Quality Control of Polymer-Based Rubber Components

Non-Contact Thickness Measurement on Polymer-Based Rubber Components Using Terahertz Technology

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Polymer-based rubber materials are widely used in aerospace structures for vibration isolation, thermal insulation, electrical and environmental protection, sealing, and interface management. For these components, controlling thickness uniformity is important because local non-uniformity, air-gap-like defects, and interface discontinuities can affect fit, bonding, assembly repeatability, and service reliability. TeraNIM, Terahertz Time-Domain Spectroscopy (THz-TDS) used to perform non-contact inspection on low-loss polymer-based rubber components.

As per our experience, below typical materials are widely used in aerospace systems. These materials thicknesses and material consistency directly influence quality, performance and reliability of aerospace assemblies. THz signals generate reflections from internal interfaces, enabling accurate non-contact thickness measurement, defect detection, and quality verification without damaging the component.

Typical Materials

- EPDM Rubber
- Silicone Rubber
- Nitrile Rubber (NBR)
- Fluoroelastomer (FKM)
- Neoprene
- Polyurethane Elastomers
- Rockasin
- Low-Density Ablative (LDA) Tiles
- Medium-Density Ablative (MDA) Tiles

In this application note, TeraNIM was used to perform non-contact THz thickness measurement on an EPDM rubber layer bonded inside a composite cylindrical aerospace assembly. The objective was to verify rubber layer thickness against the design requirement and support manufacturing quality control without cutting, deforming, or accessing both sides of the component.

Inspection Challenges

Contact Measurement

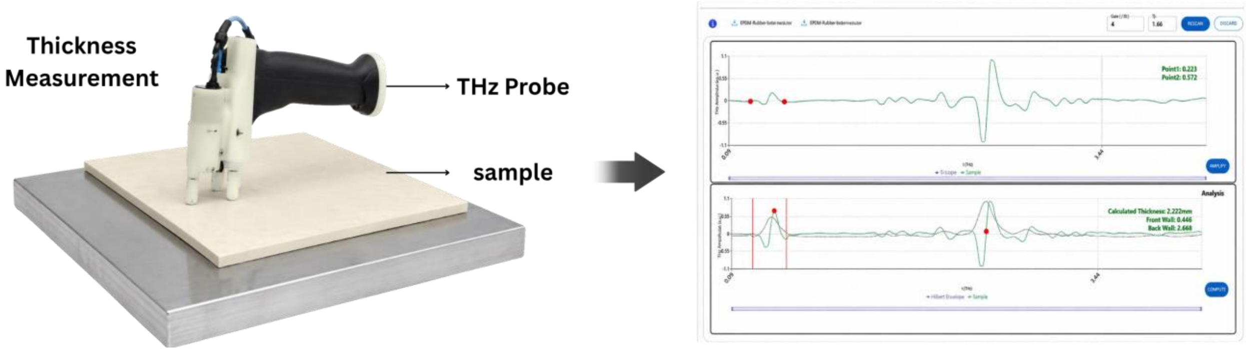
Micrometers and calipers require physical contact and two-side access. Low density rubbers deform under contact pressure, causing measurement bias.

Ultrasonic Testing

Ultrasonic inspection often needs couplant and surface preparation. Bonded, curved or multilayer rubber assemblies can reduce signal repeatability.

X-ray Inspection

Radiography can show internal density variations but is not usually the simplest method for routine rubber thickness QC liner inside a casing. The technique also requires Linac system, radiation safety measures and higher operating costs.



Terahertz Inspection Workflow

STEP 1 — Inspection Requirement

Defined Part type, material family, nominal thickness, tolerance, surface condition and acceptance criteria with below requirement.

- Thickness Mapping
- Multi-Layer Thickness
- Bonding Inspection
- Defect Imaging

STEP 2 — Principle and Setup

Check THz penetration, usable bandwidth, echo separation and signal-to-noise ratio for the selected rubber formulation.

TeraNIM operates in reflection mode for single-sided inspection. A short THz pulse is directed onto the component. Reflections are generated at material interfaces where there is a dielectric contrast. The front-wall and back-wall echo separation is used for thickness calculation.

Thickness equation: $d = (c \times \Delta t) / (2n)$, where d is thickness, c is the speed of light, Δt is the time delay between front-wall and back-wall echoes, and n is the calibrated refractive index of the rubber material.

STEP 3 — Calibration

Use a micrometer-verified reference coupon or destructive cross-section reference to calculate n for the selected material recipe.

- Measured refractive index (n) and absorption across usable THz bandwidth (0.1–3.5 THz)
- Calibrate against known-thickness polymer-based rubber reference (2.230 mm, micrometer-verified)
- Identified front-wall and back-wall echoes; found the refractive index as (n = 1.66) for EPDM rubber

STEP 4 — Measure & Report

- Acquire front-wall and back-wall reflection positions per location
- Monitor timing drift and standoff/coupling stability
- Measured Thickness as 16.129 mm as show in the graph
- Generate report with settings, data, echo positions, thickness table and with remarks

Key Advantages & Practical Limitations

- Non-contact measurement reduces risk of deforming soft rubber components during inspection.
- Single-sided access is useful for bonded or installed parts where a micrometer cannot be used.
- The test result is traceable because waveform data, echo positions, settings and calculated thickness can be stored.
- The supplied case study showed clear echo separation with 1% agreement after calibration against a known-thickness reference.
- Thickness variation of approximately 0.25 mm was resolved across seven measured points on part

Conclusion

The conducted study on EDPM thickness measurement with TeraNIM THz-TDS system provides an accurate, reliable, and repeatable solution with non-contact thickness measurement. Calibration against a micrometer reference achieved with THz was validated successfully. The ability to perform single-sided, non-contact measurements makes THz-TDS particularly suitable for aerospace manufacturing, quality assurance, and in-situ inspection of bonded or installed components. The results indicate significant potential for integrating THz inspection into routine production quality-control workflows.
