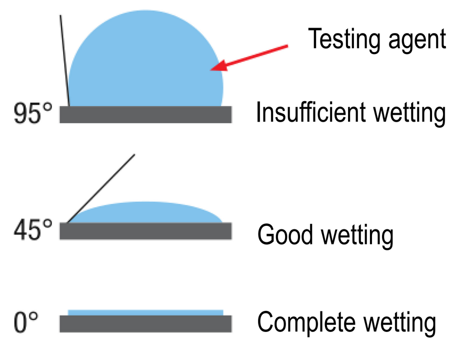
Flaw Indications with Magnetic Particle Inspection and Penetrant Testing

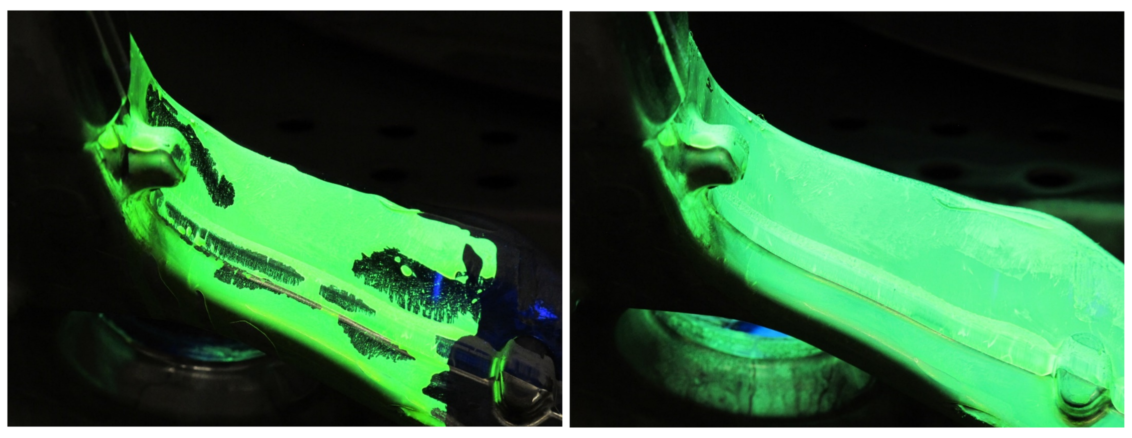
Physical and Chemical Influence Factors

Wettability



The wetting behavior describes the property of a liquid to spread on a surface. For MT and PT testing agents, it is important that a small contact angle is formed between the media and the component surface. Then a good wetting ability is achieved. An incomplete wetting of the surface can lead to deterioration of the crack indications. The surface condition of the test parts needs also to be taken into account. Wetting on parts with a rough surface is completely different from that on parts with a machined surface. Wetting of smooth surfaces is much more difficult. Reflections during illumination or inspection need to be avoided as well.

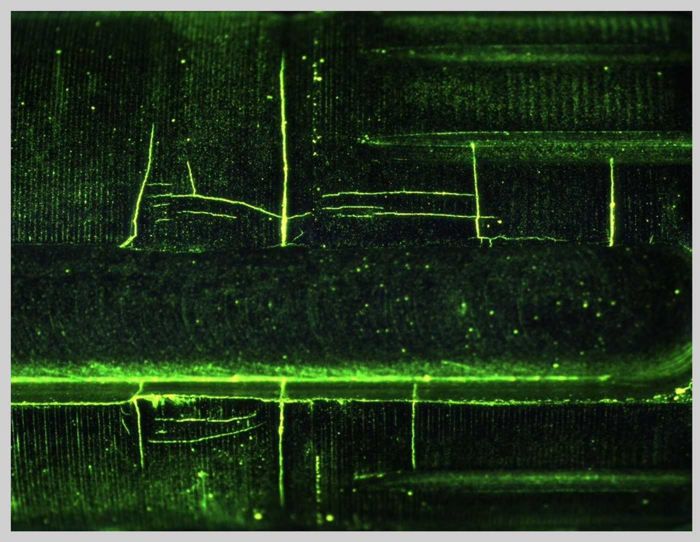
Residues of cooling lubricants from upstream mechanical processing can cause difficulties during magnetic particle testing. Pre-cleaning would mean an additional process step and in many cases this step is undesirable. For this reason, there are special formulations that also allow wetting of slightly soiled test parts.



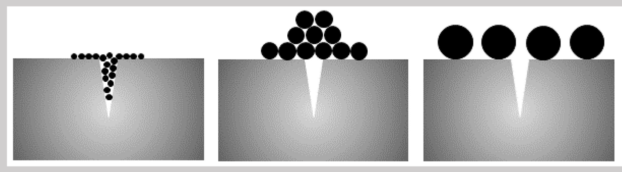
Forged part with very smooth surface: Poor wetting with water-based penetrant (left) and good wetting with oil-based penetrant (right).

Grain sizes of magnetic particle testing agents

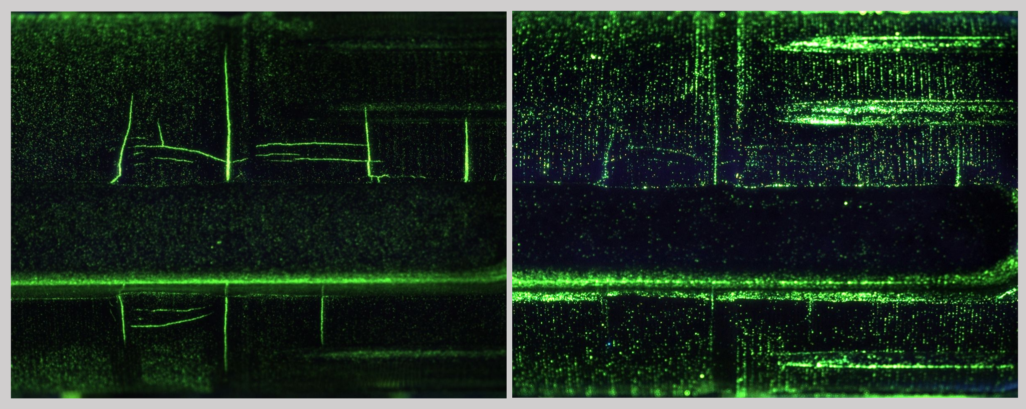
For the detection of defects, it is necessary that the magnetic powder particles can accumulate at a crack. The indications appear wider than the actual crack due to the magnetic flux leakage at the crack. Among other things, the size of the particles is very important. Particles that are too small can migrate into the crack and cause a reduction in flux leakage by filling it. On the other hand, if the particles are too large, the flux leakage formed cannot fix the particles to the crack. The particle size should approximately correspond to the expected crack width to achieve the best results.



The optimal grain size of 3 µm also shows fine cracks.



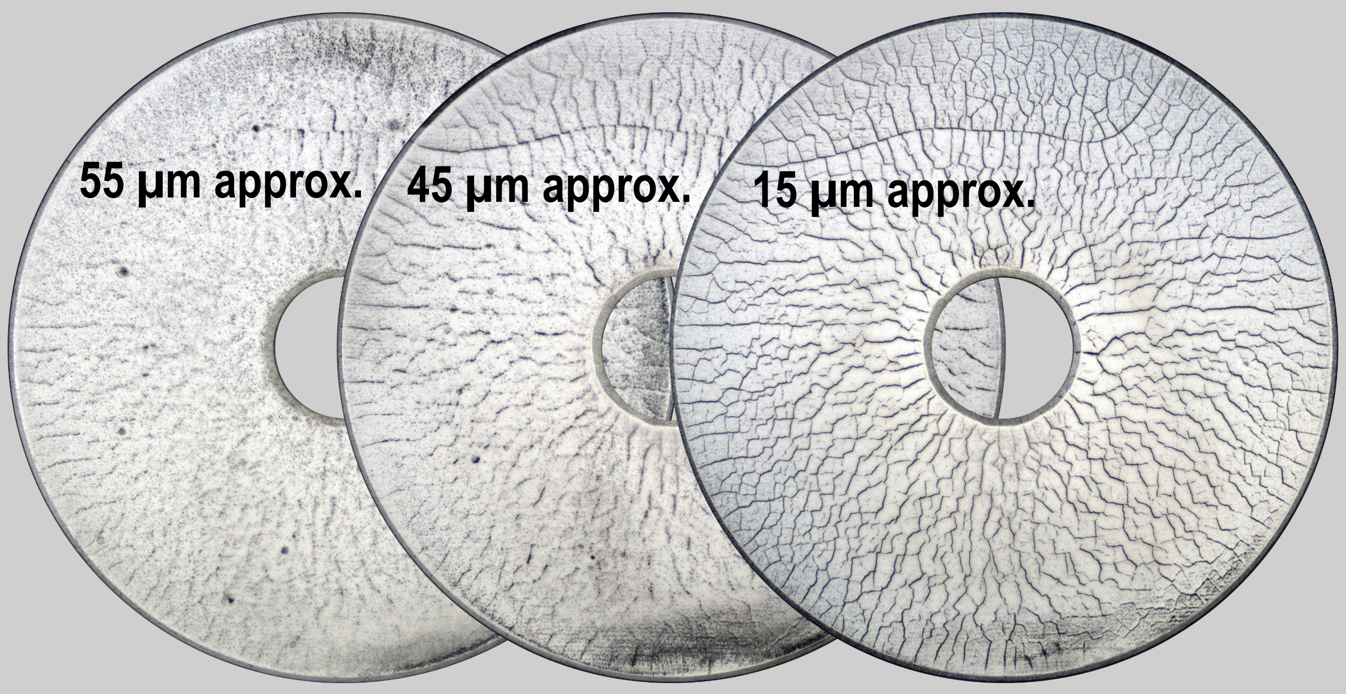
Schematic representation of grain sizes in relation to crack width. The crack indication is optimal if the grain size corresponds approximately to the crack width (center image).



Suboptimal choice of grain size: loss of fine crack indications with grain size of 9 µm (left) and unusable indications with grain size of 40 µm (right, loss of all fine crack indications, loss of contrast of all crack indications compared to background).

Influence of the layer thickness with contrast paints

A layer thickness below 50 µm for non-ferromagnetic coatings, such as paints, is considered unproblematic for magnetic particle testing according to EN ISO 9934-1 and ASTM E 709. For coating thicknesses above 50 µm, the indication sensitivity deteriorates considerably. To verify this threshold, the following experiment was conducted. The reference block 1 (formerly called MTU test block) was coated with white contrast paint of different thicknesses. The layers were measured with a LEPTOSKOP 2042. The effects of different thicknesses are clearly visible.



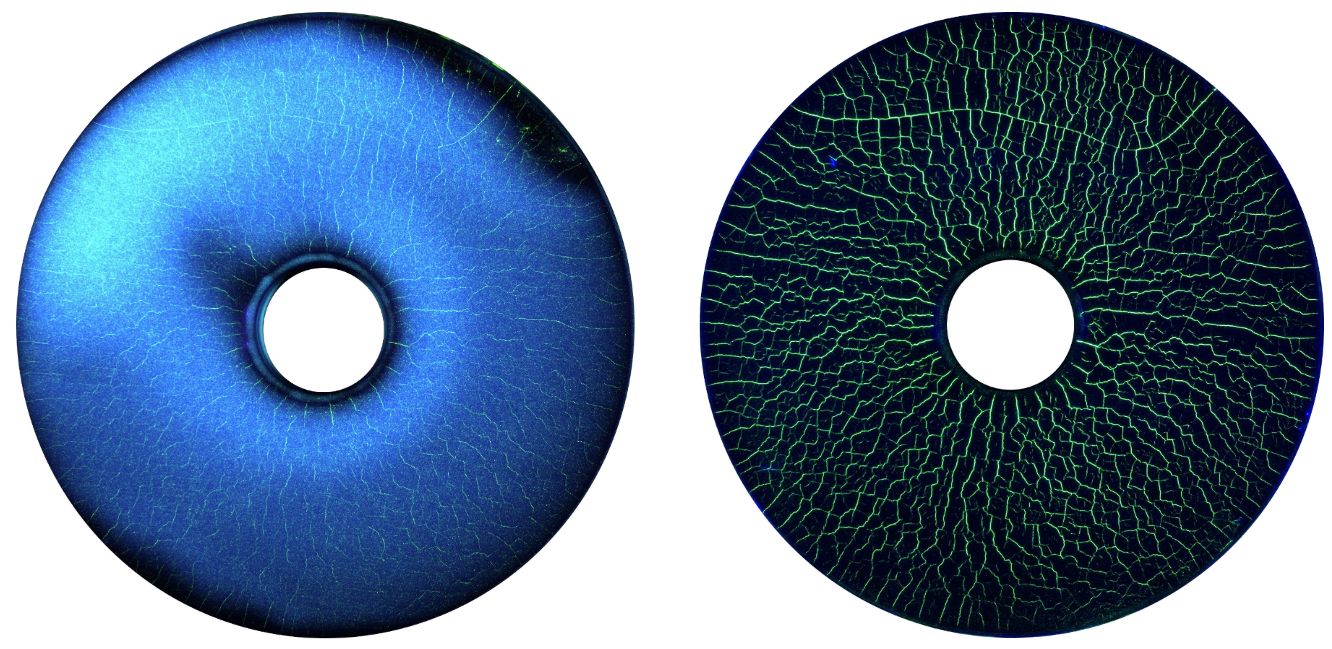
Indications with black MT testing agent on reference block 1, which was previously coated with white contrast paint of different film thicknesses.

Intrinsic fluorescence of MT testing oils

When wet testing with oil, it is very important for the indication quality that the carrier medium shows as little or no intrinsic fluorescence as possible. To determine whether the fluorescence is within an acceptable range a quinine sulfate solution is used as a reference for optical comparison.

Testing oils especially those used in metalworking often contain UV markers that complicate crack evaluation with fluorescent magnetic particle testing. The fluorescence of the crack indications is superimposed by the fluorescence caused by the UV markers. The indications become difficult to recognize.

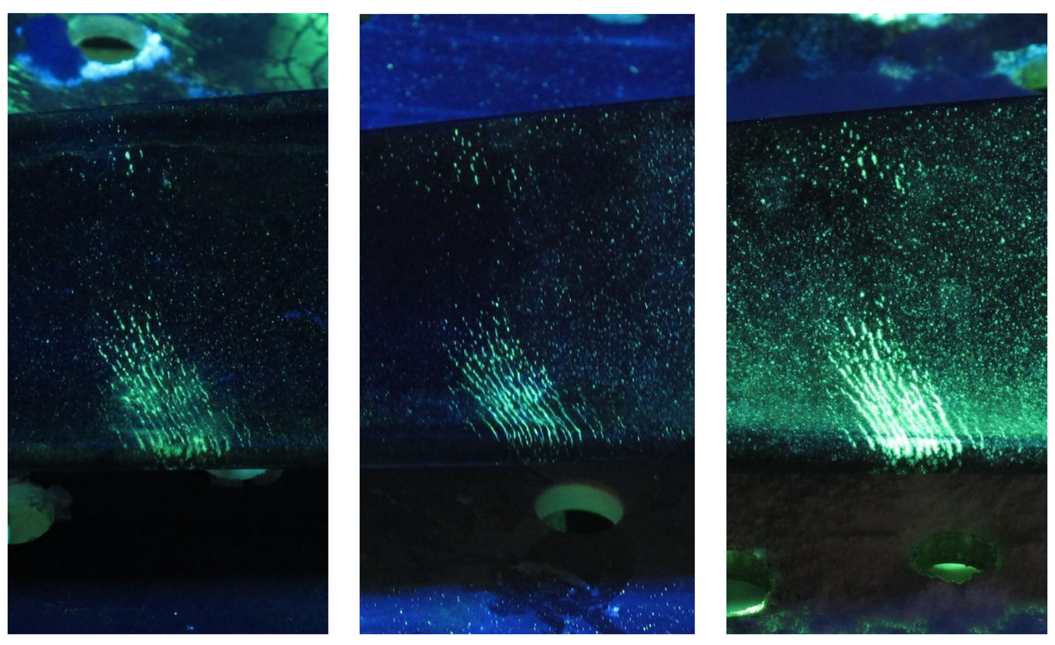
Oils without intrinsic fluorescence avoid disturbing background fluorescence. High-contrast indications can be achieved and lead to higher test reliability.



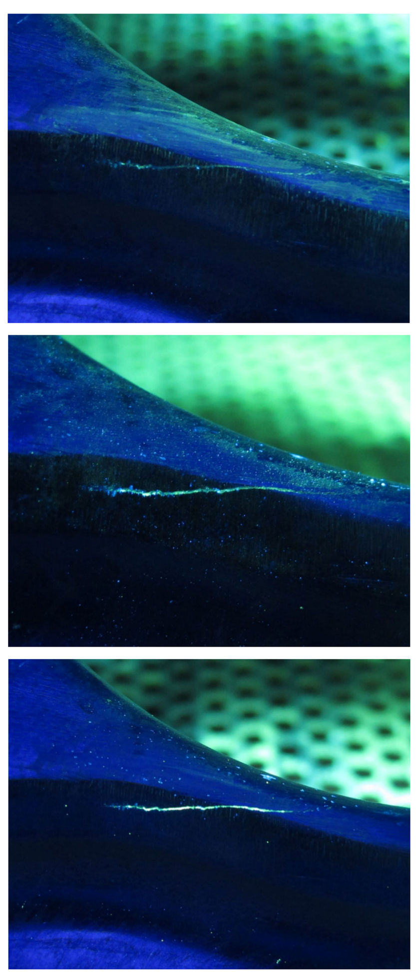
Testing with oil on reference block 1 using an unsuitable oil with high fluorescence (left) and an MT testing oil without fluorescence (right).

Sensitivity classes for fluorescent PT agents

The sensitivity classes of Type I penetrants result from the type of chemical composition, the wash-off behavior during intermediate cleaning and the interaction with the respective developers. For good detection sensitivity, not only the sensitivity class should be considered when selecting the testing agent system. The type of microstructure separation to be expected, the surface condition and the material to be tested, especially with regard to sufficient wettability, are also essential selection criteria.



Indications on a titanium turbine blade with fluorescent penetrant and dry developer according to method IAa. The sensitivity class 2 shows the best result of the three sensitivity classes 0.5 / 2 / 4 according to EN ISO 3452-1.



Indications on a forging with fluorescent penetrant and dry developer according to method IAa. In this case the sensitivity class 4 shows the best result of the three sensitivity classes 0.5 / 2 / 4 according to EN ISO 3452-1.

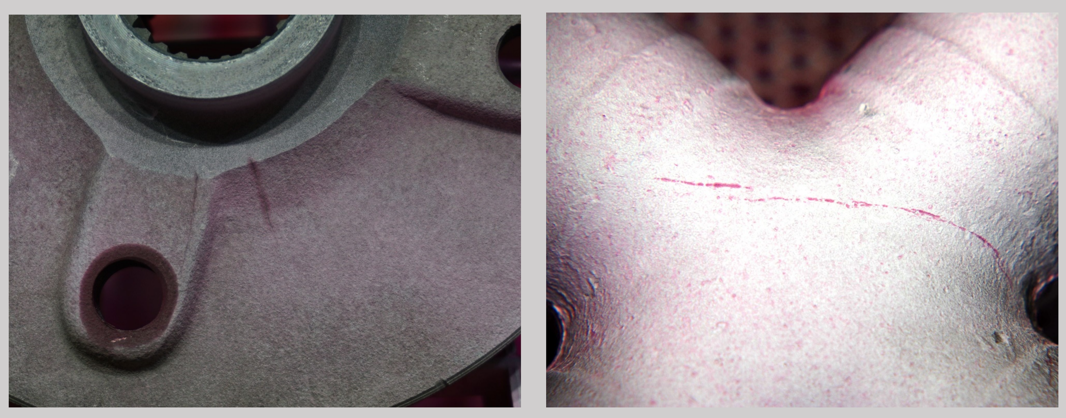
Contrast with penetrant testing

Good color contrast with dye penetrant testing and good luminance contrast with fluorescent penetrant testing are basic requirements for standard-compliant evaluation of indications on defective components.

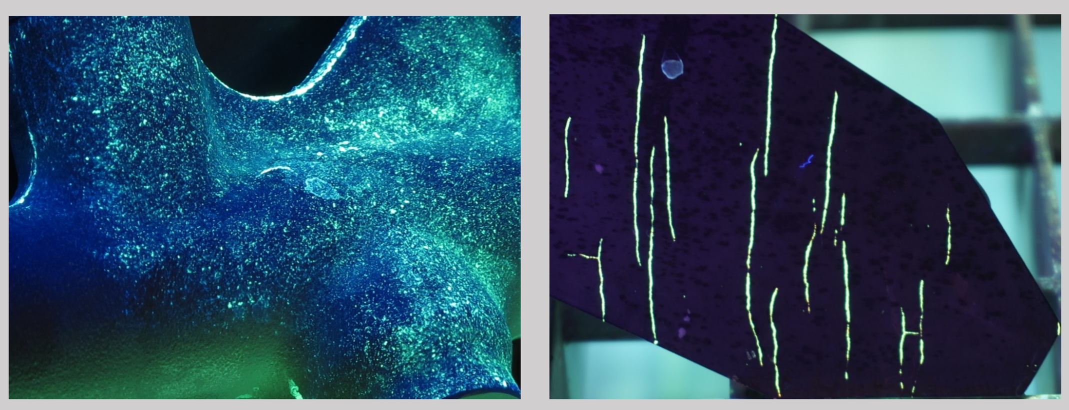
There are a number of factors that can influence the contrasts:

- Testing system
- Testing technique
- Material of the component
- Surface condition and preparation
- Visible light intensity (color contrast) and black light intensity (luminance contrast)

Four test results, obtained in different test tasks, are intended to illustrate the range of different contrast levels in PT testing.



Test results with the dye penetrant testing (red/white). The developer application on a forging is insufficient. The contrast between background and display is considerably reduced (left). The uniformly covering developer layer on the casting provides a good color contrast (right).



Test results with the fluorescent penetrant testing. Use of a solvent-based wet developer on a forging with a rough surface. The luminance contrast is reduced (left) due to increased background fluorescence. Indications on a ground component surface without disturbing background fluorescence ensure optimum evaluability.

Stephan Robens, Oliver Goerz, Wolfram A. Karl Deutsch, 1st prize of the poster competition at the DGZfP annual meeting 2021

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