



# Kingpin load measurement of a semi-trailer

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**Abstract.** This paper presents a sensor platform to measure the forces acting on a semi-trailer fifth wheel (kingpin). All parts of the measurement chain are taken from a commercially available wheel force transducer. Adapters to the semi-trailer and a replacement kingpin are designed and build as prototypes. Basic load assumptions are made to dimension the parts. The sensor platform is calibrated on a wheel force transducer test rig to ensure accuracy and stability against the attacking forces. During a measurement campaign with a semi-trailer typical maneuvers like acceleration, braking, lane change, rough road, etc. are measured. Time series data of the maneuvers and spectra of public road driving are shown. The outlook gives a view on how the measurement data are used to validate multi body simulation models of the semi-trailer. Using those models, different properties of the trailer are predicted like center of gravity position, rolling gear and tire characteristics. Furthermore, condition monitoring of trailer components is part of the modelling to prepare the trailer for autonomous driving applications.

**Keywords:** Semi-trailer, Kingpin, fifth-wheel, load measurement, model-adjustment, digital twin validation, multibody simulation

## 1 Introduction

Autonomous driving of tractor-semitrailers is one of the current topics in the commercial vehicle industry. Studies predict increasing automation of functions for the future of road freight transport, which will result in autonomous transport processes in the long term [1]. This will, in turn, lead to requirements for future commercial vehicles and their components that have not yet been considered: On the one hand, parameters and state variables related to vehicle dynamics, such as center of gravity position, rolling gear and tire characteristics must be known and considered for autonomous driving maneuvers (evasive maneuvers, braking distance prediction, etc.). On the other hand, safety- and function-relevant component conditions that are currently monitored by the driver as part of the departure check must be automatically acquired, evaluated, and made available to vehicle operators, workshops, and authorities in the future.

In contrast to tractors, however, little attention has been paid to trailers in the development of autonomous driving, even though they play a key role in determining the driving dynamics and reliability of tractor-semitrailer units. Their relevance will increase significantly with the advance of autonomous driving and the rising expectation of supply chain efficiency. The systematic, continuous, and ideally complete digital recording, evaluation and documentation of environmental conditions (road conditions) as well as information on driving and vehicle conditions (dynamics, service life, wear) of the trailer including highly stressed, safety-critical components (e.g., rolling gear components) is essential for the future autonomous operation of tractor-semitrailers.

The research project **IdenT** (*Identifikation dynamik- und sicherheitsrelevanter Trailerzustände für automatisiert fahrende Lastkraftwagen*), which is funded by the German Federal Ministry for Economic Affairs and Climate Action, focuses on the trailer, and develops innovative solutions in various areas. The aim of the project is to build and test an IdenT system consisting of an intelligent trailer sensor network, a cloud-based data platform and methods for on- and offline data processing. This involves sensor fusion via digital twins to determine the condition and parameters of trailer components relevant to driving dynamics and safety. The information obtained is made available to the tractor unit and thus supports autonomous driving.

Condition monitoring of a trailer might be performed by measured data only or by using specific data inside the system. Multi body simulation (MBS) tools are state of the art to perform numerical results, e.g., component loads. These loads are required to accumulate the damage or to evaluate the condition of a component.

Numerical system simulation typically requires measured input data either for model validation or for excitation input at the interface in case that a subsystem must be extracted from an entire system. For a stand-alone-semi-trailer-simulation without truck, the loads at the interface between truck and semi-trailer are important for the loading of the entire trailer in all degrees of freedom. Whereas accelerations (which are preferred to be measured because of the limited effort and costs) contain only the dynamic part of the signals but not the static and the very low frequency behaviour, the measured forces contain the complete frequency range from the static to the dynamic parts of the signal.

Within the corresponding research project, the semi-trailer model will be excited on the kingpin using estimated velocities. The measured kingpin loads are essential to evaluate the quality of the estimated trailer excitation on the kingpin and their validity depending on the variation of the driving manoeuvre, road condition as well as the trailer condition.

## 2 System Design

The kingpin or fifth-wheel coupling provides the link between a semi-trailer and the towing truck. **Fig. 1** shows a kingpin with acting loads. Since all loading between the truck and the trailer are transferred through the pin a knowledge of this loading is relevant for different tasks like

- tuning of the brake balance between truck and trailer,