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TRAFFIC HAZARD DUE TO HIGH CENTRE OF GRAVITY

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RESEARCH ARTICLE

ABSTRACT: The combination of a trailer and load presents significant hazards on motorways, particularly due to high speeds and sharp curves. Proper loading is crucial to prevent load displacement during heavy braking or sudden directional changes. A load shift, especially when the centre of gravity is high, can initiate critical situations, increasing the risk of tipping and rolling.

This paper analysis the critical situations, emphasizing drivers responsibility in ensuring safe loading practices to avoid causing dangerous road conditions, such as vehicle overturning. Such incidents are unfortunately common. The paper will explore characteristic vehicles, safety systems, cornering dynamics, and both theoretical and practical demonstrations of load behaviour under various forces. Side-slip and rollover phenomena will also be examined.

KEY WORDS: *traffic, road danger, vehicle composition, high centre of gravity, driver responsibility*

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ISPITIVANJE ČVRSTOĆE 3D ŠTAMPANIH UZORAKA

REZIME: Kombinacija prikolice i tereta predstavlja značajne opasnosti na autoputevima, posebno zbog velikih brzina i oštrih krivina. Pravilno opterećenje je ključno za sprečavanje pomeranja tereta tokom jakog kočenja ili naglih promena smera. Promena opterećenja, posebno kada je centar gravitacije visok, može da izazove kritične situacije, povećavajući rizik od prevrtanja i kotrljanja.

Ovaj rad analizira kritične situacije, naglašavajući odgovornost vozača u obezbeđivanju bezbednih praksi utovara kako bi se izbeglo izazivanje opasnih uslova na putu, kao što je prevrtanje vozila. Takvi incidenti su, nažalost, česti. U radu će se istražiti karakteristična vozila, bezbednosni sistemi, dinamika skretanja, te teorijske i praktične demonstracije ponašanja opterećenja pod različitim silama. Takođe će se ispitati fenomeni bočnog klizanja i prevrtanja.

KLJUČNE REČI: *saobraćaj, opasnost na putu, sastav vozila, visoko težište, odgovornost vozača*

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INTRODUCTION

The safe operation of vehicles on motorways requires careful consideration of numerous factors, with the height of the centre of gravity being one of the most critical. The centre of gravity (C.G.) plays a pivotal role in determining a vehicle's stability, particularly when negotiating sharp curves or during sudden manoeuvres. Vehicles with a high centre of gravity are inherently more prone to tipping and rolling, especially when subjected to the dynamic forces encountered at high speeds [1-3].

The modern transportation industry increasingly relies on high-capacity trailers and semi-trailers to move large loads efficiently. However, this efficiency can come at a significant cost if proper precautions are not taken. The challenge of safely transporting goods becomes even more significant when dealing with loads that are bulky, tall, or unevenly distributed. The risk is exacerbated when such loads are not properly secured, as any sudden shift can drastically alter the vehicle's balance, leading to a loss of control. Example is shown in figure 1 [1].

Over the years, there have been numerous documented cases of accidents caused by improper load securing and the resulting shift in the centre of gravity. These incidents often lead to severe consequences, including vehicle rollover, multi-vehicle collisions, and, in the worst cases, fatalities. Despite advancements in vehicle safety technologies, the human factor—particularly the responsibility of the driver and those involved in the loading process—remains crucial in preventing such accidents [3, 4].

This paper seeks to shed light on the dangers associated with a high centre of gravity in vehicle compositions and to provide guidance on best practices for loading and securing cargo. By analysing the dynamics of cornering, the impact of speed, and the role of safety systems, we aim to equip drivers and transport professionals with the knowledge necessary to minimize the risk of accidents. The paper will also include case studies and practical demonstrations of how forces act on a load during different driving scenarios.

Figure 1 Consequence of serious influence of load on vehicle balance.

1 GENERAL PROBLEMS ASSOCIATED WITH HIGH C.G. LOADINGS

The composition: the towing vehicle, the semi-trailer and the load on it can be perfectly safe as long as the centre of gravity is low. However, if this is altered, the following scenarios can become reality:

1.1 Increased Risk of Vehicle Rollover

One of the primary concerns when a truck is loaded with a high centre of gravity is the increased risk of rollover. When the centre of gravity is raised, the vehicle becomes more top-heavy, making it more susceptible to tipping over, particularly when making sharp turns, sudden stops, or during evasive manoeuvres. This risk is especially pronounced in vehicles such as flatbed trucks, which often carry large, bulky items like machinery or construction materials that are difficult to load evenly.

Case study

A flatbed truck carrying a stack of steel beams that are not properly secured and are loaded too high is a common example of a scenario where the vehicle's centre of gravity is dangerously elevated. In this case, even a moderate turn at standard road speeds could cause the beams to shift, leading to a rollover. Another example is shown on Figure 2.

Figure 2 Dangerously elevated centre of gravity due to inappropriate truck loading.

1.2 Load Shift During Transit

When a load is not adequately secured, it can shift during transit, significantly altering the vehicle's centre of gravity. This sudden change can lead to loss of control, particularly if the driver is forced to brake suddenly or swerve to avoid an obstacle. The load shift not only affects the balance of the vehicle but can also lead to severe structural stress on the trailer, potentially causing it to fail.

Case study

Consider a situation where a truck is transporting large barrels of liquid that are not securely fastened. As the truck takes a sharp turn, the barrels roll to one side, dramatically shifting the centre of gravity and causing the truck to tip over. This is especially dangerous in conditions where the road surface is wet or uneven, as the reduced friction can exacerbate the risk of rollover.

1.3 Decreased Vehicle Manoeuvrability

A higher centre of gravity adversely affects a vehicle's manoeuvrability. The higher the centre of gravity, the more difficult it becomes to control the vehicle, especially when making sudden directional changes or when driving on uneven terrain. This reduced manoeuvrability can lead to accidents, particularly in situations where the driver needs to respond quickly to avoid a collision.

Case study

A delivery truck loaded with high C.G. elements (as show on Figure 3), will experience significant change in dynamics and behaviour of it during lateral acceleration. This situation can make it difficult for the driver to maintain control, especially in emergency situations where quick steering adjustments are required.

Figure 3 Heavy high C.G. load on truck.

1.4 Increased Stopping Distance

A high centre of gravity, combined with an uneven load, can also increase a vehicle's stopping distance. This is due to the fact that the load may shift forward during braking, transferring more weight to the front axle and reducing the effectiveness of the brakes. This is even more dominant in non-braking trailer. In extreme cases, this can lead to brake failure or jack-knifing in articulated vehicles.

Case study

A truck carrying a tall, unsecured load of construction materials that suddenly brakes to avoid a collision could find that the load shifts forward, increasing the vehicle's stopping distance and leading to a rear-end collision.

1.5 Strain on Vehicle Components

A poorly loaded truck with a high centre of gravity can place undue strain on various vehicle components, including the suspension, tires, and axles. This not only increases the

risk of mechanical failure but also contributes to higher maintenance costs and shorter vehicle lifespan.

Case study 1

A heavy load concentrated high above the truck bed can cause the suspension to compress unevenly, leading to premature wear and tear. Over time, this can result in component failure, such as a broken axle, which could lead to a serious accident on the road.

Case study 2

In 2019, a truck transporting large wind turbine blades overturned on a motorway due to the improper loading of the blades, which raised the centre of gravity. The driver attempted to take a curve at a speed slightly above the recommended limit, which caused the vehicle to tip over. The accident resulted in a complete road closure and significant delays, highlighting the dangers of transporting loads that elevate the centre of gravity.

2 CALCULATING VEHICLE SLIP AND ROLLOVER IN A BEND

This section will delve into the mathematical and physical principles governing vehicle slip and rollover in bends, emphasizing the importance of load securing and speed control. The analysis will cover the key factors that influence these phenomena, including the radius of the curve, the speed of the vehicle, and the height of the centre of gravity.

The rollover threshold, a critical concept in understanding vehicle stability, thus are analysed in detail. This threshold is influenced by the lateral acceleration experienced by the vehicle, which increases with the speed of the vehicle and the sharpness of the turn. The height of the centre of gravity is directly proportional to the likelihood of rollover, as a higher C.G. reduces the amount of lateral force needed to tip the vehicle.

2.1 Centrifugal Force on Vehicle Components

When a truck with trailer is travelling into a bend (figure 4), the maximum speed can be determined according to the radius of the bend, the gradient of the road surface and the road-to-tire friction coefficient.

The coefficient of friction for dry asphalt is estimated to be μ=0.6. The lateral coefficient of friction is 67% of the maximum friction coefficient. In the concrete case this means μ =0.4. The centre of gravity *h* can be determined from the individual centres of gravity and masses:

$$h = \frac{6000 \cdot 0.6 + 21641 \cdot 2.6}{27941} = 2.15\ m, \tag{1}$$

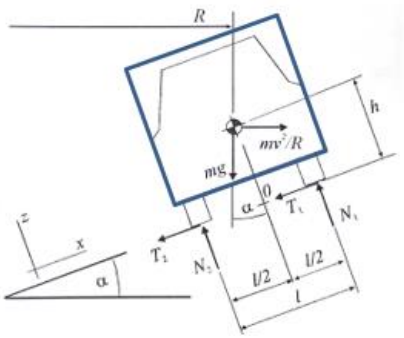

Figure 5 Analysis of slip and rollover threshold in turn.

$$v_{mejna-zdrs} = \sqrt{Rg\frac{\mu cos\alpha + sin\alpha}{cos\alpha - \mu sin\alpha}} = \sqrt{80 \cdot 9.81\frac{0.4cos4 + sin4}{cos4 - 0.4sin4}} = \mathbf{70\ km/h}$$

$$v_{mejna-prevrnitev} = \sqrt{Rg\frac{\frac{l}{2}cos\alpha + hsin\alpha}{-\frac{l}{2}sin\alpha + hcos\alpha}} = \sqrt{80 \cdot 9.81\frac{1.05\ cos4 + 2.15sin4}{-1.05sin4 + 2.15cos4}} = \mathbf{76\ km/h} \quad (2)$$

Figure 4 Road situation for rollover case in a bend/turn.

As a result of too high speed, the truck has rolled over as is shown in figure 6.

Figure 6 Crossing the rollover tresholdof truck.

3 CONCLUSIONS

The transportation of goods, particularly in vehicles with a high centre of gravity, presents significant challenges and risks that cannot be ignored. This paper has highlighted the critical role that proper loading and securing practices play in maintaining vehicle stability and preventing accidents. The examples and analyses provided demonstrate that a high centre of gravity increases the likelihood of vehicle rollovers, reduces manoeuvrability, and places additional strain on vehicle components.

Drivers, as well as those responsible for loading, must be acutely aware of these risks and take proactive measures to mitigate them. This includes ensuring that loads are evenly distributed, properly secured, and kept as low as possible within the vehicle. Moreover, adherence to safe driving practices, such as maintaining appropriate speeds and avoiding sudden manoeuvres, is essential to preventing accidents.

The consequences of neglecting these safety measures can be severe, leading not only to vehicle damage but also to potential loss of life. It is imperative that the transportation industry continues to prioritize safety by investing in training, adopting best practices, and utilizing advanced safety technologies designed to prevent rollover incidents.

In conclusion, while advancements in vehicle safety systems have reduced some risks, the human factor remains the most critical element in ensuring safe transportation. By fostering a culture of responsibility and awareness among drivers and transport professionals, the dangers associated with a high centre of gravity can be significantly minimized, leading to safer roads for everyone.

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