Design and Tolerance Stack up Analysis of Car Side Door Latch

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Abstract
Side door latch protects the vehicle occupants from being ejected through the doors which have known to be opened during motion or accidents. The intent of this work was to redesign an existing passenger car side door latch to improve the manufacturability using Design for Manufacture (DFM) guidelines and tear down analysis. Tolerance stack up analysis is used to find the clearance or interference between two features on a part and their assembly variation. The check sheet clearly indicated that there was no interference fit present between any features of assembled parts which naturally simplifies the assembly process. The assembly variation for inside release of the latch was found to be ± 1.5mm compared to that of outside release of the latch which was determined to be ±1mm. The analysis opens opportunities for reducing the assembly time significantly as the fastening process is eliminated.

Keywords
Side Door Latch (SDL), DFM & A, Tear Down Analysis, Tolerance Stack Up Analysis

I. Introduction
A car door latch refers to the mechanical device used to align the door in a closed position relative to the vehicle body framework. The major role of a latch is to perform lock/unlock and latch/unlatch functions. A latch unit consists of several components. The number of components varies according to the complexity and the mechanical/electromechanical features specified by the customer [1].

Generally the side door latches of a car contain the following components:

Maintaining government safety standards and satisfying the different Original Equipment Manufacturer (OEM) design specifications in a cost-effective, timely manner is a major challenge for a automobile latch manufacturer. Latch manufacturers have to meet the standards set by governments. At the same time each manufacture has its own testing requirements.

Tolerance analysis is used to estimate the effects of manufacturing variation on the finished products. Either design tolerances or manufacturing process data may be used to define the any variation. Conventional methods used for tolerance stack up analysis are worst-case statistical analysis [2].

Manual construction of tolerance check sheet is a commonly used tool for tolerance analysis. Tolerance check list is used in the industry by draftsmen and designers to calculate the maximum or minimum distances (clearance or interference) between two features on a part or assembly.

The tolerance analysis is different from tolerance allocation. In tolerance analysis the component tolerances are known and the resulting assembly variation is calculated by summing the component tolerances. In tolerance allocation, the assembly tolerance is known from the design requirements, whereas the available assembly tolerance must be distributed or allocated among the components in some rational way.

Fig. 1(a): Tolerance Analysis

II. Concept Development
The concept development consists of the following steps,
1. Tear down analysis
2. Component analysis
3. CAD models of the SDL
4. DFM & A of SDL

Fig. 1(b): Tolerance Allocation
A. Tear Down and Component Analysis
Tear-down analysis and component analysis are the pre-stages of the concept development which helps to understand the importance of the functional parts, interaction between the parts, functional features, etc.,

B. Cad Models of the SDL
The SDL was modelled using CATIA V5 R20 software. The models were created from the customer requirements and the existing side door and back door latch drawings. It provided the complete data of the SDL and other profiles. All other dimensions were measured by Vernier calliper.

C. DFM & A of SDL
The design for manufacturability and assembly guidelines were directly and indirectly applied to redesign the SDL. The following objectives were established for the redesign of SDL,
1. Fastening process was eliminated.
2. Stopper feature on the top plate was eliminated.
3. Double side riveting process was designed.
4. Functional improvement was achieved.

III. Concept Selection
The SDL has been selected based on the five important parameters that are listed below,

A. Functionality
The functionality was captured from the existing SDL and it has been implemented in the new SDL. All the concepts have been worked on without any functional loss.

B. Manufacturability
The requirements for load conditions vary from one car manufacturer to another. So the new SDL has been designed with a special attention given on the load improvement.

C. Assembly
The assembly process was improved by eliminating the housing part and fastening process.

D. Package
The package size is maintained the same as the existing SDL, and some of the non-functional profiles has been modified. Hence, the new SDL has been packaged in the existing door module.

E. Cost
The cost of the new SDL will be reduced, as the fastening assembly process is eliminated. Bending feature in the top plate has been eliminated along with three screws and a housing part.

IV. Design Verification
In general terms, Verification is a quality control process that is used to evaluate the product that complies with the specifications and conditions imposed at the start of a development phase. Design verification is a process to examine design outputs and to use objective evidence to confirm that output meets input requirements. Verification activities are conducted at all the stages and levels of product design. The verification can be determined by inspection, demonstration, test and analysis [3].
V. Tolerance Stack Up Analysis

A. Tolerance Check Sheet

Manual construction of tolerance check sheet is a popular technique for analyzing tolerance accumulation in parts.

For SDL assembly, tolerance check sheets were developed for all parts listed below.

1. Base plate vs. Catch / Pawl rivet
2. Catch vs. Catch rivet
3. Pawl vs. Pawl rivet
4. Top plate vs. Catch / Pawl rivet
5. Top plate vs. Inside release lever rivet
6. Inside release lever vs. Inside release lever rivet
7. Outside operating lever vs. Outside release lever rivet
8. Top plate vs. Outside release lever rivet
9. Outside operating lever vs. Outside operating lever rivet
10. ALH release lever vs. Outside operating lever rivet

The manual construction of tolerance check list only deals with the worst-case analysis and it considers variation in only one direction at a time, i.e. length or diameter. In Table 1 the length was considered for the first direction. The catch and catch rivet is indicated by A and B respectively. The basic dimensions and its tolerances as per drawing are added in the check list. The values of all the clearance fits are calculated and the same is tabulated. (Table 1)

Table 1: Tolerance Stack Up Check Sheet- Catch vs. Catch Rivet

<table>
<thead>
<tr>
<th>S.NO</th>
<th>PART NO</th>
<th>PART NAME</th>
<th>DESCRIPTION</th>
<th>IDENTIFICATION</th>
<th>BASIC DIMENSION</th>
<th>TOLERANCE AS PER DRAWING</th>
<th>REFERENCE VIEW</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>L1730600</td>
<td>CATCH</td>
<td>THICKNESS</td>
<td>A</td>
<td>5.4</td>
<td>0.1</td>
<td>CLEARANCE</td>
</tr>
<tr>
<td>2</td>
<td>L1700500</td>
<td>CATCH RIVET</td>
<td>LENGTH</td>
<td>B</td>
<td>5.6</td>
<td>-0.1</td>
<td>CLEARANCE</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.15</td>
<td>CLEARANCE</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
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<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.45</td>
<td>CLEARANCE</td>
</tr>
</tbody>
</table>

1. Calculations

Minimum condition:

\[ B_{\text{min}} - A_{\text{max}} = 5.6 - 5.7 = 0.1 \]

= Clearance
Nominal condition:
\[ B - A = 5.6 - 5.4 \]
\[ = 0.2 \text{ Clearance} \]

Maximum condition:
\[ B_{\text{max}} - A_{\text{min}} = 5.75 - 5.3 \]
\[ = 0.45 \text{ Clearance} \]

For the second direction, diameter was considered. Here the catch and catch rivet diameter is identified by C and D respectively.

Minimum condition:
\[ C_{\text{min}} - D_{\text{max}} = 7 - 6.9 \]
\[ = 0.1 \text{ Clearance} \]

Nominal condition:
\[ C - D = 7 - 6.9 \]
\[ = 0.1 \text{ Clearance} \]

Maximum condition:
\[ C_{\text{max}} - D_{\text{min}} = 7.15 - 6.8 \]
\[ = 0.25 \text{ Clearance} \]

B. Tolerance Analysis

Tolerance analysis is a method of predicting and analysing assembly variation due to tolerance of individual components and assembly operations. Tolerance analysis is carried out when the tolerances of individual parts are known and the designer intends to find out or allocate the dimensions for assembly. This involves:

- Gathering data on the individual component variations.
- Creating an assembly model to identify which dimensions contribute to the final assembly dimensions.
- Applying the manufactured component variations to the model to predict the variations in assembly dimension.

1. Assembly Variation for Inner Release of the Side Door Latch

(i). Nominal Assembly Variation

The Free, Operating and Full length for inside release of the latch is shown in fig. 6.

(ii). Maximum Assembly Variation

The contributing dimensions for maximum variation condition was identified and applied to the model to find the variations for inner release of the latch. Fig. 7 shows the maximum variation.

(iii). Minimum Assembly Variation

The contributing dimensions for minimum variation condition was identified and applied to the model to find the variations for inner release of the latch. Fig. 8 shows the minimum variation.
(ii). Maximum Variation
The contributing dimensions for maximum variation condition was identified and applied to the model to find the variations for outer release of the latch. Fig. 10 shows the minimum variation.

![Fig. 10: Outer Release Variation for Maximum Condition](image)

(ii). Minimum Variation
The contributing dimensions for minimum variation condition was identified and applied to the model to find minimum variations for outer release of the latch. Fig. 11 shows the minimum variation.

![Fig. 11: Outer Release Variation for Minimum Condition](image)

VI. Results
The tolerance analysis for inner release assembly variation from maximum to mean for free length, operating length and full length were found to be 1.1mm, 1.1mm and 1.3mm respectively. Similarly, for the inner release assembly variation from mean to minimum for free length, operating length and full length was 1.1mm, 1.1mm and 1.3mm. Therefore, the total variation for inner release is computed to be ±1.5mm. The total variation of the outer release assembly from the tolerance analysis was revealed to be ±1mm.

VII. Conclusion
A redesign of an existing passenger car side door latch has been carried out to improve manufacturability using Design For Manufacture (DFM) guidelines and tear down analysis. This helped in improving the design as double side riveting is achieved compared to the single side riveting in the older design. This eliminates the fastening process in the assembly which previously consisted of inserting three screws and a housing part. In order to determine the clearance or interference between two features on a part and their assembly variation, tolerance stack up analysis was done. The check sheet clearly indicated that there was no interference fit present between any features of assembled parts which naturally simplifies the assembly process. The assembly variation for inside release of the latch was found to be ±1.5mm compared to that of outside release of the latch which was determined to be ±1mm.

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References
[1] Portillo, Oscar, Dobson, Kimberly,“60g Inertia Load Analysis of Automotive Door Latches – F2008-SC-033”.
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