SMC-TR-96-07

AEROSPACE REPORT NO.
TR-94(4464)-1

Ultrasonic Backscatter Technique for Corrosion Detection in Solid Rocket Motors

15 October 1994

Prepared by

J. R. LHOTA, G. C. PANOS, and E. C. JOHNSON
Mechanics and Materials Technology Center
Technology Operations

M. C. GREGORY
United Technologies Chemical Systems Division

Prepared for

SPACE AND MISSILE SYSTEMS CENTER
AIR FORCE MATERIEL COMMAND
2430 E. El Segundo Boulevard
Los Angeles Air Force Base, CA 90245

Engineering and Technology Group

THE AEROSPACE CORPORATION
El Segundo, California

APPROVED FOR PUBLIC RELEASE;
DISTRIBUTION UNLIMITED

This report was submitted by The Aerospace Corporation, El Segundo, CA 90245-4691, under Contract No. F04701-93-C-0094 with the Space and Missile Systems Center, 2430 E. El Segundo Blvd., Los Angeles Air Force Base, CA 90245. It was reviewed and approved for The Aerospace Corporation by S. Feuerstein, Principal Director, Mechanics and Materials Technology Center. This report has been reviewed by the Public Affairs Office (PAS) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nationals.

This technical report has been reviewed and is approved for publication. Publication of this report does not constitute Air Force approval of the report's findings or conclusions. It is published only for the exchange and stimulation of ideas.

John Hocutt, Maj. USAF
SMC/CLUE

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (*Leave blank*)

2. REPORT DATE
15 October 1994

3. REPORT TYPE AND DATES COVERED

4. TITLE AND SUBTITLE
Ultrasonic Backscatter Technique for Corrosion Detection in Solid Rocket Motors

5. FUNDING NUMBERS
F04701-88-C-0089

6. AUTHOR(S)
Lhota, J. R.: Panos, G. C.: Johnson, E. C.: and Gregory, M. C.

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
The Aerospace Corporation
Technology Operations
El Segundo, CA 90245-4691

8. PERFORMING ORGANIZATION REPORT NUMBER
TR-94(4464)-1

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Space and Missile Systems Center
Los Angeles Air Force Base
Los Angeles, CA 90009-2960

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
SMC-TR-96-07

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT (*Maximum 200 words*)

The need within the aerospace industry to requalify hardware that has exceeded its nominal design life is being partially addressed by the development of techniques to periodically inspect hardware for material changes, such as corrosion. Unfortunately, minor corrosion-induced surface changes that can weaken a bondline or prevent the sealing of an O-ring do not lead to a significant change in a normally reflected ultrasonic signal. An alternate approach was developed that involves monitoring the backscattered signal from pulses striking the interface at an oblique angle. In this instance, most of the acoustic energy is forward-scattered so as not to compete with the relatively small back-scattered signal from small surface changes. Such an approach is very similar to the angle beam techniques commonly used in the inspection of welds. The results from two applications of this technique to the inspection of flight hardware indicate that the presence of detrimental corrosion can be successfully discriminated from the nominal surface finish of the metal.

14. SUBJECT TERMS
Corrosion, Nondestructive Evaluation, Ultrasonics

15. NUMBER OF PAGES
8

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

CONTENTS

FIGURES

INTRODUCTION

The need within the aerospace industry to requalify hardware that has exceeded its nominal design life is being partially addressed by the development of techniques to periodically inspect hardware for material changes such as corrosion. In many instances, access is limited to one side of the component under test, and the most common inspection method involves using the signature of ultrasonic pulses reflected at normal incidence from a backwall. However, often this technique is not sensitive to the minor corrosion-induced surface changes that can cause disbonds at a bond interface or prevent the sealing of an O-ring. To cope with this problem, an alternate technique is being studied where the ultrasonic pulse is directed at an oblique angle, and the monitored signal is that scattered directly back to the transducer by surface imperfections on the backwall. The basic principle and the application of this technique to two cases of flight hardware inspection are discussed herein.

PRINCIPLE

The simple concept underlying the technique is illustrated schematically in Figure 1. The probing beam is directed off the normal of the surface to be inspected. If the surface is unblemished, then most of the sound energy is forward-scattered, and little or no signal is backscattered to the transducer. If the surface or interface is nonuniform, such as caused by pitting, then a greater amount of sound energy is backscattered and detected by the transducer. In Figure 2, the signals from a relatively smooth, grit-blasted surface with and without a ~15 mil Electric Discharge Machined (EDM) pit are plotted. The backscattered signal from the pit is dramatically larger. Pits of less than 2 mil are detectable with this technique.

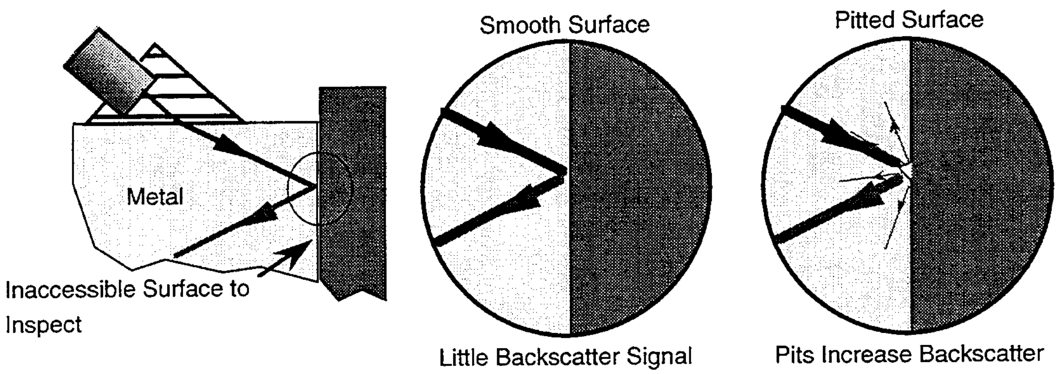

Figure 1. Backscatter technique principle.

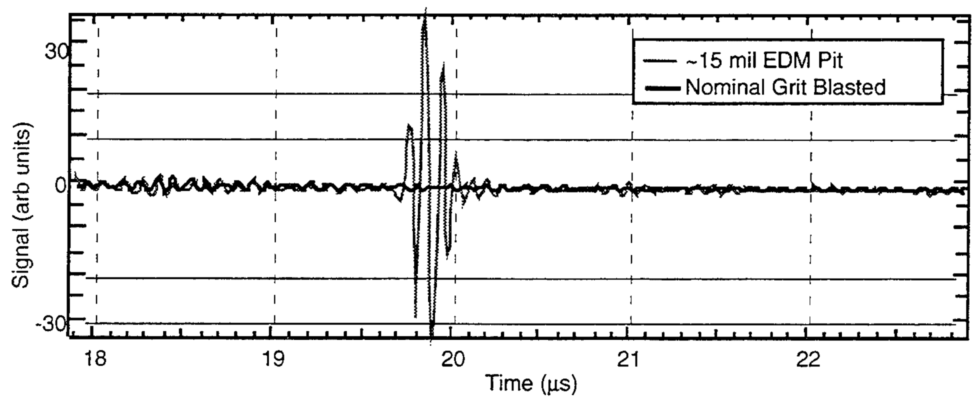

Figure 2. The backscattered signal from the single pit is dramatically larger than from the unpitted grit blasted surface.

CASE STUDY I - BONDLINE INSPECTION

The backscatter technique was applied in two different types of inspections of solid rocket motors. In the first case, the inaccessible surface was a bondline between an aluminum polar boss and a filled rubber insulator, which is shown in Figure 3. Concerns were raised regarding the integrity of the

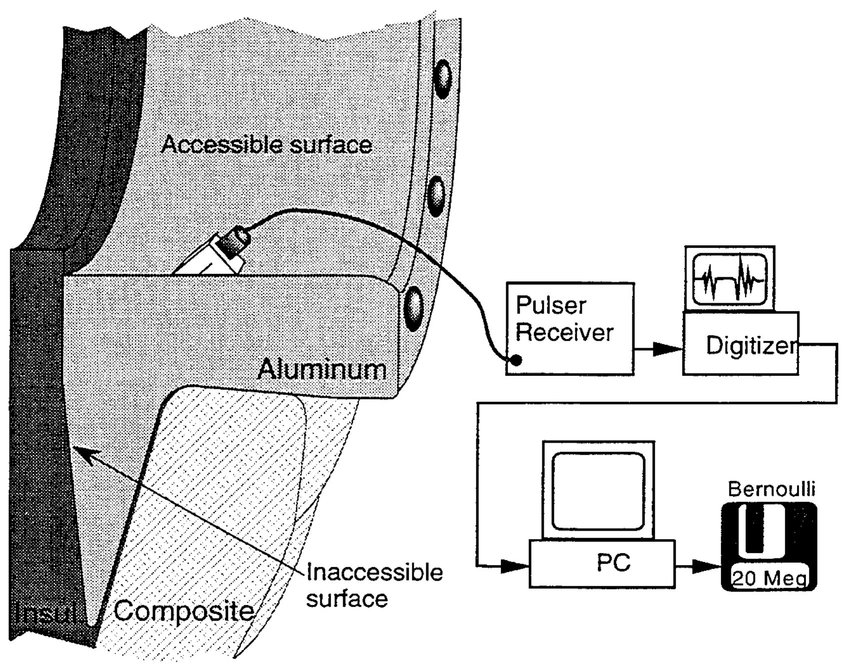

Figure 3. A schematic showing a cross-section of the interface and the inspection hardware set-up.

flight hardware, which had aged beyond the original qualification period, after corrosion was found in sectioned hardware from an aged, scrapped motor case. The backscatter ultrasonic inspection for corrosion was implemented as a part of the requalification process. The region of interest in the inspection was the from the aluminum-insulator interface for the first 1.8 in. from the inner diameter for the entire 360°. A standard scan recorded the signal at seven positions along the 1.8 in. for every degree, i.e., a 7×360 grid. The rf signals were digitally recorded and post-processed for analysis.

The hardware geometry required scanning the transducer on the inner surface of the boss; a surface that is perpendicular to the aluminum-insulator interface. The signal path varies as the transducer is scanned at a given degree. A sliding gate and Distance Amplitude Correction (DAC) were used to process the data. The attenuation constant for the DAC was taken from pre-recorded data measured on a laboratory sample of similar material and from measurements on a calibration standard at the time of inspection. Both sets of data, plotted in Figure 4, are in good agreement. The value of 17.4 Np/m was used for the DAC.

An example of a C-scan plot of the processed data is shown in Figure 5. In the upper C-scan, the data is plotted one pixel for each data point. The lower C-scan is a plot of the same data interpolated to a finer grid to aid in visualizing patterns. The data was normalized such that a value of 4 corresponded to a reportable indication level. No reportable indications were found in this piece of hardware.

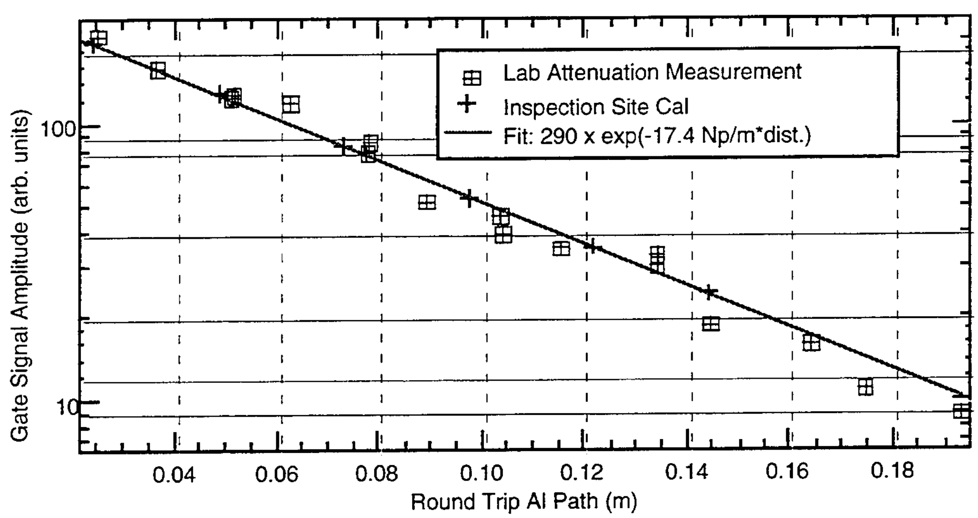

Figure 4. The attenuation constant of 17.4 Np/m used for DAC was extracted from lab measurements and calibration data.

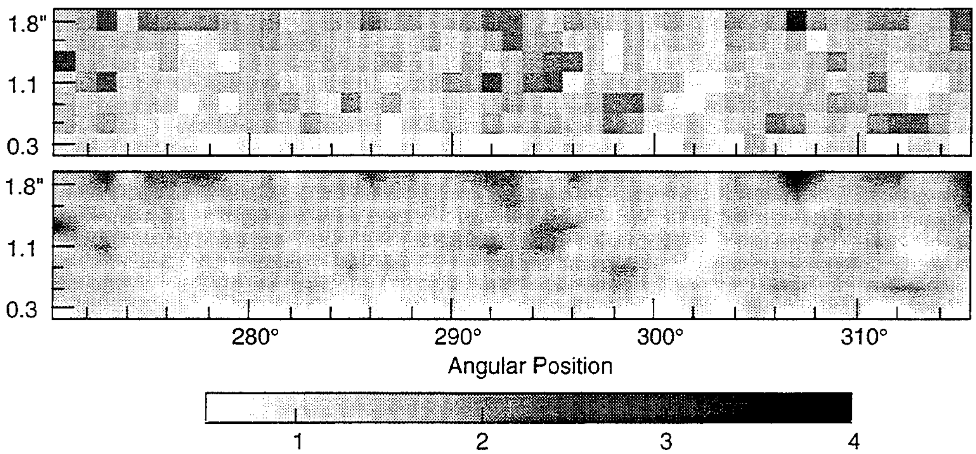

Figure 5. Example of C-scan plots of the ultrasonic data after gating, peak detection, DAC and normalization.

CASE STUDY II - INTERNAL SURFACE INSPECTION

Aging concerns were raised about solid rocket motors remaining stacked for extended time periods at humid, coastal launch sites. Following a destack, corrosion was found in joint regions; see Figure 6. The concern for corrosion causing inadequate O-ring sealing resulted in the contractor implementing an ultrasonic backscatter technique to periodically inspect stacked vehicles. Unlike the previous case, the inaccessible surface to be inspected was an interior surface rather than a bondline. The geometry constraints required the design and manufacture of a custom transducer wedge by co-author M. C. Gregory.

Parallel studies of the corrosion mechanisms and corrosion detectability were undertaken in collaboration with metallurgists. Samples were prepared and exposed in representative corrosive environments. In addition to metallurgical analysis, the samples were ultrasonically inspected to build an experience database. In Figure 7, a comparison of visible corrosion and an ultrasonic scan for one sample is presented. The laboratory ultrasonic scanning system is shown in Figure 8. The sample had been heat treated (hardened to R_C42), and the surface grounded flat and grit blasted. A rusted condition was produced by 20 days exposure in a humidity chamber maintained at 90% relative humidity at 40° C. The resultant corrosion shows up as dark indications in the video image to the left of Figure 7. The lower right spot was grit blasted to remove a portion of the corrosion. There is good correlation between the visible corrosion and the high ultrasonic amplitudes exhibited in the C-scan on the right of Figure 7. Some preliminary data has indicated that the O-ring grease and O-ring may have some effect on the ultrasonic signal amplitudes. This is currently under investigation.

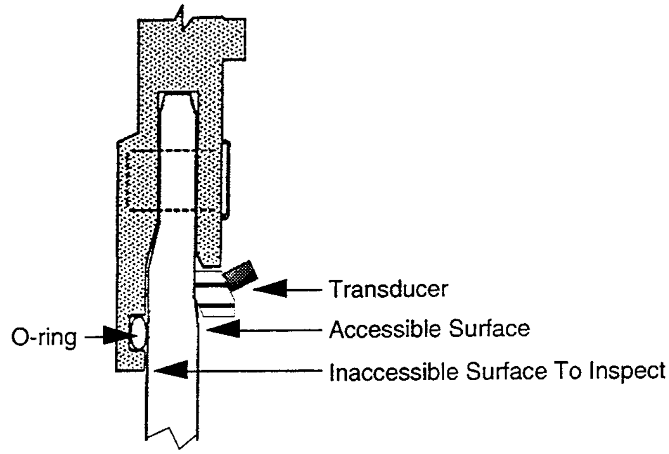

Figure 6. Sketch of a solid rocket motor joint region. Corrosion was found on destacked hardware in the vicinity of the O-ring sealing surface.

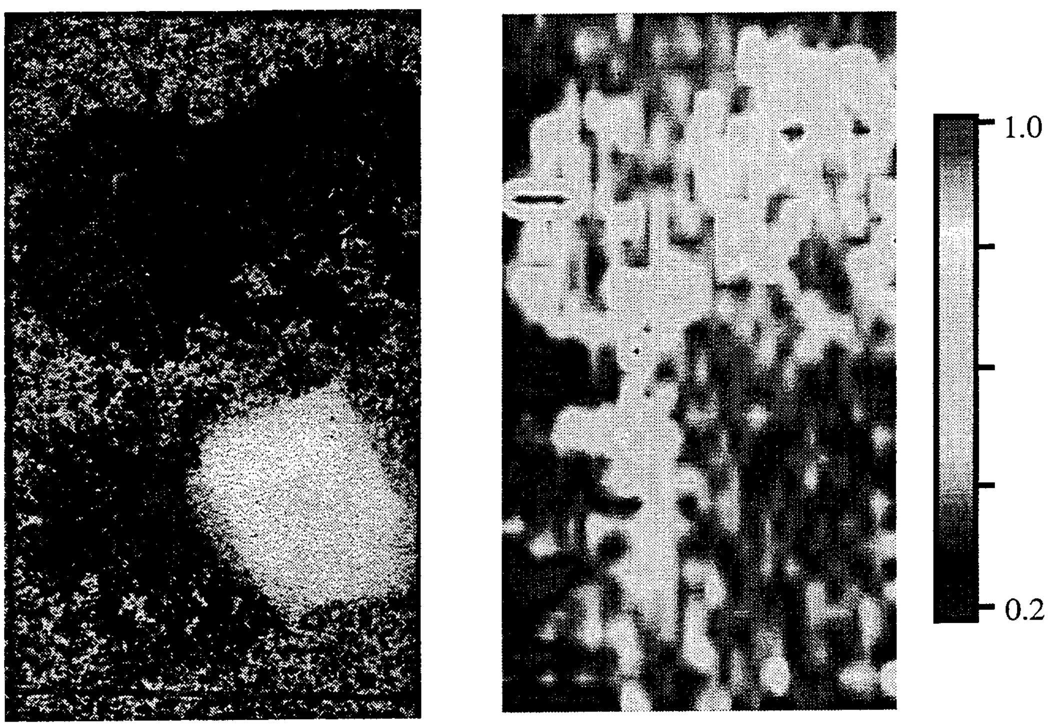

Figure 7. Comparison of visible corrosion and an ultrasonic C-scan. On the left is an optical image of a corroded D6AC steel sample, and on the right is an ultrasonic C-scan of the same sample. The C-scan data was taken with the apparatus depicted in Fig. 8. In Fig. 8, the corroded surface is opposite the surface scanned.

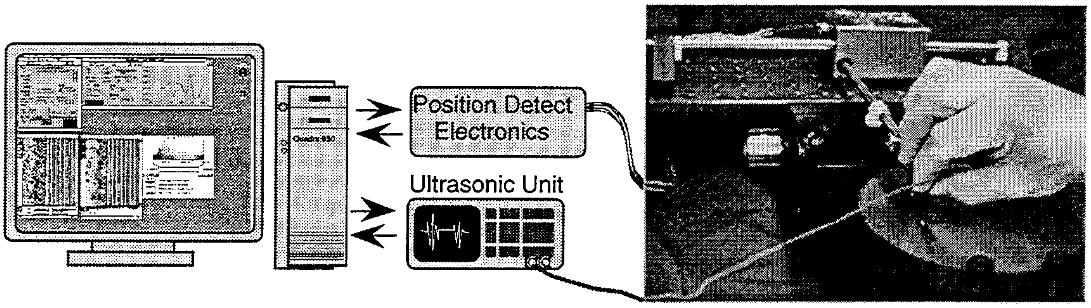

Figure 8. Sketch of a laboratory ultrasonic scanning system.

CONCLUSION

The backscatter ultrasonic technique is a valuable tool to detect corrosion on inaccessible surfaces. As was demonstrated in the two cases discussed, the technique is relatively simple in concept and simple to implement in practice. Further work is currently in progress to explore the sensitivity to surface conditions and capabilities of detecting unbonds at interfaces.

TECHNOLOGY OPERATIONS

The Aerospace Corporation functions as an "architect-engineer" for national security programs, specializing in advanced military space systems. The Corporation's Technology Operations supports the effective and timely development and operation of national security systems through scientific research and the application of advanced technology. Vital to the success of the Corporation is the technical staff's wide-ranging expertise and its ability to stay abreast of new technological developments and program support issues associated with rapidly evolving space systems. Contributing capabilities are provided by these individual Technology Centers:

Electronics Technology Center: Microelectronics, solid-state device physics, VLSI reliability, compound semiconductors, radiation hardening, data storage technologies, infrared detector devices and testing; electro-optics, quantum electronics, solid-state lasers, optical propagation and communications; cw and pulsed chemical laser development, optical resonators, beam control, atmospheric propagation, and laser effects and countermeasures; atomic frequency standards, applied laser spectroscopy, laser chemistry, laser optoelectronics, phase conjugation and coherent imaging, solar cell physics, battery electrochemistry, battery testing and evaluation.

Mechanics and Materials Technology Center: Evaluation and characterization of new materials: metals, alloys, ceramics, polymers and their composites, and new forms of carbon; development and analysis of thin films and deposition techniques; nondestructive evaluation, component failure analysis and reliability; fracture mechanics and stress corrosion; development and evaluation of hardened components; analysis and evaluation of materials at cryogenic and elevated temperatures; launch vehicle and reentry fluid mechanics, heat transfer and flight dynamics; chemical and electric propulsion; spacecraft structural mechanics, spacecraft survivability and vulnerability assessment; contamination, thermal and structural control; high temperature thermomechanics, gas kinetics and radiation; lubrication and surface phenomena.

Space and Environment Technology Center: Magnetospheric, auroral and cosmic ray physics, wave-particle interactions, magnetospheric plasma waves; atmospheric and ionospheric physics, density and composition of the upper atmosphere, remote sensing using atmospheric radiation; solar physics, infrared astronomy, infrared signature analysis; effects of solar activity, magnetic storms and nuclear explosions on the earth's atmosphere, ionosphere and magnetosphere; effects of electromagnetic and particulate radiations on space systems; space instrumentation; propellant chemistry, chemical dynamics, environmental chemistry, trace detection; atmospheric chemical reactions, atmospheric optics, light scattering, state-specific chemical reactions and radiative signatures of missile plumes, and sensor out-of-field-of-view rejection.