# Feasibility of Transferring Variant Input Loads for the Semi-Analytical Multi-Body Simulation of Bicycles

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# Feasibility of transferring variant input loads for the semi-analytical multi-body simulation of bicycles

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## Abstract

The utilization of multibody simulation in the design and dimensioning of bicycles has great potential in increasing safety against component failure and enabling lightweight and cost-efficient design. This is especially true when considering that test standards only provide a minimum level of safety and are not able to represent the stresses and strains of real-world operations [6]. Without accurate results from multibody simulations, the connection between real driving loads and the determination of operating loads on individual components is missing [2]. The latter is for example mandatory for performing accurate stress investigations using finte-element analyses [4]. Although these methods are widely used and well-researched in other fields of vehicle development, they are rarely used in the bicycle industry. One of the main reasons for this are unsolved challenges in the integration of the diverse driving tracks and the driver impact into the simulation in a way that the complex human behavior and track conditions especially in demanding driving situations can be represented accurately. A promising approach to overcome these challenges is to use a semianalytical simulation approach (SAA). Instead of full analytical models, measured input loads are used to excite the system at connection points between the structure and the environment [8, 5]. In this way, the influences of the human, tire, or track are represented in these input loads with their full complexity without modeling simplifications. In [1] it was shown, that it is possible to estimate accurate frame loads by exciting a bicycle system only with measured forces at hubs, handlebar, seat and pedal bearing.

Although it is possible to simulate accurate loads in the system, the measured input loads are in principle variant as they depend on the specific bicycle system that is used in the measuring drives. In contrast to the invariant full-analytical simulation approach, in which the structure can be exchanged in a numerically modeled environment, the question arises to what extent measured input loads can be transferred to other bicycle structures. To this end, this paper presents a comparison of the occurring fatigue damage on bicycle frames using measurements from the investigated bicycle struture and alternate bicycle loads. The subjects of the research are two full-suspension mountain bike models with different frame kinematics and component dimensions. Full analytical measurement drives were used to generate synthetic input load sets for both bicycles frames 1 and 2, shown in Fig. 1, left.

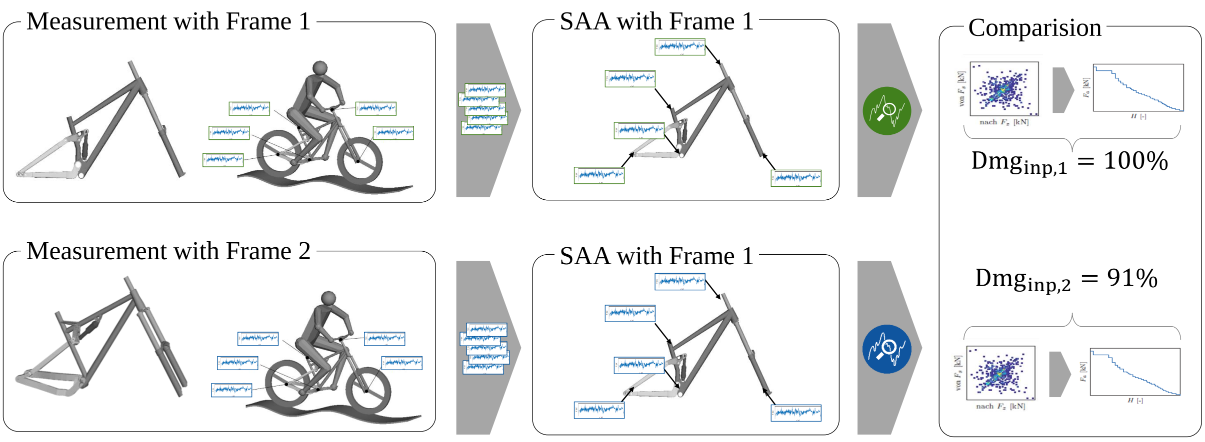


Figure 1: Comparison of accumulated damage from using semianalytical Simulations that are excited with measurement data conducted with the same bicycle structure (measured with Frame 1 applied to Frame 1, top) and a alternate bicycle structure (measured with Frame 2 applied to Frame 1, bottom)

The simulations are performed with a passive rider model connected to the bicycle model via handlebars, seat, and pedals. Position and speed-dependent properties of the legs and arms are represented by force elements [3]. The wheel-track contact is simulated via a one-sided constraint with spring and damper properties in the contact point. Besides the different bicycle structures, environmental properties such as tires, tracks, and drivers are equal for both simulations.

Based on the measurement runs, Frame 1 is excitated with both measured load sets in a semianalytical multibody simulation, see Fig. 1 middle. In conjunction with the evaluation of force-time informations, further investigations are conducted to compare the resulting fatigue damage of both load inputs on Frame 1. Using rainflowcounting to determine load collectives in combination with damage accumulation according to the established Palmgren-Miner methods, a total damage value can be calculated, see Fig. 1 right [7]. With the objective of an accurate determination of the resulting fatigue damage, the total damage value provides conclusions about the similarity between the usage of input data sets of measuring runs resulting from original or alternate frames. This makes it possible to assess the feasibility of transferring input loads from measurements conducted, for example, with a standard measuring bicycle to the design process of a new or modified frame structure.

The investigations have shown that, despite deviations in the force-time curves, very good agreements in the component damage could be found between input loads generated with the original frame as well as a alternate frame. Conclusively, measured loads can be used to some degree as inputloads for a semi-analytical multibody simulation, even in the presence of changes in the frame kinematic or component dimensions.

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