Work with ASTM Digital Reference Images

Digital reference image catalogues and image viewing

Dr.-Ing. Klaus Bavendiek
YXLON International GmbH
Hamburg, Germany

Durban, April 14th 2012
Contents

1. Introduction to Reference Images
2. List of the available ASTM Reference Images
3. Look on the Hardware
4. History of Digital Reference Images
5. Producing YOUR Reference Images
6. Requirements for Display and Viewer-Software
7. Work with the digital Reference Images
   - Example with Aluminum Casting
   - Example with Steel Casting
8. Conclusion

Practical demonstration in the coffee break …
Example of ASTM Reference Film Standard

What you get if you buy a Film-based ASTM Reference Image Set:
Standard Reference Image for Casting Applications

List of Standard Reference Radiographs for:

E155-10  Inspection of Aluminum and Magnesium Castings
E186-10  Heavy-Walled (2 to 4½-in. (50.8 to 114-mm)) Steel Castings
E192-10  Investment Steel Castings of Aerospace Applications
E272-10  High-Strength Copper-Base and Nickel-Copper Alloy Castings
E280-10  Heavy-Walled (4½ to 12-in. (114 to 305-mm)) Steel Castings
E310-10  Tin Bronze Castings
E446-10  Steel Castings Up to 2 in. (50.8 mm) in Thickness
E505-11  Inspection of Aluminum and Magnesium Die Castings
E689-10  Ductile Iron Castings
E802-10  Gray Iron Castings Up to 4 1/2 in. (114 mm) in Thickness
E1320-10 Titanium Castings
Standard Reference Image for Weld Applications

List of Standard Reference Radiographs for:

E390-11 Steel Fusion Welds

E1648-11 Examination of Aluminum Fusion Welds

E1955-09 Standard Radiographic Examination for Soundness of Welds in Steel by Comparison to Graded ASTM E 390 Ref. Radiographs
Additional Reference Image Standards

List of Standard Reference Radiographs for:
E242-10  Appearances of Radiographic Images as Certain Parameters Are Changed
E1936-07 Standard Reference Radiograph for Evaluating the Performance of Radiographic Digitization Systems

List of Standard Guides to:
E431-07  Interpretation of Radiographs of Semiconductors and Related Devices
E592-09  Obtainable ASTM Equivalent Penetrometer Sensitivity for Radiography of Steel Plates 1/4 to 2 in. (6 to 51 mm) Thick with X Rays and 1 to 6 in. (25 to 152 mm) Thick with Cobalt-60
Why Digital Reference Image Standards?

The world of NDT is going DIGITAL. Why?
- Cheaper
- Faster
- More reliable
- Better Image Storage (lossless)
- Image transferable over the network – worldwide

Films as reference images look different and handling is different
- Inverse display to digital detectors
- Manual magnification (with Magnifying Glas and Distance to the film)
- Brightness adjustment with the lamp
- No contrast relationship between Digital Image and Film

⇒ ASTM went DIGITAL with the Reference Images, too
   (in parallel to the Standards for CR and DDAs)
Digital Reference Image Standards

Standard Digital Reference Images for
- E2422-11 Inspection of Aluminum Castings
- E2660-11 Investment Steel Castings for Aerospace Applications
- E2669-11 Titanium Castings

In progress:
- WK32179 New Specification for Standard Digital Reference Images for Inspection of Magnesium Castings (Film: E155 – Magnesium)
- WK36384 New Practice for Digital Reference Images for Steel Castings Up to 2 in. (50.8 mm) in Thickness (Film: E446)
- WK 3?? New Practice for Digital Reference Images for Aluminum and Magnesium Die Castings (E505)
How do the Reference Plates look like?
How do the Reference Hardware Plates look like?

3 Reference-Shims with +/- 4% difference in material thickness

Wire IQI and Plate hole IQI not on plate!
Film sheets in folders

How do the Reference Hardware Film Plates look like?

ALUMINUM-SHRINKAGE CAVITY - ¼ in.

1  2  3  4
5  6  7  8

... as pictures of the film plate (with a digital camera)

the Reference-Shims are not visible on the film
How do the Reference Plates look like in a digital image?

... and as images taken with a digital detector (PerkinElmer XRD1620)
How do the Reference Plates look like in a digital image?

ALUMINUM - SHRINKAGE CAVITY - 1/4"
<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>First approach of BOEING to digitize the E155 Aluminum images. Digitization at BAM in Berlin with 10μm resolution and 16 Bit depth.</td>
</tr>
<tr>
<td>2002</td>
<td>Reference Plates were captured with different DDAs (BOEING / YXLON).</td>
</tr>
<tr>
<td>2005</td>
<td>Films were scanned again (BAM) and DVDs were distributed.</td>
</tr>
<tr>
<td>2010</td>
<td>Digital reference image standards for Steel and Titanium Casting.</td>
</tr>
<tr>
<td>2011</td>
<td>Contrast Normalization skipped as mandatory procedure (POD study).</td>
</tr>
</tbody>
</table>
### Example of ASTM Reference Images: E155 Aluminum

8 Levels (1 .. 8) of severity for all type of discontinuities;
2 material thickness levels (1/4“ and 3/4“);
7 type of discontinuities:

<table>
<thead>
<tr>
<th>Type of Discontinuity</th>
<th>material thickness</th>
<th>1/4“</th>
<th>3/4“</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminium Gas Holes</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Aluminium Shrinkage Cavity</td>
<td></td>
<td>X</td>
<td>n.a.</td>
</tr>
<tr>
<td>Aluminium Foreign Material, less density</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Aluminium Foreign Material, more density</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Aluminium Shrinkage Sponge</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Aluminium Gas Porosity Round</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Aluminium Gas Porosity Elongated</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
Procedure of creating YOUR digital Reference Images

What is in the box?

- 2-3 DVDs with the images in 10μm geometrical resolution

- Software Tool for creating YOUR images (10 - 400μm resolution)

- ASTM standard text
Procedure of creating YOUR digital Reference Images

What is in the box?
- DVD(s) with the images in 10μm geometrical resolution
- Software Tool for creating YOUR images (10-400μm geometrical resolution)
- ASTM standard text

How to make your reference images?
- select the system resolution(s) for the applications
- install the Reference image creation program from DVD and start the program „makeDRI“
- store the images in the ASTM reference image folder on your PC
- repeat with another resolution

How to get the right resolution?
- the right resolution is the pixel pitch of the detector divided by the magnification
  (as long as the detector pixel size do not differ by >30% to the measured SRb)

How to select the proper discontinuity type and severity level?
- this shall be provided with the software of your X-Ray system supplier ...
Work with the digital Reference Images

What is needed to work with the DIGITAL reference images?
- large monitor or two (identical) monitors
- software which is able to display two images in parallel on the monitor(s)
- conjunction between both images in contrast, brightness and resolution
- SNR measurement feature in the software
- measurement of distances in the software

- Display of positive or negative format
Work with the digital Reference Images

Requirements for the Viewing Software – Part 1

✓ Import of the Ref. Images in 16-bit TIFF or DICONDE format
✓ Select the required resolution (in 10µm steps)
✓ Ref. Images selectable by discontinuity type
✓ Display of production and Ref. Image on same monitor or on two monitors with matched to provide same brightness and contrast
✓ Lock the zoom level for production and Ref. images
✓ Display the RAW data value and Display value at current cursor position
✓ Show the distance of two points in the image
✓ Adjustment of Contrast for production image (window width)
✓ Independent Adjustment of Brightness for production and ref. image (window level)
Work with the digital Reference Images

Requirements to the Viewing Software – Part 2

- Generating Line Profile in RAW or Display grey value units
- Select ROI and calculate Average and Standard Deviation in the ROI
- 1:1 Pixel mapping of image to display
- Equivalent image processing functions as filters, smoothing, edge enhancement, conversion data through LUT, ...
- Step wedge in one production image per X-Ray setting to do contrast normalization
  - the step wedge made of appropriate material
  - step wedge covers used material thickness range
  - adjustment of contrast and brightness in both images that change in displayed grey levels versus change in thickness is the same in production and Ref. Img.
  - software feature to do the contrast normalization
Work with the digital Reference Images

Requirements to the Display Unit (Monitor)

✓ Brightness >250cd/m²
✓ Contrast >250:1 (max. brightness divided by min. brightness)
✓ Display of linear patterns of alternating pixels with full contrast without aliasing (hori. and vert.)
✓ Display of linear patterns of alternating pixels with 100% modulation
✓ Monitor free of discernible geometric distortion
✓ Monitor free of screen flicker (high frequency fluctuation of high contrast image details)
✓ Differ between 0% and 5% and simultaneously 95% and 100% grey level blocks clearly perceptible by the user

NOTE 5:
Use SMPTE test pattern as defined in RP133 in the validation of system requirements.
Prove of monitor resolution

Available as YXLOON tool
Work with the digital Reference Images

Start image capture and select ASTM Reference Image set:
Here: E2422 (Aluminum), 200μm Resolution.
Work with the digital Reference Images

Select the proper resolution

![Digital Reference Image](image-url)
Work with the digital Reference Images

Magnify to a size that the flaws are clearly visible (e.g. 1:1)
Work with the digital Reference Images

Select the type of discontinuity (here: Gas Hole – GH)
Work with the digital Reference Images

... material thickness range (3/4") and select the Level (will be centered on the display)
Work with the digital Reference Images

... material thickness range (3/4") and select the Level (will be centered on the display)
Work with the digital Reference Images

Select the material thickness range do be displayed with the reference image
Work with the digital Reference Images

Select the material thickness range do be displayed with the reference image
Work with the digital Reference Images

If a flaw is on a gradient, a filter will help. It may be applied on the ref. image, too.
Work with the digital Reference Images

If required (and available), select a contrast normalization set for thickness measurement.
Work with the digital Reference Images

Lock the scaling for contrast normalization and thickness measurement
Work with the digital Reference Images

The covered material thickness ranges is displayed – based on the stepwedge calibration
Work with the digital Reference Images

The spatial resolution may be verified with the Line Profile on the EN462-5 IQI.
Work with the digital Reference Images

In this example Duplex Wire D7 is resolved (200µm resolution)
Work with the digital Reference Images

For Steel Castings the reference images are in the E2660 folder

Calibrate thickness with the two step wedges
Work with the digital Reference Images

Look for the first flaw and grade type and level (Shrinkage Cavity, Level 4)
Work with the digital Reference Images

Look for the next flaw and grade type and level (Cold Crack, no Level)
Material Thickness Evaluation by Grey Value differences

For contrast normalization a thickness calibration is needed

Asure to have a stepwedge with known sizes and same type of material in the image.
Material Thickness Evaluation by Grey Value differences

For contrast normalization a thickness calibration is needed
Material Thickness Evaluation by Grey Value differences

For contrast normalization a thickness calibration is needed

A box will open and you put in the thickness and mean greyvalue of all steps of the stepwedge.

Start with the „background“ value (0“ material thickness)
Draw a ROI in an area with no material and see the grey value

\[ \text{Mean} = 45440.40 \]
Material Thickness Evaluation by Grey Value differences

For contrast normalization a thickness calibration is needed

Press Set1 and the mean grey value of the ROI will be transferred to step no.1.
Material Thickness Evaluation by Grey Value differences

For contrast normalization a thickness calibration is needed

Continue with the next step and enter material thickness (here: 2mm == 0.07874")
Material Thickness Evaluation by Grey Value differences

For contrast normalization a thickness calibration is needed

Continue with the next step and enter material thickness (here: 2mm == 0.07874\" until the last step is entered (16mm == 0.63\").
Material Thickness Evaluation by Grey Value differences

For contrast normalization a thickness calibration is needed

Save the thickness calibration and make active.
Material Thickness Evaluation by Grey Value differences

Now you will see the material thickness at the mouse pointer (in “) beside the hole.

And the scaling of the image in material thickness difference.
Material Thickness Evaluation by Grey Value differences

If you move the pointer in the center of the hole you get another material thickness.
Material Thickness Evaluation by Grey Value differences

The software will calculate the grey values to material thickness values.
The difference is the depth of the hole:

\[
\begin{align*}
0.367" \\
-0.322" \\
0.045"
\end{align*}
\]

\( (1.14 \text{mm}) \)

\( dv = 1010(0.322) \)

\( dv = 780(0.367) \)

(same can be done with the line profile function …)
Material Thickness Evaluation by Grey Value differences

Display the hole depth with the calibrated line profile

1. Set the Zero-Pointer at the lowest material thickness
2. Move the Pointer beside the hole and see the difference in thickness

YXLON
Technology with Passion
Level Estimation by size and depth

This technology may normally be used to compare the diameter and depth of an indication with the diameter and size of an ASTM Reference Image Level.

For this presentation it is used to evaluate the diameter and depth of a Gas hole of an 3/8" ASTM Reference Image by reference to a drilled hole of known size.
Level Estimation by size and depth

Select the thickness for the reference image set (3/8”) and the type of indication

(215.547) V = (131) dV = 23890 (0.368), Z:1.00,

(1.1 mm, 0.3657 inch, dY = 0.0451 inch)
Level Estimation by size and depth

Measure the diameter of the known hole in actual image

(1.2 mm, 0.3585 inch, dY=-0.0043 inch)
Level Estimation by size and depth

Do the same with the gas hole in reference image; compare the size
Level Estimation by size and depth

Select the minimum and maximum thickness in the line profile on both images.
Level Estimation by size and depth

Select the minimum and maximum thickness in the line profile on both images.
Level Estimation by size and depth

Select the minimum and maximum thickness in the line profile on both images

Actual Image
(1.2 mm, 0.3585 inch, dY=-0.0043 inch)
(0.7 mm, 0.3615 inch, dY=0.0168 inch)

Reference Image
(1.2 mm, 0.3685 inch, dY=-0.0001 inch)
(0.7 mm, 0.3685 inch, dY=0.0152 inch)

Diameter
Depth

The sizes of both indications are similar.
Use Stepwedges together with the Reference Images

Strongly Recommended!

INCLUDES 7
1/4 in. (6.35 mm)
CASTINGS

Standard Digital Reference Images for Inspection of Aluminum Castings

YXLON
Technology with Passion

1/4”

3/4”
Conclusion

Three (+ three future) types of ASTM reference image sets are available.

Clear way of use is described in ASTM standards.

Digital Reference Images are an Equivalent to Film Reference Images – no more reason to wait for going digital when having „old contracts“

Reference in area and intensity is possible with contrast normalization.
Thank you for your attention