OPTIMIZING ULTRASONIC SIGNAL RESPONSES OF PRODUCTION NONDESTRUCTIVE TESTING SYSTEM

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In general, all ultrasonic systems require calibration prior to their use for screening a product; furthermore, their calibration must be verified frequently. Specially designed calibration standards which contain machined notches simulating actual material defects are used for the calibration of the equipment. Some tolerances must be allowed for machining the simulated defects. When all the tolerances in the ultrasonic system, instrument, sensor, and standards are accumulated, the resulting signal responses are usually less than desired. To maintain the required uniform sensitivity, compensation must be made for these undesirable losses in signal amplitude.

Ultrasonic standards are made from defect-free production items. Electric discharge machine (EDM) notches are cut to simulate natural defects. A cross section of an EDM notch is shown in Fig. 1. EDM notch locations are selected to assure complete coverage of the entire area to be inspected. Emphasis is placed on high stress locations.

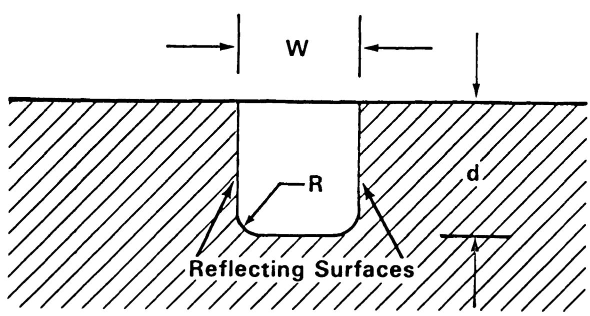

Fig. 1. Ultrasonic Test Standard Notch Cross Section

Natural defects reflect less energy than the standard machined notches. Through destructive analysis, it has been determined that a 4-to-1 relationship between natural defect size and a standard notch size will provide for adequate safety in the detection of critical defects. A critical crack size for each location is determined from the stress profile using the worst-case fracture toughness value. A typical effective stress map is shown in Fig. 2. The effective stress can be resolved into circumferential and axial components. The critical longitudinal crack sizes are based on the tensile hoop stresses, and critical circumferential crack sizes are based on the tensile axial stresses.

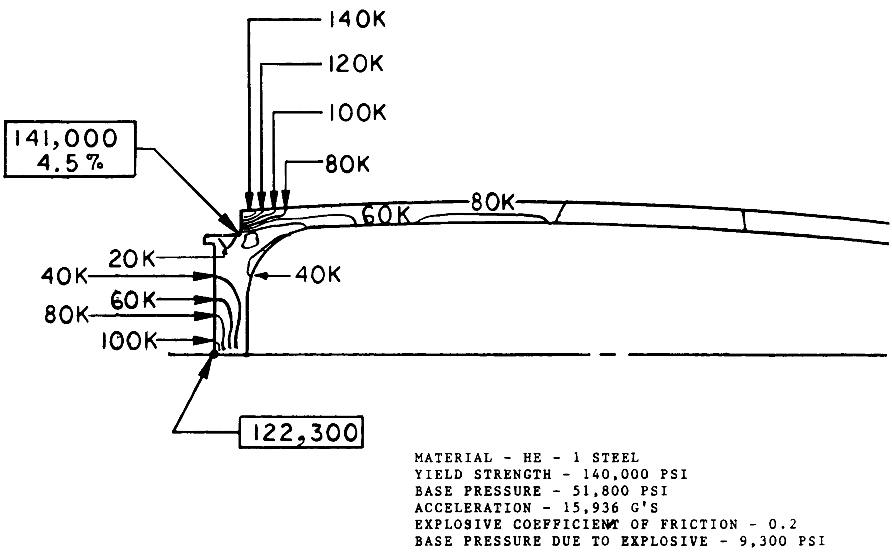

Fig. 2. Stress Map for 155-mm M549 Warhead

A combination of stationary and scanning channels is used in automated ultrasonic inspection systems for artillery projectiles. In the scanning channels, the signal responses from the standard notches may vary throughout the scan. This is due to the following conditions:

Varying path of sound beam

Variation in wall thickness

Inside or outside notches

Attenuation within the wall

Undesired reflections and refractions at all interfaces

Surface finish of the EDM notch

Bottom radius of the EDM notch

Orientation of the notch with reference to the sound beam.

Figures 3 and 4 attempt to illustrate reduction in the returned sound energy due to the above factors.

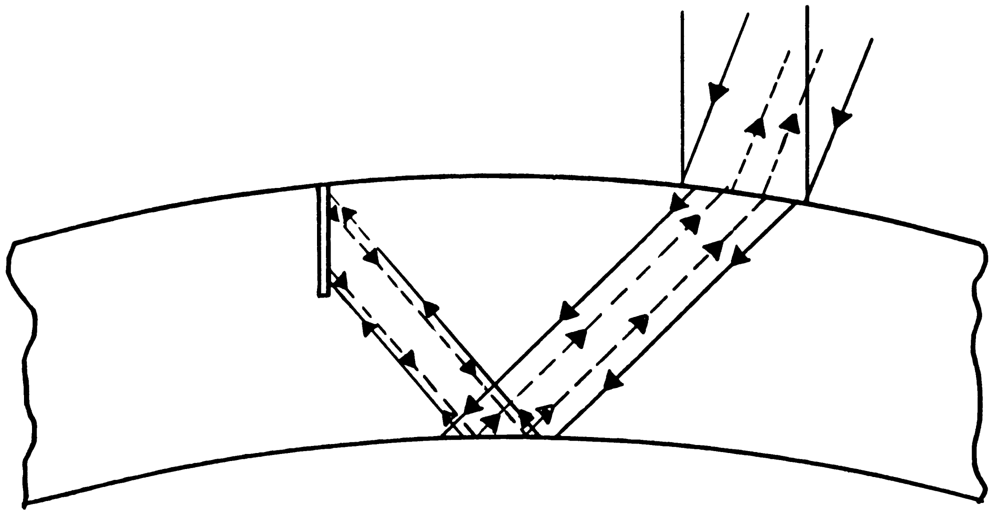

Fig. 3. Drop in Return Energy

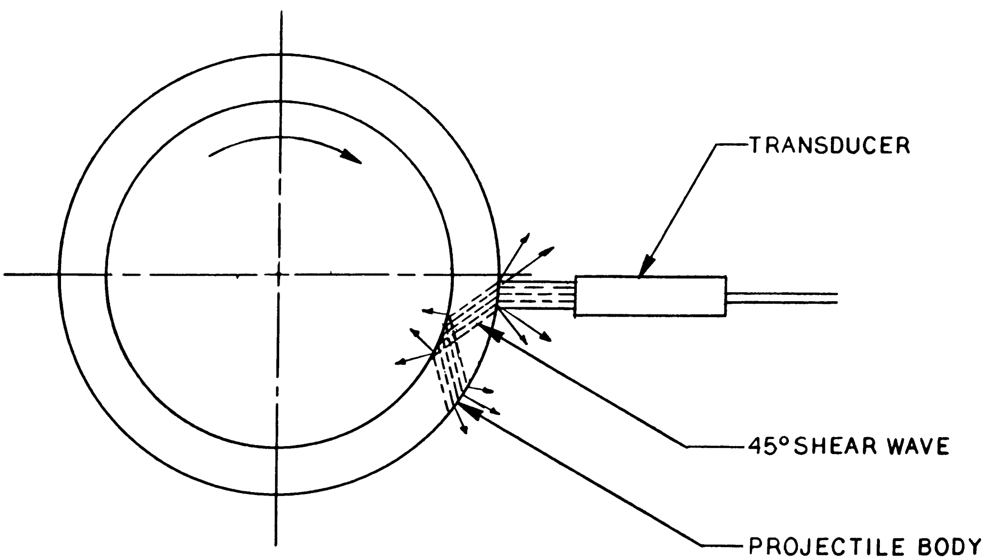

Fig. 4. Ultrasonic Inspection of 155-mm HERA M549 Projectile

Figure 5 is an example of a typical variation in the signal amplitude for the same size EDM notch placed in different locations on the projectile. It can be seen that the variation in dB level required to maintain the same signal height can be as much as 17 dB. In other terms, if the DB level is kept constant, the signal will fluctuate more than 300%.

100% SIGNAL	
NOTCH LOCATION	DB
3	27
4	24
5	22
6	29
7	21
8	22
9	20
10	20
11	20
12	14
13	10
14	12

Fig. 5. Actual Data 1-20-83, M549 Warhead
Response from Channel 1 (Circumferential)
Transducer 3/4 dia, Beam Corrected 2.25 MHz

There are two different ways of avoiding the false rejects caused by the high sensitivity of inspection: Programmable Gain Control (PGC) and Variable Reject Level (VRL) Control.

The principle of PGC is to control the gain in small intervals of scan length so that the gain can be adjusted in each zone to maintain a uniform sensitivity throughout the scan. To obtain a flexible scan increment, an encoder is used at the end of the lead screw which carries a scanning transducer. With a proper combination of the lead screw and the encoder, the scan length can be divided into the desired number of zones as shown in Fig. 6. Thus the disparities among the signals can be reduced to zero within any scanning length as indicated in Fig. 7. A constant reject level then will eliminate the false rejects.

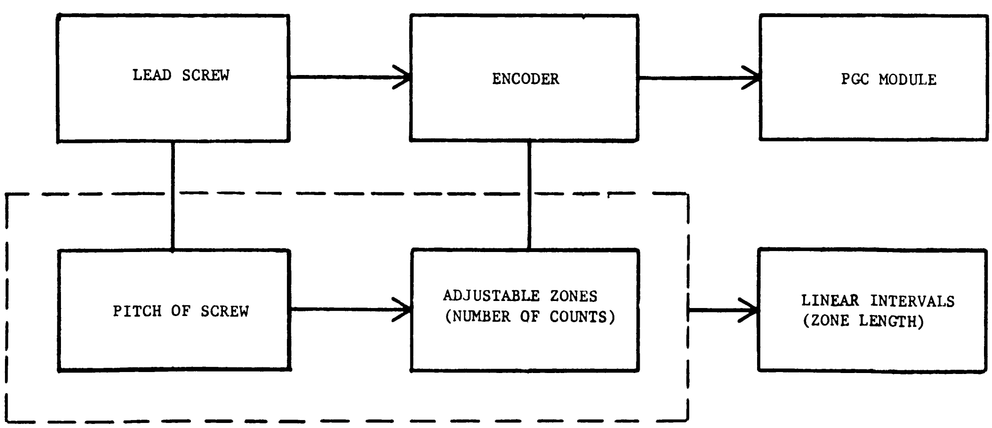

Fig. 6. PGC Layout

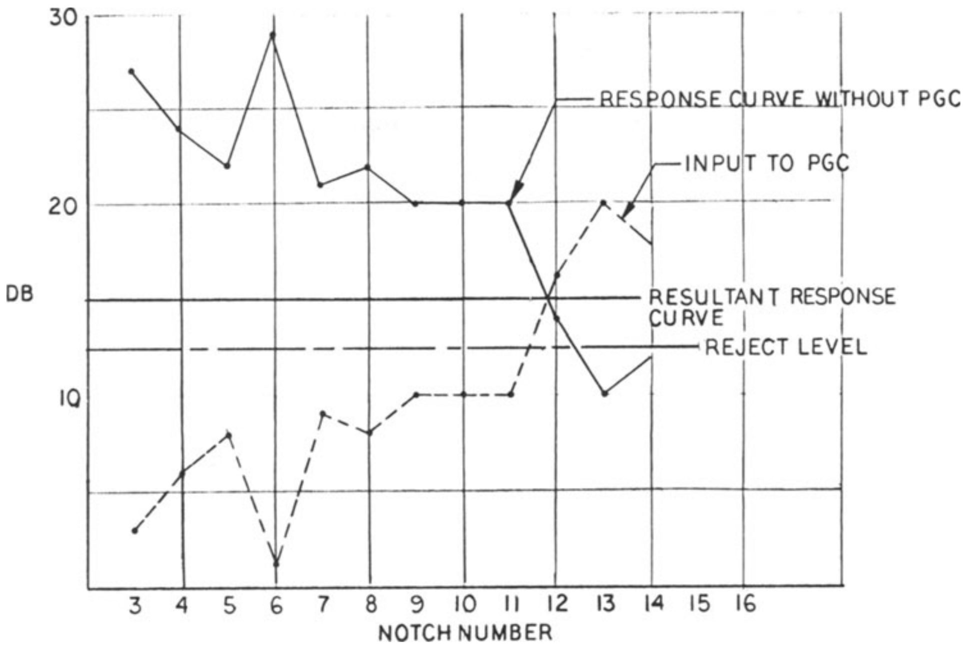

Fig. 7. PGC Response

The VRL Control uses the same principle of an encoder and zones as the PGC, but instead of the signal amplitude being manipulated, the reject level is individually set in each zone so that the reject level line is parallel to the response curve, as shown in Fig. 8. The drawback with this approach, however, is that if the signal in any zone is too low, it will still create false reject signals in that zone.

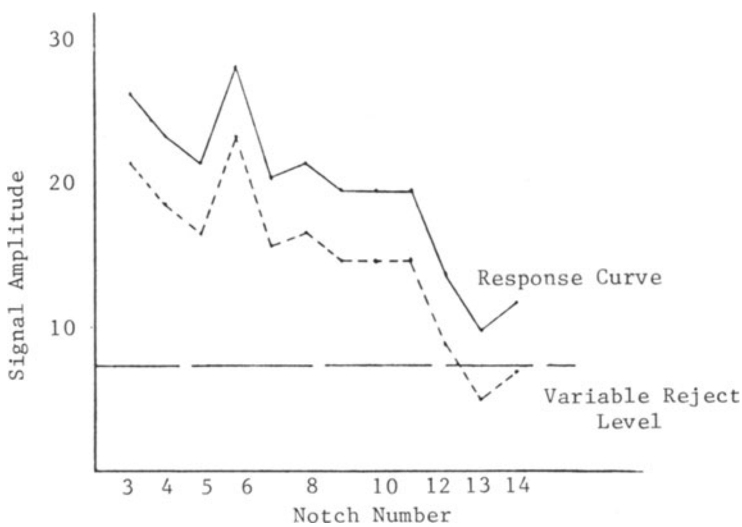

Fig. 8. Variation in Reject Criteria

PGC has proven to be a reliable method of compensating for the signal amplitudes in production ultrasonic testing systems.