# Multibody Elastic Simulation of a Go-Kart in Project-Based Education: Correlation Between Frame Stiffness and Dynamic Performance

Krisztián Horváth, Ambrus Zelei

Department of Whole Vehicle Engineering, Audi Hungaria Faculty
of Automotive Engineering, Széchenyi István University,
Egyetem tér 1, 9026, Győr, Hungary
horvath.krisztian@ga.sze.hu, zelei.ambrus.miklos@ga.sze.hu

**EXTENDED ABSTRACT**

## 1 Introduction

Project-based learning and the classical frontal teaching are usually considered as opposing concepts. However, project-based learning are more and more favorized also in multibody dynamics [1-5]. A new education form in the Széchenyi University (Győr, Hungary) for BSc Vehicle Engineer students allows us to combine the two approaches: in parallel to the frontal teaching of the fundamental knowledge, such as math and mechanics, most of the technical skills are gained through student projects. One of these projects is based on the simulation and measurement a go-kart.

In order to meet the philosophy of simplicity, the race go-karts cannot be equipped with suspension or differential. Therefore, the flexible properties of the frame, the absence of suspension elements, and the global dynamic behavior are primarily influenced by the geometry and stiffness of the frame, the steering system, and the characteristics of the tires [6-8]. Therefore, in this specific vehicle type, the flexible properties of the frame structure play an important role in the dynamic behavior of the go-kart. The stiffness of the vehicle frame affects the vehicle dynamics, e.g. wheel hopping. The lack of a differential can be compensated by lifting the rear inner wheel in a turn, and this way, slipping of the tires can be avoided. These phenomena are studied by the students by using a combined flexible–rigid model under ADAMS and measurements on real vehicles. The students gain valuable insights into mechanics of complex structures, numerical modeling techniques and in vehicle dynamics optimization.

## 2 The racing go-kart model

The project focuses on the construction and simulation analysis of a multibody dynamic model of a race go-kart, examining the effect of torsional stiffness of the frame on the vehicle dynamic properties. Each component in the model is rigid, except the frame and the tires. The simulations incorporate Finite Element Method (FEM) analysis and multibody techniques for evaluating the dynamic behavior of a race go-kart. The specific go-kart in our focus is used by a race team in cooperation with our university.

The first step of model creation is to conduct a numerical investigation of the go-kart frame and determine the main configuration parameters that influence torsional stiffness and therefore the driving dynamics. The most important configuration parameters are the material and lengths of the axles, the type of the torsion bar, the bumpers, the floor plate and even the properties of the seat. A numerical FEM model is created and then validated using specific experimental analyses, mainly by experimental modal analysis. During the validation process, the eigenfrequencies determined by the FEM model and the measurements are matched.

Parallelly to the FEM analysis of the frame, the rigid body model and the tire model are built up in MSC Adams View, since the model of the available go-kart is not provided in the Adams Car template library. The frame geometry is imported from a CAD file created based on the manufacturer’s homologation specification. For the study of the flexible behavior of the frame, the eigenmodes are transferred from the FEM analysis to the MSC Adams, via modal neutral files (MNF). The resulting model is capable of maneuver simulations, for which the road is built manually, and the driver actions are modeled in a custom way. The validated model is used as a virtual testing tool for evaluating the dynamic behavior of different configurations of race go-karts.

## 3 Subtasks for the students

The whole model development is indeed a complex task, even for an experienced engineer. Consequently, properly chosen subtasks can only be assigned to the groups of BSc students. Furthermore, go-karts and go-kart multibody models are continuously evolving due to the pressure on the competitive race teams. The implementation of these additional features in the model will always serve as a possible project task for our BSc students. Our first attempt to organize a project-based multibody course is planned for May 2023 with the following variety of subtasks:

**FEM and modal analysis of the frame**: The FEM model is validated using the results of experimental modal analysis on the physical model at different settings (axles lengths, torsion bar type, bumper settings, floor plate, properties of the seat). The dynamic response of the frame is evaluated using a modal hammer impact test and the results of this analysis are compared with the results of ANSYS 2022/R2 Workbench model modal analysis. Five to ten mode shapes are obtained additionally to the six rigid body modes.

**FEM model enhancement**: The material properties of the actual go-kart frames are assessed by experimental methods and the result are input in the FEM model instead of the nominal material properties. Not only the stiffness, but the damping parameters are important too. As another possibility for model enhancement is related to the geometric inaccuracies within specified tolerances coming from the manufacturing process of the frame. The study of the effect of geometric deviations from the nominal values is a potential student project. 3D scanning of the actual frames would be possible.

**FEM and multibody model integration and testing:** The latest flexible frame model is integrated in the multibody environment and is tested with different settings via dynamic simulations. The students also decide which modes of the frame are important. The students investigate which eigenmodes are important regarding the vehicle dynamics.

**Tire model**: The modeling of tire forces is always a big challenge even in the industry. Currently the Pacejka-model is used. A new iteration step in the enhancement of the tire modeling is a continuously available student task.

**Steering kinematics and driver actions**: The enhancement of the steering mechanism by modifying its geometry is a further option for improving the performance. Additionally, the modeling of the existing steering mechanisms can be done by students: the elastic properties of the properly chosen components can be handled by a similar methodology as the flexibility of the frame.

**Additional components and multibody model enhancement**: The current model does not contain every important component of the go-kart. The integration of the each component is a separate student task. These components are the bumpers, the torsion bar, the seat, the drivetrain and the brake system. The engine and the driver are currently represented by point masses. The mass moment of inertia parameters and the flexibility of the driver's body (possibly further degrees-of-freedom) can be included in the model by the students. The center of gravity (CoG) of the go-kart is measured experimentally and applied in the model.

**CoG of the driver's body**: The driver's CoG is continuously moving depending on the maneuvers and the acceleration effects. The drivers can actively and consciously affect their CoG position in order to reach better driving dynamics. The students come up with an idea for the modeling and they implement their concept in the multibody model.

**Model validation, parameter sensitivity analysis**: The students change the setting of a selected parameter both in the model and in the real vehicle. The effect of the parameter change is compared for the simulations and the physical experiment on the race-track. They inspect if the driving dynamic changes in similar way in the model and in the reality. This test can be repeated for a variety of maneuvers (such as cornering, acceleration and deceleration) and track configurations. Ultimately, lap time simulations can be done. This task incorporates the application of inertial measurement sensors (IMU) and GPS tracking.

## 4 Conclusions

The multibody modeling of go-karts and the extension of the models with flexible components has been a current trend. Using numerical simulations in vehicle dynamics reduces the cost of physical testing. Although, large set of literature results is available, the models and the go-karts are continuously evolving. New and new features are integrated into the go-kart vehicles. This sets up always new engineering challenges, especially in the modeling and in the optimization of driving dynamics. Since this topic will always have open questions, it is perfect for establishing student projects in university education. The plan for the project-based course is ready at the time when the present abstract is submitted. The outcome of the actual testing of our teaching ideas will be reported in the Eccomas Multibody Dynamics conference and possibly in further papers.


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