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Reproducible Production of Magnetic Powder Crack Detecting Agents

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An informative paper, by

W.A.K. Deutsch, R. Wagner, W. Weber

Summary

Reproducible production of magnetic-particle inspection medium.

The magnetic particle method is one of the oldest and simplest non-destructive tests. The method is applied for many components, mainly in the automotive industry. In case that for a given serial component the needed testing sensitivity is once defined, the most important requirement then is to guarantee a permanently constant realisation of this sensitivity with each individual testing procedure. In order to ensure that with the method of magnetic particle testing of safety-components reproducible results are obtained, the constant quality of the applied magnetic-particle inspection medium is the most important requirement. A water-based ready-concentrate for the fluorescent test method serves as an example for the discussion of the specific acceptance criteria like magnetic-particle content, operating life time, corrosion inhibition properties, fluorescence ability and wetting properties.

Reproducible Production of Magnetic Particle Agents

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1 Introduction

Magnetic particle testing (MT) is one of the oldest and simplest methods of the non-destructive testing (NDT). It is used for many workpieces, mainly in the automotive industry. Once the required testing sensitivity for a certain workpiece has been defined, this sensitivity must be kept constant for each individual inspection.

In order to guarantee the reproducibility of test results for MT of safety parts, the following factors are of major importance:

- Proper functioning of the used magnetising instruments
- Keeping the viewing conditions in conformance to the relevant standards (e. g. ISO/FDIS)
- Trained personnel (EN 473)
- The constant quality of the used magnetic particle agents.

2 Classification of Magnetic Particle Agents

The various MT-agents are classified according to their type of contrast generation and the application procedures. The following types are typically used:

I. Fluorescent (UV-irradiation)
II. Non-fluorescent (daylight), and
III. Daylight- and UV- fluorescent.

For MT with stationary magnetic benches, e. g. of forged parts, mainly fluorescent MT-agents under UV-irradiation (I) are used. For the mobile inspection (outdoors), mainly non-fluorescent (II) or daylight- and UV-fluorescent testing agents (III) are used. The required darkening of the surrounding area for fluorescent media (I) is then avoidable.

Another subdivision for given contrast generation depends on the possible application methods. Here, it is distinguished between:

- Dry testing powder and
- Wet testing agents

The carrier medium for dry powders is air. Nowadays they are hardly used due to their inconvenient handling and their comparably coarse grain (approx. 20 µm to 300 µm) of the magnetic particles. Testing of semi-finished products where only coarse cracks shall be indicated is still a typical application.

Caused by the increased sensitivity requirements, nowadays mainly wet testing agents are used. Here, magnetic particles down to 1 µm grain size can be used. Therefore, the detection sensitivity for finest cracks is remarkably increased. Water or oil are used as the carrier medium. Currently, water is usually preferable: It is cheaper than oil, generates much lower or no costs for disposal, does not burn, has no bad smell, and does not cause allergic reactions for the testing personnel. Oil as a carrier medium nowadays is only used if the testing standards enforce oil, require it, or if highly corrosion-sensitive parts are tested, or if the specimen surface is very oily.

In order to guarantee a uniform testing sensitivity, the user hardly combines the various ingredients, such as magnetic powder, wetting agent, and anti-corrosives by himself. The current state-of-the art suggests the use of

a) Ready-for-use MT-agent suspensions, or
b) Ready-concentrates.

Ready-for-use suspensions (a) are often supplied within spray cans (aerosols), e.g. for construction sites and for sampling inspection. In this case, the user has no possibility of influencing the composition of the testing agent.

A ready-concentrate (b) has only to be mixed with the carrier medium (water or oil) according to the recommendations of the MT-agent producer. This is currently the preferred method of choice, because the chances for incorrect handling are reduced to a minimum. Also, the user can influence the testing sensitivity by varying the mixing ratio in order to match the specific needs for a given testing task.

3 Acceptance Criteria for a Fluorescent, Water-Suspendible MT-Concentrate

The producers of MT-agents have to guarantee a constant sensitivity of their products. This is achieved by defining final acceptance criteria, e.g. for a fluorescent, water-suspendible MT-concentrate.

All results of the final acceptance test are documented in the acceptance protocol, which is enclosed with each delivery. The protocol is a document in accordance with EN ISO 9001 with quality standards defined and supervised by the responsible expert. First, it shows the precise identification of the product: Indicated are the product name, the date of production, and, most important, the batch number which is needed for a later identification and for retracing. In tabulated form, all relevant acceptance criteria are listed with their nominal and their measured values. The respective batch is released for delivery after the protocol is signed by the responsible person in charge. In detail, the following acceptance criteria must be fulfilled:

3.1 Fluorescence Coefficient acc. to DIN 54 132

The fluorescent brightness of a magnetic agent is of major importance to the indication sensitivity. The property "fluorescent" can be quantitatively measured with the set-up shown in fig. 1, which yields the fluorescence coefficient $\boldsymbol{b}$ [*cd/W*]. It is defined as the relation of the luminance $\boldsymbol{L}$ [cd/m^2] of a plane area to the UV irradiation strength $\boldsymbol{E_e}$ [W/m^2]. The sample under test is exposed to even UV-A irradiation under an angle of 45°. The UV-irradiation is converted into visible light which is then measured by an illumination density meter. The testing agent under discussion has a fluorescence coefficient $\boldsymbol{b}$ of typically 2.0 [*cd/W*] and is, therefore, suitable even for the detection of finest cracks.

To obtain a uniform product quality, it is interesting to monitor the variation of $\boldsymbol{b}$ during several years. In fig. 2, the fluorescence coefficient $\boldsymbol{b}$ [*cd/W*], measured for each individual batch is depicted versus the respective date of production. Therefore, smaller variations of $\boldsymbol{b}$ with time are visible in the chart. By defining and observing of the acceptance criteria, it is, however, a well-defined product during many years.

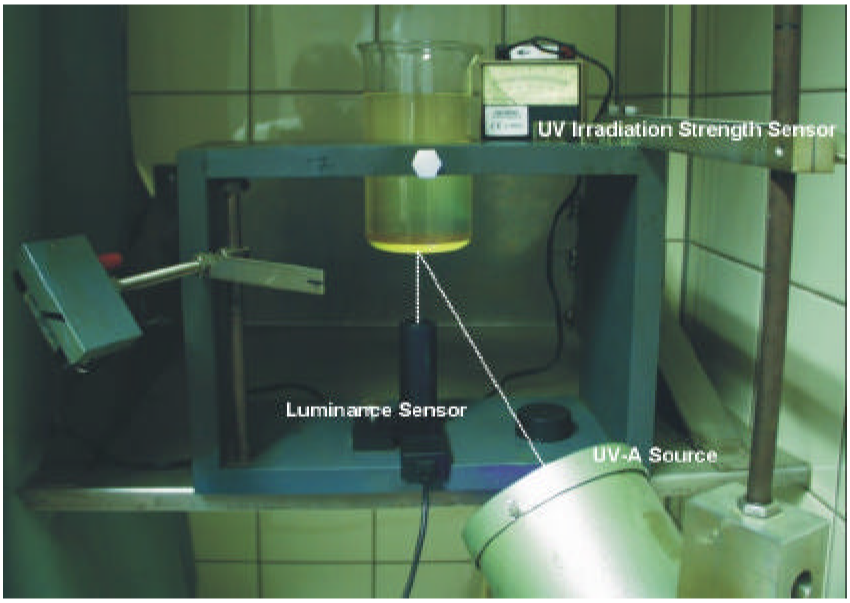

Fig. 1: *Measurement set-up to determine the fluorescence coefficient*

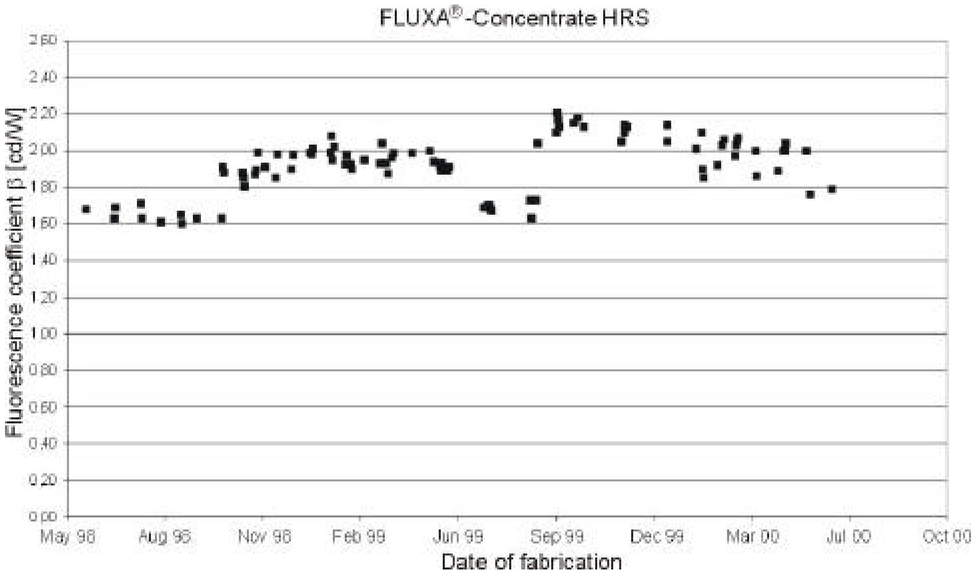

Fig. 2: *Variations with time of fluorescence coefficient*

3.2 Corrosion Test acc. to DIN 51 360 Part 2

One of the most important properties for water-suspendible MT-agents is the prevention of corrosion. The goal is to prevent corrosion during and also after the inspection. Since water-based MT-agents only allow water-soluble rust inhibitors, only a time-limited corrosion protection is possible. A long-time conservation cannot be reached. Depending on the conditions of storage, 6 weeks or even more can be reached under optimum conditions; under poor conditions (e. g. humid surrounding, low testing agent concentration) only a few hours or days. The standard DIN 51 360, part 2, "Determination of anti-corrosive properties of water-based cooling lubricants" describes a simple laboratory method to determine these anti-corrosive properties. Grey cast iron chips are put onto round filter papers. They are wetted with the fluid to be tested. After 2 hours, all occuring corrosion stains are evaluated regarding their quality and size. Fig. 3 shows the results obtained from three different concentrations. The requirement for MT-agents states that for a concentration of 5 per cent (dilution 1 : 20 with water) rust stains are not permissible.

Fig. 3: *Corrosion Test acc. to DIN 51 360 Part 2*

3.3 Magnetic Powder Concentration / Sedimentation acc. to AMS 3044 / ASTM D 96

The magnetic particle concentration of a fresh prepared, unused testing suspension can be determined by checking the sedimentation volume within a centrifuge tube acc. to ASTM D 96. In AMS 3044 and 3045, a concentration between 0.19 g/l and 1.3 g/l is prescribed for fluorescent testing agents These concentrations correspond to sedimentation volumes between 0.1 and 0.4 ml / 100 ml.in the centrifuge tube acc. to ASTM D 96.

This determination method of magnetic particle concentration is not very precise (fig. 4) and is useful only for freshly prepared, unused testing agent suspensions. It cannot be used for supervision during the inspection process, because disturbing materials dragged-in by the specimen under test (e.g. scale, abrasives, surface treatment media)

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also accumulate in the centrifuge tube and lead to increased levels of MT-agent concentrations. Furthermore, it should be noted that the permissible minimum and maximum values cover a large range, i. e. allow a factor 4 for the sedimentation volume. For the permissible range of concentration (given in g/l), an even larger factor 6.8 is tolerable. Such large tolerances indicate that this method of concentration determination must be considered questionable.

Nevertheless, this procedure is used world-wide and it is included in many testing standards to make it internationally accepted.

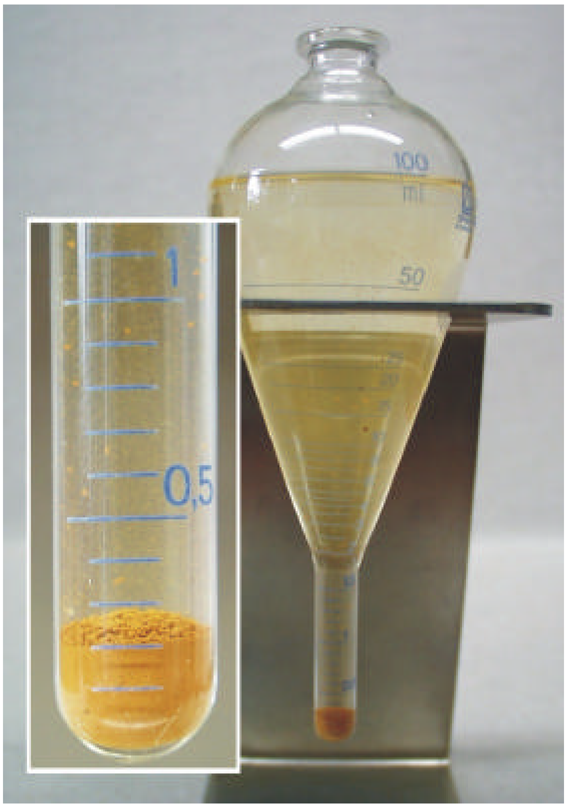

Fig. 4: *Measurement of magnetic particle concentration according to AMS 3044 / ASTM D 96*

3.4 The pH-Value

The pH-value is defined as the negative decadic logarithm of the concentration of hydrogen ions H^+. Small pH-values (from 0 to 7) represent acid solutions and correspond to high hydrogen ion concentration, whilst large pH-values (from 7 to 14) represent alkaline solutions of low hydrogen ion concentration. A pH-value of exactly 7, therefore, means that it is a neutral medium, i.e. neither acid nor alkaline.

The pH-value of an aqueous, ready-for-use MT-agent must be within the alkaline range (i. e. pH > 7), since acid media offer no corrosion protection. If the pH-value is larger than 9, the corrosion protection is improved, but on the other hand, more and more skin irritations among the testing personnel occur. Therefore, many standards (e. g. in DBL 6785.00), enforce that only testing agent suspensions of a pH-value less than 9 are permitted for use.

3.5 The Surface Tension

The surface tension is measured because it corresponds to the wetting ability of the testing agent. Only where the specimen is wetted by the testing agent, a crack indication is possible. If wetting problems occur, e. g. on oily or greasy surfaces,cracks are not reliably detected.

Pure water with a surface tension of 72 [mN/m] does not sufficiently wet metallic surfaces. This value is halved for MT-agents by adding surface-active substances (e.g. wetting agents, tensides, detergents, emulsifiers, antifoaming agents). The surface tensions of common testing agent suspensions are in the order of 30 [mN/m] and, therefore, in a range where metallic surfaces are well wetted.

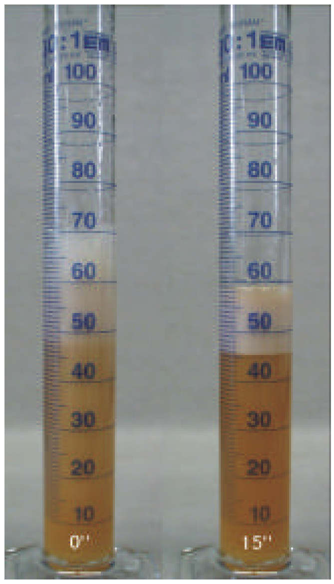

Fig. 5: *Determination of the foam behaviour of an MT-agent*

3.6 The Foaminess

The foaming behaviour of an MT-agent suspension is important, because foam on the specimen surface can strongly disturb the detection of a crack. The quantitative evaluation of the foam behaviour is difficult. This becomes obvious from the different standardised procedures of foam determination. Depending on the method of foam generation, different results will be obtained. Therefore, an internal, simple and reproducible method is preferred to judge the foam behaviour:

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A 100 ml measuring cylinder is filled with 50 ml of the testing agent. Is closed by a plug, and then strongly shaken by hand for 15 seconds. Immediately afterwards, the height of the generated foam column (in ml) is read from the scale. As a further criterion, the decaying speed of this generated foam is observed. Fig. 5 shows the result for MT-agent immediately after shaking (left) and 15 seconds later (right).

3.7 Density

The density of an MT-agent is without influence for the inspection. It is, however, used as an acceptance criterion for different reasons:

- The density can easily be measured.
- The density must be constant for each batch within pre-given tolerances. Deviations are always indicating incorrect production steps.

The absolute value of density is mainly determined by the content of corrosion protecting agents in the concentrate. Deviations, therefore, are indications of an inaccurate dosing of the amount of rust inhibitor.

3.8 The Longterm Stability

For serial tests in stationary benches, the MT-agent is normally filled into 40 l to 80 l containers. Inside, the inspection medium is permanently stirred by a pump to prevent a sedimentation of the magnetic particles on the bottom of the container. Within pre-given intervals, the homogenised suspension then is sprayed onto the specimens during the inspection. During this procedure, the inspection medium is subject to a hydromechanical load. This may lead to a gradual separation of luminescent pigments and magnetic particles, which means a continuous decrease of the indication sensitivity. It is obvious that the lifetime of the testing agent, besides the drag-out by the tested parts, is determined by the resistivity to the hydromechanical load.

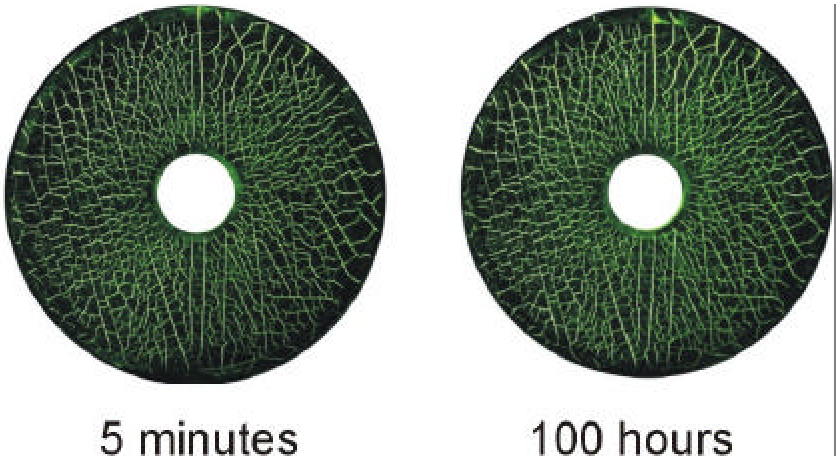

Fig. 6: *Longterm Stability of an MT-agent*

This longterm stability is checked in lengthy trials acc. to DBL 6785.00 in a testing agent container. The indication ability of the respective testing agent is checked by an MTU-reference block and photographically documented. It is required is, that after more than 100 hours of continuous circulation the indicating sensitivity has not decreased. Fig. 6 shows the crack indications on an MTU-test block after 5 minutes and 100 hours circulation. A sufficient longterm stability is the condition for reproducible test results.

4 Conclusion

A lot of factors have influence on the result of MT-agent. Every NDT expert knows that it is not trivial to carry out a magnetic particle testing over a period of several months or even years with always the same sensitivity. If this shall be reached, an uniform quality of the magnetic particle agent is of immense significance to get reproducible test results. The main task for the producers of MT-agents is, to obtain and guarantee a constant indication sensitivity of their products. This is only possible through many years, if the product quality is reproducibly fixed by introduction of relevant acceptance criteria with defined reference values and appropriate tolerances.