRn: > 300



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Speed



One Click Automation

Sector

- Major aerospace and aviation inspection house
 Requirements
- No more than one swipe (for techniques) and one click
 Solution
- Supporting High Energy Linac in bunker
- Automatically turn on, warm-up, and take images, shutting down
- Lower dose required because of automation
- Can leverage QR codes, one click automation



One Click



System	Linac, High Energy DDA	
Pixel Pitch:	various µm	
Energy Range:	2-3 MeV / various filters	
Integration time:	.5 to 150 seconds	
Defects:	Cracks, Porosity, etc.	

Defect	Indication Classify	Classification	Location	Dimension
1	Conforming	Porosity /Void	2.45 x 9.92 cm	Small
2	Non-conform	Crack	8.57 x 17.33	Large
3	Non-conform	Porosity /Void	13.87 x 37.88	Large
4	Conforming	Lack of Penetration	18.33 x 45.22	Medium
5	Info only	Lack of Fusion	23.77 x 66.81	Small



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Artificial Intelligence

Generative Al

What? NDT aware large language models built into software.

What is technique should I use to shoot this 7 inch pipe? .. Use ...

Explain to me Contrast in X-rays? .. CNR and CR are 2 means of ..

Why?

- Batter remote support
- Faster learning of NDT concepts
- Faster learning of software
- Better NDT results: quality, safety, efficiency

ADR AI

What?

- ADR for FRAD weld, corrosion, parts
- ADR for CT batteries, BGA
- ADR for other domains



Why?

- Assisted or automated finding defects for faster analysis
- Results is accepted if no large defects automatically



What?

- Gantry and bots in fixed systems
- In field robots
- Sensors adding data for conditions
 and reliabilty



Why?

- Handle strenuous or dangerous inspections
- Reduce inspection time and costs
- Add data for analytics





Continuous Improvement



Get Better





Archiving

Sector

Major aviation firmRequirements

Requirements

- Store images for dozens of years in DICONDE compliant way
- Multi-modal support, barcode for DICONDE tags

Solution

- Archival system PCS based, run at multiple factories, images on AWS
- Multi-vendor acquisition and analysis software
- Multi-modal support for X-ray and UT







The Future Software Stack



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Conclusion



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