

Literature Review of Current Motorcycle Dynamic Studies

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Abstract

A brief literature review of motorcycle dynamics was carried out considering publications made within the last two years. It is seen that the main focuses of this topic are stability and optimal manoeuvre simulation. Methods of simulation of motorcycles at low and high speed have been proven independently whilst understanding of stability is still ongoing, with studies on frequency and vibrations producing valuable knowledge useful to this.

Keywords: Motorcycle, Two wheeled vehicle, stability, dynamics, weave, multibody systems, racing, Centre of Gravity, Review

Introduction

Motorcycle dynamics is a complex subject that can be considered to be in its infancy. This is made evident by the amount of works produced on each subject, with 5.2million ‘vehicle dynamics’ search results [1] compared to only 100,000 ‘motorcycle dynamics’ results [2] returned from an all-time google scholar search [3]. Whilst traditional vehicle dynamics is a largely researched area, the theories developed here can not be directly correlated motorcycles due to the complex nature of two-wheel vehicle behaviour. A significant contributing factor to this is the particular instability of motorcycles at slow speed which can be evaluated using the bicycle stability model [4]. This complexity leads to many studies being undertaken with generalised conditions and assumptions to simplify models [5]. This review will cover papers directly focusing on the dynamics of motorcycle behaviour with a goal to summarise current research topics and suggest potential avenues for future research. Only open access papers available on google scholar published from 2021 onwards are considered for review, however previous works may be referenced if current work is dependant on information presented in earlier publications. When reviewing the literature of motorcycle dynamic studies

multibody systems are referenced extensively. Multibody systems can be simplified to mean a group of bodies, rigid or deformable, restrained by kinematic joints influenced by external forces[6].

Justification for research investment

Safety

Upon unfiltered searches of motorcycle dynamics and motorcycle behaviour, crashing, risk, and subsequent rider injury is a clear dominant area of study. Further filtering reveals that a minimal amount of these papers is supported by the motorcycle dynamics. However, with motorcycle crashes providing a close 800% increased chance of fatality than that of a car driver [7], resulting in 23% of all deaths due to road traffic incidents [8], there is clear motivation for studies in this area. [9,10] take rider safety into consideration when discussing motorcycle stability control regarding weave and wobble, and mass and vibrations respectively.

Road and Track Performance

It is important to note the intended outcome from each study varies greatly depending on the motorcycle's application. Non-performance motorcycle studies must incorporate a wide range of variables to allow for generalised use. This is understood in [11] where off-road motorcycle suspension systems are optimised to account for comfort during recreation, commuting and racing. Motorcycles developed for racing can be studied under more specific conditions, as the only intended outcome is to decrease lap times. Dynamic theories such as chatter can be studied in detail using real world data, competition feedback, as well as simulation methods [12] as previously discussed. Another important aspect of racing is understanding optimal rider control inputs and

vehicle manoeuvres. This avenue of research builds on the understanding of dynamic fundamentals and how these characteristics can be manipulated. Bobbo et al [13] first published work concluding with ‘Optimal Manoeuvre’ and ‘Ideal Rider’ theories in 2008.

Recent Studies

2021

Stability in terms of weave and wobble of motorcycles is a well understood concept. Bova and Massaro investigated this using a screw axis approach rather than a traditional compass diagram approach to analyse vehicle vibration in correspondence to different planes [14]. The results from this publication present a new way to accurately predict control methods and the consequences of over and understeer. This work however displays results which vary greatly depending on the choice of reference plane and are affected by individual bike and rider geometry therefore highlighting a suggested method with non-uniform results across cases.

Further study into a rider’s position’s affect on motorcycle geometry was undertaken by Carputo et al. The work presents a novel approach to analysing rider behaviour and supports the theory of rider and bike being treated as a single multibody system. This approach to understanding the complete system could be viable for improvement in complete motorcycle simulation by providing live centre of gravity data via image processing algorithms[15].

The effect of rider position and rider to bike mass ratio is reiterated in the vibration analysis method presented by Dębowski. This approach splits a single multibody system into many smaller systems to simplify the calculations. This method suggests that the geometric setup of the machine paired with rider inputs make a greater

difference to resonant frequency of the steering system than typical operating factors[10].

Grottoli investigates low speed instability using simulation of lateral and longitudinal manoeuvres of a motorcycle, focusing on the bicycle model range of operation via motion cueing algorithms. The work of this study resulted in a complete low speed simulator for position and acceleration prediction of a motorcycle with data validated against real world measurements[4].

2022

Lovato and Massaro published two papers covering minimum lap time optimal control methods for race vehicles using three-dimensional fixed and free trajectory models [16,17]. Before this work, models were constrained to two-dimensional environments for free-trajectory projections or three-dimensional environments with fixed trajectory. This work successfully developed a model which can accurately reproduce racing data without relying on inputted variables to be accurate.

Flexible multibody systems are complex as the definition of rigid or deformative bodies complicates flexibility characteristics. However, an accurate model can aid predictions of model frequencies, and as is discussed in other papers, this can aid in improving stability. Bonisoli et al. proved a method to accurately detect critical mode-shapes within a flexible multibody system, proving the results through analysis of a motorcycle frame. The benefit of the method proposed is a great reduction in computational time needed to recover results, suggesting that design processes of components which negatively effect motorcycle vibration can be significantly improved[18].

Summary of Current Works

After reviewing current literature, it can be said that the range of study in motorcycle dynamics is vast, but great interest is shown in understanding and compensating for the effects of high frequencies found within motorcycle models due to their clear negative impact. Researchers from University of Padova are producing work frequently which accounts for a significant proportion of new knowledge published. Whilst there are many different approaches to creating models appropriate to understand individual theories, it is not yet clear that a model exists that can exhaustively express the behaviour of a motorcycle in motion.

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