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An Accurate Method of Measuring a Bicycle's Physical Parameters
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Abstract

Accurate measurments of a bicycle's physical parameters are required for realistic dynamic simulations. For the most basic models the geometry, mass, mass location and mass distributions must be measured. More complex models require measurements of tire characteristics, stiffness, damping, etc. This paper concerns itself with the measurement of bicycle parameters required for simulations of the benchmark bicycle presented in [4]. This bicycle model is made of four rigid bodies, has ideal rolling, frictionless joints, and is assumed to be symmetric about the frame center plane. A set of 25 physical parameters are used to describe the geometry, mass, mass location and mass distribution of each of the rigid bodies. These parameters are presented relative to a reference frame when the bicycle is in the nominal upright configuration. The methods described herein are based primarily off of the work done in [2] but have been refined for improved accuracy and methodology. [5] measured an experimental bicycle frame in a similar fashion and both [1] and [6] have used similar techniques with scooters. We measure the characteristics of six different bicycles, two of which are setup in two different configurations, for a total of eight different parameter sets that can be used with, but not limited, to the benchmark bicycle model. The parameters set is also complete for non-linear benchmark bicycle model.

The bicycles were chosen for both variety and convience. The six bicycles are as follows:

Batavus Browser A Dutch style city bicycle. The bicycle was measured in two configurations. One with the instrumentation described in [3] and one as from the manufacturer.

Batavus Stratos Deluxe A Dutch style city bicycle

Batavus Crescendo Deluxe A Dutch style city bicycle

Gary Fisher Mountain Bike A hardtail mountain bicycle

Bianchi Pista A modern steel frame track racing bicycle

Yellow Bicycle A stripped down aluminum frame road bicycle. This bike was measured in two configurations, the second being the fork was rotated in the headtube 180 degrees for larger trail.

Geometry

The benchmark bicycle needs five basic geometric measurements: the wheelbase w, steer axis tilt λ, trail c, and the wheel radii r_{F} and r_{R}. The wheelbase and steer axis tilt were measured directly with a scale and a digital level, respectively. The trail and wheel radii were measured indirectly by fork offset and loaded wheel circumference.

Mass

The mass of each of the rigid bodies were measured with a precision scale.

Mass location

The center's of mass of each of the rigid bodies were measured by hanging the rigid bodies through their centers of mass and assuming symmetry. The orientation angle of the headtube angle and the point of suspension were measured and the center's of mass of the frame and fork were calculated from these values. The wheel centers of mass were assumed to be in their ideal geometric center.

Mass Distribution

The moment's of inertia of the rigid bodies were measured with both a torsional pendulum and a compound pendulum. Once again the assumed symmetry of the bicycle was utlized to reduce the amount of measurements needed. The in-symmetric-plane moments of inertia were calculated from measurements of the rigid bodies period of oscillation when hung from a torsional pendulum at different orienatation angles. The out of plane moments of inertia were measured by swinging the rigid bodies as a compound pendulum.

Results

Parameter sets for all six bicycles (and all eight configurations) 1 will be presented, along with basic comparisons of the open loop dynamics of the different types of bicycles. By examining the mass, damping and stiffness matrices of the system and the eigenvalues at different speeds anedoctal descriptions of handling are compared to the dynamics.

References

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Table 1. COMBINED BICYCLE AND RIDER PARAMETER VALUES FOR THE BATAVUS BROWSER.

Parameter	Symbol	Value
wheel base	w	1.121 m
trail	c	0.069 m
steer axis tilt	λ	0.400 rad
gravity	g	9.81 N kg^{-1}
forward speed	v	various m s^{-1}
R*ear wheel R*		
radius	r_R	0.341 m
mass	m_R	3.11 kg
mass moments of inertia	$(I_{\mathrm{R}xx},\ I_{\mathrm{R}yy})$	(0.088, 0.152) kg m^2
rear **B***ody and frame B*		
position center of mass	$(x_\mathrm{B},\ z_\mathrm{B})$	(0.276, −0.538) m
mass	m_B	9.86 kg
mass moments of inertia	$\begin{bmatrix} I_{\mathrm{B}xx} & 0 & I_{\mathrm{B}xz} \\ 0 & I_{\mathrm{B}yy} & 0 \\ I_{\mathrm{B}xz} & 0 & I_{\mathrm{B}zz} \end{bmatrix}$	$\begin{bmatrix} 0.527 & 0 & -0.114 \\ 0 & 1.317 & 0 \\ -0.114 & 0 & 0.759 \end{bmatrix}$ kg m^2
front **H***andlebar and fork assembly H*		
position center of mass	$(x_\mathrm{H},\ z_\mathrm{H})$	(0.867, −0.748) m
mass	m_H	3.22 kg
mass moments of inertia	$\begin{bmatrix} I_{\mathrm{H}xx} & 0 & I_{\mathrm{H}xz} \\ 0 & I_{\mathrm{H}yy} & 0 \\ I_{\mathrm{H}xz} & 0 & I_{\mathrm{H}zz} \end{bmatrix}$	$\begin{bmatrix} 0.253 & 0 & -0.072 \\ 0 & 0.246 & 0 \\ -0.072 & 0 & 0.096 \end{bmatrix}$ kg m^2
F*ront wheel F*		
radius	r_F	0.344 m
mass	m_F	2.02 kg
mass moments of inertia	$(I_{\mathrm{F}xx},\ I_{\mathrm{F}yy})$	(0.090, 0.149) kg m^2

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