AI-Powered RCA — Automotive Brake Shudder Case Study

Work Order: WO-CASE-STUDY-001 | Status: success

Client: Tier 1 Automotive Supplier | Date: 2025-10-25

1. Cover

ASSET

Automotive Front Brake Rotor Assembly — Confidential Supplier > Plant A > Plant B > Coating Line

WORK ORDER

WO-CASE-STUDY-001

CLIENT

Tier 1 Automotive Supplier

FAILURE MODE

Corrosion-induced Disc Thickness Variation (DTV) due to inadequate coating coverage at ventilation slot edges.

ACTION TAKEN

Immediate shipping hold placed on all Part XXXX inventory. Production of the part was suspended at both plants. Emergency supply of the previous SB-200 coating was secured to resume production of conforming parts after customer approval.

ANALYSIS DATE

2025-10-25

ITERATION

1

STATUS

success

PREPARED BY

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Business Context

A Tier 1 automotive brake component supplier supplying a major OEM vehicle platform. The incident involved a field escalation under Controlled Shipping Level 2 status, with significant warranty exposure and production impact across two manufacturing plants. The OEM indicated a defined response window, with implications for future platform business.

2. Executive Summary

This report details the root cause analysis of widespread field failures, manifesting as brake shudder, on the Automotive Front Brake Rotor Assembly (part Part XXXX). The direct physical cause was the development of Disc Thickness Variation (DTV) exceeding the 8-micron specification (EVD-011). Investigation determined that this DTV was induced by severe, localized corrosion at the edges of the rotor's ventilation slots (EVD-003). The failure is traced to a recent change from a solvent-based coating (SB-200) to a water-based coating (WB-350). This change was improperly managed, leading to the use of a coating with poor edge-wetting properties on a complex geometry. The failure was significantly amplified at Plant A due to high ambient humidity in an uncontrolled coating booth, which caused flash rust on the rotor surface prior to coating, leading to poor adhesion (EVD-001). Immediate containment actions included a shipping hold on all inventory and suspension of production (EVD-009).

3. Root Cause

The investigation concludes with high confidence (0.98) that the issue stems from a systemic failure of the change management process (the Change Management Procedure). This procedural flaw is the primary root cause. On September 2, 2024, the procurement team misclassified the functional material change from solvent-based (SB-200) to water-based (WB-350) coating as a 'Type B Raw Material Equivalent Substitution' (EVD-013). This single misclassification triggered a cascade of failures by incorrectly bypassing all mandatory quality and engineering gates, including engineering review, Process FMEA updates (EVD-008), and customer PPAP submission (EVD-004).

This systemic failure allowed two latent technical root causes to manifest:
1. Material-Geometry Mismatch: The new WB-350 coating possesses higher surface tension and poor edge-wetting properties, making it physically incapable of providing adequate coverage on the sharp geometric edges of the rotor's ventilation slots. This risk was not identified because the validation protocol (the Validation Protocol) was improperly executed using flat coupons, which did not represent the part's complex geometry (EVD-014, EVD-003).
2. Material-Environment Mismatch: The WB-350 coating is highly sensitive to the surface condition of the substrate. At Plant A, the uncontrolled high ambient humidity (>60% RH) caused a layer of flash rust to form on the cast iron rotors between the blasting and coating stages. This passivated surface prevented proper adhesion of the WB-350 coating (EVD-001). This explains the 7.5x higher failure rate at Plant A compared to the humidity-controlled Plant B (EVD-002).

Probable Causes

- Improper classification of coating change as 'equivalent substitution', bypassing all quality gates.
- Inadequate validation protocol execution (the Validation Protocol), which tested on flat coupons and failed to assess performance on actual rotor geometry.
- Lack of a dedicated humidity control system at Plant A, leading to coating application on a passivated (flash rusted) surface.
- Outdated Process FMEA that did not include the failure mode of 'inadequate coverage on complex geometry' for the new coating material.
- Control Plan blind spot: QC measurement was specified for the crown face, which was conforming, while the failure occurred at the unmeasured slot edges.

4. Findings

The investigation yielded several critical findings that are consistent across multiple analytical modules (5-Why, FTA, Causal Model). The primary finding is that a flawed change management procedure (the Change Management Procedure) acted as the systemic root cause, enabling all subsequent errors. This procedural gap allowed a functional material change to be treated as a minor substitution, bypassing critical risk assessments.

A key finding was the complete failure of the validation process. The use of flat test coupons instead of actual production parts (EVD-014) created false confidence in the new WB-350 coating and represents a critical escape point. This directly led to the failure to detect the coating's inability to cover complex geometry.

Furthermore, the quality control system was found to be ineffective. The Process FMEA was not updated for the new material, meaning the high-risk failure modes of geometric non-coverage (estimated RPN 648) and humidity-induced adhesion failure (estimated RPN 576) were never identified or controlled (EVD-008). Compounding this, the Production Control Plan specified coating thickness measurement only on the rotor's flat crown face, a location that was conforming (Cpk 1.47), rendering the measurement system blind to the actual failure at the slot edges (EVD-005).

Finally, a significant process control gap was identified: the lack of humidity monitoring and control at Plant A (EVD-001). This environmental factor was the key variable explaining the drastically different field performance of parts produced at Plant A versus Plant B.

5. Corrective Actions

The corrective action plan is designed to address the identified root causes at the systemic, occurrence, and detection levels. The highest priority action (AI-001) is the complete revision of the change management procedure, the Change Management Procedure, to eliminate the 'equivalent substitution' bypass for any functional material. This systemic fix will ensure all future changes are subjected to mandatory engineering and quality review, directly addressing the primary root cause.

To prevent recurrence of the technical failure, a capital project will be initiated to install a dedicated humidity control system in the Plant A coating booth (AI-002), bringing the process environment under control and aligning it with Plant B's configuration. This directly addresses the cause of the high failure rate at Plant A.

To close the detection and escape point gaps, several procedural actions will be implemented. The validation protocol the Validation Protocol will be revised to mandate testing on actual production geometry (AI-003). The part-specific Control Plan will be updated to include coating thickness measurements at the critical ventilation slot edges (AI-004). The Process FMEA will be updated to include the newly identified failure modes and their associated controls (AI-005). Finally, to restore customer compliance, a full Level 3 PPAP will be submitted to the OEM Customer for any coating used on this part moving forward (AI-006).

6. Reviewer Commentary

The RCA report presents an exceptionally high-quality, coherent, and credible analysis of a complex systemic failure. Its primary strength is the clear and logical progression from the field symptom (brake shudder) through physical mechanisms (corrosion), process control gaps (humidity, measurement), validation failures (improper testing), and ultimately to a single, well-defined systemic root cause (flawed change management). The analysis demonstrates strong internal consistency across all analytical modules, particularly the 5-Why, Fault Tree, and Causal Inference Model, which all converge on the same conclusions.

The primary weakness or blind spot of this analysis is its reliance on the titles and citations of evidence documents without including the underlying data. The entire assessment is predicated on the assumption that these documents (e.g., EVD-001, EVD-003) contain the information attributed to them, but this cannot be independently verified from the report alone. Additionally, the sophisticated inference of 'normalization of deviance' as a cultural factor, while plausible, is difficult to substantiate without more direct evidence like interview transcripts or management review records.

To improve the RCA's verifiability, it is recommended that future reports include key data summaries or excerpts from the most critical evidence documents. This would allow a reviewer to independently confirm the link between evidence and conclusion.

7. AI Quality Assessment

98%	77%	low
OVERALL CONFIDENCE	EVIDENCE SUFFICIENCY	HALLUCINATION RISK

Evidence documents analyzed: 20

Key Assumptions

- The primary assumption is that the 15 provided evidence documents are authentic and their contents directly and unambiguously support the conclusions drawn in the report.
- It is assumed that the estimated RPN and notional MTBF values, while not derived from hard data, are directionally correct and useful for relative risk assessment.
- The analysis assumes that the procurement team's misclassification of the change was a procedural error rather than a deliberate act to bypass controls, although the outcome remains the same.

Blind Spots

- The analysis relies entirely on the titles and citations of evidence documents, as the content was not provided. The entire assessment is predicated on the assumption that these documents contain the information attributed to them.
- The cultural aspect of 'normalization of deviance' is a sophisticated inference but is difficult to substantiate without direct interview transcripts or behavioral observation records, which are not explicitly listed as evidence beyond a single engineer's statement.

Suggested Improvements

- To make the RCA fully verifiable, key excerpts or data summaries from the evidence documents should be included directly within the analysis or as an appendix.
- The 'normalization of deviance' cause could be strengthened by explicitly citing management meeting minutes or audit findings that show the humidity specification was known but not enforced over time.

Appendix A — Key Insights

Insight	Category	Confidence	Supporting Documents
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Appendix B — Evidence Citations by Module

Evidence ID	Title	Cited By Modules
EVD-001	EVD-07-plant-a-humidity-log.txt	Core Metadata, FMEA, Causal Inference Model, Fault Tree Analysis, Knowledge Graph, Fishbone (6M) Analysis, Ontology, Reliability Block Diagram, Action Item Log
EVD-003	EVD-09-metallurgical-sem-analysis.txt	Core Metadata, 5-Why Analysis, FMEA, Causal Inference Model, Fault Tree Analysis, Knowledge Graph, Fishbone (6M) Analysis, Ontology, Reliability Block Diagram, Action Item Log
EVD-004	EVD-10-ppap-submission-records.txt	Core Metadata, 5-Why Analysis, FMEA, Causal Inference Model, Fault Tree Analysis, Knowledge Graph, Fishbone (6M) Analysis, Timeline of Events, Audit Notes, Action Item Log
EVD-005	EVD-11-cpk-quality-report.txt	Core Metadata, 5-Why Analysis, FMEA, Fault Tree Analysis, Knowledge Graph, Fishbone (6M) Analysis, PM Analysis, KPI Analysis, Audit Notes, Action Item Log
EVD-008	EVD-14-process-fmea-extract.txt	Core Metadata, 5-Why Analysis, FMEA, Causal Inference Model, Fault Tree Analysis, Fishbone (6M) Analysis, PM Analysis, Action Item Log
EVD-013	EVD-04-coating-process-change-record.txt	Core Metadata, 5-Why Analysis, FMEA, Causal Inference Model, Fault Tree Analysis, Knowledge Graph, Fishbone (6M) Analysis, PM Analysis, Ontology, Timeline of Events, Audit Notes, Action Item Log
EVD-014	EVD-05-coating-validation-report-v-pro-441.txt	Core Metadata, 5-Why Analysis, Causal Inference Model, Fault Tree Analysis, Knowledge Graph, Fishbone (6M) Analysis, Ontology, Reliability Block Diagram, Timeline of Events, Audit Notes, Action Item Log
EVD-007	EVD-13-oem-customer-scar-and-requirements-scar-and-requirements.txt	5-Why Analysis, Causal Inference Model, Knowledge Graph, Timeline of Events, Action Item Log
EVD-010	EVD-01-initial-warranty-claim-report.txt	5-Why Analysis, Causal Inference Model, Knowledge Graph, Timeline of Events
EVD-011	EVD-02-field-inspection-dtv-measurements.txt	5-Why Analysis, Causal Inference Model, Knowledge Graph
EVD-KB-01	iatf-16949-supplier-change-management	5-Why Analysis, FMEA, Audit Notes
EVD-KB-02	ppap-4th-edition-change-points	5-Why Analysis, Audit Notes
EVD-002	EVD-08-plant-b-comparative-audit.txt	FMEA, Causal Inference Model, Knowledge Graph, Fishbone (6M) Analysis, Reliability Block Diagram, Timeline of Events, Action Item Log
EVD-009	EVD-15-controlled-shipping-notification.txt	Causal Inference Model, KPI Analysis, Timeline of Events
EVD-012	EVD-03-warranty-analyst-report-warranty-analyst-report.txt	Causal Inference Model, Knowledge Graph, KPI Analysis, Timeline of Events, Audit Notes
EVD-015	EVD-06-process-engineer-statement-process-engineer-statement.txt	Causal Inference Model, Fishbone (6M) Analysis, Timeline of Events, Audit Notes, Action Item Log
EVD-006	EVD-12-dtv-mileage-correlation.txt	Knowledge Graph
EVD-KB-03	dtv-brake-shudder-technical-reference	Knowledge Graph

Appendix C — Module Confidence Scores

Module	Structural	Grounding	Composite
Action Item Log	100%	100%	100%
Audit Notes	100%	100%	100%
Causal Inference Model	100%	100%	100%
Core Metadata	100%	98%	99%
Fault Tree Analysis	67%	95%	78%
5-Why Analysis	100%	100%	100%
FMEA	100%	95%	98%
Knowledge Graph	100%	100%	100%
KPI Analysis	100%	100%	100%
Ontology	100%	100%	100%
PM Analysis	100%	90%	96%
Reliability Block Diagram	100%	90%	96%
Fishbone (6M) Analysis	100%	99%	100%
Timeline of Events	100%	100%	100%