

The effect of suspensions and racetrack three-dimensionality on the minimum lap time of motorcycles

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ABSTRACT

The aim of this work is to analyse the effect of suspensions and racetrack three-dimensional features on the minimum-time performance of a full dynamic multibody model of a sports motorcycle. The optimal-control minimum-lap-time problem is solved with indirect methods on both a two-dimensional and a three-dimensional track model, and the results are compared. The effects of suspensions is also analysed.

Keywords: motorcycle dynamics, minimum-time problem, 3D road modelling, optimal control, free-trajectory.

1 INTRODUCTION

The solution of optimal control problems (OCPs) for minimum-lap-time simulations have been applied to both two-wheeled and four-wheeled vehicles in the last decade [1]. Some examples of the application to race cars are [2, 3, 4], while in [5, 6] the optimal control of motorcycles is discussed. All of these works assume the track to be flat. This hypothesis constitutes in many cases a strong approximation of the real track geometry, and neglecting the three-dimensional (3D) features of the road can lead to inaccurate results. In [7, 8, 9] a 3D track model is used in the minimum-time optimal-control simulation of race cars. The literature dealing with the optimal control of a motorcycle riding on a 3D circuit only employs simplified motorcycle models [1, 10, 11].

In this work the effect of racetrack three-dimensionality on the lap time of motorcycles is investigated for a full motorcycle model. There are three main effects related to road three-dimensionality.

1. The slope of the track induces a non-zero component of the gravity acceleration along the longitudinal axis of the vehicle, which sums with the accelerations related to the longitudinal controls of the vehicle (throttle and brakes). The related effect on the speed profile can be sensible.
2. The rate of change of the slope affects the tyre loads, e.g. when going over the brow of a hill the vehicle appears ‘lighter’. Also in this case the effect on the acceleration and braking performance can be sensible.
3. The road banking angle has a strong effect on the cornering performance of the vehicle. Indeed, for a given lateral acceleration, a part of the centripetal force necessary to drive through the turn is generated from the tyre normal load, with a corresponding reduction in the required tyre lateral (tangential to the road) force. In addition, the increase in the tyre