#05 Design and Experimental Implementation of an Active Stability System for a High Speed Bogie

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Abstract : This paper describes an experimental active stability system for a high speed railway vehicle. Two models are developed in the study: one for control system design and one for control system performance assessment. A number of possible control schemes are described, these include single axle control schemes and modal control schemes. Results both from comprehensive simulations and from experimental implementation are presented.

1. Introduction

A solid axle wheelset of a conventional railway vehicle is unstable at all speeds, the technique used to stabilise this behaviour consists of linking two wheelsets together with a stiff primary suspension using a bogie frame. This stabilises the wheelset but degrades the natural curving behaviour of the wheelset, and this stability-curving trade off is the fundamental problem faced by railway designers.
Recently there has been increasing interest in the use of active control technology within the primary suspensions of railway vehicles. This offers the potential freedom to the designer to control stability and steering independently, substantially improving the curving behaviour of the vehicle while allowing higher operational speeds. This paper focuses upon the design of an active stability control system, the steering controller is a subject of another paper [1].

2. Vehicle Scheme and Mathematical Modelling

Two mathematical models of the vehicle have been developed. The first is a relatively simple plan view half vehicle linear model containing 14 states, both yaw and lateral modes have been modelled for the two axles and the bogie frame, the lateral mode only of the body is modelled. The second model is for simulation and performance predictions, this is a non-linear model which incorporates particular features of railway vehicles such as:- the non-linear wheel/rail contact geometry, non-linear characteristics of some suspension components, large displacements and rotations between bodies etc with high degrees of accuracy, this model contains in excess of 130 states. These models are shown in Figure 1.

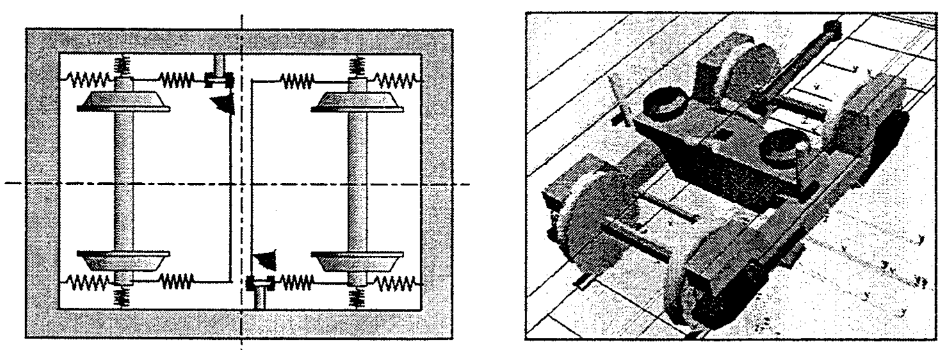

Figure 1. Control System Design Model (Simulink) and Vehicle Simulation Model (Simpack)

3. Single Axle Control Strategies

A control-oriented analysis of a wheelset has shown that, whereas passive damping does not assist with stability, active damping will stabilise a solid axle wheelset [2]. The approach used in this study is to apply a yaw torque between the bogie frame and the wheelset proportional to the lateral velocity of the wheelset (termed active yaw damping [3]). Figure 2 shows the overall scheme, although the two axles are treated as being independent clearly there are interactions between the two axles through the bogie frame. However, analysis has shown these interactions are small and that the two axles can be essentially considered decoupled.

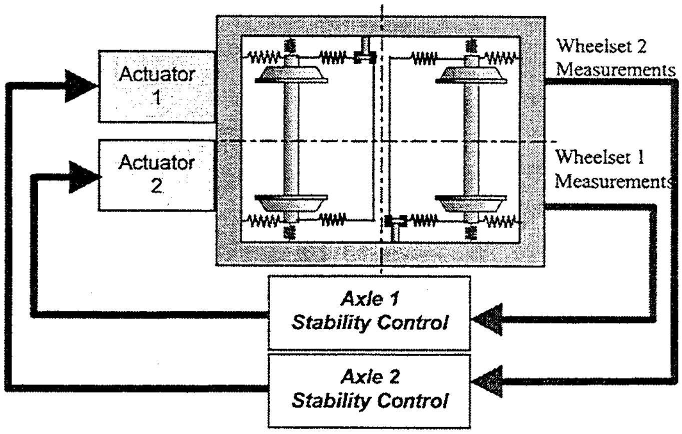

Figure 2 Single Axle Control Scheme

4. Modal Control Strategies

Figure 3 shows the general form of the modal control scheme. The output measurements from the two wheelsets are decomposed to give feedback signals required by the lateral and yaw controllers respectively, and the output signals from the two controllers are then recombined to control the two actuators for the two wheelsets accordingly [4]. This enables the lateral and yaw controllers to be developed individually, at least as far as stability is concerned.

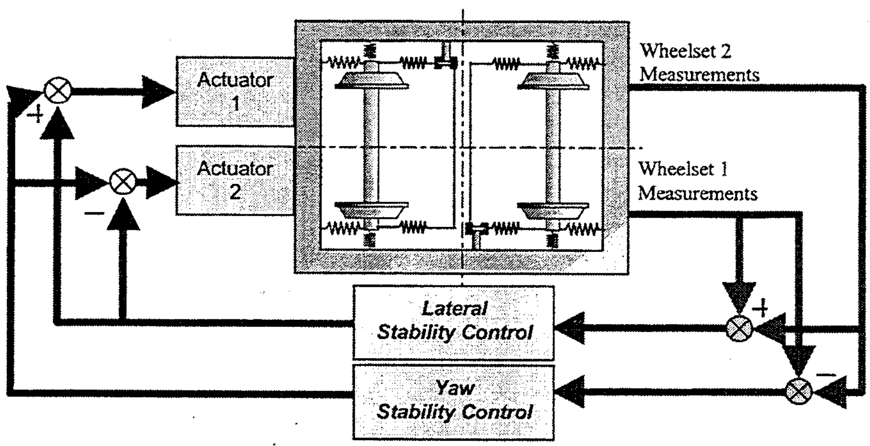

Figure 3 Modal Control Scheme

5. Simulation and Experimental Results

Comprehensive simulation studies have been performed of the various control options. These studies have included stability tests and straight track tests using recorded track data. Following the simulation study a period of testing on an experimental train has been conducted on a full size roller rig. During this testing phase extensive stability tests and track file tests have been performed and the controller has successfully operated at speeds in excess of 300km/h. Figure 4 shows two typical results for the stability test (a 1-cosine input onto the leading axle with an amplitude of 7.5mm). Both results clearly show the stabilising effect of the controller (this vehicle in a passive configuration was unstable at speeds above 100km/h - Figure 5 shows results for both active control and the passive vehicle at 100km/h).

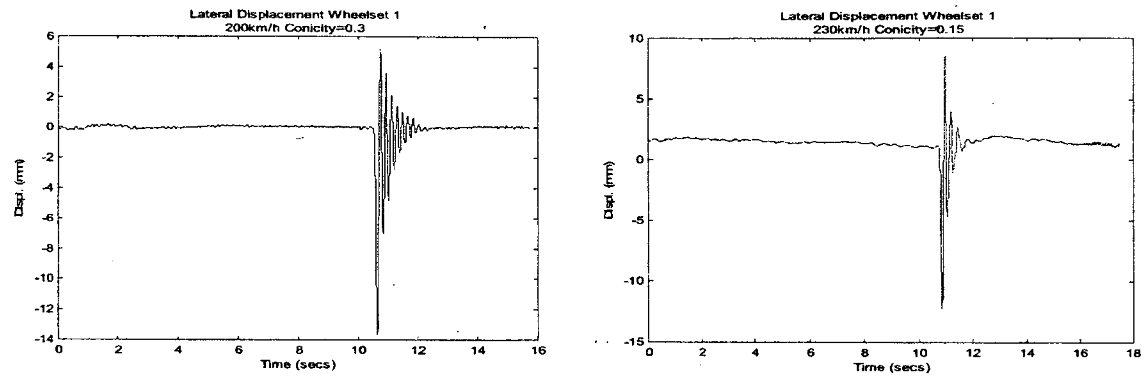

Figure 4 Rig Stability Test Result

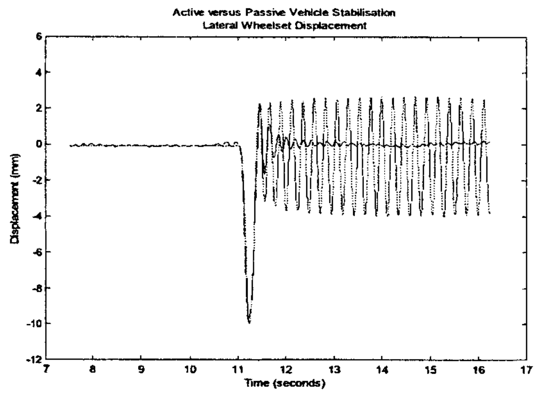

Figure 5 Rig Stability Test Result - Active and Passive Control

6. Conclusions

This paper describes the implementation of an active stability controller for a high speed railway vehicle. It has shown through simulation and through practical implementation that the lateral velocity signals can be used for the active yaw damping controls scheme in both single axle and modal control formats.

7. Acknowledgements

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8. References

1. S.Shen, T.X.Mei, R.M.Goodall, J.Pearson and G.Himmelstein: A Study of Active Steering Strategies for a Railway Bogie. *IAVSD03, Kanagawa Japan, 2003.*
2. Goodall, R. and Li, H., "Solid axle and independently-rotating wheelsets-a control engineering assessment", *Journal of Vehicle System Dynamics*, 1999
3. Li, H. and Goodall. R.M., "Modelling and Analysis of a railway wheelset for active control", *UK Control 98*, Swansea, Sep. (1998)
4. Mei, T.X. and Goodall, R.M. "Wheelset Control Strategies for a 2-Axle Railway Vehicle", *Journal of Vehicle System Dynamics.* Vol. 33 Supplement, 2000, pp.653-664