Fig. 1: Peraves AG Monotracer

Modeling, Simulation and Dynamic Analyses of a Closed Single-Track Vehicle

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The need for mobility and transportation are becoming increasingly important. More energy-efficient transportation options — including electric vehicles — are being developed to meet the performance demands of today's clients. The Monotracer is a comfortable single-track electric vehicle protected from weather and accidents by a closed cabin.

This study focuses on the Monotracer. It will illustrate the fundamentals of driving dynamics for this single-track vehicle, and reproduce them in a simulated model. At a later stage in the project, the pendulum and oscillating behavior of the Monotracer at low speeds will be analyzed.

BACKGROUND AND KEY PROJECT CHALLENGES

At its current stage of development, the Monotracer exhibits oscillating motions at low speeds on straight roads. The driver can feel these vibrations, particularly through the handlebars. The strength of the vibration depends on the vehicle's speed; the slower the Monotracer goes, the greater the amplitude of the pendulum motions. The strongest oscillations occur between 30 km/h and 50 km/h. At 60 km/h, the Monotracer stabilizes itself and drives straight without oscillating behavior. Such oscillations are observed in typical motorcycles only at very high (> 250 km/h) or very low speeds (< 12 km/h).

"...a simulation-capable model of the Monotracer was created and validated."

GOALS AND OBJECTIVES

In cooperation with the FHNW University of Applied Sciences and Arts Northwestern Switzerland, a simulation-capable model of the Monotracer was created and validated. Vehicle parameters were also important, and had to be defined accordingly. Performance tests were also necessary to define the model. With these, the driving dynamics simulations of the program could be optimized and adapted to the program. Through such processes, the influence of geometry on driving be-

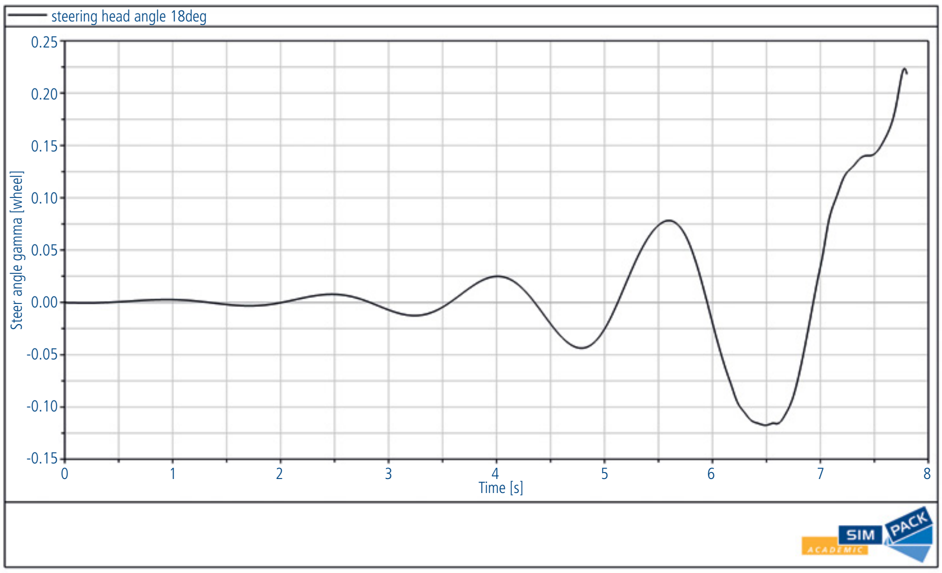

Fig. 2: Steering behavior of the Monotracer on a straight road with released handlebar; test speed 40 km/h

havior could be examined. At the end of the project, a functionally compatible model of the Peraves AG Monotracer MTE-150 was created, with which the driving behavior of a given driving situation could be simulated. This main goal was broken down into parts: Monotracer stabilization, modeling, and driving dynamics tests of oscillation.

PHYSICAL STABILIZATION THEORY OF A SINGLE-TRACK VEHICLE

Vehicle stabilization is an important component of the dynamic pendulum motion testing on the Monotracer. The basic stabilizing moments of a motorcycle are the result of the centrifugal forces of the spinning wheels. All stabilizing moments can be derived from these forces. The centrifugal force results from the inertia and rotational speed of the rotating wheel. In accordance with stabilization theory, a motorcycle moves straight as long as the moments generated through structural measures do not exceed the stabilizing gyroscopic moment.

MONOTRACER MODEL

The model for the project was very simple. It was created with the additional SIMPACK licenses Automotive and Delft MF-Tyre/MF-Swift 6.1.2. The model consists of a chassis similar to a CAD drawing of the original Monotracer, the handlebars which have the form of the original CAD drawing, and the front and rear tires (Fig. 3). The corresponding Force Elements have also been included. Two wheel dampers were created in the model. The wheels also included wheel/ground contacts. For the validation, different lateral impacts and steering angles were simulated.

General parameters are defined as part of the modeling process. Among the most important parameters are mass and the inertia of various components. Videos from test drives were analyzed to determine the vehicles movement on a straight road. By the end, a model was created that expresses the driving dynamics characteristics of the examined motorcycle.

“..., measure to suppress the pendulum vibration could be found.”

DYNAMIC TESTS WITH THE MODEL

Dynamic tests are an important aspect of this project. The questions of where the pendulum oscillations at low speeds come from, or how they can be reduced, can now be studied through various theses and experiments performed on the model. The dynamics of a motorcycle are determined by the overall structure: from the entire system’s geometry, inertia and wheels. Therefore, the oscillations could be originating from a number of places, and it is unlikely that the properties of each individual piece could be understood and physically accounted for. For these reasons, a simple model was

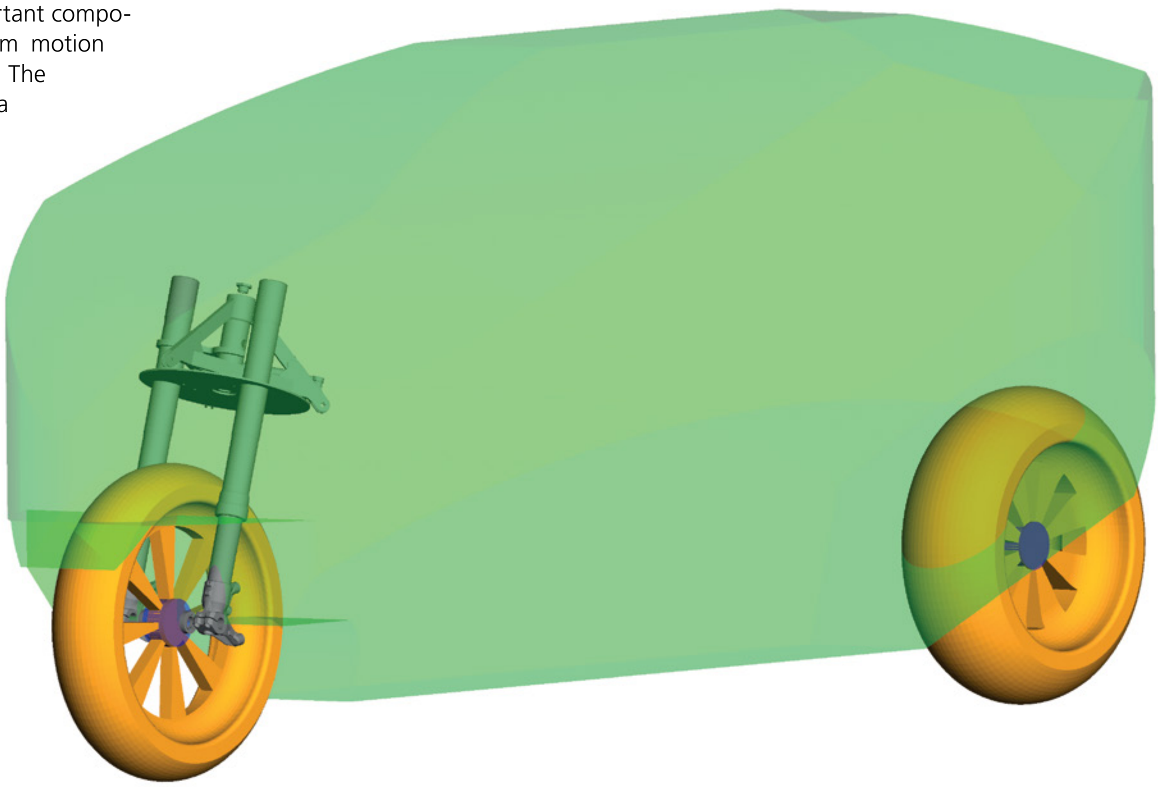

Fig. 3: Monotracer model in SIMPACK

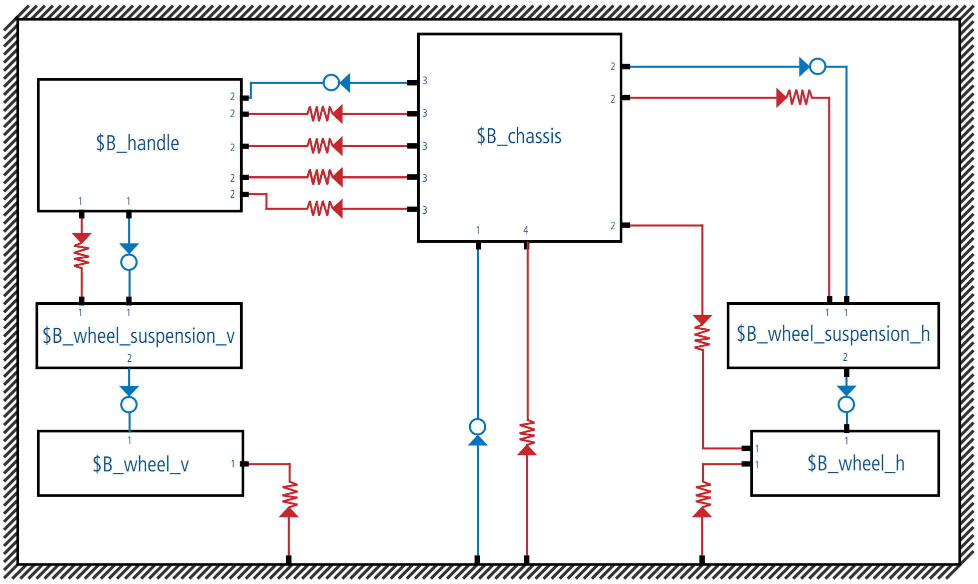

Fig. 4: 2D-view of the model

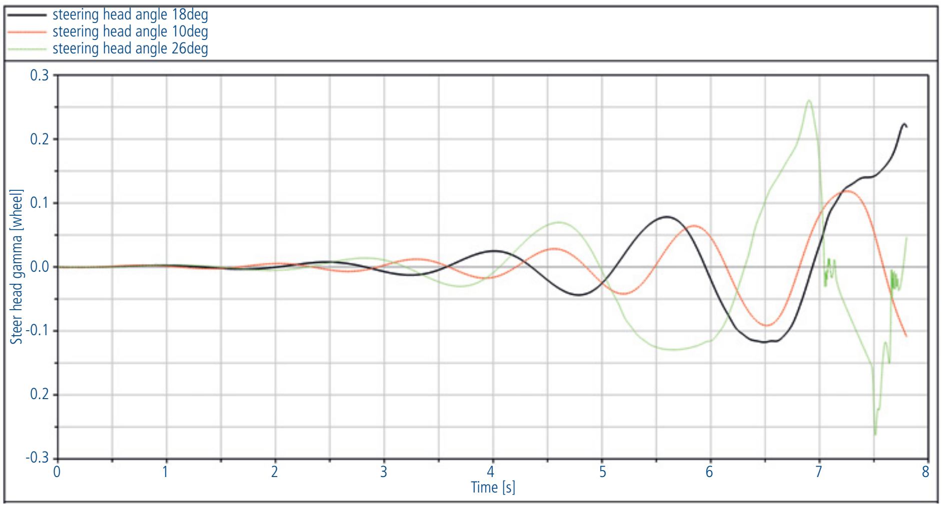

Fig. 5: Influence of the head angle on vibration

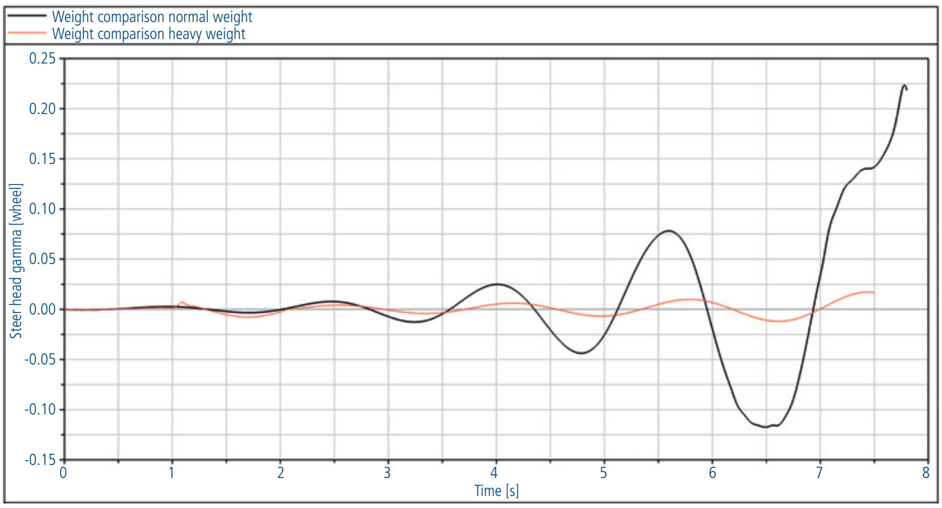

Fig. 6: Influence of the total weight on oscillation; the red curve shows the relationship with half of the original mass

created that limited itself on account of the stabilization theory of the steering system and its components.
The first experiment studied the influence of the pendulum by changing the steering geometry. With the movements of the head angle, the running of the tires and the entire steering system changed. The studies have shown that by reducing the head angle, pendulum oscillations become smaller, but cannot be eliminated altogether. The origin of the pendulum oscillations that exist at low speeds could not be determined by this investigation. Fig. 5 shows the vibration behavior of various head angles.
The second experiment regards the mass distribution of the entire motorcycle. The pendulum oscillations of the Monotracer are, like the centrifugal forces of the individual wheels, dependent on speed. These parallels were studied. The centrifugal force of a wheel is defined at a constant speed, and the motorcycle must be stabilized with this force. If the vehicle is too heavy or the force is too small, the motorcycle will not be entirely stable (Fig. 6). This hypothesis was proved by two studies. For one, the inertia of the wheel was increased; for the other, the total system mass was reduced. Both tests had an eliminating effect on the Monotracer's pendulum oscillations.

RESULTS

All objectives for the project were met. The resulting model can be used for dynamic studies and corresponds to the original Monotracer. As a result of the studies conducted on the model, measures to suppress the pendulum vibration could be found. The increase in wheel inertia is one of the most important measures. Its impact on driving safety must be taken into account, as does the decrease in overall mass, which can be taken into consideration for further developments. In this way, the study demonstrated solutions for improving the dynamic behavior of the Monotracer.

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