Product & Motion
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Masterclass Bicycle Dynamics

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Homework Assignment MBD

In this assignment you will investigate the handling qualities of various bicycle designs. Unfortunately, little is known about handling qualities in bicycles. However, we know some things about the uncontrolled dynamics of a bicycle with rigid rider attached. We know that the stability of an uncontrolled bicycle changes with forward speed. In a bicycle of the common construction the stability increases with increasing velocity. And we know that we can change the design of a bicycle such that it will always be unstable for any forward speed or, vice versa, very stable from a minimal speed until infinity. How does this relate to handling qualities? Well, we suspect that an unstable bicycle is hard to handle and that a stable or mildly unstable bicycle is easier to handle. Therefore we will focus on bicycle stability to predict proper handling.

With the Whipple bicycle model [1] we are able to calculate the stability of the lateral motions of a bicycle for various designs at various forward speeds. A Matlab tool has been build which has the implementation of these equations and stability calculation, called JBike6. You can download JBike6 for free, just google "JBike6" or click on download JBike6.

Please answer the following questions:

1. For your own bicycle determine the necessary bicycle parameters like wheelbase, headangle, trail, mass and mass moments of inertia of the parts and put these in JBike6 and investigate the stability. Determining the mass and the mass moments of inertia of the individual parts is not easy. Check out the existing models in JBike6 and guess your way around for your bicycle. Mass is do-able but for mass moment of inertia you need some reference, all objects below have mass m, and I's are at the centre of mass:
   - Beam, length l: $I_{zz} = (1/12)ml^2$.
   - Solid disc, radius r: $I_{zz} = (1/2)mr^2, I_{xx} = I_{yy} = (1/4)mr^2$.
   - Hoop (all mass at rim), radius r: $I_{zz} = mr^2, I_{xx} = I_{yy} = (1/2)mr^2$.
2. Remove the gyro effect of the wheels from your model by setting I_{zz} to zero for both wheels. Is your bicycle still stable in some speed range?
3. Reverse the trail (make negative). Is your bicycle still stable in some speed range?
4. Keep the gyro effect and the positive trail but change the mass distribution of the front fork such that the bicycle is always unstable.
5. Make a design with negative trail which still shows some stable speed range.
6. Make a design with a forward titled steer axis which shows some stable speed range.
7. Make a rear-wheel steered design which shows some stable speed range.

References

[1] J. P. Meijaard, Jim M. Papadopoulos, Andy Ruina, and A. L. Schwab. Linearized dynamics equations for the balance and steer of a bicycle: a benchmark and review. *Proceedings of the Royal Society A*, 463:1955–1982, 2007. download