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Design of Kinematic Coupling of the Rear Wheels of a Road Trailer

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Abstract
This paper discusses the design of the kinematic coupling for the passage of an articulated vehicle combination through a bend. A lorry (tractor unit) and a semi-trailer as a trailer are used as an articulated vehicle combination. In the standard design of an articulated vehicle combination, the track of the wheels of the tractor unit wheels and the semi-trailer differs when passing through a bend. As a result, the track of the articulated vehicle combination (lane width) is increased when a bend is negotiated compared to when driving in a straight line. This situation restricts the handling of the vehicle in a limited space, such as city streets and lower-class roads. A mathematical relationship defining the steering angle of the steerable wheels on the axles of the semi-trailer is presented in the paper. The outcome is a set of kinematic equations indicating the partial steering angles of the steerable wheels of the semi-trailer, ensuring that these wheels copy the steering path of the tractor unit while simultaneously rolling smoothly on the road. The theoretical approach is also applied to a real interaction tractor unit and semi-trailer. The use of steerable wheels on a semi-trailer will significantly improve the handling of the entire articulated vehicle combination. A key benefit of this work is its relevance to autonomous vehicle control, where a smaller number of sensors monitoring the vehicle's surroundings—while maintaining a high degree of safety—is fully sufficient for a semi-trailer.

Keywords Driving · Steerable wheels · Semi-trailer · Ackermann equation

List of symbols

L_a	Wheelbase of the car, [m]
B_a	Front-axle track width, [m]
B_{a0}	Steering-axle track width, [m]
c	Distance between the steering axle and the tyre centre plane, [m]
$B_{a\,pneu}$	Tyre width, [m]
D_a	Distance between the coupling joint axle and the axis of the rear axle on the vehicle, [m]
L_p	Wheelbase, [m]
L_{p4}	The distance between the axis of the first axle of the semi-trailer and the axis of the coupling pin, [m]
B_p	Width of the semi-trailer axle track, [m]
B_{ppneu}	Semi-trailer axle tyre width, [m]
R	Theoretical turning, [m]
D_1	Outer turning circle diameter, [m]
D_2	Inner turning circle, [m]
α,β	Angle of steering of the outer and inner wheels [°]

1 Introduction

The current trend in the development of road vehicles is focussed not only on improving electric propulsion, but also on optimising the movement of two-track road vehicles on roadways (Haghani et al., 2024; Liang et al., 2023; Ye et al., 2023). The main goal of this optimization is to enhance road safety while also increasing comfort. From a safety perspective, a key objective is to achieve the European Union's goals, such as the "Vision Zero" initiative—zero fatalities in road transport (Mofolasayo et al., 2024; Lopoo et al., 2024). That is why intensive work is being carried out on developing autonomous driving for road vehicles (Kanbur et al., 2023; Padmaja et al., 2023). Today, the vehicles with varying levels of autonomous driving can already be found on the roads. For autonomous

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