RAPID ULTRASONIC INSPECTION OF ARMY PROJECTILES

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ABSTRACT

The electromagnetic acoustic transducer (EMAT) is a device of particular interest for rapid nondestructive evaluation (NDE) in assembly line applications because of its noncontact mode of operation. Speed is a crucial factor in the performance of an NDE system designed for the inspection of artillery projectiles where production rates may be on the order of several shells per minute. These requirements severely restrict the reliability of conventional ultrasonic techniques that use fluid couplants.

A fully automated micro-processor based inpsection system utilizing multiple EMATs to launch shear vertical acoustic waves traveling at 30 degrees with respect to the surface normal is being assembled to inspect 155 mm projectiles for both ID and OD flaws. The system's ability to detect small defects has been demonstrated by locating semi-elliptical EDM notches having surface lengths of 2.5 mm (0.1 in.) and maximum depths of 0.8 mm (0.03 in.).

INTRODUCTION

The principles of electromagnetic transduction will not be discussed in detail in this paper. It is sufficient to note that a transducer consists of a coil of wire carrying a dynamic current at the desired frequency and a magnet to impress a static bias field. Ultrasonic waves are launched as a reaction to electromagnetic forces exerted when the transducer is placed adjacent to the surface of a metal part, and they are detected by reciprocal processes. Absolutely no physical contact is required, hence transducers and the part can be moved rapidly relative to each other with no fear of disturbing the coupling medium. The approach thus combines the scanning convenience of eddy current techniques with the many advantages of ultrasonics. One of the most important of the later is the ability to excite directed beams which propagate through the thickness or around the circumference of a projectile and interrogate large volumes of material in a single measurement.

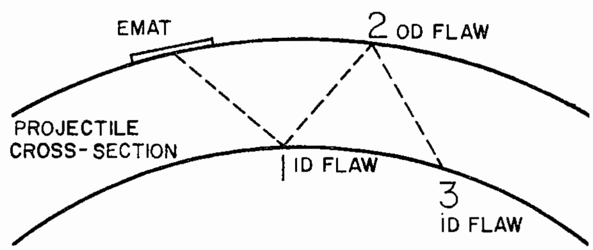

Figure 1. Inspection of projectile wall with shear-vertical acoustic waves.

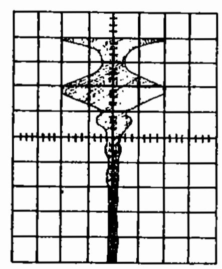

Figure 2. Oscilloscope photograph of reflected signal from ID notch.

Inspection Technique - The details of the ultrasonic inspection scheme used to detect flaws in the wall of the projectile are shown in figure 1. The EMAT which operates in the "pulse-echo" mode, generates an ultrasonic wave launched at approximately 35° with respect to the surface normal. A flaw that exists in the path of the wave reflects a signal which is then detected by the same EMAT that delivered the transmitted ultrasonic wave.

Shown in figure 2 is an oscilloscope photograph of a typical reflected signal from a 0.020 inch deep EDM notch of the ID surface of an M-549 projectile. The first signal is the electrical feedthrough from the transmitted burst at 1.94 MHz, and the second is the signal reflected from the simulated flaw. The reflected signal, appearing approximately 20 μsec after the transmission burst, represents a third bounce signal as indicated in figure 1.

The location of the flaw, either ID, bulk or OD, is determined by the elapsed time between transmitted and received signals.

A total of forty EMATs arranged in pairs are located between the projectile and each adjacent pole piece as shown in figure 3. One-half of the EMATs launch ultrasonic waves circumferentially and the other half longitudinally. The EMATs are fired sequentially every 200 μsec as the projectile is rotated which assures complete inspection. The total inspection time for a single projectile is less than one second.

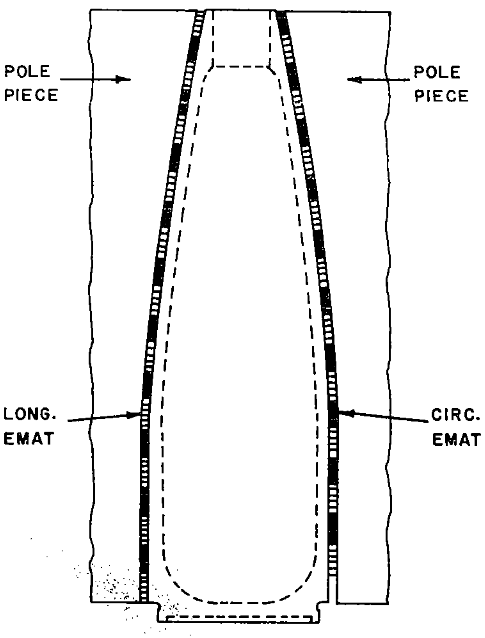

Figure 3. EMAT and pole piece configuration.

System Operation - Shown in figure 4 is a simplified block diagram of the overall inspection system. The system is composed of the following major components:

Hydraulically controlled projectile handling unit which houses the electromagnet, pole pieces and EMATs.

Hydraulic power pack and handling unit control panel.

Electromagnet power supply.

Micro-processor based analog and digital processor.

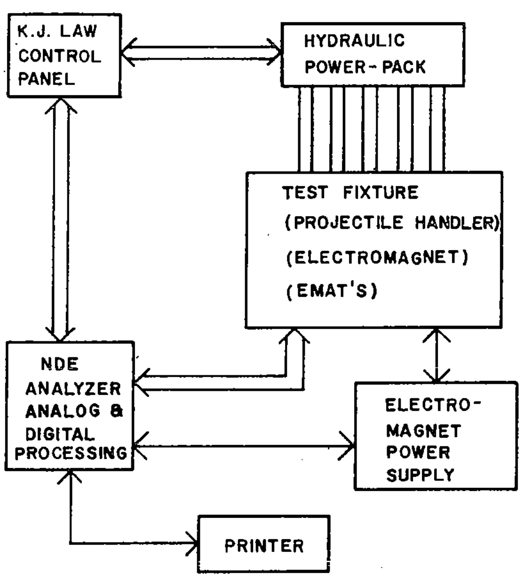

Figure 4. System block diagram.

The handling unit automatically places the projectile between the electromagnet pole pieces and relays a signal to the processor that the inspection mode may begin. The electromagnet power supply is brought up to voltage and approximately forty amperes is delivered to the coils during the short inspection cycle.
A 19 kilo-Gauss normal field is generated in the 3/32 inch gap between the projectile and each pole piece. Each EMAT is fired as the shell is rotated and if flaws exist, are recorded by the processor. Flaws may be located to within a one-half inch square area based on information gathered from range-gating and shaft encoding. At the end of the inspection cycle, a print-out of the flaw locations is available for permanent record.

The actual determination as to what constitutes a flaw is based on a set of "standards" generated by the U.S. Army Armament Research and Development Command, Dover, New Jersey. The "standards" are actually a set of projectiles containing calibrated EDM notches with depths ranging from 0.010 in. to 0.030 in. The reflections from these circumferential and longitudinal notches are used to establish accept/reject criteria applicable to production line standards.

CONCLUSIONS

Objectives which have been met as a direct result of this effort have been to demonstrate that an ultrasonic inspection system using noncontact, electromagnetic acoustic transducers can function effectively and is capable of performing inspection of the complete projectile at full production line rates.