CLEARROOT MATERIALS LLC

Example Investigations

Representative Materials Failure Analysis & Characterization Examples

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Root Cause. Clear Solutions.

ABOUT THESE EXAMPLES

How ClearRoot approaches complex materials challenges.

The following representative investigations demonstrate how ClearRoot Materials LLC approaches complex materials challenges through a structured process of problem definition, evidence collection, analytical characterization, and technical interpretation. These examples are educational demonstrations rather than client engagements, but the investigation strategies and engineering principles reflect real-world approaches commonly used in materials failure analysis, contamination investigations, supplier qualification, and materials characterization.

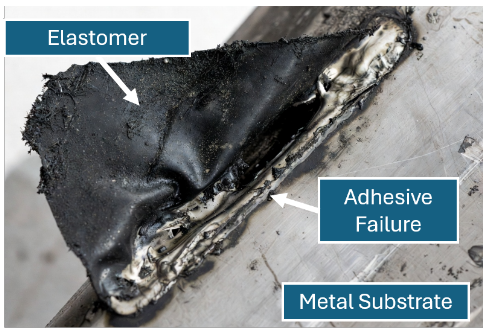
01	02	03	04
Define	**Investigate**	**Analyze**	**Deliver**
Clarify failure mode, business impact, history, constraints, and the question that needs answering.	Review samples, documentation, field conditions, process inputs, and relevant analytical evidence.	Connect observations to likely mechanisms using materials science and analytical chemistry.	Provide clear findings and practical recommendations that support technical and business decisions.

CONTENTS

CRM-CS-001

Adhesive Bond Failure Investigation

Silicone contamination in elastomer-to-metal bonds



Bond failure surface with visible adhesive delamination

Client overview

A manufacturer of industrial equipment experienced recurring adhesive bond failures in elastomer-to-metal assemblies. The failures contributed to increased warranty claims, production delays, and reliability concerns.

The challenge

Assemblies that passed initial inspection began showing bond-line delamination after several months in service. Internal review could not determine whether the issue was adhesive selection, surface preparation, environmental exposure, or manufacturing variation.

Analytical approach

- Optical microscopy to document the failure mode and initiation sites.
- SEM/EDS to examine fracture surfaces and elemental composition.
- FTIR-ATR spectroscopy to identify surface contamination.
- Water contact angle testing to evaluate surface wettability.
- Manufacturing process review to identify likely contamination sources.

Key observations

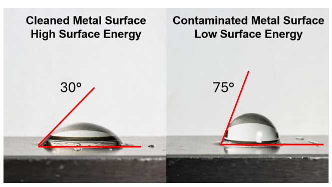
Elemental mapping revealed localized silicon-rich regions at the failed bond interface that were absent in control specimens. FTIR identified the contaminant as polydimethylsiloxane (PDMS), consistent with silicone-based release agents.

CRM-CS-001

Adhesive Bond Failure Investigation

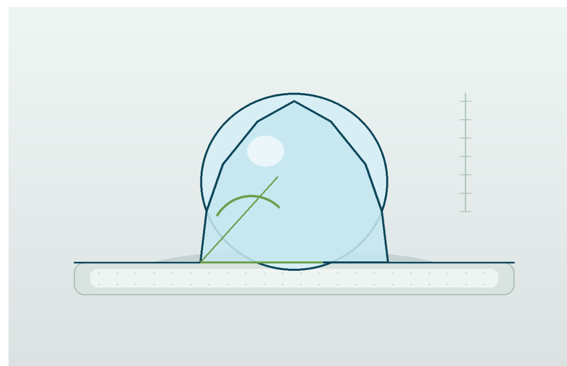
Representative visual evidence

The visual materials below are formatted to preserve the original technical content while aligning the document with ClearRoot Materials LLC website styling.



Surface Condition	Water Contact Angle (°)
Control Surface	30°
Failed Surface	75°

FTIR spectrum identifying silicone residue



Surface energy / contact angle comparison

CRM-CS-001

Adhesive Bond Failure Investigation - Findings & Recommendations

Likely failure mechanism

The likely failure mechanism was adhesion loss caused by silicone contamination on the bonding surface. The residue lowered surface energy, prevented proper adhesive wetting, and created a weak boundary layer that propagated under thermal and humidity cycling.

Key technical insight

Even trace silicone contamination can cause premature adhesive failure. Routine surface energy verification is an important quality control step for elastomer-to-metal bonding.

Recommended corrective actions

- Eliminate silicone-containing materials from upstream handling and molding processes.
- Implement line-side water contact angle screening prior to bonding.
- Standardize surface cleaning and preparation procedures.

Potential business value

Reduced uncertainty

Objective analytical evidence can focus troubleshooting and reduce speculation.

Lower recurrence risk

Root-cause clarity supports corrective actions that prevent repeat failures.

Better supplier decisions

Independent characterization supports technical and procurement decisions.

Clear communication

Findings are translated into practical recommendations for engineering, quality, procurement, and leadership teams.

CRM-CS-002

Premature Elastomer Cracking Investigation

Root cause traced to ozone-induced degradation and improper material selection

Cracking pattern and service context

Client overview

A manufacturer of outdoor industrial equipment experienced recurring cracking and premature failure of elastomer sealing components, resulting in water ingress, maintenance costs, and reduced product reliability.

The challenge

The seals passed initial qualification but developed surface cracks after outdoor service. Early assumptions pointed to mechanical overload or installation damage, but the failure pattern did not align with those hypotheses.

Analytical approach

- Visual and optical microscopy.
- SEM examination of crack morphology.
- FTIR spectroscopy for elastomer identification.
- Environmental and service-condition assessment.
- Comparative review against ozone-resistant materials.

Key observations

Fine surface cracks were observed perpendicular to the applied strain direction, a pattern consistent with ozone attack. FTIR identified the material as natural rubber, an unsaturated elastomer with limited long-term ozone resistance.

CRM-CS-002

Premature Elastomer Cracking Investigation

Representative visual evidence

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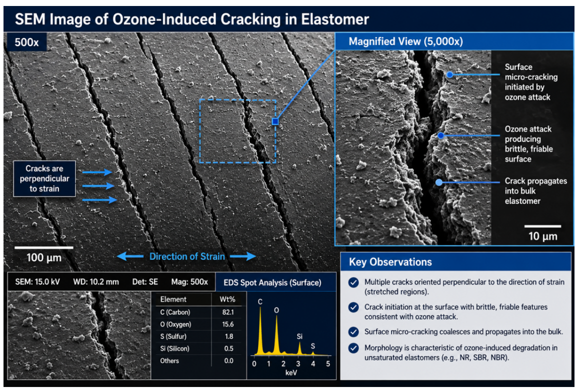

SEM image of ozone-induced cracking

Failed natural rubber versus passed EPDM material

CRM-CS-002

Premature Elastomer Cracking Investigation - Findings & Recommendations

Likely failure mechanism

The likely mechanism was ozone-induced degradation of an unsaturated elastomer that lacked adequate outdoor resistance. Atmospheric ozone attacked double bonds in the polymer backbone, causing chain scission and progressive surface cracking.

Key technical insight

Ozone cracking is often misdiagnosed as mechanical fatigue. Crack orientation and morphology should prompt immediate material compatibility review.

Recommended corrective actions

- Replace natural rubber with ozone-resistant EPDM where appropriate.
- Update material specifications to include ozone exposure requirements.
- Add accelerated ozone testing to qualification protocols.
- Implement supplier material verification requirements.

Potential business value

Reduced uncertainty

Objective analytical evidence can focus troubleshooting and reduce speculation.

Lower recurrence risk

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Clear communication

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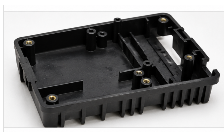
CRM-CS-003

Unknown Injection Molded Plastic Characterization

Supplier qualification and cost reduction through material identification

Unknown Molded Plastic Housing Component Submitted for Material Identification



Close-Up of Injection Molded Housing Features

Parameter	Value
Component	Injection Molded Housing
Industry	Industrial Equipment
Annual Volume	50,000+ Units
Objective	**Qualify Second Supplier**

Injection-molded housing submitted for identification

Client overview

A manufacturer sought to qualify a second supplier for a critical injection-molded plastic housing. The incumbent material was described only as a black engineering thermoplastic, which was insufficient for supplier qualification.

The challenge

The manufacturer needed to determine the polymer identity, evaluate whether replacement materials were equivalent, and qualify lower-cost suppliers without increasing product risk.

Analytical approach

- Visual inspection and comparative review.
- FTIR spectroscopy for polymer family screening.
- Py-GC/MS for definitive polymer identification.
- TGA for filler and inorganic content.
- SEM/EDS to evaluate reinforcement distribution and composition.

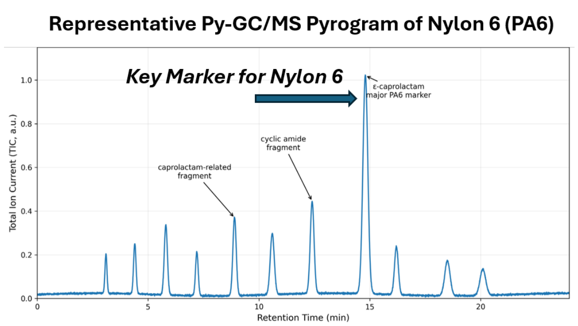
Key observations

FTIR identified the material as a polyamide. Py-GC/MS confirmed Nylon 6 chemistry, while TGA and SEM/EDS revealed meaningful differences in glass fiber reinforcement between the incumbent and candidate suppliers.

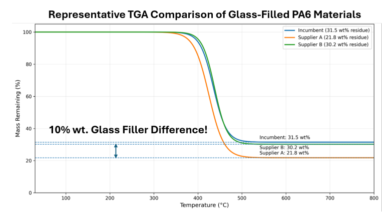
CRM-CS-003

Unknown Injection Molded Plastic Characterization

Representative visual evidence



Py-GC/MS pyrogram confirming Nylon 6 chemistry



Material	Glass Fiber Content (% weight)
Incumbent	31.5%
Supplier A	21.8%
Supplier B	30.2%

TGA comparison of glass-filled materials

CRM-CS-003

Unknown Injection Molded Plastic Characterization - Findings & Recommendations

Likely failure mechanism

One candidate material was not compositionally equivalent despite similar supplier descriptions. Lower reinforcement content and formulation differences would likely reduce mechanical performance and durability.

Key technical insight

Materials with similar supplier descriptions may be chemically and structurally different. Analytical characterization supports supplier qualification, substitution, and cost-reduction decisions.

Recommended corrective actions

- Establish analytical acceptance criteria for incoming materials.
- Qualify alternative suppliers based on objective equivalency data.
- Add FTIR verification for critical components.
- Document material composition for future procurement decisions.

Potential business value

Reduced uncertainty

Objective analytical evidence can focus troubleshooting and reduce speculation.

Lower recurrence risk

Root-cause clarity supports corrective actions that prevent repeat failures.

Better supplier decisions

Independent characterization supports technical and procurement decisions.

Clear communication

Findings are translated into practical recommendations for engineering, quality, procurement, and leadership teams.

Ready to solve your materials challenge?

Whether you are investigating a product failure, contamination issue, material identification question, supplier qualification concern, or need an independent technical perspective, ClearRoot Materials LLC can help.

Typical areas of support

- Polymer and elastomer failure analysis
- Adhesive and bonding failures
- Materials identification and characterization
- Contamination investigations
- Supplier material verification
- Technical consulting and root-cause analysis

The ClearRoot difference

Independent & unbiased Testing recommendations are driven by the problem - not laboratory utilization.	**Ph.D.-level expertise** Deep expertise in polymers, elastomers, adhesives, coatings, and material characterization.
Actionable solutions Clear findings and practical recommendations for technical and business decisions.	**Clear communication** Complex analytical data translated into decision-ready insights.

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