

# Multi-Body Simulation and Multi-Objective Optimization Applied to Vehicle Dynamics

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Received 13 April 2009, Accepted 14 August 2009

**Abstract** – This paper describes a demo application, where modeFRONTIER, a commercial software for design optimization, is coupled with a parametric 2D Multi-Body model of a touring motorcycle. The optimizer is asked to identify the characteristics of the front suspension (telelever scheme) that deliver more safety, more stability, and more riding comfort for a braking maneuver in straight running. All objectives are described through 4 scalar indexes, extracted from the braking kinematics.

As expected, results highlight that trade-off relationships connect the objectives. Only 13, among the 1900 tested configurations, are able to simultaneously improve the 4 indexes. Moreover, no design in this selection assures a decisive improvement of the stability. In order to accomplish this priority requirement, the best design is chosen accepting a slight reduction of stability.

**Key words:** Motorcycle Optimization, Braking Maneuver, Telelever, Multi-Objective Optimization, Design Optimization

## 1 Introduction

Dynamical performances of two wheeled vehicles largely depend on the response of each component. Among all components, tires and suspensions are the most important sub-systems, because their role is to modulate any force going from the road to the chassis [1, 2, 3, 4]. Therefore, a deep knowledge of such parts can be the turning key to develop better and safer motorcycles.

Multi-Body Simulation is the most suitable approach to perform vehicle dynamics investigation [5, 6, 7]. By creating parametric models, different configurations can be quickly evaluated, even at the earliest stage of the entire development process. From a business perspective, this means that wrong gateways can be dropped long before they lead to costly and useless real prototypes.

These benefits can be further increased by coupling the Multi-Body Simulation software with modeFRONTIER, which automatically plans and drives sets of simulations in order to perform complex tasks such as Design of Experiment, Parameter Sensitivity Analysis, and Multi-Objective Optimization.

This paper describes a demo application, where modeFRONTIER is asked to identify the parameters of a motorcycle front suspension to deliver more safety, more stability, and more riding comfort for a braking maneuver in straight running. Although the research is targeted to a very specific case, the proposed methodology can be straightforwardly extended to any user-defined running condition. Potentially, it is possible to build a single modeFRONTIER project to optimize different vehicle parts for various maneuvers.

As expected, results highlight that trade-off relationships connect the objectives, hence full optimization is almost impossible. Only 13, among the 1900 tested configurations, are able to simultaneously improve the 4 scalar indexes that have been previously defined to measure the objectives.

Moreover, no design in this selection promises a decisive improvement of the stability. In order to meet these primary requirements, the best design is chosen accepting a slight reduction of stability. The decision task has been totally supported by the Multi Criteria Decision Making tool implemented in modeFRONTIER.

## 2 The 2D Motorcycle Model

The Motorcycle is a complex multi-body system and special efforts are necessary to reliably simulate the overall dynamics. The broad range of literature available on this topic covers all simulation fields, such as time domain behavior [6, 7], optimal maneuver [8, 9], steady trim [10], frequency response [11], modal properties [5, 14, 15], tire dynamics [12], and so on. Since this research aims at highlighting the benefits of implementing an optimizer into the simulation chain, a detailed and validated model is not available. Model features have been implemented following state-of-art guidelines [13] to ensure sufficient result reliability.

As a simple test case, the vehicle behavior at braking during straight line motion is considered. In general, lateral dynamics plays an important role and a detailed 3D model would be recommended to perform thorough investigation. However, a 2D model includes enough features to study the influence of the front suspension on the braking distance, keeping the simulation complexity at reasonable level. Indirect considerations on stability and vehicle comfort can be made in any event by examining the variation of some in-plane quantities [4, 14].

The motorcycle model used in this research consists of 7 rigid bodies, such as chassis (which includes the rider), rear wheel, swinging arm, front wheel and three bodies for the front suspension with telelever scheme. Bodies are connected using proper joints to obtain the exact number of in-plane degrees of freedom.

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## **Table of Contents Multi Body Simulation And Multi Objective Optimization**

1. Understanding the eBook Multi Body Simulation And Multi Objective Optimization
  - The Rise of Digital Reading Multi Body Simulation And Multi Objective Optimization
  - Advantages of eBooks Over Traditional Books
2. Identifying Multi Body Simulation And Multi Objective Optimization
  - Exploring Different Genres
  - Considering Fiction vs. Non-Fiction
  - Determining Your Reading Goals
3. Choosing the Right eBook Platform
  - Popular eBook Platforms
  - Features to Look for in an Multi Body Simulation And Multi Objective Optimization
  - User-Friendly Interface
4. Exploring eBook Recommendations from Multi Body Simulation And Multi Objective Optimization
  - Personalized Recommendations
  - Multi Body Simulation And Multi Objective Optimization User Reviews and Ratings
  - Multi Body Simulation And Multi Objective Optimization and Bestseller Lists
5. Accessing Multi Body Simulation And Multi Objective Optimization Free and Paid eBooks
  - Multi Body Simulation And Multi Objective Optimization Public Domain eBooks
  - Multi Body Simulation And Multi Objective Optimization eBook Subscription Services
  - Multi Body Simulation And Multi Objective Optimization Budget-Friendly Options

6. Navigating Multi Body Simulation And Multi Objective Optimization eBook Formats
  - ePub, PDF, MOBI, and More
  - Multi Body Simulation And Multi Objective Optimization Compatibility with Devices
  - Multi Body Simulation And Multi Objective Optimization Enhanced eBook Features
7. Enhancing Your Reading Experience
  - Adjustable Fonts and Text Sizes of Multi Body Simulation And Multi Objective Optimization
  - Highlighting and Note-Taking Multi Body Simulation And Multi Objective Optimization
  - Interactive Elements Multi Body Simulation And Multi Objective Optimization
8. Staying Engaged with Multi Body Simulation And Multi Objective Optimization
  - Joining Online Reading Communities
  - Participating in Virtual Book Clubs
  - Following Authors and Publishers Multi Body Simulation And Multi Objective Optimization
9. Balancing eBooks and Physical Books Multi Body Simulation And Multi Objective Optimization
  - Benefits of a Digital Library
  - Creating a Diverse Reading Collection Multi Body Simulation And Multi Objective Optimization
10. Overcoming Reading Challenges
  - Dealing with Digital Eye Strain
  - Minimizing Distractions
  - Managing Screen Time
11. Cultivating a Reading Routine Multi Body Simulation And Multi Objective Optimization
  - Setting Reading Goals Multi Body Simulation And Multi Objective Optimization
  - Carving Out Dedicated Reading Time
12. Sourcing Reliable Information of Multi Body Simulation And Multi Objective Optimization
  - Fact-Checking eBook Content of Multi Body Simulation And Multi Objective Optimization
  - Distinguishing Credible Sources
13. Promoting Lifelong Learning
  - Utilizing eBooks for Skill Development
  - Exploring Educational eBooks
14. Embracing eBook Trends
  - Integration of Multimedia Elements

- Interactive and Gamified eBooks

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