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ANALYSIS OF THE OVERTURNING OF HEAVY VEHICLES IN THE "THE ADIOSES" CURVE OF THE HIGHWAY PAMPLONA-CÚCUTA

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ABSTRACT

Over time, it has been observed that accidents due to vehicle overturning in the "The Adioses" curve of the Pamplona - Cúcuta road are a fairly frequent problem due to several factors such as: high speeds, absence of traffic signs, driver maneuvers, among others. This is why this section of the road has been classified as a critical accident point. The vehicles that are most affected are heavy vehicles (truck tractors), which due to their large size have a high gravity center, which hinders their stability compared to other vehicles. Another important aspect that it is taken into account is the characteristics of the road that can modify the load distribution in the vehicle. All these aspects are evaluated through a case study which allows calculating the stability factor for a particular heavy vehicle and calculating the safe traffic speed for this vehicle in the specified sector.

Keywords: accidents, rollover, speed, heavy vehicles, road, stability factor.

1. INTRODUCTION

An important part of a country's economy depends on its cargo transportation system. In Colombia due to its geographical conditions the most widely used cargo transportation method is that of heavy vehicles transport. Due to their large size and road conditions, these vehicles are prone to overturning, which represents a problem in certain locations of some roads.

The Cucuta - Pamplona road is not alien to this problem, according to [1] 11 sectors of the road have been marked as high accident risk locations, one of these sectors is called the "The Adioses curve", which according to the reports of the National Police [2], is a point of high accidentally due to overturning of heavy vehicles.

These accidents, depending on their severity, often have implications that affect public health, road safety, road mobility, and the country's economy [3].

Taking into account all these aspects into account in the present paper, the stability model developed by [5, 6] is used, which allows determining the stability factor (Static Rollover Threshold - SRT) for a heavy vehicle that travels on a road with similar characteristics as the curve in question.

Additionally, this stability factor allows predicting the safe speed limit with which a heavy vehicle can travel on a road with certain characteristics [5, 7], which substantially improves the safety on the road for the drivers who use it.

2. STABILITY MODEL

As mentioned above, in the present paper, the stability model developed by Moreno [5] was used, which makes a three-dimensional representation of the trailer of a heavy vehicle (Critical part of the vehicle) (Figures 1 and 2), and later Using the methodology developed by Davies [8, 9, 10], the vehicle stability factor is calculated (Eq. 1).

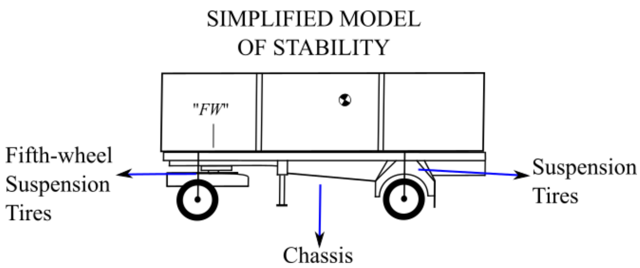

Figure-1. Tráiler de un vehículo pesado Adaptado de Moreno [5].

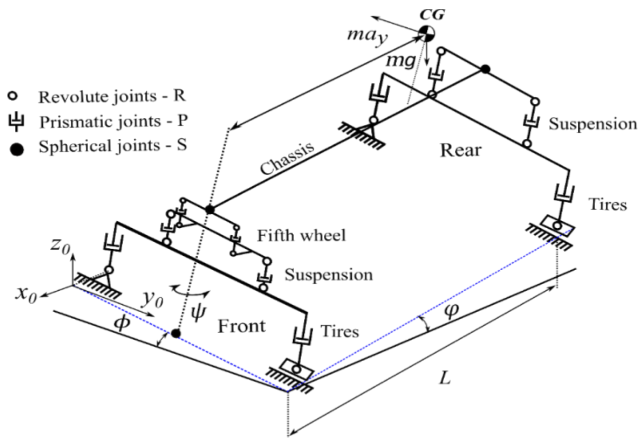

Figure-2. Modelo del tráiler de un vehículo pesado. Adaptado de Moreno [5].

$$\mathrm{SRT}_{3D\phi\varphi} = \frac{a_y}{g} = \frac{h_1 \cos\varphi + h_2 e \cos\varphi}{h_2 - (h_1 + P_1)e} * \left(1 - \frac{P_1(F_{z17} - W\cos\phi\cos\varphi)}{W\cos\phi(h_1\cos\varphi + h_2 e\cos\varphi)}\right) \quad (1)$$

Where $SRT_{3D\psi\phi\varphi}$ s the three-dimensional stability factor of a heavy vehicle, h_1 is the lateral distance of theCG in reference to the coordinate axis, h_2 is the height ofCG, e the tangent of the bed angle (lateral slope of the track), P_1 is a system variable, $F_{z3} y F_{z17}$ are the normal vehicle support forces (F_{z3} external tire to the curve, front axle, F_{z17} inner tire to the curve, rear axle), W is the vehicle's weight, ϕ is the angle of lateral slope of the road, and φ is the longitudinal slope angle of the road.

Additionally, since the stability factor of equation (1) is a function of the lateral acceleration ($\boldsymbol{a_y}$), and this in turn is a function of the speed of the vehicle (V) and the curvature radius (r) of the road, vehicle speed can be determined for a curve with a certain geometry (Ec. 2).

$$SRT_{3D\phi\varphi} = \frac{a_y}{g} = \frac{V^2/r}{g}$$
$$V = \sqrt{SRT_{3D\phi\varphi} * r * g} \qquad (2)$$

This last equation makes it possible to predict the safe traffic speed with which a vehicle can travel through a certain curve without risking a rollover accident.

3. CASE STUDY

3.1 Selecting the Critical Point of the Road

According to Patiño [1], through a survey of road users, police and journalistic reports, several critical accident points for heavy vehicles were determined on the Pamplona-Cúcuta road, among which the "The Adioses curve" stands out On it, the risk of rollover is quite high (Figure-3).

Figure-3. Tractor truck rollover accident.

The Adioses curve is located at kilometer 1 + 80 (Pamplona - Cúcuta), as shown in Figures 4 and 5.

Figure-4. Location of the critical point The Adioses curve (Km 1 + 80) on the Pamplona-Cúcuta road.

Figure-5. Critical point The Adioses.

For the calculation of the vehicle stability factor and the determination of the traffic speed in this sector, it is important to detail the specific characteristics of this point, as detailed in Table-1.

Table-1.

Critical point	Lateral slope angle (ϕ)	Longitudinal slope angle (φ)	Curve radius (m)
The Adioses curve	12.2	8.3	26.5

3.2 Vehicle Selection and Characteristics

In the study developed by Patiño [1], in addition to determining the critical points of the road, the cargo vehicle with the highest incidence or probability of road accidents was determined, with the truck tractor with 5 o 6 axes being most prone to accidentally, like the one seen in Figure-6 having the characteristics of Table-2.

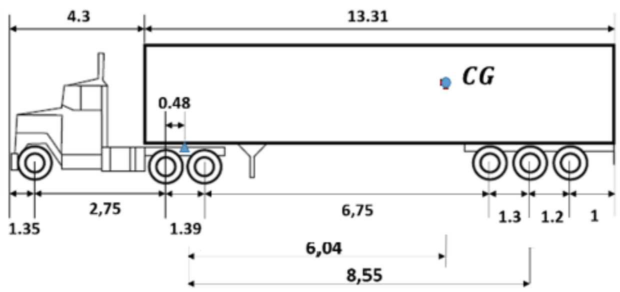

Figure-6. Tractor-truck (dimensions in meters).

Table-2. Vehicle characteristics.

PARAMETER	VALUE	UNIT
Tire height	0.499	m
Distance of the fifth-wheel to CG (a)	6.04	m
Distance of the fifth-wheel to the rear axle (L)	8.55	m
Height of the chassis to the CG	1.24	m
Suspension spring height	0.22	m
Vertical suspension stiffness	1800000	N/m
Number of frontal axles	2	
Number of rear axles	3	
Vehicle weight (W)	400000	N
Vertical stiffness of the tire	840000	N/m

3.3 Calculations and Discussion

In addition to the characteristics of the vehicle and the road, for the implementation and similarity of the stability model in the sector known as the Adioses curve, the following standards were taken into account:

- ISO-14792 Standard - Steady State Circular Tests [11],
- As a road safety measure, the lateral load transfer on the rear axle of the vehicle cannot exceed 60% [12-14], since for larger transfers the vehicle is unstable and tends to overturn quickly.
- The stability factor was determined, for the moment on which the vehicle is going downhill, since this modifies the load distribution of the vehicle, making it lighter at the rear, and therefore more prone to overturning [15].

Once the model was implemented, and following all the recommendations, and taking into account these aspects, the centripetal force (ma_y), caused by the turning of the vehicle, was gradually increased until the lateral load transfer on the rear axle was then recommended.

Table-3 and Figure-7 show the value of the stability factor (SRT) obtained for this section of track and the tipping angle of the vehicle.

Table-3. Stability factor of the Adioses Curve.

Critical point	$SRT_{3D\phi\varphi}$
The Adioses curve	0.3364

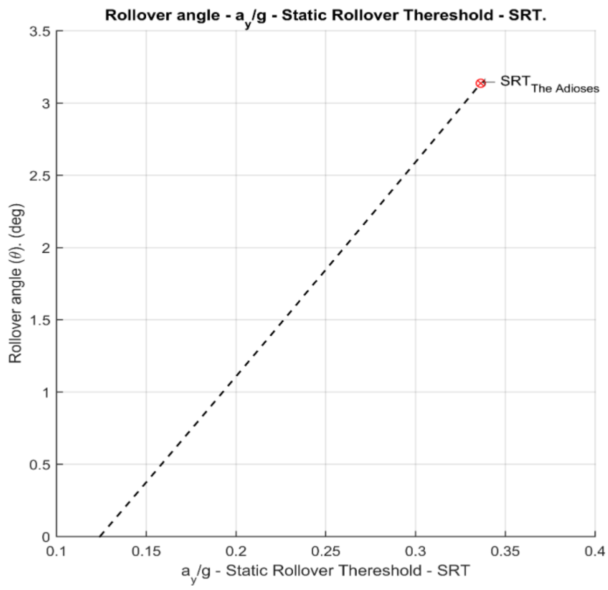

Figure-7. Stability factor of the critical point The Adioses.

Finally, the safe speed (Eq. 2) with which the model vehicle can move through the curve without risking overturning was calculated ($V=33.66$ *km/hr*), for this the calculated stability factor is used ($SRT_{3D\phi\varphi}$) and the curve radius (Table-2).

As a comparison and discussion of road safety, according to article 107 of the National Traffic Code in Colombia [16], the maximum speed for freight vehicles on national or primary roads should not exceed eighty kilometres per hour (80 *km/h*).

When comparing these speeds, it can be observed that the speed with which the vehicles travel through this sector of the road is very high, about 2.37 times given the calculations according to the stability model, this causes traffic accidents to occur frequently, which in many times are due to unfamiliarity with the road.

Additionally, to this stability problem, it was also observed that vehicles travel in both directions on the road, and that its radius of curvature is small, which makes it difficult for drivers to manoeuvre in the face of possible risky situations.

4. CONCLUSIONS

When analyzing the different aspects associated with the accidents due to overturning of heavy vehicles on the Adioses curve of the Cúcuta - Pamplona road, it is observed that there are serious road safety problems associated with the lack of road signs due to the characteristics of it.

That is why this type of study is important, since through them, aspects of the dynamics of vehicle movement can be made known. with these, decisions that allow a better design of the roads can be made, that traffic authorities can adopt rules, and place road signs to minimize the risks that a driver may encounter when traveling through a certain sector.

At present, this road is being subjected to several structural works, which are expected to increase the safety of road users, so it is important to re-evaluate its operation in the future and verify speed limits at various critical points.

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