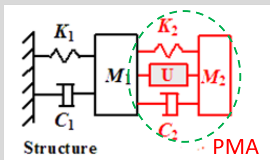
Active Vibration Control Using Proof Mass (Inertial) Actuators

Proof mass actuators (PMAs) are used to add tuned damping and tuned dynamic absorption to a test structure as well as the rear sub-frame of an all-wheel drive vehicle.

The choice of active vibration control strategy, with a PMAs as the actuator, depends on whether the PMA's natural frequency is placed below or within the frequency(ies) of the structure targeted for damping/dynamic-absorption. A sample of such controllers are:

> A proof mass actuator (PMA) is comprised of parallel arrangement of spring and an active element pushing/pulling against a mass (known as proof mass or inertial mass). Some damping is also built in its make-up.
>
> PMAs generate force by pushing against a suspended mass and thus do not need an anchor point.



1. With the natural frequency of the PMA set substantially lower than the natural frequency of the structure targeted for damping/absorption. This arrangement enables the control designer to use traditional and familiar active control schemes.
2. With the natural frequency of the PMA set within (or at) the frequencies of the structure targeted for damping/dynamic-absorption, the dynamics of the actuator will be introduced into the dynamics of the structure. This in turn, makes the synthesis of active control strategy somewhat more involved/elaborate. The advantage of such strategy is lower power consumption of the actuator.

Active Vibration Control of a Test Structure

With the goal of adding tuned damping and/or tuned vibration absorption to a test structure, two controllers dubbed TMD and DA fashioned after the dynamics of a passive tuned mass damper and dynamic absorber were designed and implemented, experimentally. One piezoelectric proof mass actuator was used in this experiment.

A TMD controller was used to damp the 3rd mode of the structure. Moreover, with an external excitation force (causing forced vibration) at the frequency of 750Hz, a DA controller tuned to that frequency was used to absorb the corresponding forced vibration of the structure.

The frequency response functions (FRFs) mapping the disturbance to the measured acceleration of the uncontrolled and controlled structure are shown in Figure 1. Around 20dB damping effectiveness (10 times reduction) is obtained at the target mode. Moreover, at the frequency 750 Hz to which the DA controller was tuned, a substantial absorption of vibration was realized.

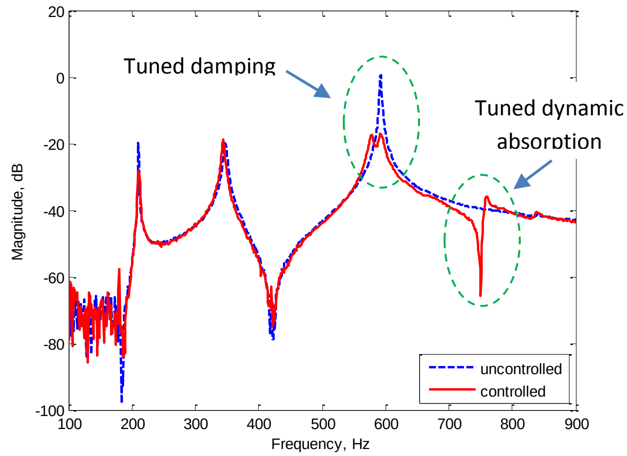


Figure 1 FRFs mapping the perturbation input to the acceleration without (dashed line trace) and with (solid line trace) TMD/DA and active control

Active Vibration Control of a Rear Sub-frame

Two electromagnetic PMAs were used to actively absorb the forced vibration of the rear differential of a car and thus lower its transmission to the vehicle cabin. An active DA controller was used in this application.

2 PMAs installed on rear sub-frame

Using the acceleration measured by the feedback sensor on the front bushing of the rear sub-frame, the frequency response functions mapping the voltage driving a shaker (installed on the drive shaft) to the aforementioned accelerations were measured. Figure 2 shows the magnitude of these FRFs with the control loop open (blue/solid line traces) and closed (red/dashed line traces). The presence of a zero (a notch) at 420 Hz on the FRF of they system with controls (the red trace) points to the effectiveness of the active vibration control scheme in absorbing vibration at the frequency of interest.

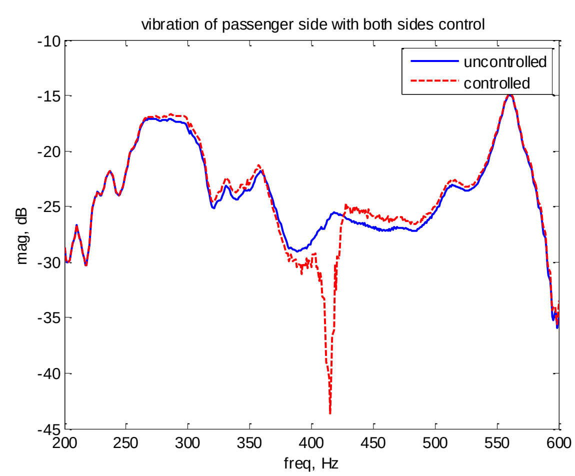


Figure 2 FRFs of accelearion of driver side sub-frame busing