

## Application of Non-Contact Ultrasonic Testing for Interface Inspection of Multi-layered Pressure Vessels

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### Abstract

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For non-destructive inspection of solid rocket propellant grains, RT and UT are the best suited techniques. RT of the propellant grains is a well established technique to investigate propellant as well as interfacial defects and UT is also used to detect similar flaws with modern equipments. In ACEM, all filled rocket propellant grains are inspected by RT, as conventionally done. Present work describes the application of non-contact ultrasonic through-transmission technique to investigate interface defects within the medium sized rocket motors of web thickness (150mm-250 mm) over the conventional tangential radiography. Complete inspection of propellant-insulation interface in a rocket motor is important considering its consequences; it is seen that these interfaces may get de-bonded over the period due to many reasons. Tangential radiography is generally carried to detect these defects however with through-transmission non-contact ultrasound testing technique complete multilayer-interfaces inspection is possible in cylindrical region in quick time.

To study the application of non-contact UT, through-transmission technique was used and artificial defects were induced over the motor surface. For experiments, low frequency gas jet emitter probes were used for good SNR values and transmitted signals were detected using channel based piezoelectric detectors. Rocket motor scanning was carried out in automated mode. The suitability of the use of technique was arrived based on the results obtained.

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### Introduction:

Solid Rocket Motors (SRMs) segments are usually consisting of a rigid cylindrical shell, an elastomeric insulation liner and propellant grain. For the production of the quality SRMs, good bond integrity is required between the motor case to insulation liner and insulation liner to propellant to prevent any detrimental effects on mission. However due to large reasons, some defects may get introduced in the interfaces during the processing or during handling. Hence, a reliable NDT technique is essential for detection possible debonds. With application of Non Destructive Evaluation (NDE) technique evaluation of structural integrity of SRMs without affecting their functionality and useful lifetime is possible. There are large numbers of NDT methods, but for SRMs interfaces inspection most suitable methods are X-Ray radiography (tangential), computed tomography and ultrasonic testing. Conventional UT (contact type) is the most useful technique to study the interfaces between motor casing and insulation layer, but it has limitation for multilayer structures.

This study presents the merits of Non contact through transmission UT method for examination of multilayered pressure vessels for interfaces defects over conventional tangential radiography. In non-contact ultrasonic testing, compressed gas i.e. air is used to produce Ultrasonic waves by passing through a small nozzle opening, based on the principle of Hartzmann generator. The principle of emitter operation consists of transforming the kinetic energy of gas flow supplied from a compressed gas source into the

energy of Ultrasound vibrations. The sound waves travel through the material with some loss in energy (attenuation) and are also reflected at interfaces. The transmitted ultrasonic vibrations are then channelized toward piezoelectric crystals and analyzed to determine the presence, size and location of flaws and discontinuities.

### Experimental Set-Up:

The experimental set-up comprises of the low frequency ultrasonic transducer/emitter, ultrasonic receivers, SRMs under inspection, automated handling system and software to archive signals and to analyse. Ultrasonic transducer generates the ultrasonic waves in the port area of SRMs from compressed air coming from a compressor. Position of the outgoing wave front is parallel to the propellant surface i.e. all interfaces. Detector Piezoelectric receivers are mounted on other side of the object just above the SRM surface as shown in fig1(a). For the scanning of the SRMs line-by-line or ring-by-ring mode of scans were used. Cantilever boom/emitter end should be carefully aligned w.r.t. SRMs port so that it is well isolated from propellant surface for safety. Schematic diagram of the experimental set up is as shown below in fig 1(b).

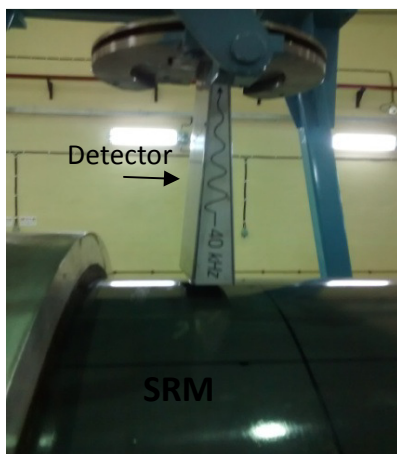


Fig1(a) Detector setup

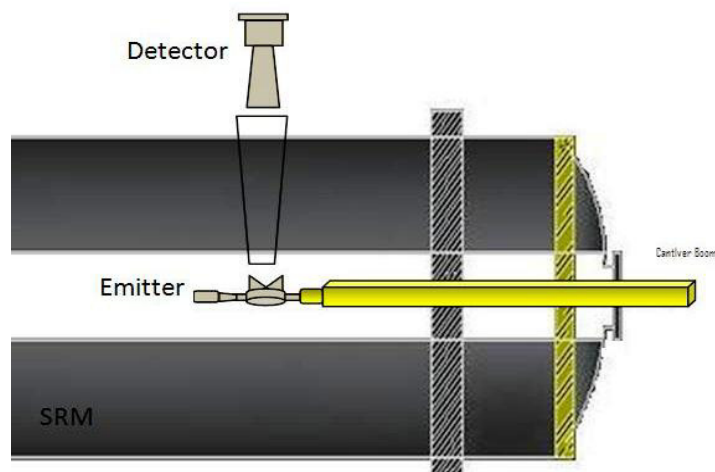
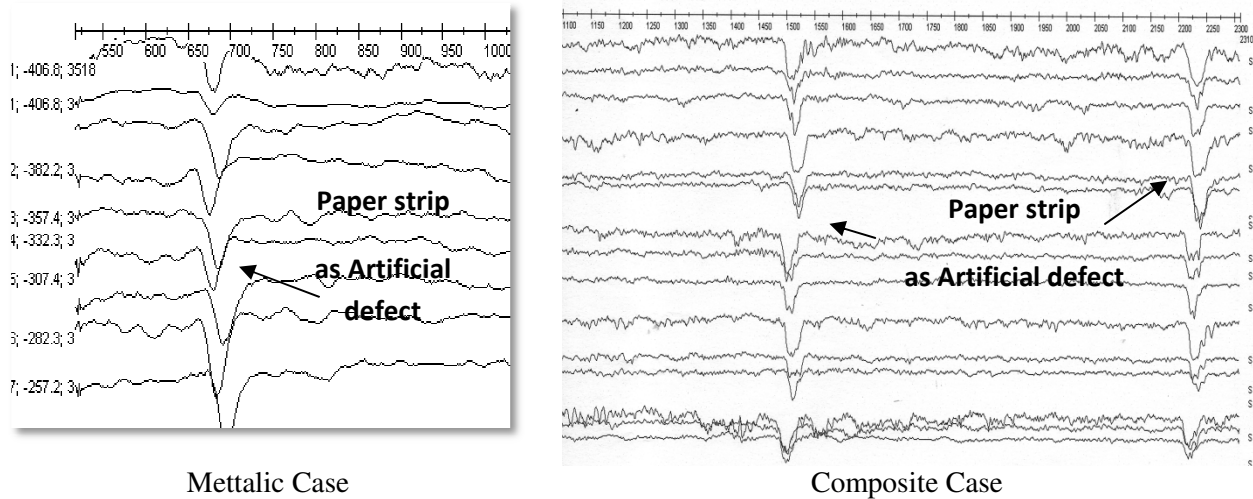


Fig1(b) Schimatic diagram

The rocket motor is mounted on an automated roller stand allowing longitudinal and rotational movements of the rocket motor. The position of the UT emitter and detector was fixed and SRM was moved. To stimulate defects, different sized paper pieces were pasted on the external surface of the SRMs. The artificial defects (paper strips) were also used as scan quality indicators for every scan. Various parameters used during the study are listed below in table 1(b). The results obtained for the above experiments shows received signal strength Vs time scale.

Transducer operating frequency	40 kHz
Output type	Digital
Ultrasonic operating pressure range	3-4 bar
Used Web thickness of the propellant grain	150-250 mm
Scanning speed	10-15mm/sec



**Fig.(b) SNR level corresponding to artificial defect (Amplitude Vs Time)**

### **Result & Discussion:**

Non contact ultrasonic testing was performed using 40kHz probes for the multilayered pressure vessel involving interfaces of metallic casing/composite casing, elastomeric insulation liner and composite propellant.

- (1) Artificial debonds defect created with an opening <300 microns using paper strips on the motor surface were clearly detected by the system with signal to noise ratio (SNR) above 3, refer fig.(b).
- (2) Good sensitivity is being seen for multilayer having varied impedances.
- (3) In conventional tangential radiography (RT) of any SRMs complete information of the interfaces is usually not received due to the limitation of number of orientations. By non-contact UT inspection complete inspection is possible with sufficient overlap.
- (4) Non-contact UT technique is found very useful in cylindrical geometry of motor case and independent of motor inner grain geometry. However dome region of SRMs could not be inspected by this technique hence RT was used.
- (5) Presence of any discontinuity in propellant grain will affect the o/p of the non-contact UT results.

### **Conclusion:**

Non contact ultrasonic testing method exhibit a unique advantage of fast and complete scanning of propellant, insulation and casing interfaces as any defect in this zone can potentially hamper the mission requirements. This method shows another potential of qualifying aged SRMs as debonding at interfaces in such motor is common.

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