ROOT CAUSE ANALYSIS OF FIELD FAILURE CONCERN FOR
IMPROVEMENT IN DURABILITY OF VEHICLE SYSTEM

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ABSTRACT

Durability and reliability of an automobile are equally important from industry as well as customer point of view. Automotive industries are still riddled with significant warranty costs that incur due to premature failure of their products in the customer hands. The key to reduce the design and development expenses and warranty expenses is to subject the product for reliability and/or durability tests for failure modes investigation. Design of the vehicle components must be adapted as accurately as possible to the operating conditions. In order to achieve these goals, durability tests are performed through a combination of physical testing, on road at a proving ground test track, and using a servo-hydraulic road test simulator in laboratory. In this study, root cause analysis is carried out for bonnet cable failure in vehicle model of an automotive industry. Various possible causes are identified using fishbone diagram, why-why analysis is carried to find root cause and solution is proposed. Modified design of hood latch reduced operating efforts for hood latch and avoided bonnet cable failure.

Keywords: Durability, Reliability, Root cause analysis, Fishbone diagram.

1. INTRODUCTION

In automotive industry, vehicle safety and product quality are prime factors on which automotive manufacturers give significant attention. During vehicle manufacturing, defects
arise during manufacturing, assembly and other processes. For continuous quality improvement and customer satisfaction, plant quality functions are planned, integrated and executed to detect these defects and make action plans, preventive measures to resolve them.

Currently, automotive industries are dedicating a lot of attention to improve product quality, durability and reliability already in a virtual simulation environment. A major issue that designers and manufacturers in this field have to face is to improve vehicle lifetime [1,2]. Durability and reliability of a vehicle are equally important from a customer point of view. Automotive industries are still riddled with significant warranty costs that incur due to premature failure of their products in the customer hands [3]. Vehicle manufacturers discover issues through their own vehicle tests, inspection procedures, or information gathering [2]. In order to achieve improved durability and reduced warranty costs, durability tests are performed through a combination of physical testing, on road at a proving ground test track, and using a servo-hydraulic road test simulator in laboratory [4].

Modern vehicles exhibit a variety of performance, safety and comfort features in which they fundamentally differ from previous models. Durability and reliability in vehicle components are prime considerations for successful functioning of vehicles in all aspects mentioned above [5, 6].

In this study, root cause analysis is carried out for bonnet cable failure in vehicle model of an automotive industry and solution is implemented accordingly. Various finished vehicle audits performed in automotive industry considered are ANOVA-C (Advanced New Overall Vehicle Audit), GD (Global Demerit) test and Durability ANOVA-C. The purpose of Durability ANOVA-C is to check and capture data on internal/known customer vehicles periodically to get early feedback on field failure and make action planning [7,8].

2. CONCERN RESOLUTION- BONNET CABLE FAILURE

Concern identified and considered for resolution is ‘High Operational Effort for Hood Latch Release Lever’ which results in bonnet cable failure. This concern is identified during durability ANOVA-C and GD audit. Effort readings taken on internal customers’ vehicle are shown in table 1. Specifications are 40-80 N. Table 2 shows hood latch release lever effort readings for 60 Ready for Inspection (RFI) vehicles. Higher operational efforts are observed for some vehicles.

<table>
<thead>
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<th>Upper Limit (N)</th>
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<th>Phase 3 (N)</th>
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Table 2: Hood latch release lever effort readings for 60 vehicles

<table>
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<tr>
<th>Sr. No</th>
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<th>Sr. No</th>
<th>Effort (N)</th>
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</table>

Bonnet cable failure is third in the list of significant field failure concerns as shown in pareto diagram in fig. 1. Analysis is already carried out for first two concerns.

2.1 Process Flow for Bonnet Cable and Lock assembly

Bonnet cable and bonnet lock are fitted and assembled on assembly line in TCF. Steps involved in this process are mentioned below,

1. Bonnet cable fitment is done on body with grommet and plugs (Trim Line).
2. Bonnet cable bracket is fitted on cockpit (Trim Line).
3. Hook of bonnet cable is assembled with bottom side hood latch (Underbody Line).
4. Bottom side hood latch is fitted on front grill upper body panel with 3 bolts by giving full torque (Underbody line).
5. Loose mounting of top side hood latch on bonnet bottom side with 2 bolts by pre torque. (Final line)
6. Alignment of bonnet as well as both hood latch parts. Tightening of top side hood latch by giving full torque to bolts (Final line)
Alignment process is done in following steps,
1. Alignment of hood by retightening hinges (both locks are in loose condition).
2. Gap & Flushness corrected by giving jerk to the hood.
3. Bonnet is locked first time.
4. Opening of bonnet by giving slight stroke to hood with mallet first time if it is not opened due to stuck. Top side lock assembly is again aligned with respect to bottom side lock assembly.
5. Full tightening of the both hood lock assemblies (body side & bonnet side)
6. Again bonnet is locked & opened 2 to 3 times.

Fig. 2 shows hood latch assembly on vehicle as well as top and bottom hood latch.

**Fig. 1** Pareto diagram for significant field failure concerns

![Pareto diagram for significant field failure concerns](image)

**Fig. 2** (a) Hood latch assembly on vehicle (b) Top side hood latch (c) Bottom side hood latch
3. ROOT CAUSE ANALYSIS

After brainstorming, various possible causes contributing to bonnet cable failure are enlisted. Cause and effect diagram (Fishbone diagram) by using relevant possible causes identified in brainstorming is shown in fig. 3. Probable causes for bonnet cable failure are highlighted in figure.

![Fig. 3 Cause and effect diagram for bonnet cable failure](image)

3.1 Verification of probable causes

1. Damage to cable while fitment:
   i. Fitment process is observed on assembly line.
   ii. No damage is observed to cable while fitment
   iii. Remark: Invalid

2. Improper cable assembly:
   i. Standard operation procedure is followed during cable assembly.
   ii. No abnormalities found during cable fitment on body as well as cable assembly with cockpit and hood latch.
   iii. Remark: Invalid

3. Improper cable routine:
   i. Bonnet cable routine is observed from release lever end to cable hook end during fitment, also on finished vehicles
   ii. Cable routine was found ok in vehicles. All clips were found on position.
iii. Cable routine found ok in vehicles for which higher efforts reported to operate hood latch release lever
iv. Remark: Invalid

4. Improper alignment of bonnet as well as latch-striker:
i. Alignment is done as per standard operation procedure.
ii. Gaps are measured for bonnet on finished vehicles and alignment found ok.
iii. However, during first locking-unlocking operation in alignment process, cable failure incidences were observed on final line
iv. As alignment is done in 2-3 attempts by operator judgment- chances that striker gets stuck in latch in first cycle.
v. Remark: Valid

5. Nut runner not applying required torque/ bolt looseness:
i. Nut runner calibration done as per scheduled frequency
ii. Bolts used for tightening of both latch and striker were checked on finished vehicles for looseness- Found ok
iii. Torque is measured on finished vehicles, also on vehicles for which higher efforts reported- torque found as per specification.
v. Remark: Invalid

6. Deviation of cable length from required length:
i. Bonnet cable length is measured for cables in storage area at side of assembly line
ii. No variation in cable length, length found as per specifications
iii. Remark: Invalid

7. Cracks on cable flap or bracket:
i. Bonnet cables were examined visually for any cracks or damages to cable flap or bracket
ii. No cracks or damage observed
iii. Remark: Invalid

8. Less thickness for cable flap or bracket:
i. Previous actions: Bracket wall thickness increased by 1.2 mm, Reinforcement added to flap
ii. Cable flap and bracket thickness measured- Found ok as per modified dimensions
iii. Remark: Invalid

9. Bottom hood latch spring has more stiffness:
i. Parameters such as free length, number of turns, coil diameter contributing spring stiffness were checked for bottom hood latch spring.
ii. No variation in stiffness- Found ok
iii. Remark: Invalid

10. Cable routine disturbed:
i. Cable routine observed in RFI area, also on customer vehicles during dealer visit.
ii. Cable clips were ensured for position (not fallen)
iii. No abnormalities found
iv. Remark: Invalid

11. Bonnet as well as latch-striker alignment getting disturbed over usage of vehicle:
   i. Bonnet alignment observed, gap measurements done and bonnet efforts were taken on customer vehicles during dealer visit
   ii. Gap variation is observed on right and left side (misalignment) also higher efforts were noted
   iii. In some vehicles (at dealer and production shop) bonnet got opened after giving slight jerk from side (because striker get stuck in latch)
   iv. Remark: Valid

3.2 Valid causes
   Bonnet cable failure occurs because striker gets stuck into bottom latch.
   i. Bonnet as well as latch-striker alignment getting disturbed over usage of vehicle.
   ii. During first locking-unlocking operation in alignment process, chances that striker get stuck in latch.

   Stack up analysis of top hood latch and bottom hood latch shows that only 2 mm clearance given between the top and bottom hood latch for alignment as shown in fig. 4. It is not getting maintained due to contribution of hinges and in process.

   On a vehicle which had run 7000 kilometers, front grill is removed; bonnet is slammed few times and observed that bonnet is not opening by operating hood latch release lever. Refer fig. 5 for explanation.

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Fig. 4 Stack up analysis of top hood latch and bottom hood latch

Fig. 5 (a) Bonnet is not opened because striker got stuck into latch (b) Stuck up marks on bottom latch
During dealer visit, customer vehicles were observed for bonnet alignment. Hood latch release lever efforts were taken and bonnet gaps were measured. Table 3 shows effort and gap measurement readings. Higher operational efforts were seen in customer vehicles.

Table 3: Effort and gap measurement readings on customer vehicles

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Hood latch lever effort (N)</th>
<th>Gaps (mm)</th>
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<th>LH Side</th>
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<td>5.5</td>
<td>3.2</td>
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</table>

3.3 Why-Why analysis

Cause for bonnet cable failure is explained below,

i. Why: Higher operational efforts for hood latch release lever
ii. Why: Striker get stuck into bottom latch
iii. Why: Striker and bottom latch not remain inline
iv. Why: Latch-striker alignment getting disturbed over usage of vehicle or during first cycle of alignment
v. Why: This factor is not considered during design

4. PROPOSED SOLUTION

As there is problem that striker of top hood latch assembly getting stuck into bottom latch due to misalignment, there is a need of keeping striker and bottom latch in one line i.e. to avoid misalignment (oblique travel of striker in latch).

After observation and study of structural design of hood latch parts of vehicle, proposal is given to implement a groove in the striker of top hood latch and guide on bottom hood to avoid misalignment and stuck up issue because of which bonnet cable failure occurs.

For this, structural benchmarking was done with hood latch of another vehicle as shown in fig. 6 and 7.
According to proposal, design changes were made in striker and bottom hood latch of vehicle. Following are the modifications in the design of hood latch bottom part, (Fig. 8)

i. Base plate center hole diameter is changed
ii. Flange is added in support plate
iii. Cable slot in cable holding bracket is changed
iv. Locking bracket (guide cup) is added

For hood latch top part, outer diameter of washer is reduced from 32 mm to 25 mm as shown in fig. 9.
5. IMPLEMENTATION AND RESULTS

Sample hood latches were received from supplier with said design modifications in given proposal.

5.1 Concept trial

Concept trial was conducted on three vehicles with new hood latch samples. Table 4 shows comparison of hood latch release lever operational efforts for three vehicles with existing and modified hood latch parts.

Table 4: Hood latch release lever operational efforts during concept trial

<table>
<thead>
<tr>
<th>Vehicle No.</th>
<th>Specification (N)</th>
<th>Readings with existing hood latch (N)</th>
<th>Readings with modified hood latch (N)</th>
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</thead>
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<td>3</td>
<td>40-80</td>
<td>76.8</td>
<td>76.5</td>
</tr>
</tbody>
</table>

i. During concept trial, fitment was observed for any difficulties in fitment process as well as alignment.

ii. No issue regarding fitment or alignment was noticed.

iii. After operating hood latch release lever and primary lock getting released, secondary lock (to be released by operating lever of top side hood latch) was found ok in all three vehicles.

iv. Bonnet opening-closing cycle was performed for 500 times on three vehicles with modified hood latch parts to check whether there is bonnet cable failure. Bonnet cable failure incidence was not observed and cable found ok.

5.2 Fitment trial

After receiving modified hood latch samples, fitment trial was conducted and completed for five numbers of vehicles.
Table 5: Hood latch release lever operational efforts during fitment trial

<table>
<thead>
<tr>
<th>Vehicle No.</th>
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No fitment related issue was observed during trial. Bonnet opening-closing cycle was repeated for five vehicles and no abnormality was observed (No higher efforts, secondary locking ok). Hood latch release lever operating efforts were measured on five vehicles and found within specifications. Readings are shown in table 5.

5.3 Validation and part trial

Validation process is conducted for modified hood latch samples. In validation, bonnet cable withstands and passed target of 5000 cycles of bonnet opening and closing for all samples. Part trial is conducted on 200 vehicles and readings were taken. All vehicles have shown effort readings within specification. No bonnet cable failure incidence was occurred. Range of effort readings was found between 45 to 62 N (Specification is 40-80 N). This shows significant operational effort reduction for hood latch release lever.

6. CONCLUSION

1. Root cause analysis is carried out for the concern “Higher operational efforts for hood latch release lever which results in bonnet cable failure.”
   i. Bonnet cable failure occurs due to disturbance in alignment of striker-latch which results in stuck up condition of striker in latch.
   ii. To avoid stuck up condition, design modifications are suggested in hood latch with provision of locking bracket (guide cup).
2. Trials with modified hood latch samples showed reduction in hood latch release lever operational effort than that in case of customer vehicles as well as new vehicles with existing design.
3. In validation, bonnet cable withstand for 5000 cycles of bonnet opening and closing. During trials as well as implementation for 200 vehicles, no bonnet cable failure incidence occurred with modified hood latch.

7. REFERENCES


