Faster Magnetic Crack Detection Using the Multi-Directional Swinging Field Method

A Paper By

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1 Introduction

Swinging Field multi-directional magnetising is used as a means to significantly reduce test and inspection times (and hence costs) and to increase sensitivity of the Magnetic Particle Inspection process to reveal defects in all directions within a test piece in a single magnetising process. Therefore only one inspection is required. It is now a widely accepted technique in the automotive, aerospace and railway industries, and has simplified many inspection processes, leading to significant cost reductions and quality control enhancement and confidence. Insight NDT personnel have been instrumental over many years in pioneering this technique.

Magnetic particle crack detection is of great value in revealing surface flaws in magnetic materials such as mild and alloy steels, cast iron, etc. Not only will the technique reveal surface defects that are not visible to the naked eye, it also facilitates the detection of cracks that would, under normal circumstances, only be found by close and tedious examination of the surface.

2 Principles of Conventional Magnetising

The principle of the magnetic method is to induce a magnetic field into the specimen to be examined, and where there are sharp discontinuities in the surface, like cracks, magnetic leakage takes place and attractive poles are formed at the discontinuity edges.

When finely divided iron oxide particles are applied to the part they are attracted to the line of the escaping magnetic field and, provided the particles are of a contrasting colour to the part, the edges of the crack will be clearly indicated against the background. The particles, which can be coloured red or black or be ultra-violet fluorescent, are suspended in a fluid such as water or kerosene. The fluid facilitates the mobility of the particles in their migration (under the influence of the magnetic field) to the crack edges. The suspension of particles and fluid is usually referred to as ‘ink’.

Most modern crack detectors generate a magnetic field by using a transformer to provide high amperage current in the test piece or in a magnetic yoke system.

Normally the test for defects, which may be at any angle on the surface of a work piece, requires two separate magnetising and two separate examinations.

2.1 Circumferential Magnetising

Firstly (Figure 1) the part is placed between the head and tailstock of the crack detector; current is passed through the part to magnetise it circumferentially; ink is applied and the part is removed and examined for generally longitudinal defects.

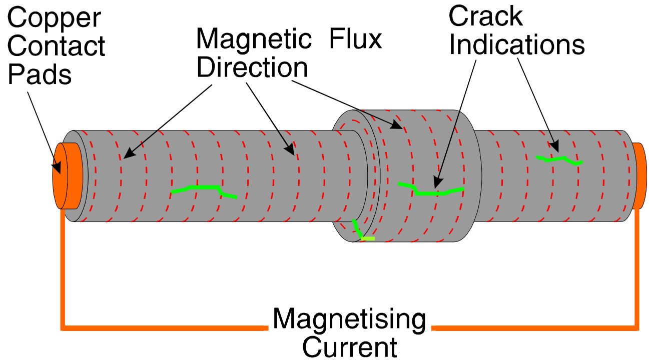

Figure 1 - Magnetising in a circular direction to indicate generally longitudinal defects by passing current through the part

In hollow parts an alternative of magnetising in a circular direction - to indicate longitudinal defects - is by means of a central conductor which passes through the bore. High current passing through the conductor, which is insulated to prevent direct contact with the work piece, induces circular magnetism in the part.

2.2 Longitudinal Magnetising

The part is then returned to the equipment to be magnetised longitudinally, either by encircling coil, as shown in Figure 2 below, or by magnetic flow. This magnetising demagnetises from the previous direction. The part is inked and then viewed again.

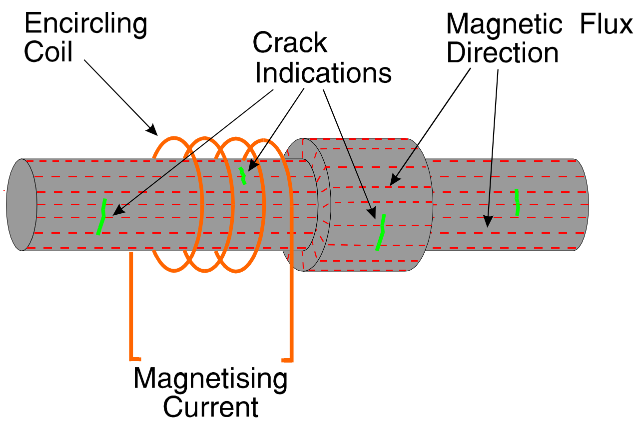

Figure 2 - Longitudinal magnetism induced by encircling coil to indicate circumferential and transverse defects

3 Principle of Swinging Field Magnetising

The above described orthodox system presents three problems - firstly the time involved, and secondly the possible confusion of untested, half-tested and completely tested parts and the reduction in sensitivity to defects in the intermediate angles. These shortcomings can be reduced significantly by the use of a single shot, single examination of the magnetised and inked parts for defects regardless of their orientation.The total inspection time is virtually halved and the risk of confusion of tested parts is eliminated.

The principle of Swinging Field magnetising is simple and depends on the simultaneous imposition of a longitudinal flux field and a circumferential field on the work piece, to form a vector of a single direction flux. A longitudinal flux of the same amplitude as the circumferential flux will provide a flux direction of 45 degrees. With changes in amplitude relative to each of the imposed longitudinal and circumferential flux fields the vector angle will change through at least 90^0 necessary to reveal all defects. In fact the field rotates through 360^0 50 times every second, see Figure 3 below.

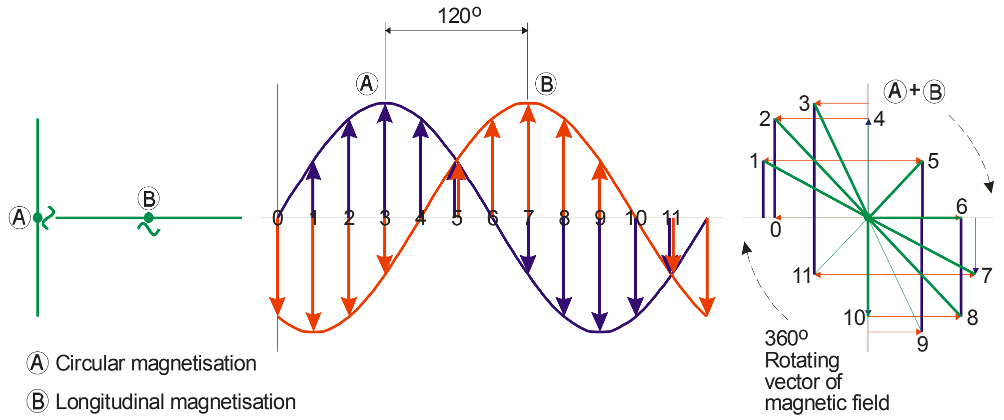

Figure 3 - Diagram showing rotating vector with longitudinal magnetising derived from Phase A and circular magnetising from Phase B

3.1 The Swinging Field Method

The necessary variation in the two basic flux directions is achieved by the use of two phases of a three phase mains supply.

One phase is connected to the longitudinal flux generating system which can be either a coil or a flux flow system. A second phase is used to generate circumferential flux, usually by current flow through the work piece. As there is in sinusoidal A.C. a cyclic change in current value from zero to maximum positive, down to zero, on to maximum negative and return to zero - fifty times per second, and as there is a lag between the two phases, at any instant there will be different amplitudes of longitudinal and circumferential fields. As two magnetic fields cannot exist in the same spot the resultant direction is a vector between longitudinal and circumferential the angle of which depends on the relative amplitude of the two fields.

As can be seen from Figure 3 the vector rotates through 360°. This is true rotating vector Swinging Field, not the rapid switching between circumferential and longitudinal field directions.

Normally the two phases are both A.C. working through two high amperage output transformers to provide the required magnitude of current. The longitudinal magnetising may be generated by either an encircling coil or by flux flow.

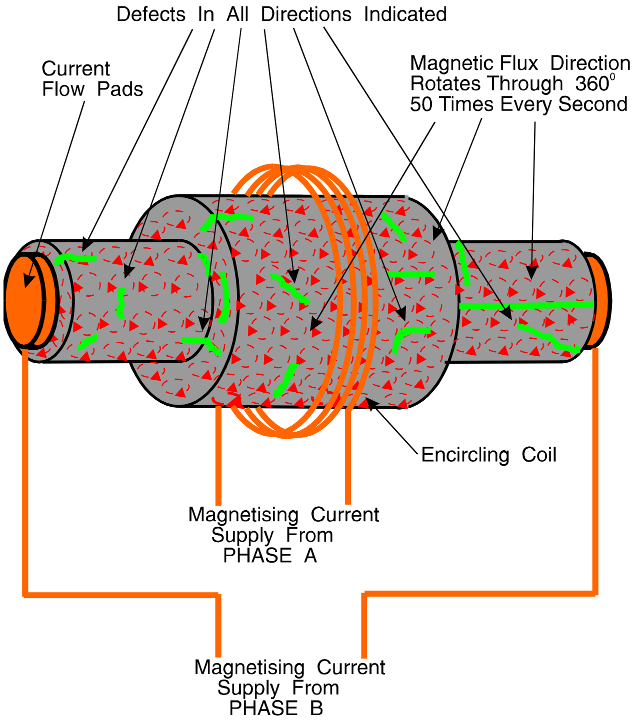

Figure 4 - Swinging Field using current flow to induce the circular magnetism and encircling coil to induce the longitudinal magnetism components of the rotating vector.

The degree to which a subject is magnetised is related to the amperage. However, there is no reason why Half-Wave-DC (for subsurface defects) should not be used on one or both legs of the vector, provided the results are acceptable.

3.2 The Induced Current Swinging Field Method

Magnetising of pieces with holes through them offer many opportunities to avoid contact current flow magnetising with its attendant risk of overheating at the contact points. The central conductor method described above is an example for circular magnetising. A similar system, referred to as the induced current method, which can be applied to generally longitudinal magnetising of a piece but with the extra facility that it will magnetise in the radial direction on the end faces of a circular test piece. Normally this magnetising direction can only be achieved by current flow across the diameter.

In the induced current method the threader bar is composed of iron laminations. These laminations used in conjunction with the magnetic flow system illustrated in Figure 5 will, when the energising coil is supplied with A.C., induce a current flowing round the hollow test piece. The piece is, in effect, a single shorted secondary turn of a transformer, the primary being the energising coil. Magnetic flux will be generated at right angles to the current therefore the flux will be toroidal.

A combination the central conductor method supplied from one phase and toroidal method from a different phase is an entirely satisfactory way of swinging field applied to hollow test pieces to indicate also circular defects on the ends.

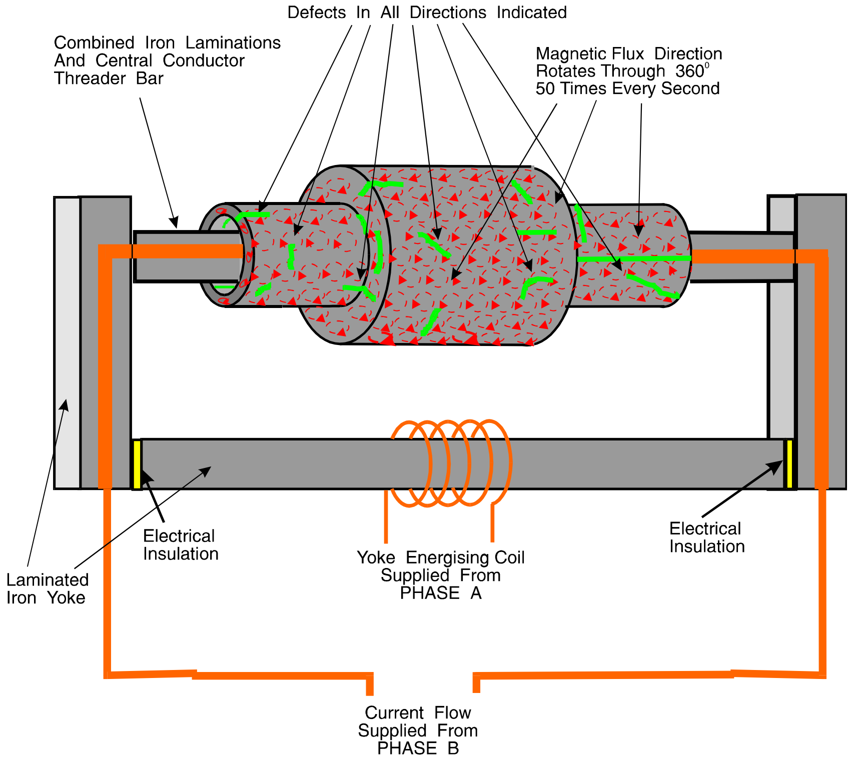

Figure 5 - Swinging field method of magnetising hollow test pieces with central conductor combined with induced current.

It is important that the values of the currents which generate the longitudinal and circumferential components of the vector are balanced for a particular work piece, so that sensitivity is even throughout the arc. This is best done empirically by the use of flux indicators.

When the magnetising shot terminates there will be a residual field, provided there is sufficient carbon (approximately 0.2%). This field will have a preferred direction, depending on its direction the instant the current was switched off. Since magnetising in one direction demagnetises in other directions, continued application of ink would wash away previously formed defect indications. It is therefore necessary that the application of ink to the work piece ceases before the magnetic shot ends. As long as there is a thin film of liquid in which the indicating particles are suspended they will migrate to the discontinuity edges.

3.3 Application of the Swinging Field Method

The Swinging Field technique is well suited to semi-automated systems in which the part is loaded into an intake system, from which it proceeds to an inking/ magnetising station and on to an examiner for disposal after inspection. The facility can also be incorporated into universal bench equipment.

Obviously the capital expense of equipments suitable for Swinging Field is more than for orthodox equipments, as there is the requirement of a second power pack with its controls. However, the extra cost is soon recouped by the reduction in the amount of labour needed.