QUALITY ASSURANCE IN THE AUTOMOTIVE FIELD BY MONITORING NON-CONFORMITIES RELATED TO WATER INGRESS IN DOORS

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Rezumat. *Infiltrațiile de apă la nivelul ușii reprezintă o problemă recurentă în procesul de asamblare finală, afectând semnificativ satisfacția clienților și costurile de garanție. Această lucrare prezintă o abordare practică pentru identificarea cauzelor principale ale defectelor de etanșare și implementarea unor acțiuni corective eficiente în cadrul procesului de etanșare a ușii. Analiza se bazează pe constatări reale din audituri și reclamații ale clienților din teren. Studiul demonstrează cum auditurile stratificate de proces, combinate cu metode de analiză a cauzei principale, pot reduce recurența acestor probleme în perioadele reci.*

Abstract. *Water ingress at door level is a recurring issue in the final assembly process, significantly affecting customer satisfaction and warranty costs. This paper presents a practical approach to identifying the root causes of water leakage defects and implementing effective corrective actions within the door sealing process. The analysis is based on actual audit findings and customer claims from the field. The study demonstrates how layered process audits, combined with root cause analysis methods, can reduce the recurrence of such issues during colder periods.*

Keywords: water ingress, door sealing, quality assurance, layered process audit, automotive assembly.

1. Introduction

This paper focuses on one of the most common and costly challenges encountered at the end of the assembly process: water ingress through car doors. This type of nonconformity directly affects the customer's perception of quality and may lead to expensive repairs during the warranty period. The objective of the study is to highlight strategies for preventing and managing such defects by using specific audit tools and root cause investigation methods.

2. Current Status

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In the specialized literature, causes such as improper sealing of weatherstrips, door frame deformations, or uncontrolled variations in the installation process are frequently mentioned as contributors to "water ingress" nonconformities. Industry standards recommend the implementation of Layered Process Audits (LPA) to monitor critical assembly stages, as well as the use of 8D and 5Why techniques to address customer complaints.

3. Methodology

The analysis was conducted using the following methods:

- Layered Process Audit (LPA) at the assembly points of the front and rear door seals.
- Verification of part conformity (seals, clips, doors).
- Examination of customer complaints using QRQC (Quick Response Quality Control).
- Ishikawa Diagram and 5Why analysis for a specific nonconformity reported during the cold season 2024–2025.

4. Results and Discussion

Water ingress defects were mainly found in models with incorrectly mounted seals or insufficient compression. The LPA evaluation revealed a consistent deviation in the pressure adjustment device. The 5Why investigation identified the absence of a visual inspection step in the work standard and the lack of verification gauges for seal positioning. The following measures were implemented:

- Revision of the work procedure to include a visual inspection point and a dedicated gauge.
- Training of operators from shifts A/B.
- 100% inspection for 3 days.
- Validation LPA audits over a period of 4 weeks.

Result: A 75% reduction in water-ingress complaints compared to the same period of the previous year.

4.1. Comparative Analysis between Project 1 and Project 2 Plants

The water-ingress issue is frequently observed on rear doors at the production unit associated with Project 1, while at the location linked to Project 2, the nonconformity is mostly found on front doors. A comparative analysis of the

DPHU indicator for the two sites reveals similarities in defect types, as well as recurring causes and manifestation modes.

Root Cause (RC): Project 1 – Water ingress due to inadequate sealing of the door weatherstrip.

Failure Mode: Lack of continuous adhesion between the seal and the door frame.

Immediate Cause (IC): The sealing bead is not fully attached to the door cassette.

Direct Sub-causes:

- SCD1: Incorrect installation process, FOS standards not respected.
- SSCD1: Difficulties in using the tool to follow the sealing bead path due to complex geometry (roller thickness = 12 mm, bead width = 6...10 mm).
- SSCD2: Sealing bead is not visible; the operator must "feel" with the hand if it's applied correctly.
- SSCD3: Operation is performed quickly (cycle time) without self-control option.
- SSCD4: Insufficient drying of the door frame after degreasing – the sealant does not adhere in wet areas.

4.2. Corrective Actions and Customer Protection

Based on the evaluation of identified causes, the following corrective and customer protection measures were defined:

- SSCD1 + SSCD2: Improved seal application procedure: adjustment of the FOS and addition of a second channel with a squeegee at the bottom of the foil.
- Inclusion of integrity and wear monitoring of squeegees in the Digital Workstation, to prevent incorrect application due to tool degradation.
- Enhancement of 5S in work areas: ensuring clean degreasing and drying cloths by using dedicated locations for each cloth type to avoid cross-contamination.
- Introduction of separators in the transport and storage boxes for sealing foils to prevent deformation or contamination during internal logistics processes.
- Customer Protection: Implementation of 100% visual and tactile checks on the production line for all front and rear doors for a 4-week period, until

the effectiveness of corrective measures is confirmed and the process is stabilized.

Figure 1 shows a screenshot comparison from the operational sheet, demonstrating the changes made to the seal foil application step. The addition of the second squeegee pass at the bottom is visible, as well as clarified points for visual and tactile checks.

This change was communicated to the installation teams via the Digital WorkStation channel and supported by in-line practical training sessions.

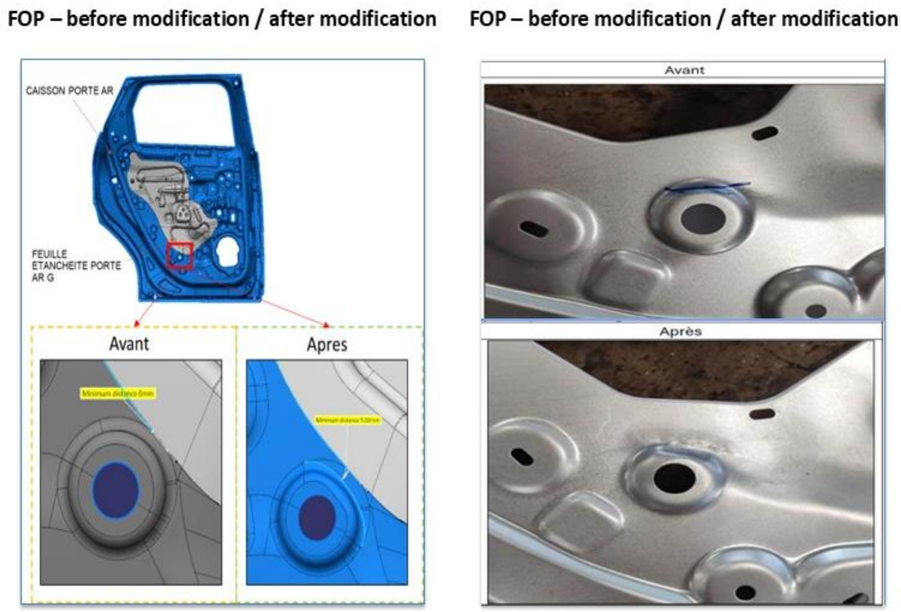

Fig. 3. FOP modification

5. Capitalization and Project Extension

To prevent the recurrence of the "water ingress" issue in future projects, the verified technical solutions at the plant were implemented as follows:

- Urgent revision of the FOS and installation methodology in ongoing projects at both sites.
- Introduction of an NRL/RTC requirement to use a 25 mm flat sealing surface instead of 20 mm, to ensure efficient and continuous adhesion of the sealing foil.

To emphasize the effectiveness of the corrective measures implemented in door sealing processes, a comparative analysis is presented between the initial condition and the post-action plan outcome (see Table 1).

Table 1. Comparative analysis

Material	*Application Temperature (°C)*	*Determinations*	
		Simulated Adhesion (N/cm) – Analytical	*Measured Adhesion (N/cm) – Experimental*
M1	23	55	42
M2	23	65	58

The table highlights the essential aspects of the intervention strategy and how they translated into measurable results. The effectiveness of optimizing work techniques, tool management, and customer protection measures is clearly demonstrated.

Conclusions

The results highlight the impact of strict assembly control on customer quality perception. The introduction of LPA audits, combined with thorough root cause investigations, significantly contributes to reducing recurring seasonal defects. It is recommended to extend process supervision to other critical components, such as moving hardware or the door drainage system.

Notations and/or **Abbreviations**

The following symbols are used in this paper:

LPA = Layered Process Audit – audit of assembly stages

FOP = Production Operational Sheet – line work standard

FOS = Standardized Operation Sheet – regulated assembly instruction

QRQC = Quick Response Quality Control – fast nonconformity management method

NRL = Logistics Reference Norm – technical product specification

RTC = Technical Design Review – technical requirement in project development

SSCD = Sub-sub-cause Direct – detailed element in a causal chain

DPHU = Defects per Hundred Units – customer quality indicator

M1 / M2 = Code for materials used in assembly – for adhesion testing

°C = Degrees Celsius – material application temperature unit

N/cm = Newtons per centimeter – adhesion force measurement unit

R E F E R E N C E S

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