Golf Car Ejection

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Golf Car Ejection

**Golf car Type**

- Golf car
- LSV - Low Speed Vehicle (Top speed 20-25 mph)
- PNV - Personal Neighborhood Vehicle
- NEV - Neighborhood Electric Vehicle

Golf Car – Maximum speed below 20[mph]
LSV – Maximum speed 20-25[mph]
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Golf cars come in different styles

Accidents Statistics

- 1990-2006 almost 150,000 accidents
- Ejection counts to more than 45% of the injuries
- More than 25% injuries to head and neck
- Accident location
  - 70% at sports or recreational facilities
  - 15% on streets
  - 15% around homes or farms
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Regulations/Standard

- SAE J2358 – Low Speed Vehicles
- ANSI Z130.1 – Safety Requirements for Golf Cars
- 49 CFR 571.500 - Low Speed Vehicles

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Safety Requirements - LSV

- Headlamps
- Stop lamps
- Turn signal lamps
- Tail lamps
- Reflex reflectors
- Parking brake
- Windshields of either type AS-1 or type AS-5 glazing
- Rearview mirrors
- Seat belts
- Vehicle identification
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Golf cars restraints

Many after market products
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Golf cars accidents: Tip over

You did it

No. He did it

I did not do anything

What we’ll do now?

www.amphithotography.net
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Golf cars accidents: with other cars

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Golf cars accidents: Self – into the woods
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Golf cars accidents: Stupid

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Golf cars accidents: Into the water
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Future Problems

- Number of Golf Cars increasing
- LSV can be used on city streets
- No need for license
- No enforcement to use seatbelt

Ejection is caused due to acceleration exerted on the driver and passengers during maneuvering of the car:

a. High speed turning
b. High acceleration
c. High deceleration (hard stop)
d. Resultant of High speed turning and High Acceleration or Deceleration
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High speed turning

The maximum acceleration is limited by the coefficient of friction between the car’s tires and the road (about 0.65g). If the acceleration is higher the car will skid laterally.

Right turn

Left turn

Radial Acceleration

<table>
<thead>
<tr>
<th>Radius [ft]</th>
<th>Speed [mph]</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>4</td>
</tr>
<tr>
<td>11</td>
<td>6</td>
</tr>
<tr>
<td>13</td>
<td>8</td>
</tr>
<tr>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>17</td>
<td>12</td>
</tr>
<tr>
<td>19</td>
<td>14</td>
</tr>
<tr>
<td>21</td>
<td>16</td>
</tr>
</tbody>
</table>

- 0.25g
- 0.5g
- 0.65g
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Lateral acceleration versus speed and turning radius

High acceleration or high deceleration (hard stop)

$\mu g \sim 0.65g$

$0.3g$

Forward acceleration

Hard Stop (Skidding)
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In the following the circles convey:

- Low risk
- Moderate risk
- High risk

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Forward Acceleration  Forward Deceleration
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Right Turn

Left Turn

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Right Turn & Forward Acceleration

Left Turn & Forward Deceleration
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Right Turn & Forward Deceleration

Left Turn & Forward Deceleration

Worst cases – Rear seated passengers
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Worst cases – Front seated passenger

0.5g

0.707g

45°

0.5g

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Forces acting on a rear seated passenger during turning and stopping

Weight

Lateral force

Contact force with Hip Restraint

Friction force

Forward force

Normal force
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Ejection Accidents Reconstruction:

Following these steps:

- Perform a set of experiments with the incident golf car or exemplar in which the acceleration, acting on the occupant, are measured during the same maneuvers.
- Construct a three dimensional model of the golf car (ATB’).
- Construct a model of the occupants sitting in the car (GEBOD’).
- Determine the angular velocity and angular acceleration of the car.
- Apply these accelerations to the ATB+GEBOD model.
- Perform the simulation and determine whether or not ejection occurs.

' ATB – Articulated Total Body program

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**Car performance – Turning Radius**

<table>
<thead>
<tr>
<th>Label</th>
<th>Steering Wheel Turn</th>
<th>Turning Radius (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td>540°</td>
<td>1.73</td>
</tr>
<tr>
<td>R2</td>
<td>360°</td>
<td>3.46</td>
</tr>
<tr>
<td>R3</td>
<td>270°</td>
<td>5.08</td>
</tr>
<tr>
<td>R4</td>
<td>180°</td>
<td>7.87</td>
</tr>
<tr>
<td>R5</td>
<td>90°</td>
<td>8.36</td>
</tr>
</tbody>
</table>
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Car Performance – Maximum Speed

\[ V = \frac{D}{T_2 - T_1} \]

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Car Performance – Maximum Forward Acceleration

Acceleration Time History Full From Rest in a Straight Line
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Car performance – Maximum Stopping Deceleration

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Car performance – Accelerations in turning
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Car performance – Acceleration during typical turn

![Graph showing typical turn at full speed with acceleration as a function of time.]

Vehicle Model

- Use measure dimensions of the incident car
- No need to model the whole car
- Properties of the seat are important:
  - Coefficient of friction
  - Seat stiffness
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Occupant Model

- Use Generator of Body Data Manual (GEBOD)
- Input: Gender, Weight and Height
- Program generates all properties of a human model consists of 15 ellipsoids and 14 joints (better model will include hands)
- Properties include: Weight, Inertia, Joints properties

Example - I

Moderate Turning
R=8.36[m] (27.4[ft])
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Example - II
Moderate Turning
R=8.36[m] (27.4[ft])

Example - III
Forward Acceleration
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Example - IV
12 year old child

Simulation Results

<table>
<thead>
<tr>
<th>Radius [ft]</th>
<th>Results</th>
<th>Time to Ejection (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.32</td>
<td>Ejected</td>
<td>950</td>
</tr>
<tr>
<td>10.65</td>
<td>Ejected</td>
<td>1200</td>
</tr>
<tr>
<td>15.64</td>
<td>Ejected</td>
<td>1450</td>
</tr>
<tr>
<td>24.24</td>
<td>Ejected</td>
<td>1500</td>
</tr>
<tr>
<td>25.75</td>
<td>Not Ejected</td>
<td>N/A</td>
</tr>
</tbody>
</table>
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Hip Restraint Modification

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Rear Seats Restraints
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Recommendations

- No Low Speed Vehicles on city streets (Their crash resistant is inferior to smallest passenger car).
- Require licensing or minimum training
- Require seat belts and enforce their use in particular in neighborhoods and facilities.
- Improve restraints