Hydraulic CVT Slip Control: New Challenges

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Stan van der Meulen, Bram de Jager, Maarten Steinbuch, and Bram Veenhuizen
Eindhoven University of Technology, Mechanical Engineering, Control Systems Technology
PO Box 513, 5600 MB Eindhoven, The Netherlands
{S.H.v.d.Meulen,A.G.de.Jager,M.Steinbuch,P.A.Veenhuizen}@tue.nl

1 Introduction

A pushbelt continuously variable transmission (CVT) is a stepless power transmission device with infinitely many transmission ratios within a certain range. This is enabled by the variator, which consists of a segmented steel V-belt that is clamped in between two pairs of conical sheaves, see Figure 1. High clamping forces are exerted by a hydraulic actuation system to prevent global slip of the belt at all times, which leads to increased hydraulic pump losses and increased friction losses.

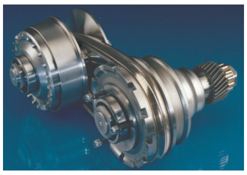

Figure 1: *Pushbelt CVT variator.*

2 Variator Slip Control

2.1 Why?

One way to reduce these losses and to improve the variator efficiency is to lower the clamping forces to a level that is sufficient to transfer the torque. This implies that global slip of the belt is allowed to a limited extent. However, in the presence of driveline disturbances this strategy possibly results in excessive slip of the belt and severe damage of the variator. Hence, it is necessary to control the slip in the variator [1].

2.2 How?

The desired slip region is based on Figure 2. For each of three transmission ratios, the desired slip region is different, since it changes in accordance with the maximum variator efficiency. A slip controller is applied to keep the slip in the desired slip region for each transmission ratio.

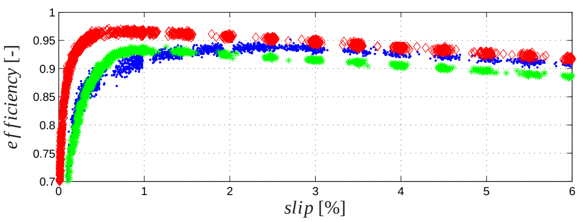

Figure 2: *Experimental variator efficiency as a function of slip* (·: *low;* ◇: *medium;* ∗: *overdrive).*

2.3 When not?

At present, the application of slip control is not feasible in several situations, due to possible unstable behaviour. These situations concern, for example, extreme driveline disturbances and fast transmission ratio changes, *e.g.*, kickdowns and emergency stops.

3 Project Objective

Demonstrate the fuel-saving potential of slip control with a vehicle implementation for all driving conditions.

4 Approach and New Challenges

The approach to achieve this objective consists of an iterative analysis / synthesis cycle between theory and experiments, see Figure 3. Relevant research questions are:
Modeling for Control: What are the characteristics of the transmission ratio dynamics and the slip dynamics in the applicable slip range?
Control Design: What are the possibilities of linear parameter varying control and extremum seeking control?
Slip Estimation: What are the possibilities of a slip observer design in comparison with a cheap, reliable, and accurate slip sensor design?
Driveline Disturbances: What are the consequences of driveline disturbances, *e.g.*, torque converter and road disturbances, for slip control?
Driveability: What are the implications of the perception of the driver for slip control?

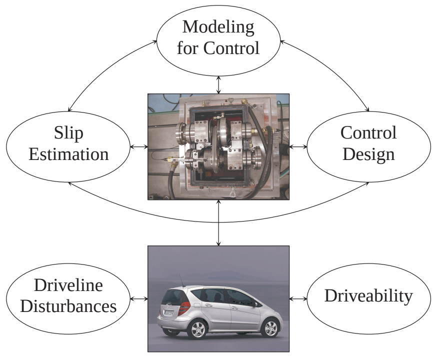

Figure 3: *Interaction between theory, test rig experiments, and vehicle experiments.*

References

[1] B. Bonsen, T. W. G. L. Klaassen, R. J. Pulles, S. W. H. Simons, M. Steinbuch, and P. A. Veenhuizen. Performance optimisation of the push-belt CVT by variator slip control. *Int. J. Vehicle Design*, 39(3):232–256, 2005.