An das
Bundesministerium für Verkehr,
Innovation und Technologie
Abteilung IV/ST2 (Rechtsbereich Straßenverkehr)

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Wien, 09.09.2018

Stellungnahme zur 30. StVO-Novelle (69/ME)

Sehr geehrte Damen und Herren,
Ich danke für die Möglichkeit zur 30. StVO-Novelle (69/ME) Stellung nehmen zu können.

Zu § 2 Abs. 1 Z 7 in Kombination mit § 11 Abs. 5 kann ich vollkommen zustimmen - das Reißverschluss-System ist bewährt.

§ 2 Abs. 1 Z 12a: Grundsätzlich ist eine Klarstellung positiv zu sehen, allerdings ist die Vorgeschlagene Markierung eher überladen. Ich würde eher für durchgezogene schmale Linien plädieren, da es einen deutlicheren Unterscheidungseffekt gibt, bin aber sicher dass es andere gute Lösungen gibt. Da es im Fall einer Änderung sehr viel Nachzubessern gibt wäre in Kombination mit § 8 Abs 4a eine Übergangsfrist zu Strafen oder Inkrafttreten wünschenswert.

§ 19 Abs. 5 ist auch eine Klarstellung und zu Unterstützen

§ 19 Abs. 6a sollte bei gleicher Fahrtrichtung/relation auch mit dem Reißverschluss-System erfolgen, da getrennte Radwege meist wie ein Radstreifen zur Kreuzung geführt werden.

§ 38 5a und 5b ist zu unterstützen und sollte sogar noch erweitert werden! Dieselbe Möglichkeit sollte es für andere Fahrrelationen geben und mit weiterer Zusatztafel oder Info auf der Tafel auch nur für bestimmte Verkehrsteilnehmer möglich sein.

§ 54 5n (oder 5o) zusätzliche Information sollten verankert werden können.

§ 65 Abs 2: Die Senkung des Mindestalters ist in Ordnung, da unmündige Minderjährige in diesem Alter bereits vernünftig genug sind, selbst ohne Aufsicht fahren zu können. Die Verknüpfung mit dem Schulalter ist nicht ganz nachzuvollziehen, da die Schulstufe auch aus anderen Gründen (als einer "nicht-Eignung") nicht mit dem vorgesehenem Alter zusammenpassen muss.

§ 68 Abs. 1 wird nur noch komplexer. Da wäre eine Vereinfachung wünschenswert. Es hängt nicht nur von der Bauart ab, ob Radfahrer auf den Radweg oder die Straße gehören. Da sind viel mehr Faktoren im Spiel.

§ 88 Abs. 2 ist absolut wünschenswert. Allerdings ist es immer eine Gefährdung auf der Straße oder dem Gehweg.

§ 104 Abs. 13: für § 56a Abs. 1 sind keine Änderungen vorgesehen.

Zusätzliche Anregungen:

- Die Katgorisierung der Radfahranlage als Fahrbahn ist zu überlegen.

- Die maximale Annäherunggeschwindigkeit von 10 km/h an ungeregelte Radfahrerüberfahrten ist realitätsfern. Dabei sei auf folgende Studie über stabiles Fahrverhalten von Fahrräder verwiesen: Moore, Jason & Hubbard, Mont. (2008). Parametric Study of Bicycle Stability. 10.1007/978-2-287-09413-2_39. (https://www.researchgate.net/publication/216750969_Parametric_Study_of_Bicycle_Stability).

- § 39 Abs. 2: Lichtzeichenanalgen, deren Unterkante unterhalb von 2m abgebracht ist, sind derzeit ohne Zusatzsignal ungültig. Radfahrsignale sind dementsprechend in vielen Fällen ungültig. Da könnte nachgebessert werden.

Zur Folgenabschätzung:

Die in der Problemanalyse genannte "Verbesserung der Akzeptanz" wird mit den hier dargelegten Maßnahmen aus meiner Sicht nur minimal Ausfallen, ist bei den Zielen aber auch nicht genannt.

Mit freundlichen Grüßen,
Florian Galler

Parametric Study of Bicycle Stability

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Parametric Study of Bicycle Stability (P207)

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Topics: Bicycle, Modelling.

Abstract: Bicycles are inherently dynamically stable and this stability can be beneficial to handling qualities. A dynamical model can predict the self-stability. Previous models determined the sensitivity of stability to changes in parameters, but have often used idealized parameters occurring in the equations of motion that were not possible to realistically change independently. A mathematical model of a bicycle is developed and verified. The model is used together with a physical parameter generation algorithm to evaluate the dependence of four important actual design parameters on the self-stability of a bicycle.

Keywords: bicycle, stability, parametric, dynamics, linear.

1- Introduction

Bicycles are an important mode of transportation for many people. Handling is an issue for bicycles, as it is for all vehicles. Poor handling can result in accidents and make it difficult for people to learn to ride a bicycle. Different bicycle designs have different handling qualities and these are a function of the physical parameters of the bicycle and rider. Vehicle handling qualities have typically been quantified by relating vehicle dynamic properties to subjective rider opinion, but some information about handling qualities can be extracted from the vehicle dynamics alone.

Many dynamicists have explored the dynamics of a bicycle with a rigid rider over the past 150 years and the bicycle has long been known to demonstrate self-stability (Meijaard *et al.,* 2007). This stability has been proven through both experimentation (Kooijman 2006) and the development of a reasonably robust dynamical model of the vehicle. A typical bicycle is stable over a range of speeds. This range can be determined by examining the eigenvalues for negative real parts when the dynamics are linearized about a constant speed upright configuration. The stable speed range is dependent on various physical parameters such as the geometry, mass location and mass distribution.

Stability may not be the means to good handling qualities, but stability can be very important when the controller (the rider) is not skilled enough to stabilize the bicycle, such as when learning to ride or under other uncontrollable circumstances. A novice can benefit from stability at very low speeds and a typical rider could benefit from a broader

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range of stable speeds (i.e. one that would cover the typical usable speed range of a bicycle).

Previous studies have shown how independently changing the idealized parameters can change the stable speed range of an uncontrolled bicycle (Åström *et al.*, 2005, Franke *et al.*, 1990, Limebeer and Sharp 2006). As an example, it has been shown that an increase in moment of inertia of the front wheel can lower the speed at which the bicycle becomes stable. But if one were to actually change the moment of inertia of a bicycle wheel there would likely also be a corresponding change in the mass of the front wheel. When designing and constructing a bicycle each physical parameter cannot be changed independently as in an idealized model. It would be beneficial to be able to estimate the change in stable speed range when adjusting the bicycle parameters dependently as one would have to do when actually constructing the vehicle.

We present a method of estimating the physical properties of a hands-free uncontrolled rigid-rider bicycle model, derive a linearized dynamical model of the bicycle, and calculate the changes in stable speed range for various parameter changes.

2- Methods

A dynamical model of the bicycle complex enough to demonstrate self-stability is needed in order to calculate the critical velocities that bound the stable speed range. The nonlinear equations of motion and the linearized system dynamics of the uncontrolled model were developed analytically with the symbolic manipulator Autolev® which is based on Kane's method (Kane and Levinson 1985). This model was then verified against the benchmark (Meijaard *et al.*, 2007) for accuracy. Also, a complementary method to estimate the physical parameters of the bicycle and rider was developed to allow for an infinite combination of realistic parameters. Using each of these, we developed algorithms that varied parameters of interest to show their effects on the stability of the bicycle model.

2.1 Bicycle Model

The Whipple bicycle model (Whipple 1899) was selected as an appropriate model. This model is made up of four rigid bodies (frame/rider, fork/handlebar and wheels) connected to each other by frictionless revolute joints. The wheels contact the ground under pure rolling and no sideslip conditions. This idealized model has been verified and benchmarked by Meijaard *et al.*, (2007) and has been shown to be representative of a realistic bicycle with high-pressure tires up to 6 m/s (Kooijman 2006).

The Whipple model was formulated using Kane's method. Four rigid bodies (C: rear wheel, D: frame/rider, F: fork/handlebar, G: front wheel), three intermediate reference frames (A: yaw, B: lean, E: steer axis) and eight generalized coordinates (q_i where $i = 1,\ldots,8$) were used to characterize the bicycle configuration (Figure 1) within the Newtonian reference frame, N. The generalized coordinates are defined as follows: q_1 and q_2 locate the rear wheel contact point in the ground plane, q_3 is the yaw angle, q_4 the lean angle, q_5 the rotation angle of the rear wheel, q_6 the frame pitch angle, q_7 the steer angle and q_8 the rotation of the front wheel. The wheel contact points for the front

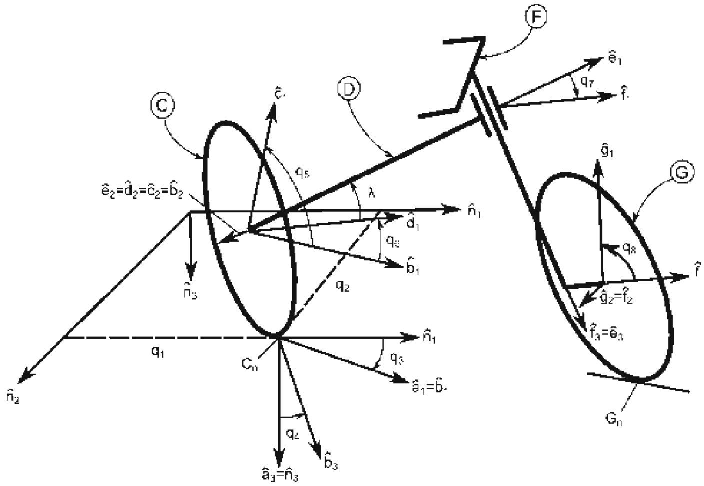

Figure 1 - Dynamical model of the bicycle.

and rear wheel are C_n and G_n, respectively. The Whipple model is further characterized by a minimum set of physical parameters. The geometrical parameters are depicted in Figure 2 and each body (C, D, F and G) has mass and moment of inertia.

A closed loop holonomic configuration constraint, arising from the fact that both wheels must touch the ground, complicates the model derivation. The constraint (Equation 1) is equivalent to a nonlinear relationship between the lean angle, steer angle and pitch angle. Pitch, q_6, is typically taken as the dependent coordinate and the constraint equation can be formulated into a quartic in the sine of the pitch (Psiaki 1979, Peterson and Hubbard 2008). To avoid having to solve the quartic algebraically, the derivative of the constraint equation is taken. This produces a velocity constraint equation that is linear in the derivatives of the pitch angle, steer angle and lean angle (Equation 2). This allows an explicit solution for the pitch angular velocity u_6, making it a dependent generalized speed.

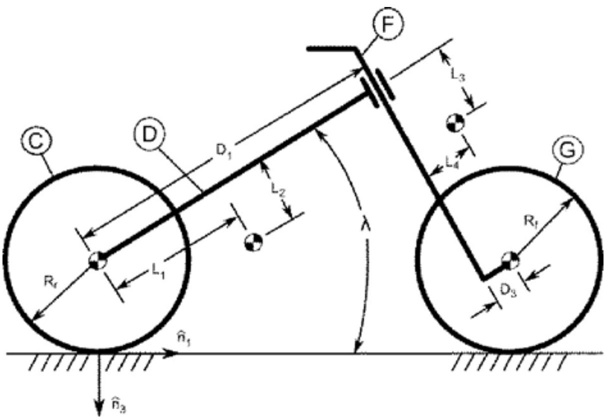

Figure 2 - Bicycle geometric parameters.

$$\bar{r}^{G_n/C_n} \cdot \hat{n}_3 = f(q_4, q_6, q_7) = 0 \tag{1}$$

$$\frac{d}{dt}\left(\bar{r}^{G_n/C_n} \cdot \hat{n}_3\right) = a \cdot u_4 + b \cdot u_6 + c \cdot u_7 = 0 \tag{2}$$

Four nonholomic constraints (Equation 3) further reduce the locally achievable configuration space to three degrees of freedom. The pure rolling, no side-slip, contact of the knife-edge wheels with the ground plane requires that there are no components of velocity of the wheel contact points in the $\hat{n}_1$ and $\hat{n}_2$ directions.

$${}^N\bar{v}^{C_n} \cdot \hat{n}_1 = {}^N\bar{v}^{C_n} \cdot \hat{n}_2 = {}^N\bar{v}^{G_n} \cdot \hat{n}_1 = {}^N\bar{v}^{G_n} \cdot \hat{n}_2 = 0 \tag{3}$$

Eight generalized coordinates, one of which is dependent, and three independent generalized speeds ($u_i = \dot{q}_i$ where i = 4,5,7) describe the system. The five generalized coordinates, q_i where i = 1,2,3,5,8, are ignorable, that is they do not occur in the dynamical equations of motion.

The nonminimal set of dynamic equations of motion (Equations 4 and 5) were formed with Kane's method. They are nonminimal because pitch angle, q_6, was not solved for explicitly. With this set of equations one must solve for the pitch angle numerically for its initial condition when simulating and for the fixed point when linearizing.

$$\dot{u}_i = f(u_4, u_5, u_7, q_4, q_6, q_7) \text{ where } i = 4,5,7 \tag{4}$$

$$\dot{q}_i = u_i \text{ where } i = 4,5,6,7 \tag{5}$$

The equations of motion are then linearized symbolically using Autolev® by calculating the Jacobian of the system of equations. The partial derivatives were evaluated at the following fixed point: q_i=0 where i=4,6,7, u_i=0 where i=4,7, and u_5=-v/R_r where v is the constant forward speed of the bicycle.

The real parts of the eigenvalues of the state matrix characterize the stability of the system and can be calculated for various forward speeds. Figure 3 shows the real parts of the eigenvalues for the model using the benchmark parameter set given in Meijaard *et al.* (2007). The eigenvalues match those of the benchmark to the thirteenth decimal place for all eigenvalues and to the fourteenth decimal place for most eigenvalues. Furthermore, the linearized system was put in the benchmark canonical form and the associated matrices (M, C_1, K_0, and K_2) matched to the same precision as the eigenvalues. The high precision verifies that the correct Whipple model has been implemented.

2.2 Parameter Generation

The components of the state matrix are functions of 25 physical parameters of the Whipple model. Varying these parameters affects the stable speed range of the bicycle.

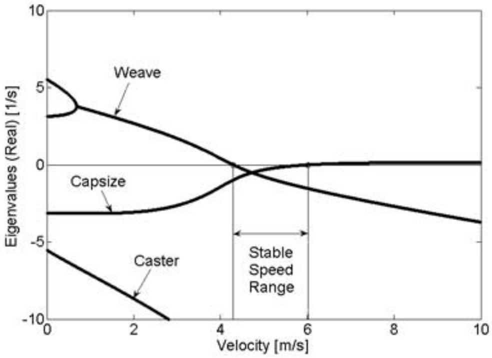

Figure 3 - Stable speed range of the benchmark bicycle showing the weave and capsize critical velocities.

We developed a method of estimating the mass, centres of mass, and inertial properties of the bicycle and rider from various typical geometric measurements such as wheelbase, trail, wheel diameter, limb length, body weight, etc. This allowed us to vary the parameter and always have a realistic bicycle and rider configuration. Unlike in previous studies, the physical parameters are interdependent (i.e. adjusting the front wheel diameter changes the wheel's mass and moment of inertia together with the bicycle's frame geometry). The bicycle frame and fork were modelled as a collection of uniform steel tubes and the wheels as tori. The rider was modelled as a collection of uniform rectangular prisms, cylinders and a sphere (Figure 4).

The nominal geometry, mass, and moments of inertia of the bicycle and rider were measured from a 58 cm 1982 Schwinn LeTour steel road bike and from a 72 kg, 182 cm tall adult male. The mass of each frame tube was determined from the volume and density of the tubes. The masses of the rider segments were calculated as percentages of the total body weight (Dempster 1955). Centres of mass and moments of inertia were

Figure 4 - Representative physical model of the bicycle and rider.

calculated based on the geometry and mass of the segments. The local parameters for each segment were summed for each rigid body and the geometry parameters were converted to the parameter set required by the Autolev® model. An algorithm was constructed to vary any input parameter and calculate the weave and capsize critical velocities.

3- Results

The stable speed range for the nominal bicycle configuration was between 3.59 m/s and 4.88 m/s. We chose four physical parameters to show the usefulness of the model: front wheel diameter, head tube angle, trail and wheelbase (Figure 5). Changes in the stable speed range were calculated by varying each parameter over a realistic range. Each figure (6-9) shows a depiction of the maximal and minimal geometry configurations and the nominal stable speed range is shown with a vertical line. The weave critical speed decreases as front wheel diameter increases but the higher capsize critical speed decreases

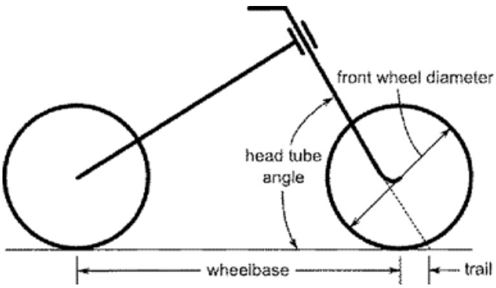

Figure 5 - Geometric parameters of interest.

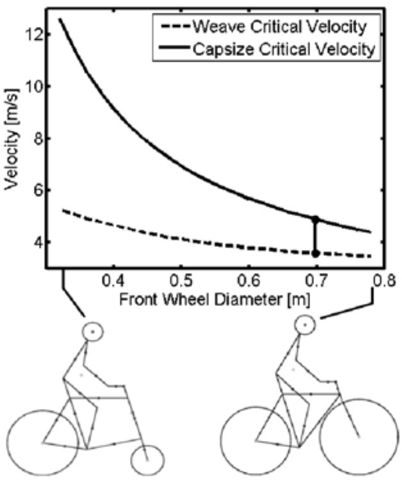

Figure 6 - Critical speed range vs. front wheel diameter.

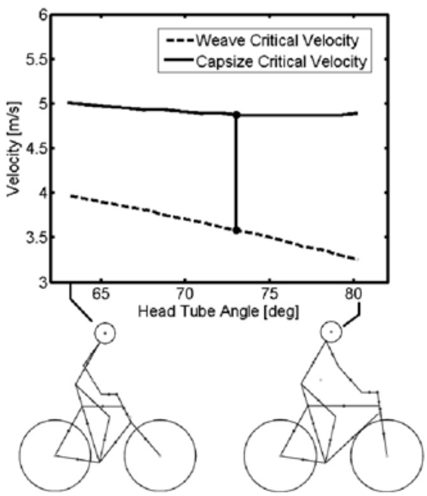

Figure 7 - Critical speed range vs. head tube angle.

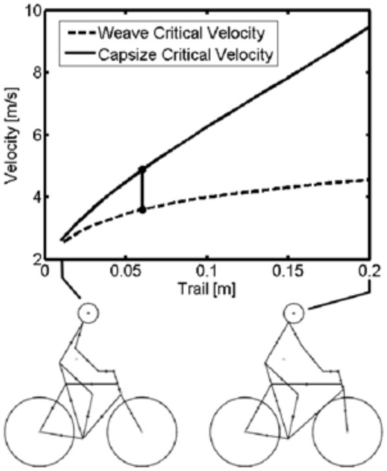

Figure 8 - Critical speed range vs. trail.

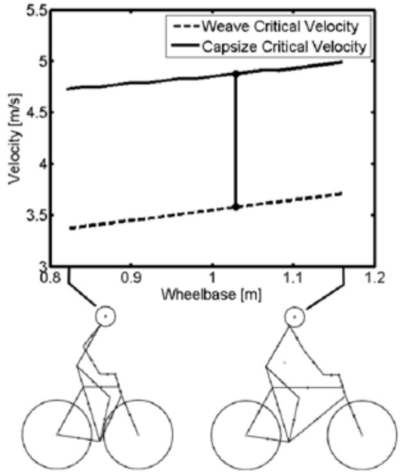

Figure 9 - Critical speed range vs. wheelbase.

even faster so the size of the stable speed envelope also decreases (Figure 6). A slack head tube angle (< 72 degrees) has a higher weave critical speed than a larger head tube angle but the capsize critical speed varies very little with changing head tube angle (Figure 7). As trail increases (Figure 8), the stable speed range broadens and the weave critical velocity increases. As wheelbase increases the stable speed range stays constant as both weave and capsize critical speeds increase at about the same rate (Figure 9).

4- Discussion

The results of these parameter studies are in agreement with previous studies and some anecdotal knowledge of bicycle handling. It has been shown that an increased idealized moment of inertia of the front wheel adds stability at low speeds (Åström *et al.,* 2005). The results (Figure 6) show that the weave critical speed does decrease with a larger front wheel thus providing inherent stability at low speeds. Slack head tube angles are found on many utility bicycles. These bicycles subjectively feel very unresponsive at low speeds and typically do not feel stable until moderate speeds are reached. The head tube angle results are in agreement with this anecdotal evidence in so far as the weave critical speed increases with decreasing head tube angle (Figure 7). The head tube angle results are interesting because the weave speed can be decreased with a steep head tube angle without adversely affecting the capsize critical speed, thus simultaneously increasing the stable speed range and decreasing the weave speed. This is ideal if it is assumed that a low weave critical speed is beneficial for take off and a broad stable speed range is beneficial for cruising with little control input. Trail is typically of particular interest, with many bicycle designers claiming that it is the most important parameter affecting handling qualities. Tim Paterek, an expert frame builder, claims that the comfort zone for trail falls between 5 cm and 6.5 cm for most bicycles (Paterek 2004). No correlation can be drawn from Figure 8 and Paterek's claims. Thus a more robust assessment of handling qualities is needed. As trail approaches zero the stable speed range diminishes and this follows the observed instability of a caster with negative trail (the caster will always flip around to the stable configuration). Long bicycles such as tandems and some recumbents are typically hard to start, but handle better at higher speeds. The weave critical speed increases as wheelbase increases (Figure 9) which correlates with the difficulty in starting long wheelbase bicycles.

The Whipple model and the parameter generation algorithms discussed here can be particularly useful in the design of bicycles used to teach people how to ride. The idea would be to design for a very low weave critical velocity so that novices would not have to travel at higher speeds to benefit from the self stability inherent in the bicycle. Bicycles such as the ones used in the "Lose the Training Wheels" program (Klein 2008) and the Gyrobike (Ward 2006) are excellent examples. Bicycles can also be designed with a broader stable speed range that could potentially be used for situations in which a bicycle rider moving at higher speeds could benefit from self-stability. The tools developed here may be of value to bicycle designers. A turnkey software package could allow a layman to select the physical parameters when designing a bicycle to meet a desired stable speed range.

5- References

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