ARGOS

one-click surface inspection
Inspection of optics – current situation
Inspection of optics – current situation

Visual inspection

- Flexible
- Subjective
- Challenging and depending on concentration and fatigue
- Time consuming
- Test reports without images and details
Advantages of automated inspection

- Objective criteria
- Reliable and reproducible results
- Detailed test reports
- Digitization of the inspection process
### Dimensional specification of surface imperfections in ISO 10110-7

#### General surface imperfections and contaminations
- Imperfections in the coating (after the coating process)

#### Long scratches
- Max. width with $L > 2\, \text{mm}$
- Edge chips (extent)

#### Specified Grades
- $\sqrt{\text{area}}$ in mm
  - Imperfections with a grade number $>16\%$ of the spec are accumulated (sum of areas)
- Width in mm
  - Scratches with a width $>25\%$ of the spec are accumulated (sum of widths)
- Extent in mm
  - Any quantity of edge chips up to this value is allowed

### Table

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A_{g,c}$</td>
<td>$\sqrt{\text{area}}$ in mm</td>
</tr>
<tr>
<td>$A_l$</td>
<td>Width in mm</td>
</tr>
<tr>
<td>$A_e$</td>
<td>Extent in mm</td>
</tr>
</tbody>
</table>

**Values:**
- $5/3 \times 0.16; C \ 1 \times 0.10; L \ 1 \times 0.006; E \ 0.1$
Effective area, width and concentration
according to ISO10110-7:2017

- Effective area = \( N_g \times A_g^2 \)
- Effective width = \( N_1 \times A_1 \)

**Concentration**

- Concentration, if effective area of defects in 5% of the test area is larger than 20% of the allowed maximum size defects
  - Smaller defects are summed to equivalent max grade number
  - If \( N < 10 \), 2 or more maximum grade defects in 5% of the test region are a concentration
Subjects to debate in manual-visual inspection

How you would interpret and evaluate the example on the right?

- A single defect?
- Many small defects? Are they even relevant?
Resolution of the method according to ISO 14997:2017

- Eye resolution approx. 1 arcminute
- 0.1 mm in the test stand

- Required resolution = 16% of the specification for digs
- Required resolution = 25% of the specification for scratches
- Minimum value for visual testing: 5/1x0.63; C1x0.63; L1x0.1
  - use magnification for smaller defects!
Segmented defects new according to ISO 14997:2017

- Defects which are further separated than the required resolution are classified as independent defects

For Example:

- The two point defects at the top shall be treated as one imperfection
- Separate the two scratch-like defects
  → If the length < 2mm, treat as general imperfection
Objectivity

- Accuracy 1 μm
- Visibility 1 μm
- Repeatability
  >99% with 5/1x0.16
  >96% with 5/1x0.04
- Calibration with reference sample
Automatic classification according to dimensional ISO 10110-7 specification
Digitization of the inspection process

- Database with classification results
- Batch analyses
- Data-driven process improvement

ARGOS® Test report

Passed

Sample
- Drawing number: 3279
- Description: Batch 001, Sample 025
- Date of production: 11.04.2016
- Component type: transmissive

Diameter: 15.5 mm
Orientation markings: None
Inspection method: IM
Surface specification: S/2x0.160;L1x0.010

Largest Defects

<table>
<thead>
<tr>
<th>No.</th>
<th>Position</th>
<th>Type*</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>R = 5.9 mm, φ = 128.6°</td>
<td>S</td>
<td>0.010 mm</td>
</tr>
<tr>
<td>2</td>
<td>R = 6.8 mm, φ = 18.9°</td>
<td>D</td>
<td>0.063 mm</td>
</tr>
</tbody>
</table>

* D = Dimp, S = Scratch, C = Coating Imperfection, E = Edge Chip

Summary

<table>
<thead>
<tr>
<th>Specification</th>
<th>Detected</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imperfection concentration</td>
<td>ISO 10110-7</td>
<td>No</td>
</tr>
</tbody>
</table>
Data analysis beyond ISO 10110-7
ARGOS – automated surface quality inspection

- Inspection of flat and curved samples
- Up to 45 mm diameter, scanned in 2 seconds
- Specifications down to 5 / 1x0.016

New:
Up to 200 mm diameter!
Image acquisition and transformation

Acquisition

Raw (polar) image

Transformed image

50000 lines

15000 x 15000 px
250 megapixel!
Inspection of curved optics

EDOF (Extended Depth of Field)

- Merged image of several optical layers
- Very flexible
- Top and bottom side
- Volume scan is possible (testing for bubbles and inclusions)
Extended depth of field

1. Capture focus stack of curved sample
2. For each defect, find best layer
3. Place defect of best layer in final image
Curved optics example

Convex surface,
21 mm diameter
4 mm sag
Curved optics example
Curved optics example – image with extended DOF

All in focus!
Example: Volume test – display of a mobile phone

Good visibility of the pixel matrix on the display

Bubbles in the glue between display and cover glass

Long scratch on the surface of the glass
Inspection of optics with large diameters

- Inspection of optics with diameters larger than 45 mm requires scanning in several rings
- Each ring is ~20 mm wide
- Up to 200 mm diameter are possible
- Limitation: Inspection times scale with the area, inspecting a 200 mm sample takes 20 times as long as inspecting a 45 mm diameter sample
Inspection of multiple flat optics

- Multiple optics can be scanned at once under the following conditions (requires an additional software package):
  - Diameter of each sample is max. 20 mm
  - Only plane substrates, as curved surfaces would cause reflections
- A custom sample holder is needed for this type of inspection, DIOPTIC can provide assistance in designing a suitable solution.
ARGOS profiles – true one-click inspections

- Inspection tasks are defined in *profiles*
  - Specification
  - Part geometry, e.g. diameter, clear aperture
  - Surfaces/regions to be inspected, multiple regions with different specs are possible
  - Layers to be scanned in focus stack
  - etc.
- New tasks can be created from templates by adjusting all relevant parameters
- The operator only selects the profile based on the part number and starts the inspection
ARGOS profiles – true one-click inspections

1. Select profile from list

2. Start scan
Beyond optical components...

Testing the “new kilogram” for surface imperfections
Acknowledgements: Rudolf Meeß, PTB Braunschweig
Thank you for your attention

ARGOS®

objectivity

industry 4.0

speed

completeness