Discussion on: "Experimental Identification of the Engine-to-Slip Dynamics for Traction Control Applications in a Sport Motorcycle"

Vittore Cossalter*, Roberto Lot, Matteo Massaro

DIMEG-Dept. of Innovation in Mechanics and Management, University of Padova, Via Venezia 1, 35131 Padova, Italy

The paper by Corno and Savaresi considers the problem of modelling the engine-to-slip dynamics and presents a protocol for their identification on a sport motorcycle. These dynamics are important for a proper design of traction control (TC) as well as to estimate its performance and feasibility. These dynamics were not properly investigated in the open scientific literature and therefore the experimental identification carried out in the paper represents an interesting contribution. Anyway, because of the black-box approach the work does not correlate the properties of the identified describing functions (frequency and damping of resonances, phase lag, etc.) to the physical characteristics of the vehicle such as engine inertia, tyre geometry, etc. Even if this is not the goal of the paper, in our opinion this correlation is essential to extend the results to other vehicles, different motion conditions and to give TC designers helpful hints. In other words, to make the results more general and not limited to the tested vehicle and tested condition only.

It is worth noting that it is not practical to identify the engine-to-slip dynamics in all typical working conditions. Indeed, the identification requires the measurement of the tyre slip that depends on tyre-road friction, tyre load, tyre rolling radius, carcass flexibility, vehicle roll angle, etc. In addition, in motorcycles the front tyre load may easily reduce to zero when accelerating thus making it difficult to have a reference longitudinal speed for slip estimation. In general, there are some riding conditions (e.g., hard acceleration, leaned vehicle) where the hypotheses of the paper do not hold anymore.

In order to investigate the riding condition where the experimental approach becomes problematic, it is useful to develop mathematical models based on the physics. Figure 1 shows that the identified black box contains three physical subsystems: the electronic throttle (when present), the engine, the transmission and tyre. In order to find the simplest yet reliable mathematical model, the contribution of the paper by Corno and Savaresi reveals to be essential. From practical experience, two main physical parameters are expected to be relevant: the flexibility of the tyre carcass [1–3] and the flexibility of the sprocket absorber [4], which is an elastic body mounted between the rear chain sprocket and the rear wheel rim. A deeper discussion of this approach is presented in ref. [5] where also a comparison with road test data provided by Corno and Savaresi is included.

References

1. Lot R. A motorcycle tire model for dynamic simulations: theoretical and experimental aspects. *Meccanica* 2004; 39: 207–220
2. Pacejka HB. Tyre and Vehicle Dynamics. SAE International, 2005, ISBN: 978-0-7680-1702-1

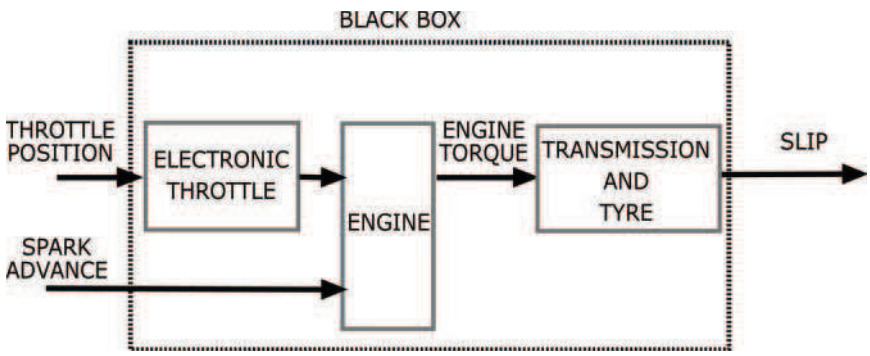

Fig. 1. Identified Black Box.

* E-mail: vittore.cossalter@unipd.it

3. Cossalter V. Motorcycle Dynamics. 2006, ISBN 978-1-4303-0861-4
4. Cossalter V, Lot R, Massaro M. The chattering of racing motorcycles. *Vehicle Syst Dynamics* 2008; 46(3): 339–353.
5. Massaro M, Lot R, Cossalter V. On engine-to-slip modelling for motorcycle traction control design. *Eur J Control* 2009, submitted for publication.

Discussion on: ''Experimental Identification of Engine-to-Slip Dynamics for Traction Control Applications in a Sport Motorbike''

Wen-Hong Zhu*

Canadian Space Agency, 6767 route de l'Aeroport, Saint-Hubert, QC, Canada J3Y 8Y9

Motorbikes represent a class of the most difficult systems to be controlled. Their instability in nature, intensively coupled dynamics among different motion axes, and highly nonlinear constraints imposed on multiple variables substantially challenge the control system designs. They are the systems that no single-equation can describe precisely.

In the aforementioned paper, a particular problem of the motorbikes, namely *engine-to-slip* in longitudinal motion, is studied. Aimed at achieving the maximum possible acceleration, this research takes the *throttle position* and *spark-advance* as the two control variables to study their impacts on the output variable namely the *longitudinal slip*.

The entire research is based on the physically measured input–output data, rather than on the analytical multi-body dynamics. Thus, an identification process aimed at obtaining the input–output relationships is necessarily needed. As expected, transfer functions are used to identify the system dynamics and the results are validated in both frequency and time domains.

Although being very original for this interesting problem, this research leaves some questions to be answered in the future. As mentioned early, motorbikes are multivariable systems. The input–output relationships are very dynamic, nonlinear, and complex. They usually involve many secondary input variables such as the quality of the road surface and the tire tread. Although it is convincible that the engine throttle is one of the primary input variables, the impacts of other secondary variables remain to be exploited. In this paper, these secondary factors were kept constant in order to emphasize the primary input–output relations linking the *throttle position* and *spark-advance* to the *longitudinal slip*. A natural question, therefore, is ''do the conclusions drawn in this paper are still valid for different road conditions and different tire treads?'' Particularly, consider the fact that the studied system is nonlinear in natural, which most likely prevents the linear-system-based superposition principle from being directly applied in the first place.

Attentions need also to be paid to the use of transfer functions. The original concept of the transfer functions in classical text books is based on an assumption that the targeted system is linear. At a given frequency, the input and output sinusoidal signals with a linear system keep the same frequency, but with different amplitudes and phases. The relations between the input–output amplitudes and phases are characterized by a complex number. Besides being already quite challenging to extend the concept of transfer functions to nonlinear systems, this paper extend the concept of transfer functions with an even more broad sense – to deal with harmonic outputs, allowing the output signal to have a different frequency from the input signal. As a result, the meaning of the transfer function is no longer a complex number at a given frequency, as the phase of the output signal varies consistently versus the phase of the input signal.

In summary, this is a very interesting paper focused on a very interesting practical problem. In the future, it is expecting that more rigorous theoretical backgrounds are to be laid and more remaining questions are to be answered.

* E-mail: Wen-Hong.Zhu@asc-csa.gc.ca