Racebike Dynamics: The Dynamic Racebike State Plot

C. Feichtinger

Institute of Automotive Engineering, Graz University of Technology; c.feichtinger@airdrop.at, ORCID 0000-0003-2082-0877

Abstract:
Riding a motorbike is characterised by permanent dynamics. In motorcycle racing the rider plays an important role in terms of its riding style – the relative position of the rider in different riding situations on the racetrack. From an engineering point of view the riding style has a huge impact on the center of gravity position of the overall racebike and rider system. The different rider positions also have a strong impact on the aerodynamics of the overall racebike and rider system. Additional changes during a race or test day due to external influences or internal signs of wear and tear must be considered – this applies to the rider as well as to components of the motorbike. This paper is based on the PhD thesis of Feichtinger (Feichtinger, 2021) and presents the \textit{dynamic racebike state plot} as well as the derived quantity $\chi$ as representative characteristic for the dynamic of a racebike. This diagram was developed as a basis for all further analyses and investigations. It helps to identify and compare different motorbike variations and different rider types.

The \textit{dynamic racebike state plot} The lean angle and the speed of the racebike are in general the leading quantities to describe the racebike state on a racetrack. Therefore, the speed – lean angle plot, or ‘dynamic racebike state plot’ is introduced here. Fig. 1 shows a generic, dynamic racebike state plot with the speed range of up to $300 \text{ km/h}$ for mid class racebikes. The plot contains the following information.

- **Maximum possible lean angle** $(\tan \varphi_{\text{bike}} = \mu_{\text{lat}})$ as limitation of the lateral tire friction coefficient – horizontal blue lines.
- **Design space limitation** for the lean angle – horizontal green lines. This is the mechanical limit where any part of the racebike is touching the ground. Usually this is the footrest or the lower part of the swingarm. The maximum lean angle from the design space limitation must be bigger than the maximum lean angle from the lateral tire friction coefficient. Only then, the racebike can be moved at the dynamic riding limit without touching the ground – which normally results in a crash.
- **Iso-lines for constant cornering radii** between $r_c = 10 \cdots 500 \text{ m}$ for a given, constant lateral tire friction coefficient of $\mu_{\text{lat}} = 1$. The Iso-lines are calculated using the simple relation between the lean angle and the racebike speed $\tan \varphi_{\text{bike}} = \nu_{\text{bike}}/(r_c \cdot g)$. They show the maximum possible lean angle $\varphi_{\text{bike}}$ for a given corner radius $r_c$ and a given racebike speed $\nu_{\text{bike}}$.
- **The motion profile** of a track segment when the racebike is accelerating out of a left-hand corner onto a long straight is shown in the lower right corner of the plot – red line. The marked points A, B and C are also marked in the main plot. The motion profile shows the individual speed – lean angle states along this track segment.
In the shown motion profile the racebike starts at a lean angle of $-55^\circ$. In the first part the racebike is raised at moderate longitudinal speed changes. Then the racebike is rolling slightly in the opposite direction ($+20^\circ$ point B), before bringing the racebike in the final upright position. The section between points B and C shows mainly a longitudinal acceleration with small lean angle changes.

The derivative of the lean angle according to the speed, is defined here. It is denoted with the quantity $\chi$, just that $\chi = d\varphi/dv$. The new introduced derivative quantity $\chi$ shows the slope of the motion profile in the speed – lean angle plot.

- Chi values of $\chi = \pm \infty$ show a pure lateral movement of the racebike – Rolling of the racebike without any speed change.
- Chi values of $\chi = 0$ show a pure longitudinal movement of the racebike – Accelerating or braking without any lean angle change.

It is task of the rider to optimize chi $\chi$, such that the combination of side forces and longitudinal forces on the grip level leads to a minimum lap time. The new quantity $\chi$, combines the complete, complex dynamics of the motorbike in one size.

The dynamic racebike state plot is used for the assessment of characteristic riding situations. In the course of the work the racebike state plot and the derived quantities and riding situations are used for the assessment of the aerodynamic characteristics of a racebike on a racetrack using a motorbike multibody model using Jourdain’s principle.

Furthermore, the dynamic racebike state plot supports the identification of riding style differences and performance relevant changes of the racebike and tires.

References