The effect of higher harmonic components on MPI process

Pavel Staněk, Zbyněk Škvor

Department of Electromagnetic Field
Czech Technical University in Prague

pavel.stanek@fel.cvut.cz

NDT in Canada
NDTiC 2018
Canada's NDT Conference
June 19 - 21
Halifax Convention Centre
Halifax, Nova Scotia

Content

MPI Principle

MPI steps:

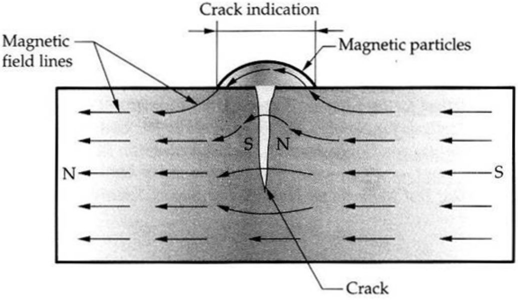
- Generate magnetic field perpedicular to the defect (ideal case)
- (Verify the generated field)
- Apply detection particles
- Evaluate the indications

Retrieved from: http://www.sssndt.com and http://shopndt.eu

MPI Principle

MPI steps:

- Generate magnetic field perpedicular to the defect (ideal case)
- (Verify the generated field)
- Apply detection particles
- Evaluate the indications



Retrieved from: http://me.aut.ac.ir

MPI Principle

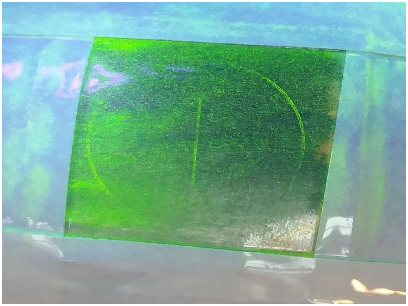
MPI steps:

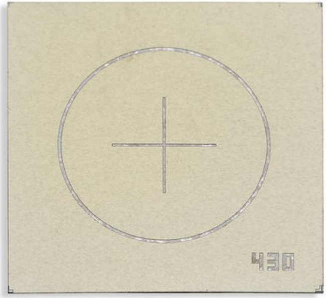
- Generate magnetic field perpedicular to the defect (ideal case)
- (Verify the generated field)
- Apply detection particles
- Evaluate the indications

Retrieved from: http://accutest-labs.com

Magnetic field verification

- Specimens with real well known defects
- Measurement of tangential magnetic component by a gaussmeter
- QQI - Quantitive Quality Indicators





[0] Retrieved from: http://www.qnde.ca

Motivation

How to verify the field?

Need for a new method, which is

- fast
- clean
- suitable for automation

$\rightarrow$ Measure the field and calculate the impulse of the force

Impulse of the force

Definition:

$$I = \int_{t_1}^{t_2} \mathbf{F}(\mathbf{H}) dt$$

Why impulse of the force?

It combines the most critical parameters of the test

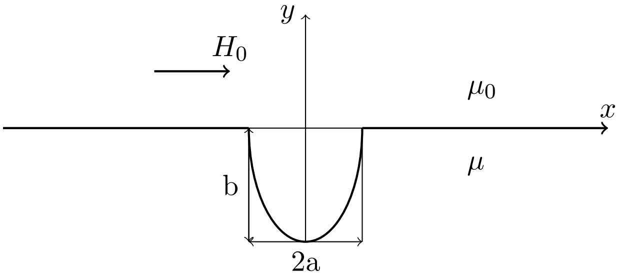
- the force exert on a detection particle
- time of duration

We need to know the leakage field above the defect and to calculate the force moving the particles.

Force impulse

The leakage field components H_x, H_y and the force components F_x, F_y were calculated by Edwards and Palmer [1]

$$F_x = -\frac{8}{3}\mu_0 \pi r^3 H_0^2 \left(\frac{\partial \bar{H}_x}{\partial x} + H_x \frac{\partial \bar{H}_x}{\partial x} + H_y \frac{\partial \bar{H}_y}{\partial x}\right) = k(x, y, \mu_0, \mu, a, b, r) H_0^2$$



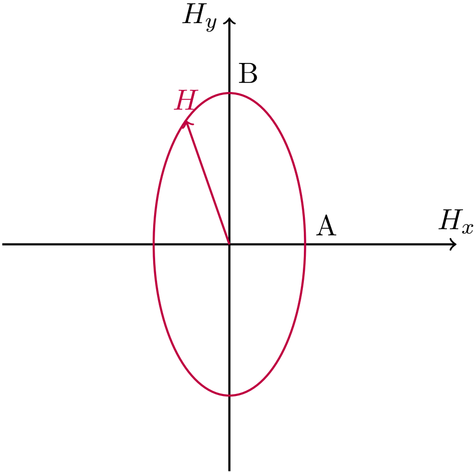
[1] Edwards, C., and S. B. Palmer. "The magnetic leakage field of surface-breaking cracks." *Journal of Physics D: Applied Physics 19.4 (1986)*: 657.

Magnetic field polarization

Example of parametric description of the polarization:

$$H_x = Acos(\omega t)$$

$$H_y = Bsin(\omega t)$$



Magnetic field polarization

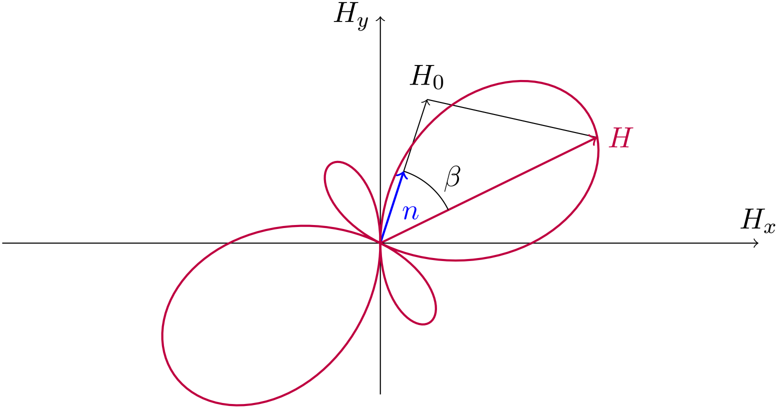
Field functions are continuos and periodic
→ describe them by Fourier series

$$\mathbf{H} = \mathbf{H}(H_x, H_y)$$

$$H_x = \frac{a_0}{2} + \sum_{n=1}^{\infty}(a_n cos(n\omega t) + b_n sin(n\omega t))$$

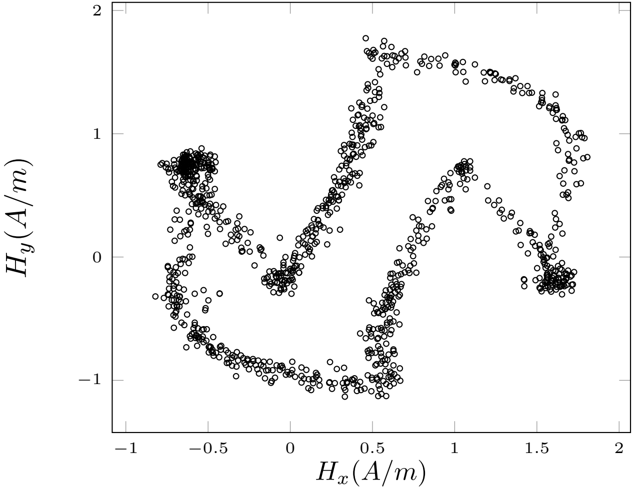
$$H_y = \frac{c_0}{2} + \sum_{n=1}^{\infty}(c_n cos(n\omega t) + d_n sin(n\omega t))$$

Magnetic field polarization



$$H_0 = |\mathbf{H}| cos(\beta) = |\mathbf{H}| \frac{\mathbf{H} \cdot \mathbf{n}}{|\mathbf{H}| \cdot |\mathbf{n}|} = \mathbf{H} \cdot \mathbf{n}$$

Magnetic field polarization measument[2]



[2] Staněk, P., Škvor Z. "Experimental gaussmeter for circular magnetization." *NDT in PROGRESS, IXth International Workshop of NDT Experts, Proceedings*: Prague, 2017. ISBN 978-80-87012-63-5.

Impulse of the force

$$I = \int_0^T \mathbf{F(H)} dt = \int_0^T k H_0^2 dt =$$

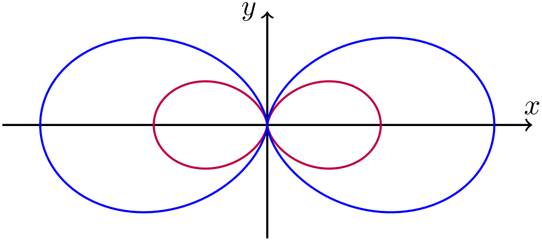
$$= \frac{k}{2f} \left[cos^2(\alpha) \left(\sum_{n=1}^{N} (a_n^2 + b_n^2 - c_n^2 - d_n^2) + \frac{a_0^2}{2} - \frac{c_0^2}{2} \right) + \right.$$

$$\left. + sin(2\alpha) \left(\sum_{n=1}^{N} (a_n c_n - b_n d_n) + \frac{a_0 c_0}{4} \right) + \sum_{n=1}^{N} (c_n^2 + d_n^2) + \frac{c_0^2}{2} \right]$$

Impulse of the force

The impuslse of the force terms

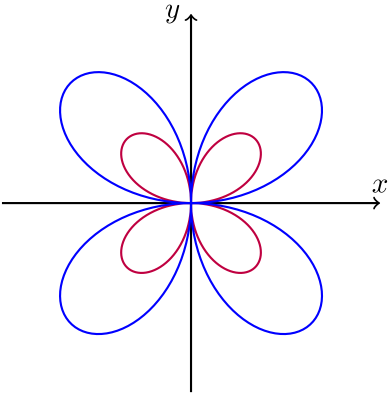
$$cos^2(\alpha)\left(\sum_{n=1}^{N}(a_n^2+b_n^2-c_n^2-d_n^2)+\frac{a_0^2}{2}-\frac{c_0^2}{2}\right)$$



Impulse of the force

The impuslse of the force terms

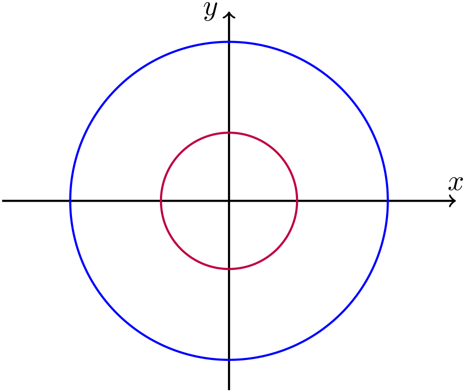
$$sin(2\alpha)\left(\sum_{n=1}^{N}(a_nc_n - b_nd_n) + \frac{a_0c_0}{4}\right)$$



Impulse of the force

The impuslse of the force terms

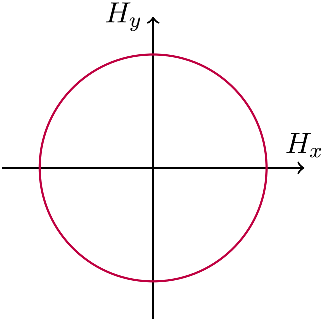
$$\sum_{n=1}^{N}(c_n^2 + d_n^2 + \frac{c_0^2}{2})$$



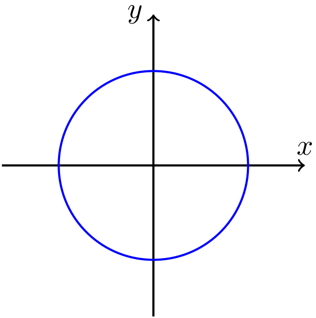
Impulse of the force

Circular polarization

Polarization



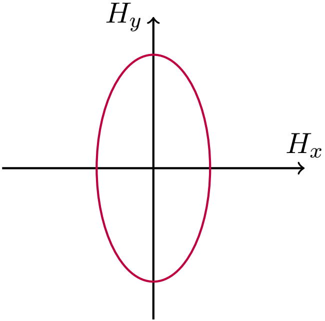
Impulse



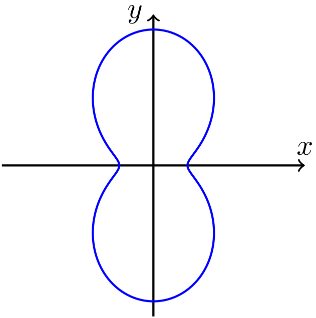
Impulse of the force

Elliptical polarization

Polarization



Impulse



Thank you for attention

Questions?