International Co-operation on Theories and
Concepts in Traffic Safety

Simulation of load restraining in heavy goods vehicles

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Introduction

Road freight transport stands out as the sector with the highest frequency and severity of accidents among all business sectors (Kan, 2017). This underscores the imperative for implementing targeted prevention measures within this sector particularly when it is related to load securing issues. Studies conducted in the 1980s estimated that approximately 50,000 spills or releases of goods occur on the road every year in France. Inspections by authorities on heavy goods vehicles have revealed that load restraint regulations are not adhered to in 80% of cases. A recent study explored the magnitude of acceleration in heavy trucks during emergency braking to better grasp the inertial forces affecting cargo (Zuska et al., 2022). While specific software exists for modeling the dynamic behavior of heavy trucks during critical maneuvers such as emergency braking, there is a notable absence of numerical models capable of simulating the impact of securing on load stability during these maneuvers. These models are indispensable for predicting load stability across various maneuvers. Thus, a significant number of securing configurations could be studied at a low cost compared to experimental tests.

In this study, a numerical model has been developed to simulate the behavior of a secured load during truck emergency braking. The model is based on multibody modeling and considers various parameters crucial for load stability, including tension in the securing straps, the friction coefficient between the load and the truck bed, the size and mass of the loads and the dynamic behavior of the truck during emergency braking. After validating the model, a parametric study is conducted to identify various configurations where the load may become unstable.

Methodology

The developed model consists of several rigid bodies representing the truck bed and secured loads. To analyze load movement, the strap tension and pallet-truck bed friction were integrated into the model. The truck's accelerations were directly derived from measurements taken during tests on the instrumented truck using Inertial Measurement Units (IMU).

The model was validated by comparing the results of simulations with experiments conducted on the instrumented truck. The dynamic behavior of the truck and the loads, the tension in the straps, and the displacement of the loads during emergency braking were measured with sensors such as IMU, force sensors, and telemeters (Riahi et al., 2023). To validate the model, the truck's deceleration and the tension in the straps, measured by sensors were used as input parameters in the model, and the displacement of the load was used as the validation criterion for the model. Figure 1 shows the experiment and the schema of the model. After the validation of the model, a parametric study is conducted to identify the influence of different parameters on the stability of the load. The parameters studied are: the deceleration level, the friction coefficient, and the tension of the straps.

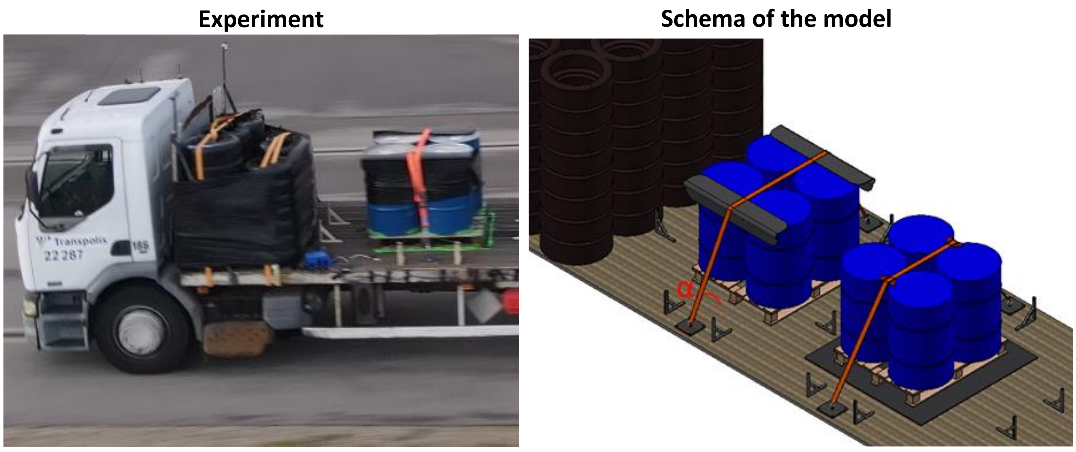

Figure 1. Photo of the experiment and the schema of the model

Results

Figure 2 shows the results of the simulated test for model validation. It compares the measured displacement of the load during emergency braking, obtained via the telemeters, with the displacement calculated by the model. These curves illustrate the three phases of load movement. The findings indicate a close correlation between the two results: the load travels 100 cm before contacting the tire wall. Subsequently, upon the truck's complete stop, the load experiences a rearward displacement of approximately 20 cm.

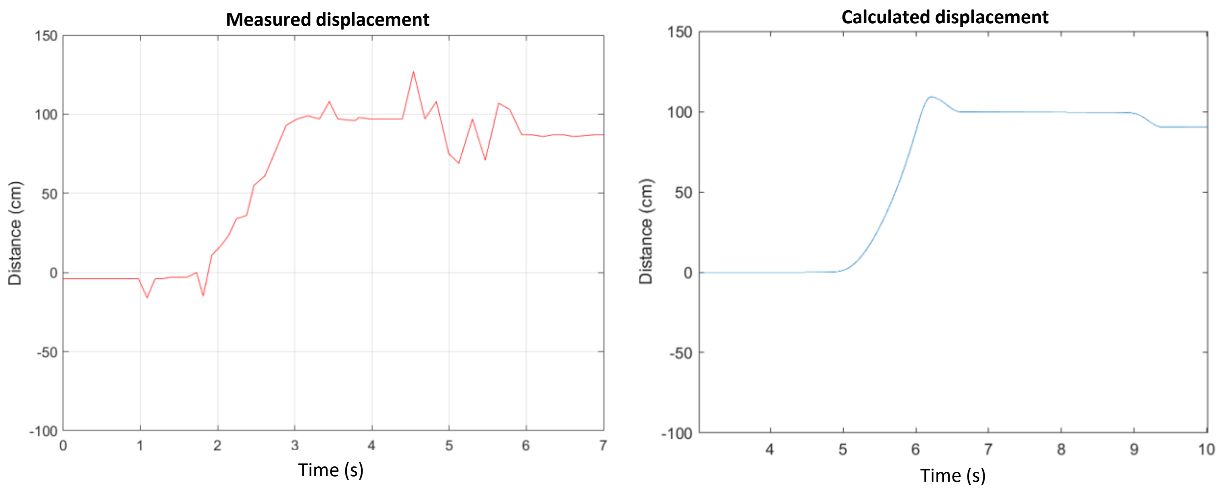

Figure 2. Measured and calculated displacement of the load under emergency braking

The figure 3 shows the result of the parametric study conducted for braking with a deceleration of -3 and -8 m/s². The results contribute for the optimization of lashing conditions to ensure being in the stability zone.

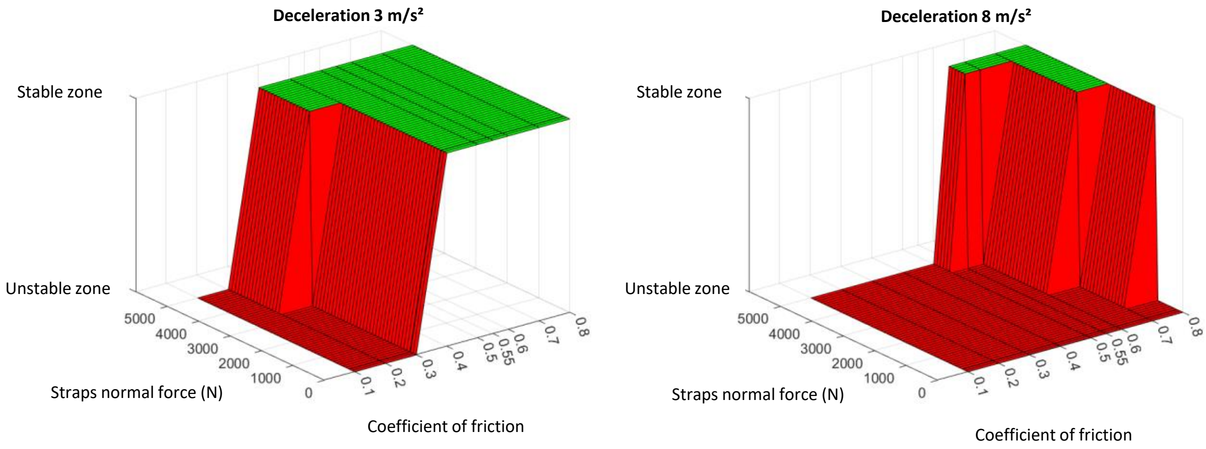

Figure 3: Stable and Unstable Zones as a function of Braking Deceleration, Strap Tension and Friction Coefficient

Discussion and conclusions

A numerical model has been developed to assess the stability of secured loads on heavy vehicles, aiming to simulate the impact of restraining quality on load stability. This model effectively replicates deteriorated restraining conditions, including variables such as low friction coefficients or inadequate tension in the straps. To enhance realism, the deceleration profile of a loaded truck during emergency braking was measured and integrated into the model. After model validation through experiments, a comprehensive parametric study was conducted, encompassing 2808 scenarios involving variations in braking, friction coefficient, and strap tension. The results obtained would contribute to facilitate the creation of a tool—such as an abacus—that aids hauliers in selecting optimal lashing conditions to ensure load stability during transportation. In perspective, further research will focus on studying load stability during curves to develop an appropriate model simulating the lateral stability.

References

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