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COMPUTER TECHNIQUES FOR ULTRASONIC INSPECTION

JAMES M. SMITH

MATERIALS TESTING TECHNOLOGY DIVISION

December 1980

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ABSTRACT

Two ultrasonic computerized inspection systems have been built: one for artillery shell rotating band inspection and the other for steel cleanliness applications. The hardware and software considerations for both systems will be described.

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INTRODUCTION

This paper will describe two prototype ultrasonic inspection systems developed in-house at the Army Materials and Mechanics Research Center (AMMRC). Both systems incorporate computers for data acquisition and analysis purposes. The first inspection instrument uses a 64-element transducer array and is capable of inspecting artillery shell rotating bands for unbonds at high inspection rates (less than 10 seconds per shell). The second instrument is designed to measure the nonmetallic inclusion content in steel billets. Steel "cleanliness" measurements are important when high quality steel is required for critical gears and bearings in aircraft engines.

LINEAR ARRAY ACOUSTICAL IMAGING SYSTEM

A description of the original AMMRC linear array inspection system has been given in previous papers.[1,2] Recently a second generation instrument (Figure 1) has been built that is portable and interfaces to a computer. The computer aspects of this system will be emphasized in the paper.

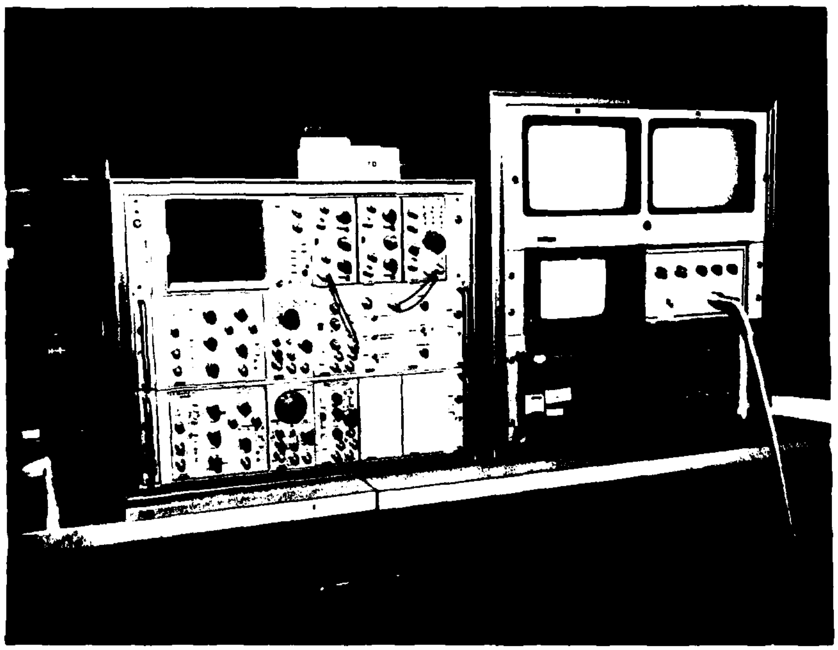

Figure 1. Portable linear array instrument.

1. SMITH, J. M. *Advanced Acoustic Imaging with Linear Transducer Arrays.* Army Materials and Mechanics Research Center, AMMRC TR 77-26, December 1977.
2. SMITH, J. M. *A Practical Linear Array Imaging System for Nondestructive Testing Applications* in Acoustical Imaging, v. 8, Plenum Press, New York, 1980, p. 641-650.

A block diagram of this instrument is shown in Figure 2. The pulser excites simultaneously four adjacent elements of the array to launch an ultrasonic compressional wave that travels through the water coupling medium into the artillery shell rotating band region. An unbond at the rotating band-shell wall interface produces a reflected wave that is received by the same four transducer elements, and peak detected. The array is then indexed by one element, and another set of four elements is excited. The pulser is capable of sweeping the length of the array in this fashion in 1/40 of a second, and a C-scan of the rotating band is accomplished by turning the shell through one revolution. The data from the peak detector is stored in an analog storage device (the scan converter) and displayed on a conventional video monitor (Figure 3).

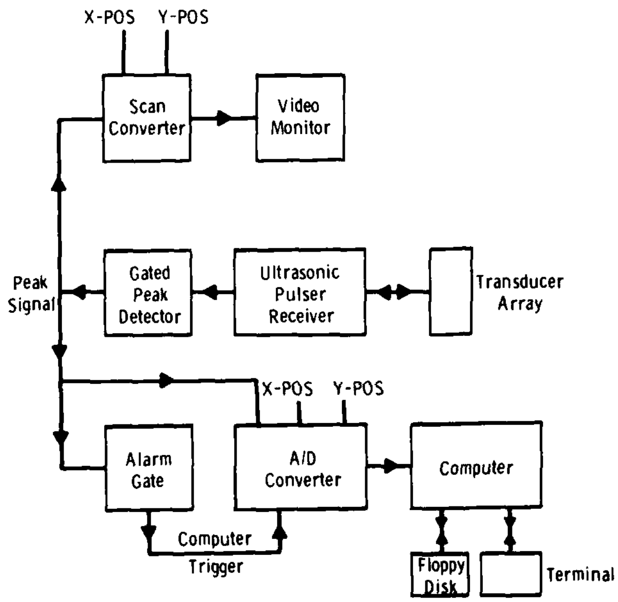

Figure 2. Linear array imaging system - block diagram.

In addition, a small minicomputer (Figure 4), consisting of an LSI-11 processor with 56K bytes of random access memory (RAM) and 1M byte of floppy disk storage, is used for data acquisition and defect sizing. An A/D converter, manufactured by Andromeda Systems, Inc., digitizes the ultrasonic signal level and the X-Y position of an unbond with 12-bit resolution. This conversion process is triggered by a gated alarm that produces a trigger pulse only when an ultrasonic defect indication exceeds a prescribed threshold. At the completion of the scan, the defect data is dumped onto the floppy disk for later analysis.

A digital C-scan (Figure 5) is produced by plotting the rotating band data on the computer terminal (Tektronix 4051). However, the important role of the computer is to determine the size and location of unbonded regions under the band. During an actual inspection this data would be compared with the critical defect sizes for the particular artillery shell configuration.

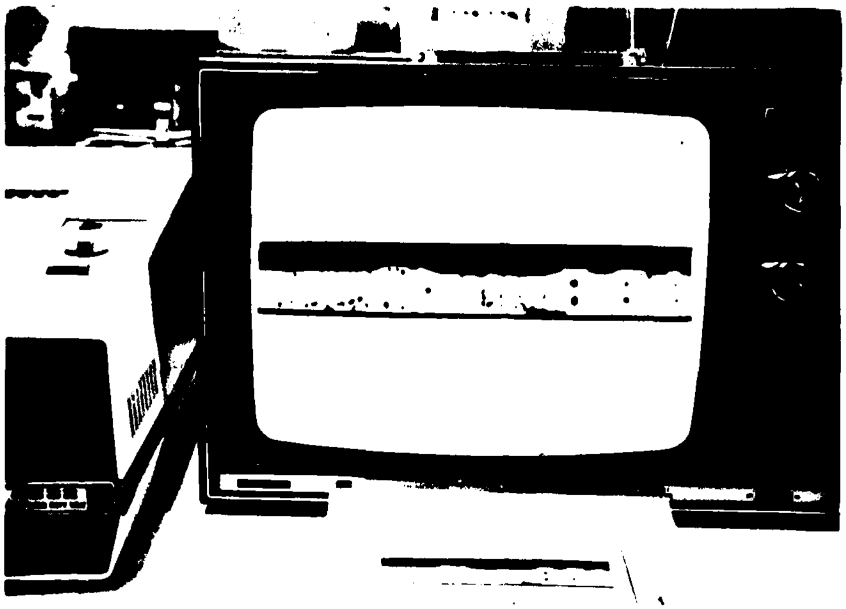

Figure 3. C-scan of rotating band. The dark circular regions represent unbonds between the band and the steel casing.

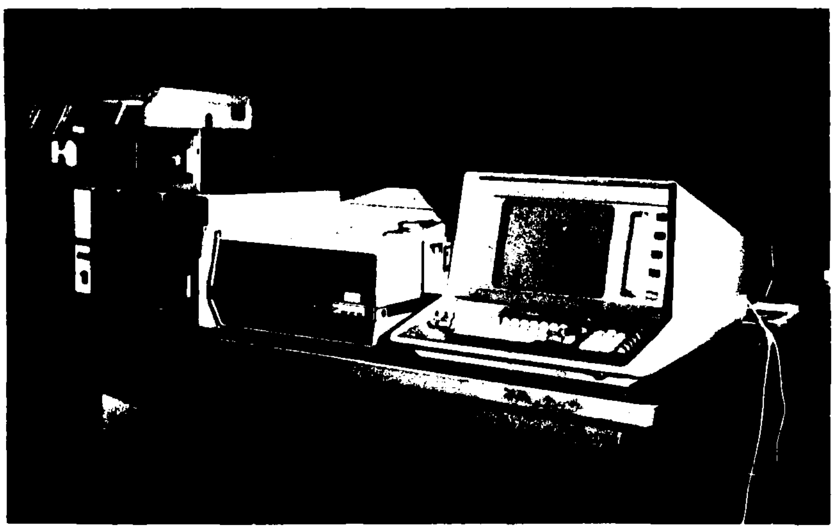

Figure 4. LSI-11 based minicomputer system.

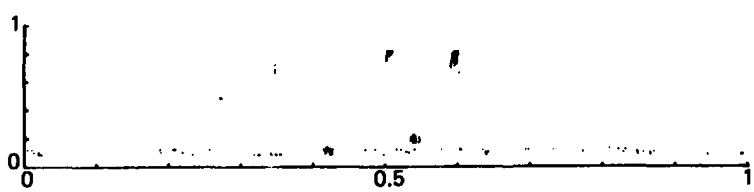

Figure 5. Digital C-scan of rotating band.

Defect sizing is accomplished by sorting the X-Y defect location data into a 20 × 100 grid for a total of 2000 pixel elements. Twenty pixels cover the width of the band and one hundred pixels run along the length. After the data has been sorted to determine which pixels contain defect information, the vertical and horizontal extent of an unbond is determined by identifying clusters of adjacent pixels with unbond information. The number of ultrasonic indications (a number proportional to the area of the defect), the X and Y location, and the largest ultrasonic signal level from each unbond are determined. A typical data display from a rotating band is shown in Figure 6. This data, when combined with critical defect size information, will be used to determine rotating band integrity.

UPPER Y-LIMIT IS 0.850
LOWER Y-LIMIT IS 0.080
THERE ARE 94 DATA POINTS

COUNTS	AMPLITUDE	X-POS.	Y-POS.	
1	0.297	1.000	0.119	LOWER EDGE
3	0.550	0.920	0.850	UPPER EDGE
3	0.396	0.770	0.850	UPPER EDGE
24	0.687	0.750	0.773	UPPER EDGE
6	0.523	0.690	0.157	
12	0.554	0.660	0.812	UPPER EDGE
7	1.000	0.610	0.850	UPPER EDGE
4	0.683	0.570	0.119	LOWER EDGE
13	0.346	0.540	0.850	UPPER EDGE
3	0.338	0.490	0.850	UPPER EDGE
1	0.314	0.430	0.619	
1	0.359	0.300	0.850	UPPER EDGE
1	0.683	0.170	0.850	UPPER EDGE
1	0.365	0.160	0.119	LOWER EDGE
5	0.687	0.120	0.850	UPPER EDGE
8	0.819	0.070	0.850	UPPER EDGE
1	0.406	0.010	0.119	LOWER EDGE

Figure 6. Computer output from defect sizing program.

STEEL CLEANLINESS SYSTEM

The steel cleanliness inspection system is designed to measure the nonmetallic inclusion content in steel billets (Figure 7) by counting the ultrasonic indications as a transducer is scanned in a raster fashion over a billet. The ultrasonic indications are sorted as to signal amplitude and location in the billet. This data can then be used to determine the cleanliness of the billet or the cleanliness of an entire heat of steel using statistical sampling methods. In certain applications, important performance characteristics,[3,4] such as the mean lifetime before failure, correlate directly with the cleanliness of the steel. This paper will discuss only the operation of the steel cleanliness system. An evaluation of its effectiveness in predicting mechanical performance is currently being investigated.

3. CARTER, C., CELLITTI, R., and ABAR, J. *An Automatic Computerized Ultrasonic Cleanliness Rating System and Calibration Standards.* International Harvester Company, Contract DA-19-066-AMC-314(X), Final Report, AMRA CR 67-10(F), May 1967.
4. MOBERG, D. V. *Establishment of a Tentative Ultrasonic Steel Cleanliness Standard.* Rock Island Arsenal, WECOM-R-RR-T-1-47-73, July 1973, AD 766289.

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The steel cleanliness system (Figure 8) consists of a computer-controlled ultrasonic pulser-receiver (Automation Industries S80), a three-axis manipulator with motor control, a 3' × 6' immersion tank, and an LSI-11 based minicomputer (the same computer used with the linear array system). A block diagram of this system is shown in Figure 9. In contrast to the linear array system in which the computer plays only a passive role during data acquisition,

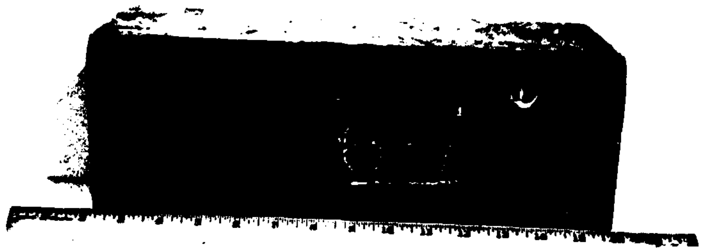

Figure 7. Typical steel billet. Dimensions are 5" x 5" x 14".

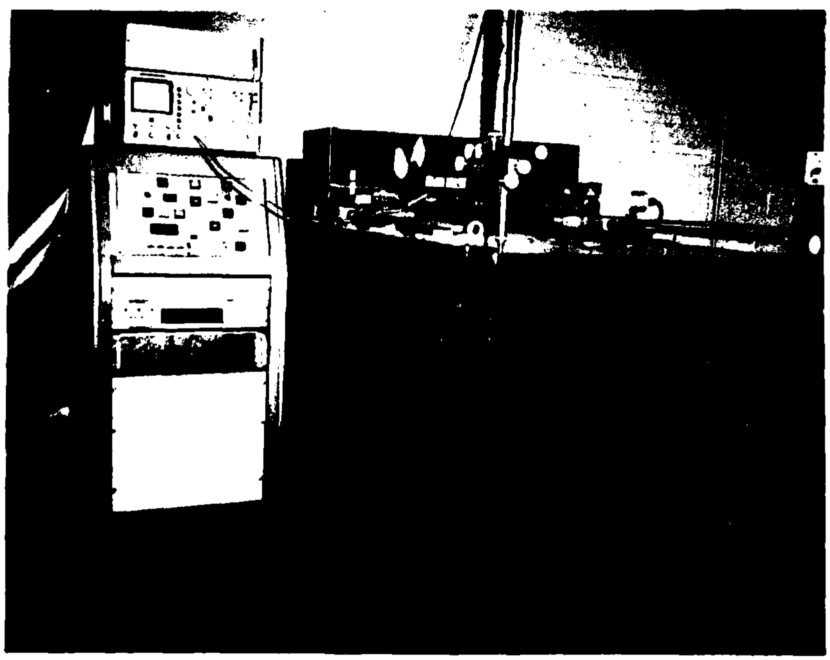

Figure 8. Ultrasonic pulser receiver and immersion tank used for the steel cleanliness measurements.

here it is used to control pulser-receiver parameters and the data gathering process. An outline of the critical computer tasks for data acquisition is given in Figure 10.

Two programs have been written that present to the operator important information to be used in determining steel cleanliness. Figure 11 shows a histogram that plots the frequency of occurence for the ultrasonic indications versus their amplitude level. The amplitude level has been sorted into 128 discrete levels. This figure is typical of the results from "clean" billets, and should be contrasted with the data from a "dirty" billet shown in Figure 12. Note the large number of high amplitude signals detected in the dirty billet

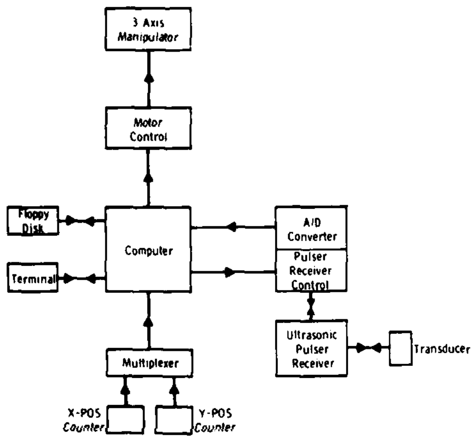

Figure 9. Steel cleanliness system - block diagram.

1. CHECK TO SEE IF TRANSDUCER IS WITHIN ASSIGNED LIMITS (X MAX, X MIN, Y MAX, Y MIN)
2. CHECK TO SEE IF THE TRANSDUCER HAS BEEN FIRED
3. WAIT FOR VALID DATA FROM THE A/D CONVERTER
4. READ DATA (AMP, X-POS, Y-POS, GATE POSITION) AND STORE IN A TEMPORARY ARRAY
5. UPDATE THE GATE POSITION (5 DISCRETE POSITIONS)
6. DURING THE TURN-AROUND OF THE TRANSDUCER, SORT AND STORE DATA IN A MORE PERMANENT ARRAY (DATA SPACE DIVIDED INTO 20 X 50 PIXELS)
7. AFTER SCAN HAS BEEN COMPLETED, DUMP DATA ONTO FLOPPY DISK

Figure 10. Outline of computer tasks for data acquisition.

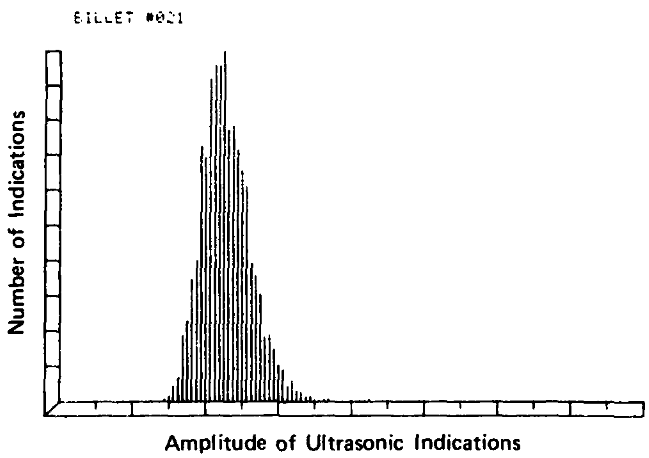

Figure 11. Histogram showing frequency of occurrence for the ultrasonic indications plotted against their amplitude. Data is typical of a "clean" billet.

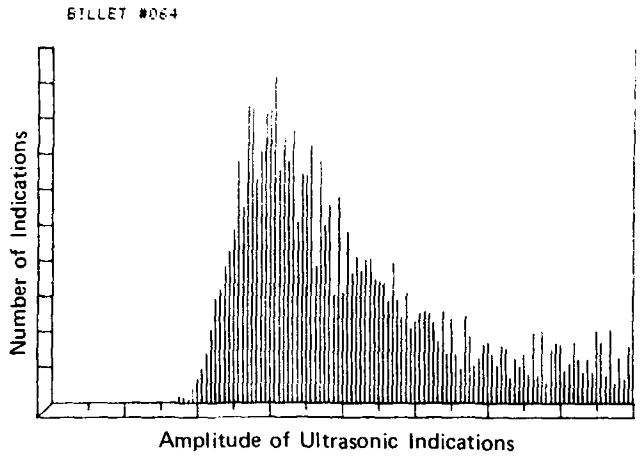

Figure 12. Histogram for a "dirty" billet.

which represent ultrasonic reflections from nonmetallic inclusions. Data of this type is available for five depth zones within the billet. The attenuation of the ultrasonic signal through the billet is taken into account by a normalization scheme so that all five zones are treated on an equal basis. In this way, it is possible to determine how the cleanliness of the billet varies with depth below the surface.

The data analysis package is also capable of generating digital C-scans for all five depth zones (Figure 13). The locations in the billet where the ultrasonic signal exceeded a prescribed threshold are plotted. This information, which is useful for locating regions in the billet that are particularly dirty, may be used to salvage the good sections of an otherwise unacceptable billet.

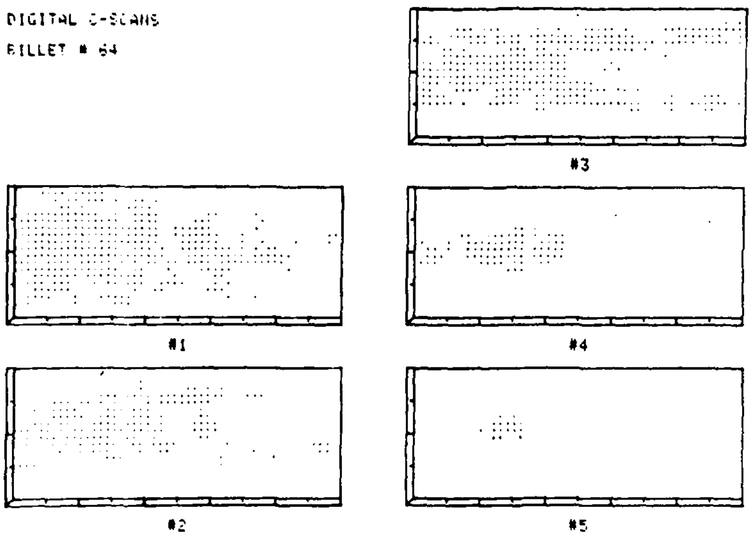

Figure 13. Digital C-scans for five depth zones in a billet.

CONCLUSIONS

Two prototype ultrasonic inspection systems have recently been built at AMMRC. The linear array acoustical imaging system uses a computer for defect sizing and location determination and is capable of inspecting an artillery shell rotating band in less than ten seconds. This instrument is currently scheduled to be sent to Chamberlain Manufacturing Company in early 1981 for an extensive evaluation of its capability for inspecting inertia-welded rotating bands on the M483 projectile.

The steel cleanliness system, which is designed to measure the nonmetallic inclusion content in steel billets, provides the operator with data plots and digital C-scans used to determine steel cleanliness. The correlation of steel cleanliness measurements with mechanical properties of helicopter gears is currently being evaluated under a joint program with International Harvester Company. In addition, preliminary studies* show that this instrument should be a valuable tool for measuring the nonmetallic inclusion content of artillery shell bodies. Further work in this area is continuing under an AMMRC Materials Testing Technology Program entitled "Critical Ultrasonic Inspection Problems Within the Army."

*BRUGGEMAN, G. A., and SMITH, J. M. *The Effect of Heat Treatment Variation on Property Variability in the M549 Projectile Warhead.* Army Materials and Mechanics Research Center, AMMRC Letter Report to TM-PM-CAWS, ARRADCOM, February 1979.

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1	DRXMR-T
1	DRXMR-E
1	DRXMR-PR
1	Author

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