Basics

Magnetic Particle Testing

KARL DEUTSCH

Principle of Magnetic Particle Testing

Ferromagnetic material (iron, cobalt and nickel) has a much better “magnetic conductivity” than air (or other material). The magnetic field is guided within the ferromagnetic material. Only at a disturbance (crack) the magnetic field leaves the work-piece. This external field is called “stray flux” and is the essential effect for magnetic particle testing.
The exit points become magnetic poles. Fine iron powder will sticks to these poles and will be held there. The pole area is larger than the crack width and this is the reason that the iron powder aggregation is better visible than the crack itself. With a coloured iron powder (e.g. fluorescent paint) an improved visibility is possible.

Fundamental formulas and definitions:

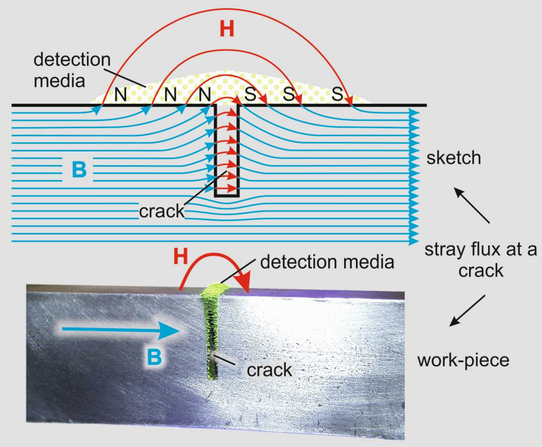
Magnetic field strength H:
H is the external field which can be applied to a work-piece.
unit: A/m (or A/cm or kA/m; 1 kA/m = 1000 A/m = 10 A/cm)
old unit: Oerstedt (Oe)
conversion: 1 Oe = 80 A/m or 1 A/m = 0.0126 Oe

Magnetic induction B:
B is the magnetic flux density within the material.
unit: Tesla (T) (1 T = 1 Vs/m^2)
old unit: Gauß (G)
conversion: 1 G = 0.0001 T or 1 T = 10,000 G

Relationship between H and B:

$B = \mu_r \mu_o H$

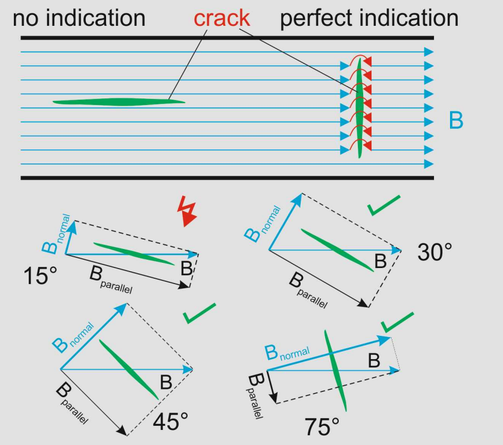
μ_o = magn. constant = 1.257 10^{-6} Vs/Am
μ_r = **permeability** (without unit);
also: magnetic **conductivity** depends upon material and magnetization
μ_r = 50 ... 26,000 for ferromagnetic material
$\mu_r \sim 1$ for all non-ferromagnetic material



Detection of cracks

Cracks are detectable with magnetic particle testing if these cracks disturb the magnetic induction (B). Only the part of B (B_{normal}) which is perpendicular to the crack orientation produces an indication. This part of B (B_{normal}) is large enough, if the angle between the direction of B and the orientation of the crack is greater than 30°. Perfect is an angle of 90°.

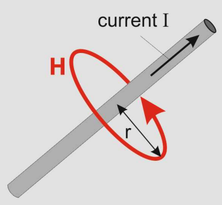
Consequence: To find all cracks with arbitrary orientation, a work-piece must be magnetized in two or more directions.



Current and Magnetism

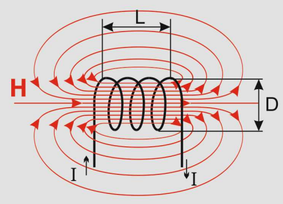
A current within a conductor produces a magnetic field. The geometry of the field is given by the geometrical set-up.

Magnetic field of a conductor with current



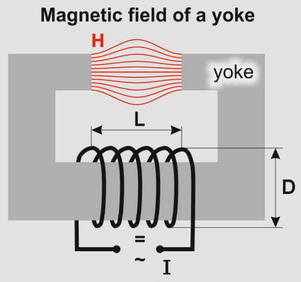
$H = \frac{I}{2 \pi r}$

Magnetic field inside a coil



$H = \frac{n I}{\sqrt{L^2 + D^2}}$

Magnetic field of a yoke



$H = \frac{n I}{\sqrt{L^2 + D^2}}$

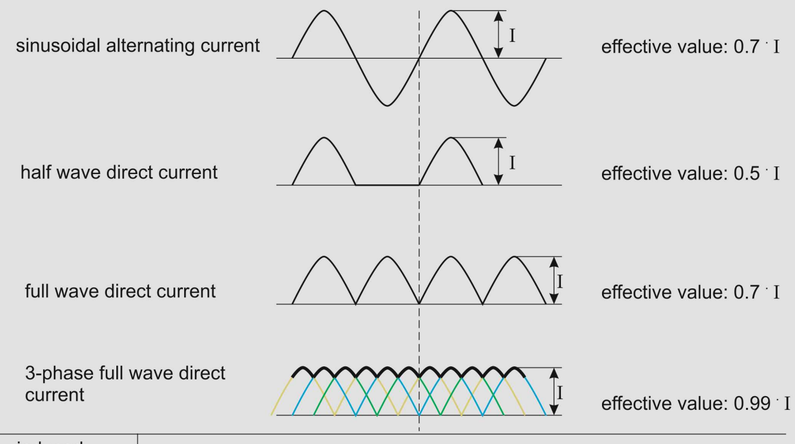
n = number of turns

Current types

The current types can be classified into direct and alternating current (DC and AC).

Alternating current (AC): Due to the skin effect the core of the work-piece is free of magnetization. The magnetization decreases from the surface to the core.
Advantage: uniform magnetic field for different work-piece diameter and smaller untested areas.

Direct current (DC) gives a constant magnetization of the whole work-piece from the surface up to the core. This will complicate the demagnetization.
DC results from the rectification of AC but only the 3-phase rectification gives a current type very close to DC.



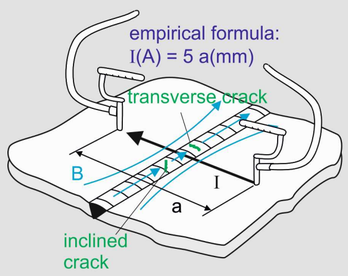
Magnetization Techniques

The magnetization techniques (or methods) can be classified into two groups:

Current flow technique: An electric current flows through the test piece. A magnetic field is formed around the conductor (test piece). This magnetic field is used for crack detection.

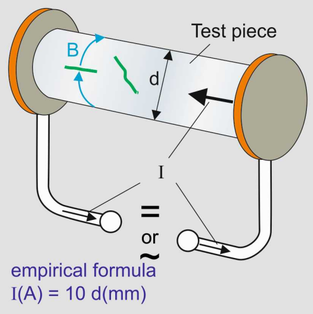
Field flow technique: The test piece is placed into an externally produced magnetic field.

Current flow techniques



Current flow with prods

Detection of transverse cracks (with respect to the weld) and inclined cracks but no longitudinal cracks



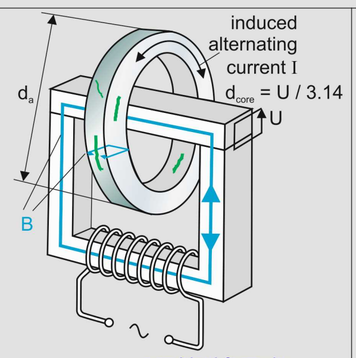
Axial current flow

Detection of longitudinal and inclined cracks but no transverse cracks.

Current induction technique

A circulating current is induced in a ring component by the influence of a alternating magnetic field.

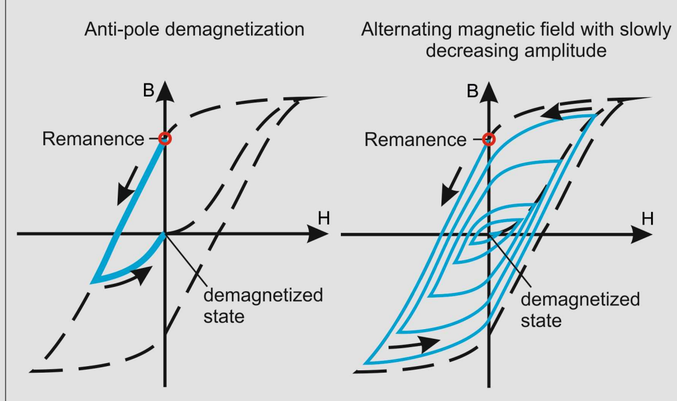
Detection of circumferential and inclined cracks but no axial or radial cracks.



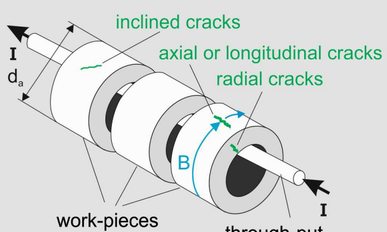
Demagnetization

There are 3 methods for demagnetization:

- **Heating above Curie temperature** (T_c): This is an impractical method, because this temperature is very high (for steel: T_c = 768°C).
- **Anti-pole demagnetization**: The workpiece will be placed in a magnetic field with a negative field strength. If a proper negative field strength is used, the workpiece will be demagnetized.
- **Alternating magnetic field with slowly decreasing amplitude:** It is the most reliable and most common method. The demagnetization can be done within the crack detecting instrument or by pulling out the work-piece of a demagnetization coil.

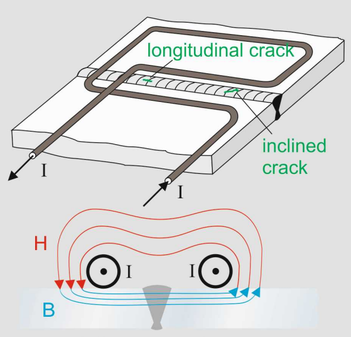


Field flow techniques



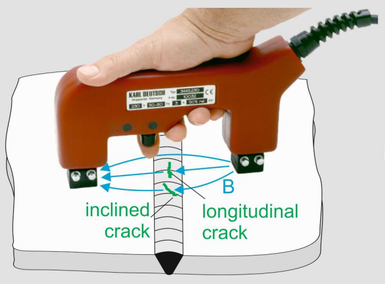
Through-put conductor

Detection of axial and radial cracks and inclined cracks on all surfaces but no circumferential cracks.



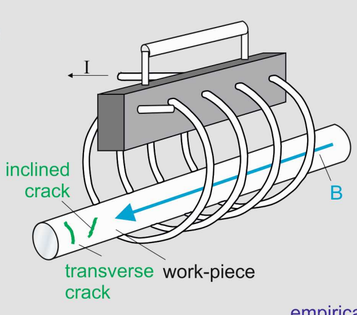
Adjacent conductor

Detection of longitudinal cracks (with respect to the weld) and inclined cracks but no transverse cracks.



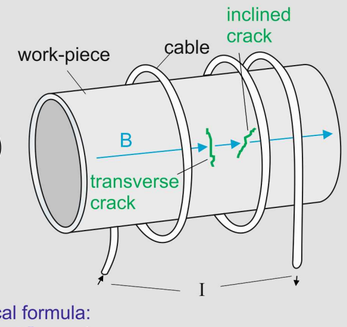
Hand yoke

Detection of longitudinal cracks (with respect to the weld) and inclined cracks but no transverse cracks.



Rigid coil

Detection of transverse and inclined cracks but no longitudinal cracks.



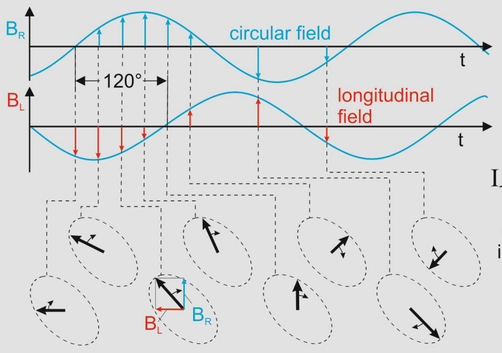
Cable coil

Detection of transverse and inclined cracks but no longitudinal cracks.

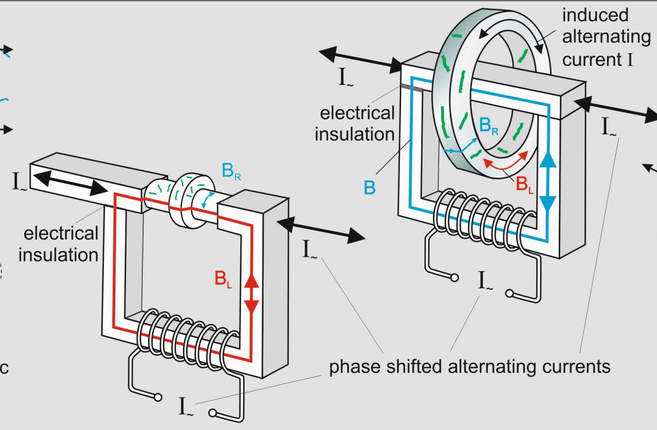
Combined Techniques

A combination of current flow and field flow allows for crack detection in all directions in one test cycle. With respect to the two currents of the current flow and field flow one of the following conditions has to be fulfilled:

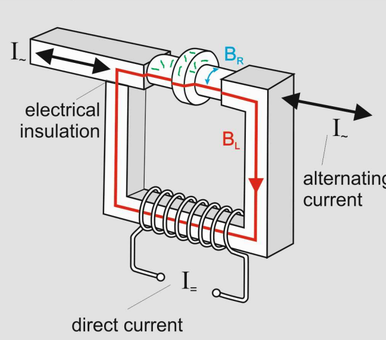
- phase shifted alternating currents or
- different current methods (eg. direct current and alternating current).

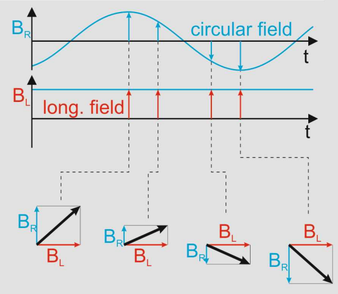


A phase shift of 120° results in an ellipsoidal magnetic field.



Detection of all crack orientations on all surfaces.
A pole free and non-contact technique.





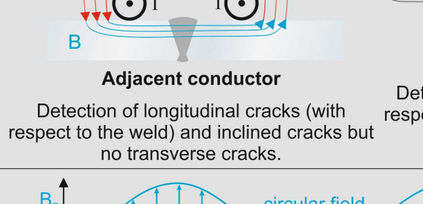
A combination of direct current and alternating current gives an oscillating magnetic field for the detection of arbitrary crack orientation (hardly used).

Controls

Different accessories are used to control the detection media and the magnetization. It is possible to control

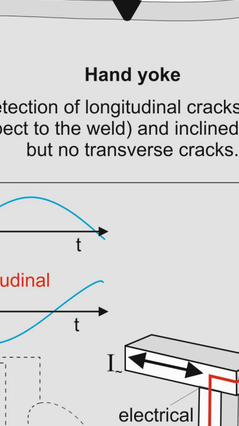
- the detection media allone (MTU-test block, FLUXA-test block),
- the magnetization allone (field strength meter) or
- both in combination (Berthold-test block).

The standard EN ISO 9934-2 mentions the control block 1 (MTU-test block) and control block 2 (principle similar to FLUXA-test block). These control blocks are used only for the detection media control.



MTU-test block and FLUXA-test block for the detection media control

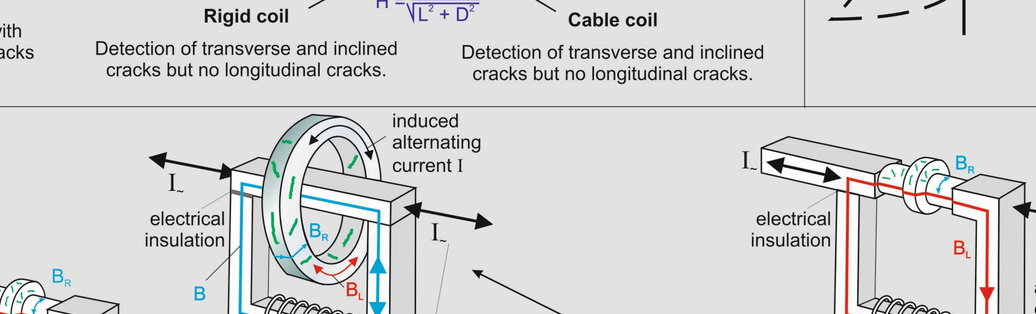
Berthold-test block to control the detection media and the magnetization



DEUTROMETER to control the magnetization

Concepts

Modern magnetic benches provide combined magnetization. Various concepts are chosen in accordance to the test task.



DEUTRO-Coil (KD patent)

(High current coil) for an uniform magnetic field (= closed yoke)

Open Yoke

for high throughput

Moving Coil

for long work-pieces

Essentials

Testing cycle: magnetization & spraying, post-magnetization, evaluation

Tangential field strength:
2 kA/m to 6.5 kA/m

Remanence (residual field after testing):
typical 0.4 kA/m to 1.0 kA/m

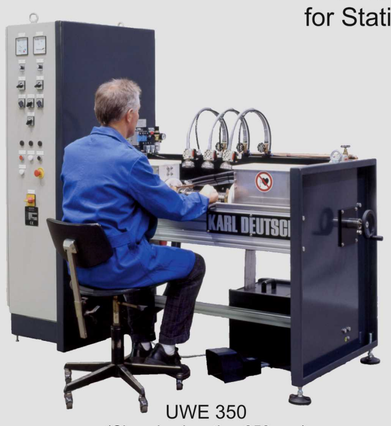
Viewing conditions:
daylight detecting media
more as 500 Lux
fluorescent detecting media
less as 20 Lux (dark room)
more as 10 W/m^2 (UV-light)

Testing standards:
EN ISO 9934-1: Basics
EN ISO 12707: Terms
EN ISO 3059: Viewing conditions
EN 473: Personal qualification

DEUTROPULS
for Mobile Testing

Hand Yoke and Current Flow Unit

DEUTROFLUX
for Stationary Testing



UWE 350
(Clamping length = 350 mm)
Small parts, Sitting Inspection

UWE 600
(Clamping length = 600 mm)
Standard-Bench

DEUTROMAT
Special Solutions

Multiple Contacts with Ejector for Complex Geometries

with Chain Conveyor for Automated Work-piece Transport

Accessories
& FLUXA detecting media

UV-Lamps
FLUXA Detecting Media
Control Blocks
Instruments

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