Effect of crosswind on bicycle with or without rider control

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1. Introduction

Crosswind has significant impact on safety, stability and performance of a cyclist. Despite the occurrence of fatal accidents due to crosswind (Fintelman, 2014), very limited work has been conducted in this area.

The current research work aims to simulate the effect of crosswind on a bicycle in stable and unstable speed ranges, with or without rider control actions. This study is the first step in understanding the crosswind effect, which would help improve safety of cyclists and equipment, as well as in defining guidelines for cycle lane infrastructure.

2. Background

The current research adopts the benchmark bicycle model developed by Meijaard et al. (2007), the rider model as identified by Schwab et al. (2013) and the experimentally obtained aerodynamic forces by Fintelman et al. (2014).

3. Methodology

- Measured physical properties for the bicycle are taken from Schwab et al. (2013) with the linearized equation:
  $M\ddot{q} + vC_1\dot{q} + [gK_0 + v^2K_2]q = f$ where, f includes the controller input and the aerodynamic forces.
- The rider is modelled as a PID controller obtained by Schwab et al. (2013), wherein the gains are estimated during lateral perturbation experiments on a treadmill.
- The control inputs are roll and steer angles with their higher derivatives, and output is the steer torque.
- The bicycle's speed is taken constant, and therefore only the following measured aerodynamic components (Fig. 1) will affect the motion:
  - Side force (CsA)
  - Yaw moment (CyA)
  - Roll moment (CrA)
- The generalized roll and steer torques are calculated from a resultant force, using the virtual power method.

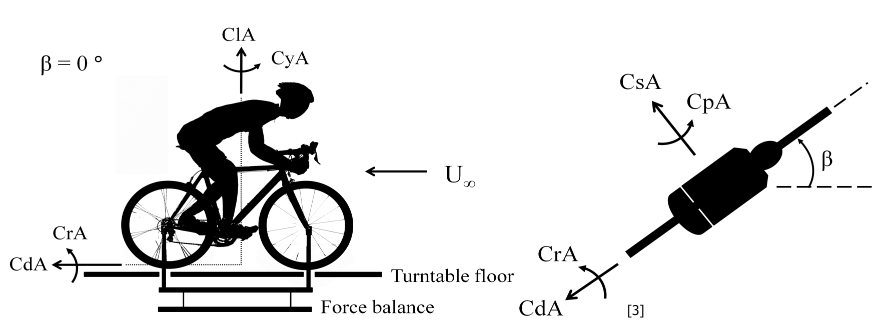

Fig. 1: Experimental study for measuring aerodynamic forces by Fintelman et al. (2014).

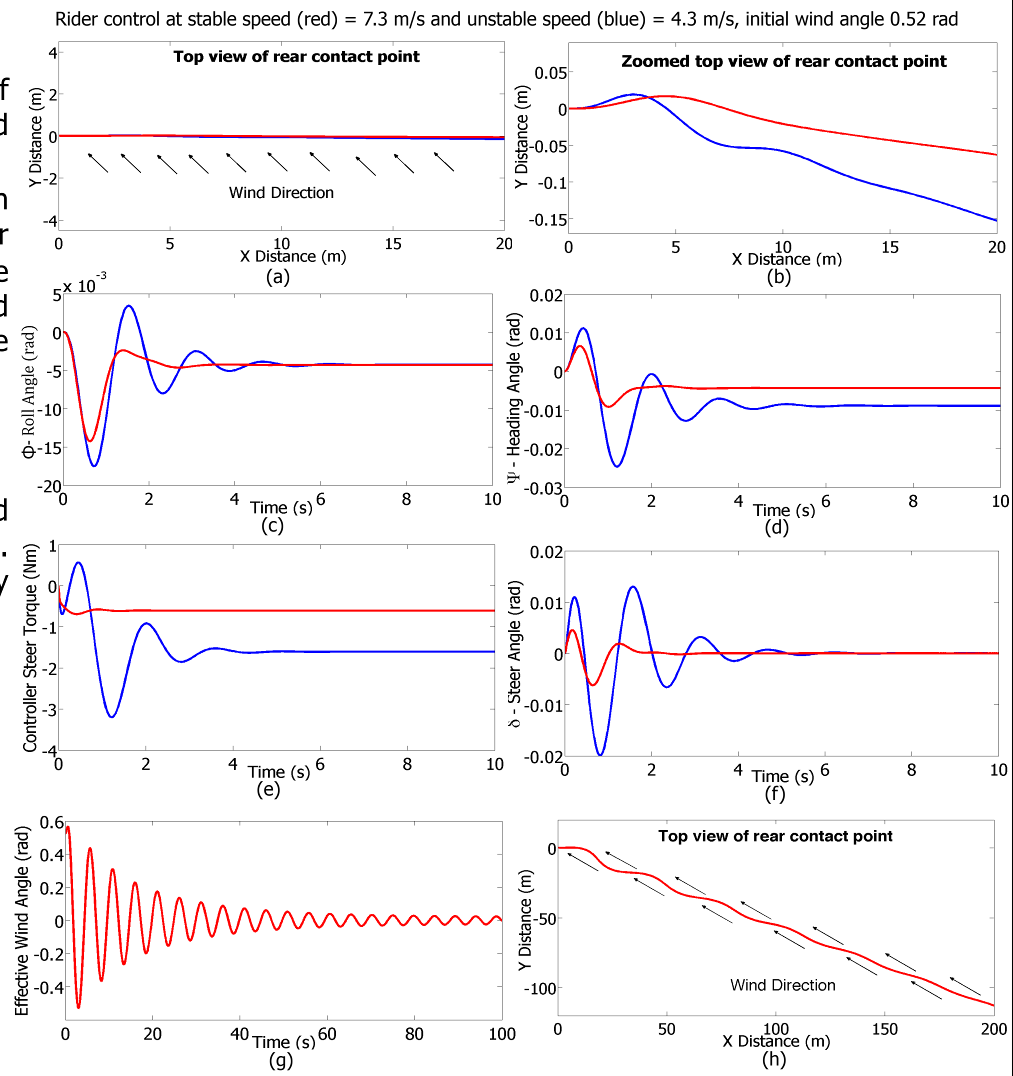

Fig. 2: Simulated results at stable and unstable speeds, with and without rider control

4. Results

- After transient controller efforts, see 2(b) & 2(e), the rider reaches near zero heading angle, 2(d), and maintains an equilibrium configuration with a small resultant roll angle, 2(c).
- The rider needs extra control efforts to stabilize the system at the unstable speed, 2(e) & 2(b).
- Hands free bicycle tends to align with the wind direction, while sustaining small oscillations, 2(g) & 2(h).

5. Next Steps

- Investigating the reason for sustained oscillations at the stable speed.
- Simulation with wind direction data up to 180 degrees, looking at tail wind effect.
- Inclusion of velocity as a variable.
- Apply a controller model for cycling on a cycle lane with fixed width and calculate the swerve width due to a gust of crosswind at various forward speeds and wind speeds.

References

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