Overturning of Vehicles at the Ejisu Roundabout on the Ehusu – Kumasi Highway in Ghana

Stephen Agyemang

School of Engineering, Accra Polytechnic, P O Box 561, Accra, Ghana

Abstract

Overturning of vehicles is normally overlooked because it is always not clear what might be the cause. At the Ejisu roundabout on the Ejisu-Kumasi highway in Ghana, there are reports of vehicle overturning almost every month. Once a vehicle speed exceeds that of the overturning speed round a curve, the vehicle is bound to overturn. It is based on this fact that the researcher calculated the overturning speeds of various vehicles with different centre of gravity based on the

\[ v = \sqrt{\frac{dgr}{2h}} \]

where:
- \( d \) = vehicle wheel track
- \( h \) = height of center of gravity above ground level
- \( r \) = radius of curve
- \( v \) = speed at which vehicle will overturn
- \( g \) = acceleration due to gravity

Analysis of the results revealed that all vehicles will have to slow down with their various speeds falling below their overturning speed as they negotiate the curve. Those vehicles with a higher centre of gravity will have to reduce their speed drastically even though they would be driving on the highway. If they negotiate the curve above the limiting speed, overturning will occur. This research deduced that the best way to overcome overturning of vehicles was to increase the radius of the roundabout, but since the area the roundabout occupied made that impossible, it would be better to remove the circle and replace it with traffic lights.

Keywords: overturning speed, vehicles, and roundabout.

INTRODUCTION

Overturning occurs when cornering forces destabilize the vehicle. As a vehicle negotiate a corner, three forces act on it: tire forces (the centripetal force), inertial effects (the centrifugal force), and gravity. The cornering forces from the tire push the vehicle towards the center of the curve. This force acts at ground level, below the centre of mass. The force of inertia acts horizontally through the vehicle's center of mass away from the center of the turn. These two forces make the vehicle roll towards the outside of the curve. The force of the vehicle's weight acts downward through the center of mass in the opposite direction. When the tire and inertial forces are enough to overcome the force of gravity, the vehicle starts to turn over.

It has always been in the news that vehicles have been overturning at the Ejisu roundabout on the Ejisu – Kumasi highway in Ghana. Most of these vehicles are mainly goods-carrying vehicles like the articulated and cargo trucks. These vehicles are normally overloaded hence they have the tendency to overturn as they negotiate the curve. In view of this the researcher, seeks to find out the causes of overturning, that is to determine the limiting speeds at which different types of vehicles may overturn as they go round the roundabout in question.

Specific Objectives

- To determine the causes of overturning at the Ejisu roundabout on the Ejisu-Kumasi highway
- To determine the speed limit of various types of vehicles as they negotiate the curved track

Methodology

In all, six different types of vehicles were considered by the researcher.

- Saloon car
- Station Wagon
- Mini bus
- 33 sitter bus
- Cargo truck
- Articulated truck

The researcher also considered those vehicles which are normally used in carrying loads in Ghana. Four of these vehicles were considered.

- Minibus with load on its carrier
- 33 sitter bus with load on its carrier
- Cargo truck fully loaded
- Articulated truck fully loaded

For all these vehicles the following measurements were taken:

- \( d \) – Vehicle wheel track
- \( h \) – Height of centre of gravity above ground level
h –Height of centre of gravity above ground level when fully loaded.
The researcher travelled to Ejisu where the roundabout in question is located and the radius \( r \) of the roundabout was measured and a picture of it taken as shown in Fig.1.

![Fig.1 Ejisu–Kumasi highway Roundabout](image1)

![Fig.2 Picture of a cargo truck fully loaded](image2)

From the values obtained and using the formula

\[ v = \sqrt{\frac{dgr}{2h}} \]

the various overturning speeds were calculated.

When a motor vehicle is rounding a curve, there is a limiting speed at which overturning just occurs.

The forces acting on the vehicle when it is turning left are shown in Fig. 3. These are

i. The gravitational force, i.e. its weight \( W = mg \), acting vertically downwards through the center of gravity.

ii. The normal reactions of the track, \( R_A \) and \( R_B \) at the inner and outer pairs of wheels respectively.

iii. The inertia or centrifugal force (C.F.) acting radially outwards through the center of gravity

Let \( m = \) mass of vehicle

\[ d = \text{vehicle wheel track} \]
\[ h = \text{height of centre of gravity} \]
\[ r = \text{radius of curve} \]
\[ v = \text{speed at which vehicle will overturn when the vehicle is at rest} \]

Normal reaction at inner wheels at \( A = \) Normal reaction at outer wheels at \( B \), i.e.

\[ R_A = R_B = \frac{W}{2} = mg/2 \]

On the point of overturning, the inner wheels at \( A \) just leave the ground and the vehicle start to rotate about the outer wheels at \( B \). Thus:

\[ R_A = 0 \] and \( R_B = W = mg \)

Then, taking moments about an axis through the center of gravity at right angles to the wheel axles Overturning Moments = Stabilizing moment

\[ \text{C.F.} \times h = R_B \times \frac{d}{2} \]

or

\[ \frac{mv^2}{r} = x h = mg \times \frac{d}{2} \]

so that

\[ v^2 = \frac{mgd}{2} \times \frac{r}{mh} \]

\[ \therefore \text{Overturning speed} \]

\[ v = \sqrt{\frac{dgr}{2h}} \]

It will be noticed from the last equation that the tendency of a vehicle to overturn when travelling round a curved track depends on the wheel track \( d \) and the height of the centre of gravity of a vehicle. The overturning speed may, however, be increased by either lowering the height \( h \) of the centre of gravity above the ground or by increasing the wheel track \( d \) or by increasing the radius of curvature of the road.
Results

Table 1 Overturning speed $V$ (km/hr) of various vehicles with center of gravity $h$ (m)

<table>
<thead>
<tr>
<th>Types of Vehicles</th>
<th>$d$ m</th>
<th>$h$ m</th>
<th>$r$ m</th>
<th>$v$ m/s</th>
<th>$v$ km/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saloon</td>
<td>1.56</td>
<td>0.76</td>
<td>12.85</td>
<td>11.37</td>
<td>40.93</td>
</tr>
<tr>
<td>Station Wagon</td>
<td>1.62</td>
<td>0.94</td>
<td>12.85</td>
<td>10.42</td>
<td>37.52</td>
</tr>
<tr>
<td>Minibus</td>
<td>1.50</td>
<td>0.98</td>
<td>12.85</td>
<td>9.81</td>
<td>35.36</td>
</tr>
<tr>
<td>33 Sitter Bus</td>
<td>1.75</td>
<td>1.16</td>
<td>12.85</td>
<td>9.75</td>
<td>34.45</td>
</tr>
<tr>
<td>Cargo Truck</td>
<td>2.17</td>
<td>1.57</td>
<td>12.85</td>
<td>9.30</td>
<td>33.60</td>
</tr>
<tr>
<td>Articulated Truck</td>
<td>2.26</td>
<td>0.00</td>
<td>12.85</td>
<td>8.44</td>
<td>30.38</td>
</tr>
</tbody>
</table>

Table 2 Overturning speeds $V$ (km/hr) of various vehicles with center of gravity $h_1$ (m)

<table>
<thead>
<tr>
<th>Types of Vehicles</th>
<th>$d$ m</th>
<th>$h_1$ m</th>
<th>$r$ m</th>
<th>$g$ m/s$^2$</th>
<th>$v$ m/s</th>
<th>$v$ km/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minibus with maximum load on carrier</td>
<td>1.50</td>
<td>1.50</td>
<td>2.85</td>
<td>9.81</td>
<td>7.94</td>
<td>28.58</td>
</tr>
<tr>
<td>33 Sitter Bus with maximum load on carrier</td>
<td>1.75</td>
<td>0.85</td>
<td>2.85</td>
<td>9.81</td>
<td>7.72</td>
<td>27.80</td>
</tr>
<tr>
<td>Cargo Truck with maximum load</td>
<td>2.17</td>
<td>2.45</td>
<td>12.85</td>
<td>9.81</td>
<td>7.47</td>
<td>26.89</td>
</tr>
<tr>
<td>Articulated truck with maximum load</td>
<td>.26</td>
<td>2.45</td>
<td>12.85</td>
<td>9.81</td>
<td>7.63</td>
<td>27.45</td>
</tr>
</tbody>
</table>

Fig. 4 Graph of vehicles showing overturning speeds ($v$), center of gravities ($h$) and length of wheel track ($d$)

Fig. 5 Graph of vehicles showing overturning speeds ($v$), center of gravities ($h_1$) and wheel track ($d$)
Discussions
From Table 1, the overturning speed of the saloon car with a center of gravity 0.76 m is 40.93 Km/hr. It means it has to travel below this speed so as not to overturn round the curve in question. As the center of gravity of the various vehicles increases their overturning speed decreases even though the width of their wheel track increases but not significantly as shown in Table 1. Hence it would be noticed that the speed of the articulated truck when negotiating the curve with its center of gravity of 2.00 m has to reduce its speed below 30.38 Km/hr, in order not to overturn. From Table 2, as the vehicles are fully loaded with their center of gravity increased, their overturning speed reduces. As depicted on the bar chart in Fig.5, the 33 sitter bus with maximum load has its center of gravity increased from 1.16 m to 1.85 m. Hence its overturning speed reduces from 35.45 Km/hr to 27.80 Km/hr. The articulated truck with maximum load with its center of gravity at 2.45 m would have to travel around this curve at only a minimum speed below 27.45 km/hr so as to avoid overturning even though they might be moving on a highway. All the other vehicles likewise have to reduce their speeds as shown in the Table 2. The speeds at which these vehicles are moving will increase if the radius of the curve is also increased by using the formula

\[ v = \sqrt{\frac{dgr}{2h}} \]

where the overturning speed is directly proportional to the square root of the radius of the curve. From the values obtained since acceleration due to gravity is constant and also the value of wheel track of the vehicles are fixed, the best thing one can think of is to decrease the center of gravity of the various vehicles or increase the radius of the roundabout. This will increase the overturning speed of the vehicles especially those which are fully loaded with their center of gravity raised.

CONCLUSION
This research has revealed that most of the vehicles overturn at the Ejisu roundabout on the Ejisu-Kumasi highway because these vehicles normally speed above their overturning speeds unknowingly. The roundabout in question should be looked at again since its radius is too small; hence if the center of gravity of a vehicle is increased, it reduces its overturning speed hence causing the vehicle to overturn.

RECOMMENDATION
Based on the findings the following recommendations have been made.

- The diameter of the roundabout should be increased but if due to lack of space it is not possible, it should be removed and be replaced with traffic lights.
- Speed limit signs should be placed some meters before a vehicle gets to the roundabout. This will enable drivers to lower their speed drastically since they are not aware at what speed their vehicle will overturn.
- Drivers should be advised not to overload their vehicles since it increases the center of gravity of their vehicles which can lead to overturning.
- Unique warning sign of curves and other areas with an increased danger of overturning for trucks and other high vehicles should be erected as shown in Fig.6. These signs may include an advisory safe speed to avoid overturning.

**Fig. 6**

REFERENCES