Unintended Ignition Switch Rotation

April 28, 2014

Joe Fedullo
Title: Key torque to turn
Project Leader: XXXX
Project Sponsor: XXXX

Project Scope
- Determine objective test that causes ignition switch to unintentionally rotate away from run towards accessory

Findings / Learnings
- Determined 8 objective events that cause unintended key rotation
- Demonstrated proposed design performance as robust

Implementation
- Ensure ignition switch torque is 20N*cm +/- 5
- Further increase robustness by changing key head to design to a hole from a slot.

Benefits
- Customer has system that is very robust to unintended key rotation

P-diagram
Opportunity Statement / Expected Outcome

Opportunity Statement: A test has not been identified that causes ignition switch to transition from 'run' to 'accessory'.

What’s in it for the customer? A robust ignition switch.

What’s in it for GM? A robust ignition switch.

Expected Outcome (Specific Deliverables to the program): A test that will establish a condition that causes the ignition switch to move from 'run' to 'accessory'. The test will be used to assess the performance of the proposed ignition switch.
Test Procedure

Controls:
- Ignition Switch Torque to Turn
- Hole vs Slot on key head
- Key ring size / quantity

Signals:
- Ride and Handling Loop @ Posted Speeds
- Belgian Blocks Durability Schedule
  - Pothole #1 @ 25MPH
  - Pothole #2 @ 25MPH
  - Cubilete @ 10MPH
  - Panic Stop from 10MPH
- R&H Chatter @ 45-55MPH
- R&H Angled RR Crossing @ 70MPH

Response:
- End Ignition Switch Position
  - Run or Accessory

Noises:
- Mass on Key Ring
- Mass Integrity
Test Results – Original Design

Data shows that increasing switch torque, increases robustness to inertial load

Plotted the maximum load for each test signal that ended with ignition switch in 'run' position. Bold line is average of all tests. Described as maximum load success line.
# Effect of Switch Torque

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Cobalt Slot</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8.4 N*cm</td>
</tr>
<tr>
<td>Switch</td>
<td></td>
</tr>
<tr>
<td>Ride and Handling loop @ posted speeds</td>
<td>0.7</td>
</tr>
<tr>
<td>Belgian Blocks durability schedule</td>
<td>0.8</td>
</tr>
<tr>
<td>Pothole #1 @ 25 MPH</td>
<td>0.7</td>
</tr>
<tr>
<td>Pothole #2 @ 25 MPH</td>
<td>0.9</td>
</tr>
<tr>
<td>Cubilete @ 10 MPH</td>
<td>0.8</td>
</tr>
<tr>
<td>Panic stop from 10 mph</td>
<td>1.0</td>
</tr>
<tr>
<td>R&amp;H Chatter @ 45 - 55 MPH Hz=MPH/3</td>
<td>0.6</td>
</tr>
<tr>
<td>R&amp;H Angled RR crossing @ 70 mph</td>
<td>0.6</td>
</tr>
</tbody>
</table>

Minimum mass with unintended rotation (pounds)
Test Results – Original Design

Effect of changing key end from Slot to Hole

Plotted the minimum load for each test signal that ended with ignition switch in ‘accessory’ position with a 12.9N*cm switch.

Conditions with hole never experienced unintended rotation, and testing was stopped @ 3.1#
## Effect of Hole vs. Slot

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Cobalt</th>
<th>Cobalt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Switch</td>
<td>12.9 N*cm</td>
<td>12.9 N*cm</td>
</tr>
<tr>
<td>Key</td>
<td>Slot</td>
<td>Hole*</td>
</tr>
<tr>
<td>Cubilete @ 10 MPH</td>
<td>Minimum mass 1.4</td>
<td>Max mass tested, 3.1</td>
</tr>
<tr>
<td>R&amp;H Chatter @ 45 - 55MPH Hz=MPH/3</td>
<td>where rotation 0.7</td>
<td>rotation did not 3.1</td>
</tr>
<tr>
<td>R&amp;H Angled RR crossing @ 70 mph</td>
<td>occurred (pounds) 0.7</td>
<td>occur. (pounds) 3.1</td>
</tr>
</tbody>
</table>

*Configurations with hole & 13mm ring never experienced unintended rotation. Testing stopped at 3.1 #
Test Results – Proposed Design

Ignition Switch Design Changes

Points are maximum success loads for proposed design

(test suspended)
(end state – ‘run’)

(original design success maximum)
(lower specification limit)
Key Concept Phase Learnings/Decisions

• Original design used to establish drive schedules and key ring loading transition
  – Increasing switch torque from run to acc increases the required mass to turn the key due to inertial loading.
  – Reducing the size of the slot in the key (to a hole) increases the mass required to turn the key due to inertial loadings.

• Proposed design (switch torque 20 N*cm +/- 5 N*cm, and change key to hole) assessed using drive schedules and key loadings. No unintended key rotation occurred.

• Proposed design performance improved from original design
Backup
Physics

Ring weight = 0.031 Newtons (0.007lb)

Slot length in key head = 2.2 cm

Moment arm = \( \frac{1}{2} \) slot length \( \times \) cos theta = 0.95 cm

Static Moment = 0.031 N \( \times \) 0.95cm = 0.03 N\( \times \)cm

*Input moment due to inertial forces is negligible with key and ring only.*

<table>
<thead>
<tr>
<th>&quot;g&quot; level</th>
<th>N*cm of torque generated</th>
</tr>
</thead>
<tbody>
<tr>
<td>33</td>
<td>1</td>
</tr>
<tr>
<td>67</td>
<td>2</td>
</tr>
<tr>
<td>133</td>
<td>4</td>
</tr>
<tr>
<td>267</td>
<td>8</td>
</tr>
<tr>
<td>533</td>
<td>16</td>
</tr>
</tbody>
</table>
Road system images

- Road test descriptions:
  - Belgian Blocks durability schedule
  - Pothole #1 @25 MPH
  - Pothole #2 @ 25 MPH
  - Cubilete @ 10 MPH
  - Panic stop from 10 mph – self explanatory
  - Ride and Handling loop @ posted speeds
  - R&H Chatter @ 45 - 55MPH  Hz=MPH/3
  - R&H Angled RR crossing @ 70 mph
  - Median crossing from 15 – 50 MPH
  - Median crossing w/ braking from 35 – 45 MPH
Belgian Blocks 25 - 35MPH

- A 1.7 mile replica of old Belgian granite block roads that are very rough, including dips and bumps to accelerate durability.
Potholes #1 & #2 @ 25 mph

- Pothole #1 – a 50th percentile customer would see at least one of these vertical load events in a vehicle’s life.

- Pothole #2 – a 80th percentile customer
La Cubilete @ 10 mph

- A replica of a severe road in Mexico, made up of river rocks
- Not part of standard durability, used to assess rack rattle
  (steering gear noise)
Ride and Handling Loop

Chatter Bumps: from 55 - 45 MPH - A series of evenly spaced bumps that excite suspension motion.

Frequency = mph / 3

Ride & Handling Angled RR crossing @ 70 MPH - An elevated, railroad crossing that is at an angle to the road direction
Physics

Significantly reduced moment arm