Research & Development of Integrated MMM/EC/MFL Testing System

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Abstract

Multi-information fusion is the trend of NDT equipments. This paper describes the principle, configuration and application of EMS-2003 —— a new device combining metal magnetic memory, eddy current and magnetic flux leakage testing techniques. By using the three complementary NDT techniques, we are able to make complete testing and analysis on early damages and established defects in in-service parts.

Keywords: multi-information fusion; eddy current (EC); magnetic flux leakage (MFL); metal magnetic memory (MMM); nondestructive testing (NDT); stress concentration.

1. Introduction

Multi-information fusion is prevailing in today's NDT technology. This technology enables smaller size and more powerful functions. Microscopic & macroscopic stress concentration is the primary cause of damage of metal parts. The stress concentration of ferromagnetic materials represents magnetic memory. Therefore, diagnosis in stress-concentrated areas is an important part of the in-service testing.

In 1990s, Russian scientists firstly developed the new generation intellectual MMM diagnosis device based on magnetic memory effect[1]. The device enables early diagnosis of in-service ferromagnetic parts to identify stress concentration and metal defects. The advantages of this technique include easy operation, no need of surface pretreatment, quick diagnosis etc. But, for precise testing of fatigue-induced cracks and defect development in the stress-concentrated area, other techniques must be used. Whereas, conventional NDT techniques (such as ultrasonic, magnetic powder, MFL, Penetrate, EC and Radial testing etc.), which are widely used in industrial testing, have some technical limitation that they can only defect established defects. In short, each NDT technique has its limitation. So, the author developed a integrated portable testing system combing the MMM, EC and MFL techniques. This system combines the advantages of the three complementary techniques. It can detect stress concentration as well as established defects, helpful for accurate testing of parts and projection of service life.

2. Principle of MMM Technique

Modern science and ferromagnetic study demonstrate[2] that under workload, the magnetic domain in the ferromagnetic domain will change and local abnormal magnetic filed, known as "MFL field", forms in the stress-concentrated area. In the stress-concentrated area, the tangential sector $H_p(x)$ is maximal; the normal sector $H_p(y)$ is zero. As shown in Figure 1.

Practically, we measure the normal sector *H*p(y) to identify the stress concentration. This is the principle of MMT. By using MMM diagnosis technique, we can identify the stress concentration and early local damages in metal parts.

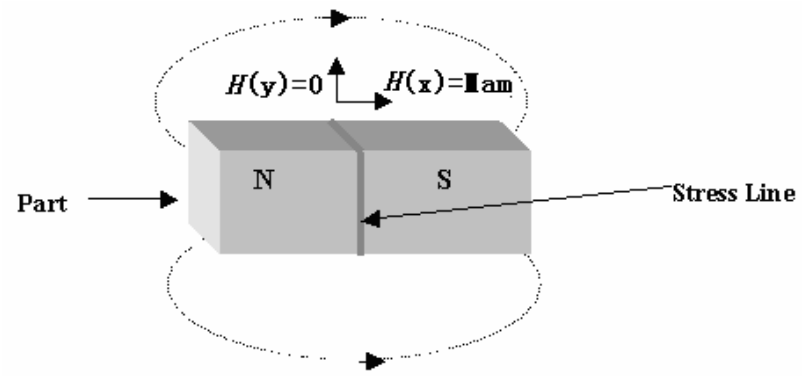

Fig. 1 Principle of MMM Testing

3. Principle of EC Testing

It is well known that the EC testing is based on electromagnetic induction principle[3]. When a coil carrying alternating current is approaching the conductive test part, EC will be induced in the part due to the magnetic field of coil. The magnitude, phase and pattern of EC are related to the conductivity of test part. And the impedance of coil varies with the counteractive magnetic field of EC. Therefore, by measuring the impedance of coil, we can determine the conductivity of coil and identify the defects. The principle is shown in Figure 2.

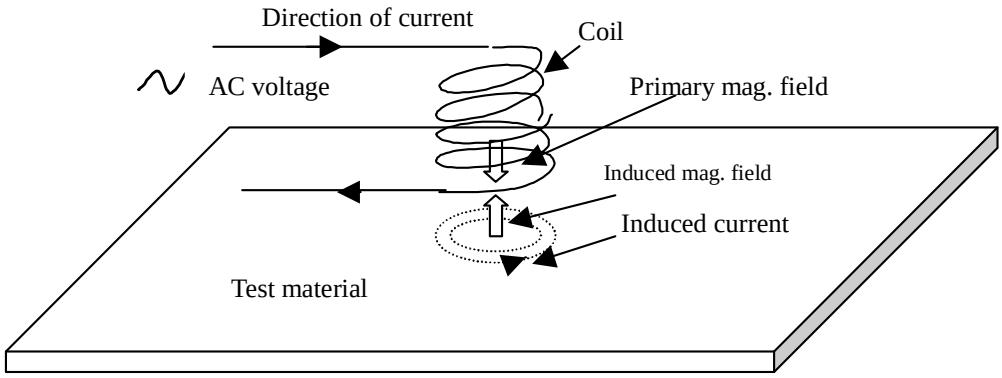

Fig. 2 Principle of EC testing

4. Principle of MFL Testing

MFL testing is a NDT technique to detect defects on surface of ferromagnetic materials. In MFL testing, firstly, the part is magnetized[4] to generate a strong enough MFL; secondly, measure the MFL with sensors (e.g. sensing coil, hall element, magnetodiode etc.). The strength of MFL is proportional to the size of defect.

5. Principle of MMM, EC, MFL Integrated Testing System

EC, MMM, MFL integrated testing system consists of host, EC probe, MMM probe and processing software. The host is the core hardware in the testing system. It consists of two ISA insert – EC board and MMM board, which are installed on the main board. The software includes three separate processing programs (EC testing software, MMM testing software

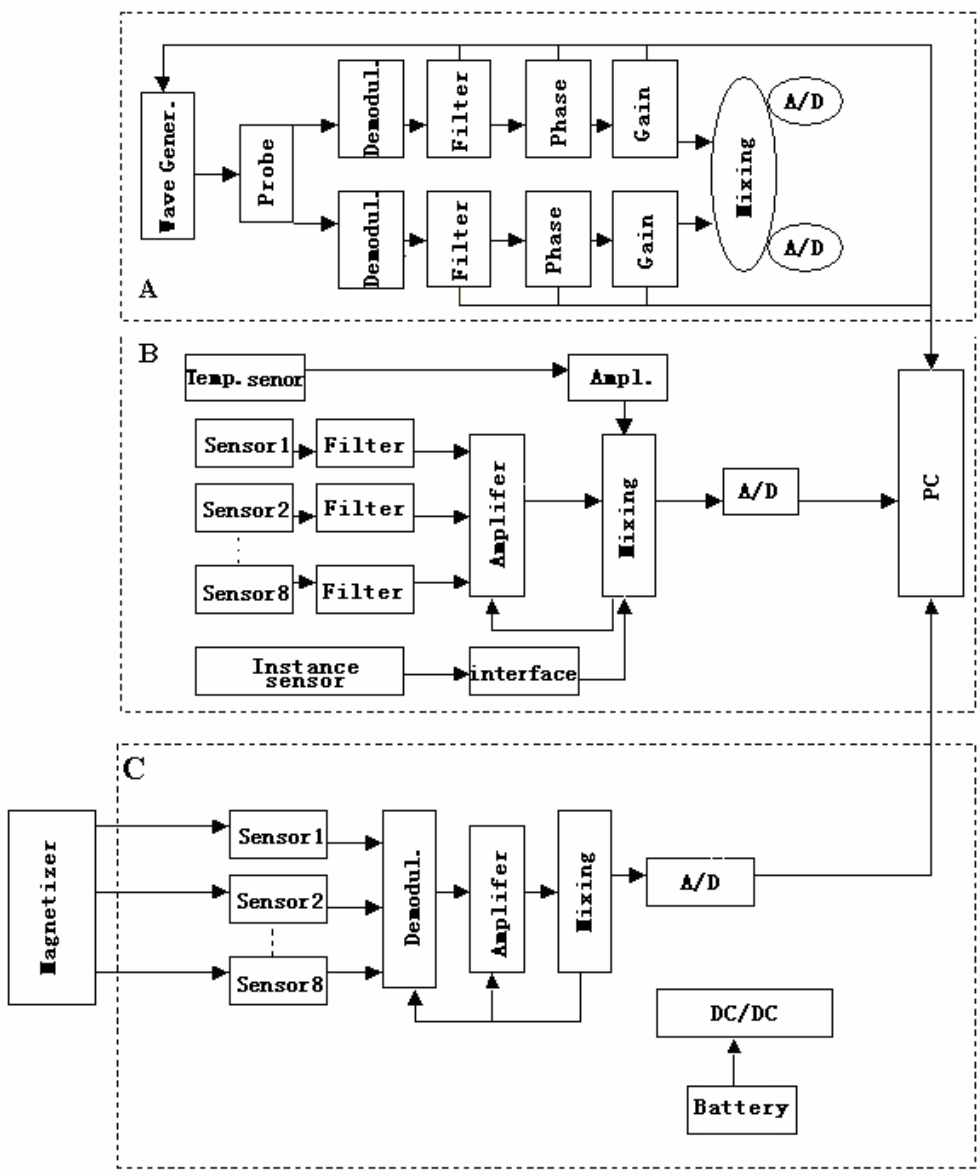

Fig. 3 Principle block diagram of MMM, EC, MFL Integrated Testing

and MFL testing software). The whole testing system includes EC testing subsystem, MMM testing subsystem and MFL testing subsystem. As shown in Figure 3, the principles of the three subsystems are as follows: the principle of EC testing subsystem: the wave generator produces sine wave at certain frequency to excite the coil[5]; the coil picks useful EC signals for amplification, filtration, detection, A/D conversion and then sends the signals into computer system; EC software processes the signals and displays the results; the principle of MMM testing subsystem: the variation of magnetic field on the part surface is converted into electrical signals via magnetic induction sensor; the electrical signals are filtered, amplified, detected and A/D converted and then sent into computer system; MMM software processes the signals and displays the results; the principle of MFL testing subsystem: the MFL is generated due to defects on part surface and sensed by sensor; the signals are filtered,

amplified and A/D converted and then sent into computer system; MFL software processes signals and displays the results. Since the principles of the three subsystems are mostly same, it is easy to combine them into the integrated system.

MMM technique enables quick testing and needs not any pretreatment on the part surface. Therefore, it can be used for quick testing of parts to identify stress-concentrated area. Then, EC subsystem is used for careful detection on this area to identify defects and measure the size of defects. In this way, complete testing of parts can be made.

6 Features and Parameters of Multitask (Integrated) Testing System

The EMS-2003 multitask device is shown in Figure 4. An example of display on MMM, EC, MFL integrated testing device is shown in Figure 5.

6.1 General Features

- Three subsystems can be separately used
- 16-bit microprocessor
- Memory: 8M (scalable to 128M)
- High-brightness screen: EL 320×256
- Human-machine dialog, menu and hotkey enable easy operation
- Simplified Chinese, traditional Chinese and English versions available
- Multiple display modes
- The functions include recording, storage, copying and analysis.

Fig. 4 Intellectual Digital MMM, EC, MFL Integrated Testing Device

6.2 Features of MMM Testing Subsystem

- 8 ways (scalable to 32 ways)
- No surface pretreatment needed; no magnetization on parts needed
- Stress-concentrated area can be identified
- Minimum measuring distance: 1mm
- Maximum measuring distance: 150mm
- Maximum scanning speed: 0.5 m/s

6.3 Features of EC Testing Subsystem

- Tow separate optional frequencies
- Frequency range: 64Hz~4MHz
- Automatic mixing processing unit
- Gain range: 0~48dB, continuously adjustable, step by 0.5dB
- Phase revolution: 0~359°, continuously adjustable, step by 1°
- Quick digital/analog electronic balancing
- Automatic/manual measurement, scaling and review of the amplification and phase of EC signals
- Unique uneven phase/amplitude alarming

6.4 Features of MFL Testing Subsystem

- 8 ways
- Digital wave filtration
- Automatic alarming
- Eight outlets for hardware alarm

■ Distance measurement

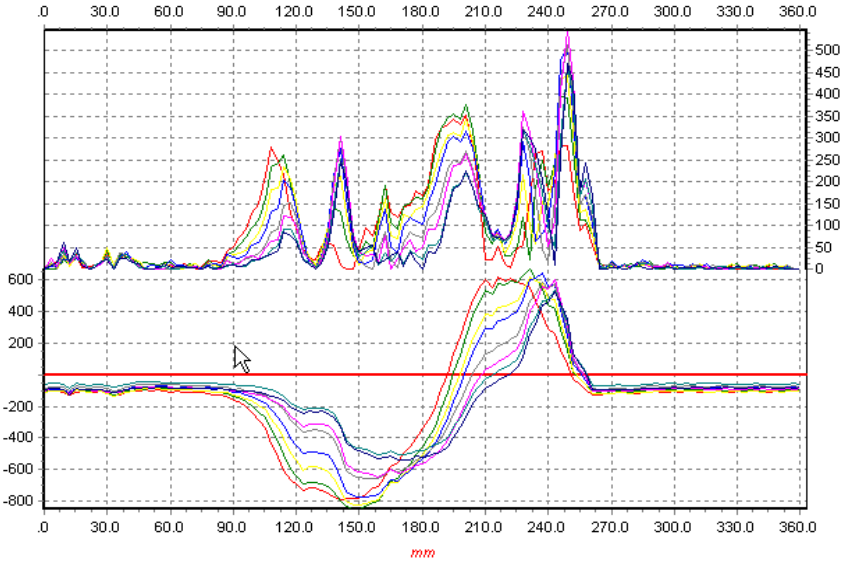

Fig. 5 Example of Display on MMM, EC, MFL Integrated Testing Device

7. Application

EMS-2003 testing system can be used for testing of boilers, pressure vessels, pipes, bridges, railroads, aircraft parts, turbine impellers, rotors and weldment[6]. For example, in case of testing of welding seam at a corner, if you use single conventional NDT technique (e.g. EC, ultrasonic) ,you have to polish the welding seam before the testing; it is time and labor consuming. If you use this testing system, you need not any pretreatment on the parts. You only need to polish the suspicious area identified by MMM testing subsystem and make further testing with EC testing subsystem. It is easy, efficient, cheap and quick. In short, the testing system enables quick scanning of equipments as well as thorough testing at suspicious area, providing a well-aimed NDT.

8. Conclusion and Expectation

EMS-2003 intellectual MMM/EC/MFL integrated testing device is a multifunctional, multi-information and portable testing system. The complementary functions and multi-information infusion achieve detection of early damages and diagnosis of established defects in in-service parts. The development of the device is a further progress of Chinese NDT equipment manufacturing industry.

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