Active Ride Control in Elevators

An important quality measure for elevators is ride comfort, which is determined by the strength of the cabin vibrations. The vibration sources in the cabin are either high-frequency disturbance sources, like the unevenness of guide rails, or low-frequency disturbances like forces originating from asymmetric cabin loads. Having reached the limits that passive elements such as springs can provide, Schindler is successfully using dSPACE Prototyper to develop and validate an active suspension system for its 9700-GL class of high-rise elevators.

The primary goal of the active suspension system is to suppress the magnitude of the cabin vibrations in all lateral directions to the frequency range of 1 to 20 Hz by using acceleration feedback. The second goal is to use position feedback to correct the orientation of the cabin in the presence of an asymmetric load.

Active Damping System Setup
To create the active damping system we mounted four active roller guide shoes onto the elevator car (see the figure below). These guide shoes have the same basic construction as passive ones with the addition of two actuators and two position sensors. The actuators exert their force on the rocking levers carrying the rollers, while the position sensors measure the distance of the levers from their zero positions. We also mounted six accelerometers to the cabin frame. The calculation of the control algorithm and the interface to the sensors and actuators is done with dSPACE Prototyper, which also includes the entire software development environment.

Control Design
The controller we implemented uses the $H_\infty$ robust control method, which ensures that there is no performance deterioration due to variations in the cabin’s load and other system parameters. We designed the acceleration and position controllers with MATLAB/Simulink as two digital, linear time-invariant systems in state-space presentation. Both controllers were set up as a single timer task at a sampling period of 1.5 ms.

To obtain the dynamic model of the system necessary for the controller design, we applied a system identification procedure by using the sensor measurements. To do so the system was excited by the actuators with a pre-defined force command signal.

The identified model was a true description of the system dynamics as it contained the dynamics of both the hardware components and the mechanical system.

Reduced Vibrations
Before becoming a true measure of ride quality, the acceleration has to pass through a filter that models the human response to vibration as defined in ISO 8041. To test the active system a test rig (see the figure on the left) was built where the deflections of the rail profiles during travel were emulated by eight hydraulic cylinders. The graph shows that the active damping system reduced the effective value of the ISO-filtered acceleration by a factor of 5.
Controller Validation in Just a Few Hours

One of dSPACE Prototyper’s main advantages is the availability of I/O hardware with numerous fast, synchronized analog input and output channels. Another advantage, the perfect integration of MATLAB/Simulink into dSPACE Prototyper, released us from manual programming. This freedom was essential during such a time-critical development project. With dSPACE’s experiment software, we could easily change parameters and measure variables online to optimize the controller during runtime. With this method the test of a entire new controller was completed in less than two hours. This enabled us to concentrate on more important aspects of the project such as the identification algorithm and performance maximization.

The active damping system is now being further developed towards a product. The first application in a customer elevator system is expected to appear soon.

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Comparison of measured ride quality during emulated lift travel.