Application of Eddy currents to the quality control and material sorting of small ferrous components

Systematic control of components

Eddy currents provide useful information on the properties of ferrous materials. Modifications of the microstructure and the dislocations distribution caused by heat treatment, tempering or work hardening result in variations of the magnetic domain wall motion. These variations, in turn, affect the magnetic permeability of the sample that can be measured using eddy currents. The relation between the magnetic permeability and the mechanical properties is a very powerful empirical tool to sort parts, both by comparison with calibration sets and by statistical analysis of batches. The technique can be advantageously applied to the systematic control of small ferrous components, such as the 20AP carbon steel parts used for watch movements. To some extent, the same procedure can be applied to non ferrous materials.

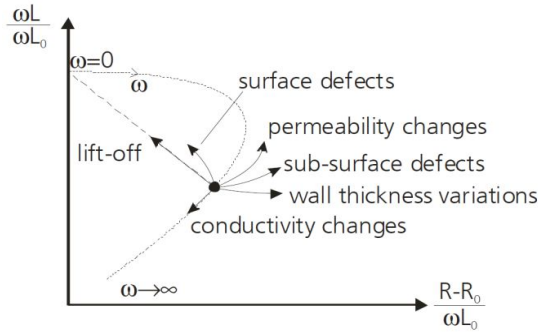

Fig 1: Eddy current response of a probe to a metallic sample (dark spot). The deviations (arrows) caused by inhomogeneties, flaws, and lift off on this response are represented schematically.

High throughput rates and remarkable reproducibility

Sensima Inspection develops and marketsequipment tailored for small component quality control with differentiating features such as bespoke sensors optimising the contrast between samples of different properties. Sensima Inspection systems include anintuitive software that can be parameterizedfor specific settings, alarm generation and reporting. Sensima Inspection offers high standard services enabling the integration of the technique into the production and assembly processes.

Key features

- Non destructive technique, no permanent magnetization of the sample;
- Non-contact measurement, no surface preparation, no couplant;
- Standardized process and technique: EN ISO 12718, 15548, 17643, 10893, ASTM E566-2014;
- Enables a systematic and efficient sorting of components (typ. 1 component / sec);
- Simple operation, facilitated training and outperforming reproducibility, compared for instance to indentation;
- Versatile integration into assembly process and production lines.

Watch industry applications

- QC of the heat treatment and tempering of small ferrous components (E.G. 20AP carbon steel);
- Hardness tests;
- QC of wires and tapes (homogeneity, dimensions, and flaw testing);
- QC of raw materials such as Alloys, LIGA, Ni-NiP, metallic coatings and films (homogeneity, cracking, and porosity testing);
- QC of special process such as welding, "roulage" or press fitting (surface hardness and residual stress testing).

Process integration

The technique can be integrated into the quality process in two different ways:

1. **Statistical testing**: A batch of components is systematically measured and samples deviating from the target range are excluded.

2. **Absolute measurement**: A set of samples with calibrated values of the physical property to be tested (e.g. the hardness) is prepared; this setis used to create a table relating the eddy current response to the physical property. Tested samples with eddy current response outside the target range defined in the physical property unit (e.g. 720 HV ± 15 HV) can be sorted out.

Case study: quality control of the hardness of sub-millimetre axles

20AP axles, 0.35 mm OD, 1 mm long, have been annealed at 10 different temperatures in the range 220°-360° C, resulting in a nominal hardness between 770 to 530 HV. The results of the electromagnetic response are given in Figure 2.

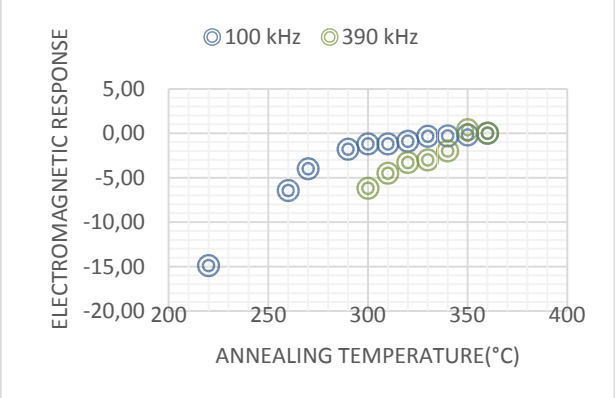

Fig 2: Electromagnetic response as function of the annealing temperature at two different measurement frequencies (100 kHz and 390 kHz). This plot illustrates how the multifrequency approach is used to improve the sensitivity over a wide range of annealing temperatures.

Two batches of 7 samples each, one annealed at 260°C and one at 270°C, have then been prepared for micro indentation measurements of the hardness. The same samples have been measured by electromagnetic technique. The results are compared in Figure 3, demonstrating how the electromagnetic response improves the reliability and reduces the dispersion of the measurements.

Sensima Inspection products & services

- Ultraportable, high performance, wireless eddy current module UPEC;
- Set of probes for axles and customised probe design for other component geometries;
- High performance miniaturised IC detection electronics reducing spurious signals, in particular for in line tests of wires;
- Integration into automated systems (digital input/output, physical alarm generation);
- System parameterisation for software "go/no go alarm", and response optimisation;
- Support for the preparation of reference samples;
- Advanced features such as multi-frequency measurement, and assisted defect recognition.

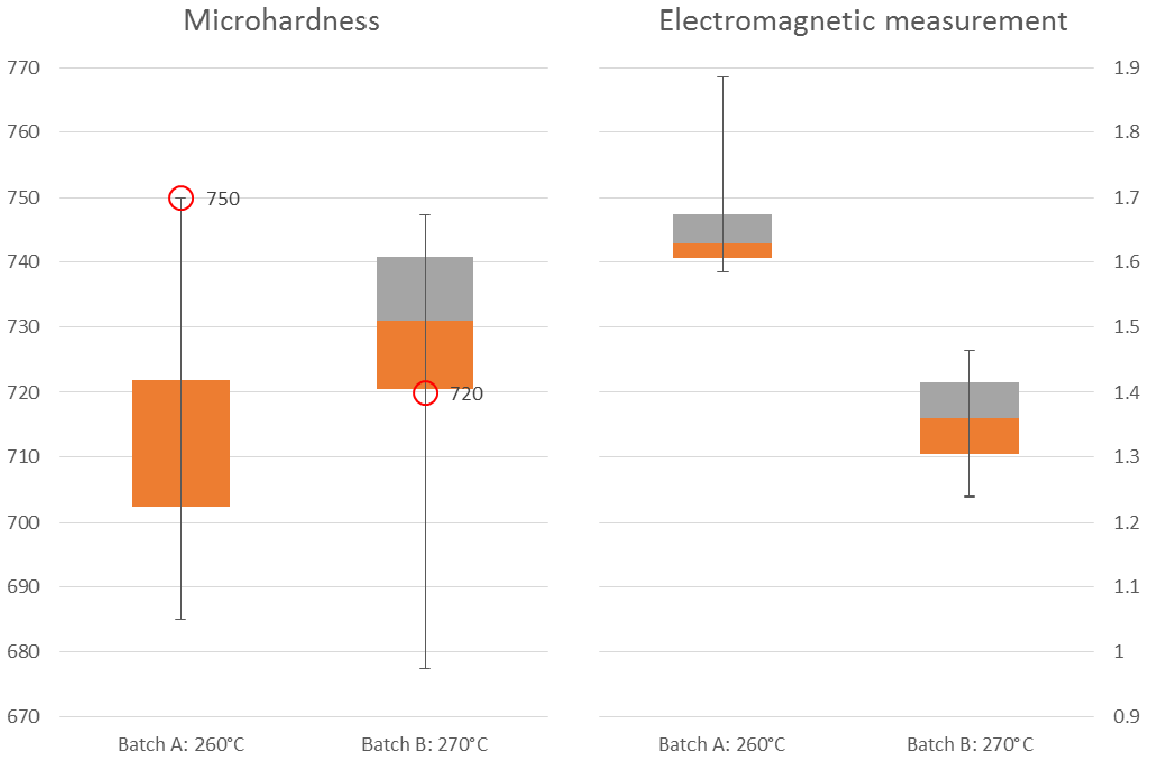

Fig 3: Box and whiskers plot of micro-indentation measurements of two series of watch parts from the same machining batch, but with two different annealing temperatures (A: 260°C, B: 270°C), compared to non-contact electromagnetic measurements of the same parts. The two different heat treatments corresponding to anominal hardness of 750 and 720 HV, can be clearly identified in the electromagnetic measurements, whereas the traditional hardness measurements overlap.