Simulation and testing of a wheelset with induction motor driven independent wheels

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Abstract

Independently rotating wheels (IRW) for railway vehicles have been under serious consideration at a theoretical and experimental level for many years. This paper presents dynamic and control simulations of a rail vehicle wheelset with induction motors for independently rotating wheels. Simulation models have been developed for both the mechanical and electrical aspects of the system. The simulation and experimental results have demonstrated that the proposed control strategy has good dynamic performance in term of response time and controllability. A test implementation on a 1/5 scale roller rig has validated the simulation results and shown that good stabilization can be achieved by the proposed wheel motor driven configuration.

1. Introduction

It is well known that railway vehicles with conventional rigid wheelsets can experience problems due to instability at high speed (hunting). The use of IRW has been proposed as a way of eliminating this instability. This paper presents dynamic and control simulations of a railway vehicle wheelset with induction motors driving independently rotating wheels. The mechanical and electrical models for the wheelset and induction motors are presented and the indirect field oriented control for the induction motors is discussed and a comparison between simulation and experiment of the induction motor shown. Simulations of IRW and conventional wheelset are presented and validation of the results with data from a 1/5 scale test rig is carried out.

2. The Wheelset Models and Control Strategy

Fig.1 shows the proposed IRW configuration. It can be seen that the induction motors can either be independently controlled by the inverters or jointly controlled by the inverters and the main computer. Fig. 1 also shows that the yaw rotation of the wheelset is used as an input variable to contol the speed difference between the two wheels. This configuration will give the maximum flexibility and accuracy in controlling the induction motors and yaw movement of the wheelset.

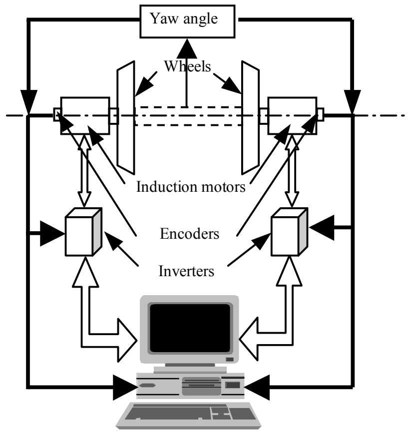

Fig. 1 The configuration of the wheelset

The wheelset is taken as having the two degrees of freedom of lateral translation motion and yaw rotation:

(1) Lateral movement:

$$m\ddot{y} + 2f_{22}(\frac{\dot{y}}{v} - \psi) + f_{23}\frac{\dot{\psi}}{v} + \frac{w\lambda y}{l_0} = 0$$

(2) Yaw movement:

$$J_w\ddot{\psi} - 2f_{23}(\frac{\dot{y}}{v} - \psi) + 2f_{11}(\frac{l_0^2\dot{\psi}}{v} + \frac{l_0\lambda y}{r_0}) + 2f_{11}\frac{l_0 r_0}{v}\dot{\phi} = 0$$

(3) Rotation difference (IRW):

$$I_\phi\ddot{\phi} + f_{11}\frac{r_0^{\,2}}{v}\dot{\phi} + f_{11}{}^{\lambda}y + f_{11}\frac{l_0 r_0}{v}(\dot{\psi} - 1/R) = 0$$

Indirect field oriented control techniques have been used to control the induction motors. Indirect field orientation is based on the slip relation $\omega_e - \omega_r = R_r I_{qs}^e / L_r I_{ds}^e$. If the above condition is satisfied, it ensures that an AC motor can be controlled in the same manner as a DC motor. In order to compensate for the flux disturbance which may slightly alter the electromagnetic torque under transient conditions, a torque controller is introduced into the control loop. Fig.2 shows the comparison between simulation and experimental results for the induction motors.

3. The simulation and experimental results

The corresponding mechanical and electrical models have been implemented and simulated using Matlab Simulink software. Fig.3 gives the simulation results for a wheelset, without wheel motor driving control, subjected to a 5mm lateral pulse disturbance at speed 30 m/s. It can be seen that the lateral and yaw oscillations of the wheelset after the disturbance increase with time. Fig. 4 shows the corresponding simulation results under the same conditions but with active driving motor control. They clearly show that the lateral ripple and yaw oscillation will die out very quickly after the disturbance. Fig. 5 presents a typical experimental result for the yaw movement of the wheelset. It clearly shows that the speed difference adjustment between left and right wheels by yaw feedback can be used for stabilization. The 1/5 test rig has demonstrated that at a speed of 18 m/s (equivalent to about 88 m/s full scale speed) good stabilization can be achieved.

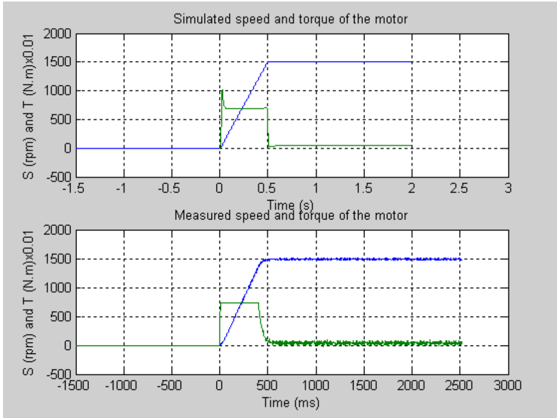

Fig. 2 A comparison between simulated and experimental results of induction motors

4. Conclusions

Indirect field orientation control for dynamic control of the induction motors has been shown to be suitable for this application in both its response and its controllability. The simulation of a wheelset with independently rotating wheels and active driving motor control has demonstrated improved stability over a conventional wheelset. These simulation results have been confirmed by a 1/5 scale test rig.

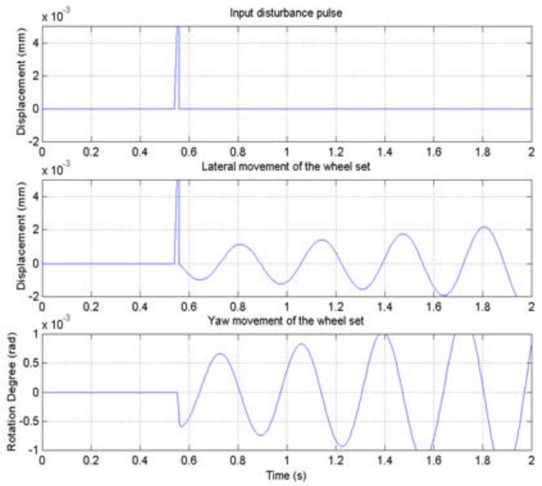

Fig. 3 A wheelset without active motor driving control

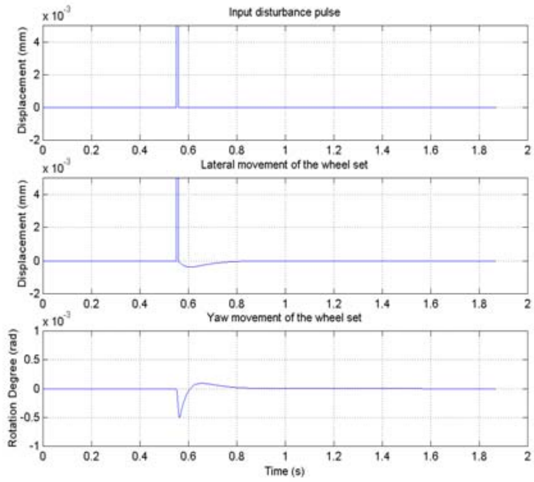

Fig. 4 A wheelset with active motor driving

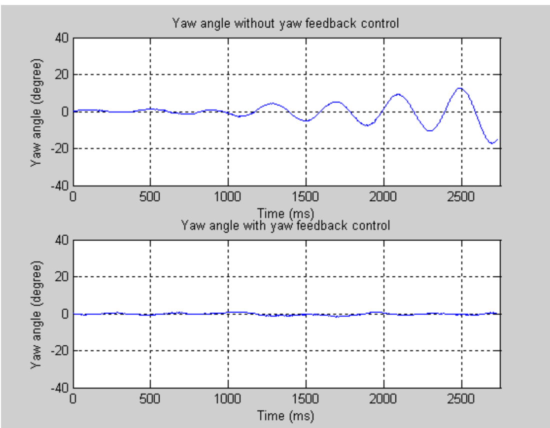

Fig. 5 The measured yaw movement with and without yaw feedback control