Chapter 8
Analysis of a Tuned Vibration Absorber for Resonant Plate Shock Testing

Adam J. Bouma and David E. Soine

Abstract Vibration absorbers have vast applications in dynamic structures and can be applied to resonant fixtures for mechanical shock testing. Resonant structure techniques using plates or beams is an accepted method for simulating high-frequency pyroshock-type environments at the component and assembly level. In this paper, the resonant plate is the primary system, and a cantilevered fixture is used as a tuned vibration absorber to modify and tune the resonant frequencies of the plate. Model driven test design of the system is used to investigate the effect of the mass of the cantilevered fixture, mounting location on the plate, and pulse duration of the input force to modify the response of the resonant plate. Initial model validation and testing shows that the response of the resonant plate is modified with the addition of a tuned vibration absorber. The goal of this paper is to investigate the response of the system when using a vibration absorber for a mechanical shock test for the intent of tunability of the system.

Keywords Mechanical Shock · Tuned Absorber · Resonant Plate · Modal Analysis

Introduction

Dynamic vibration absorbers (DVAs) and Tuned Mass Dampers are mechanical attachments consisting of auxiliary masses with stiffness and damping to assist in controlling the amplitude of a vibrating system, termed the primary system [1]. The primary system can be protected from excessively high vibration levels with the use of tuned absorbers which can be included in the original system or added to an existing system. A DVA is also used to suppress vibration over a frequency band, generally in the vicinity of a targeted frequency. In this circumstance, a good trade-off between the suppressed original peak and the two newly emerged coupled peaks induced by the insertion of the absorber is crucial to obtain a global vibration reduction within the frequency band of interest [2].

The resonant plate shock test is a dynamic test where a test article is mounted on one side of the plate and a projectile is struck against the opposite side to simulate a mid-field pyroshock environment with the goal of exciting the breathing mode of the plate [3]. Using a tuned vibration absorber, the bending modes and breathing mode can be shifted in frequency or new modes can appear, depending on the application. The first three flexible modes of a free-free plate are shown in Figure 1 [4]. In this study, a cantilever type mass is used as a tuned vibration absorber to alter the response of the resonant plate and was used for previous studies on multi-axis response of mechanical shock tests [5]. Several parameters can be adjusted to

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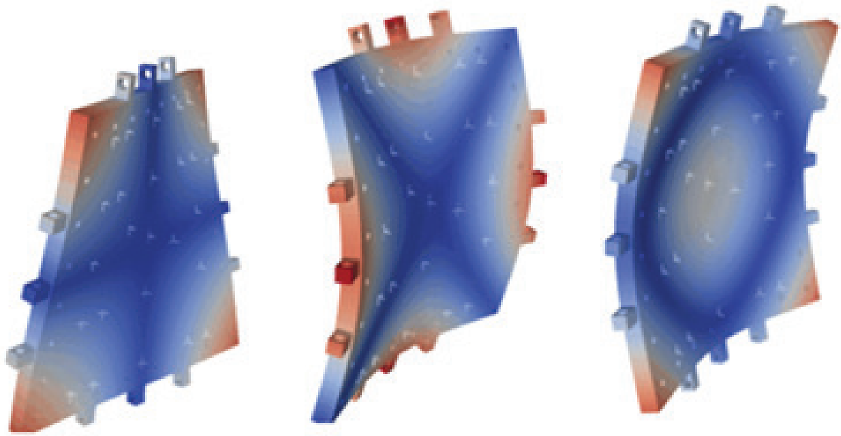
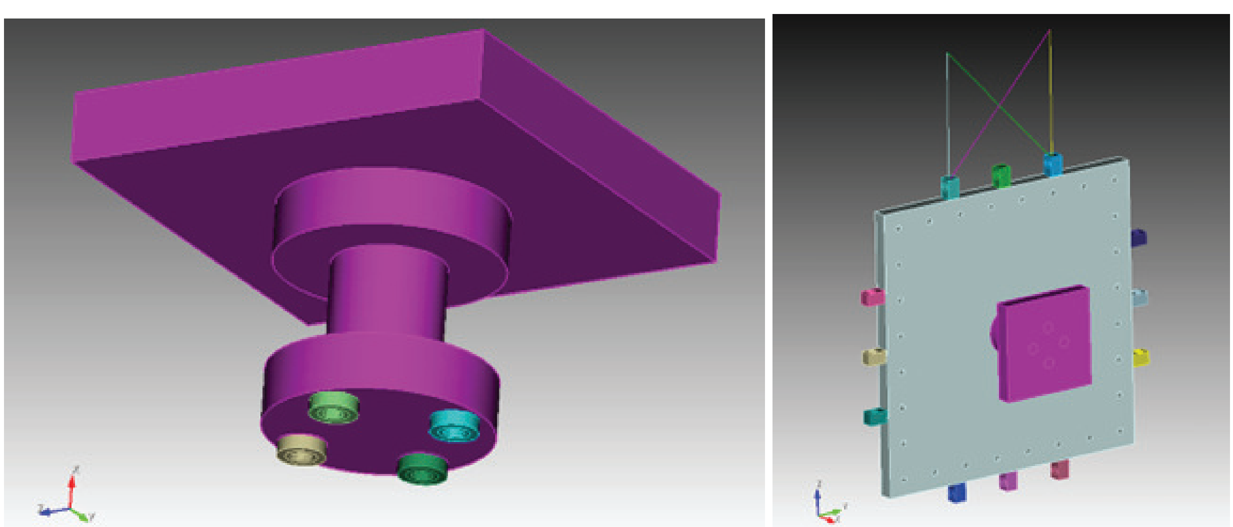


Fig. 1 First three modes of the resonant plate (twist, saddle, and breathing).

alter the modes of the plate, including tuning the mass of the cantilever fixture to the breathing mode of the plate, mounting location on the plate, and the pulse duration.

Tuned Vibration Absorber Design and Model Setup

For this analysis, the tuned vibration absorber used is a cantilever fixture consisting of a cylindrical adapter, surrogate fixture, and precision spacers with a weight of approximately 9.4 lb, shown in Figure 2a. The resonant plate used in this analysis is the 500 Hz plate, which is 23.73x23.73x1.25 inches in Figure 2b. Rope anchors are included, along with edge nodes representing the ropes that suspend the plate. Four point masses of 0.4125 lb each were added to each edge of the surrogate fixture to tune the fixture to the same frequency as the breathing mode of the resonant plate, shown in Figure 3. The untuned bending mode of the cantilever fixture is approximately 565 Hz. The breathing mode of the bare resonant plate and the bending mode of the tuned vibration absorber occurs at ~485 Hz. Several simulation runs were conducted, including impacting in the center of the plate with the fixture mounted in the center and also offset fixture configurations. The pulse duration of the input force will also affect the response of the system. The synthesized haversine pulse used for these simulations is shown in Figure 4, with a duration of 0.5 ms, 1.0 ms, 1.5 ms, 2.0 ms, and 2.5 ms and a magnitude of 10,000.



(a) (b)

Fig. 2 (a) Cantilever fixture with precision spacers and (b) cantilever fixture mounted in the center of the resonant plate.

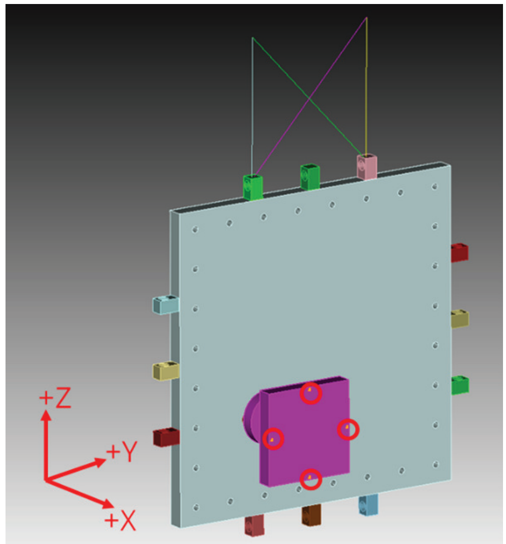


Fig. 3 Cantilever fixture mounted in the (-4.5, -4.5) configuration with point masses on each edge of the surrogate fixture.

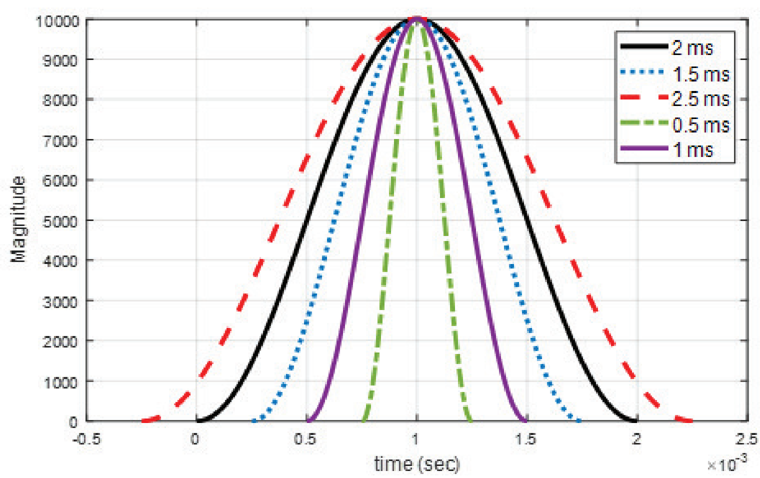
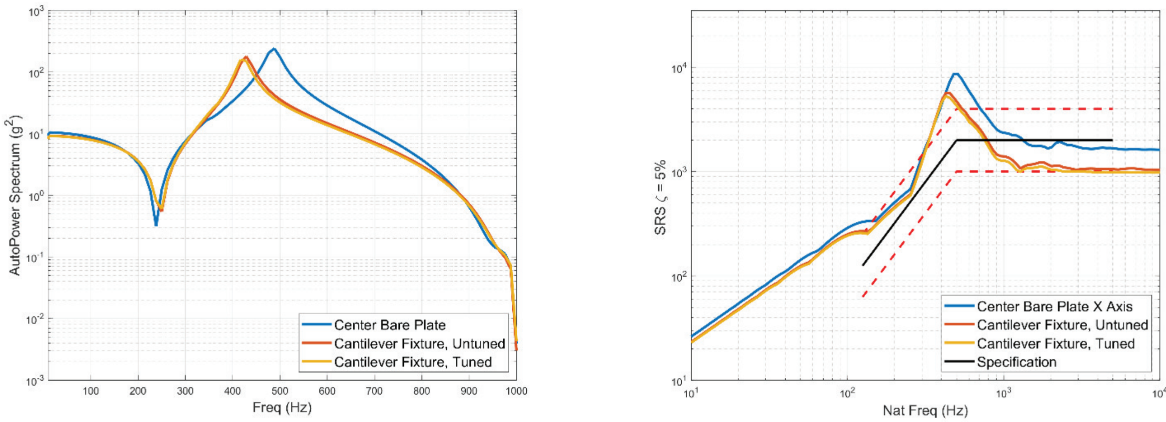


Fig. 4 Generated input force with varying pulse duration and 10,000 magnitude.

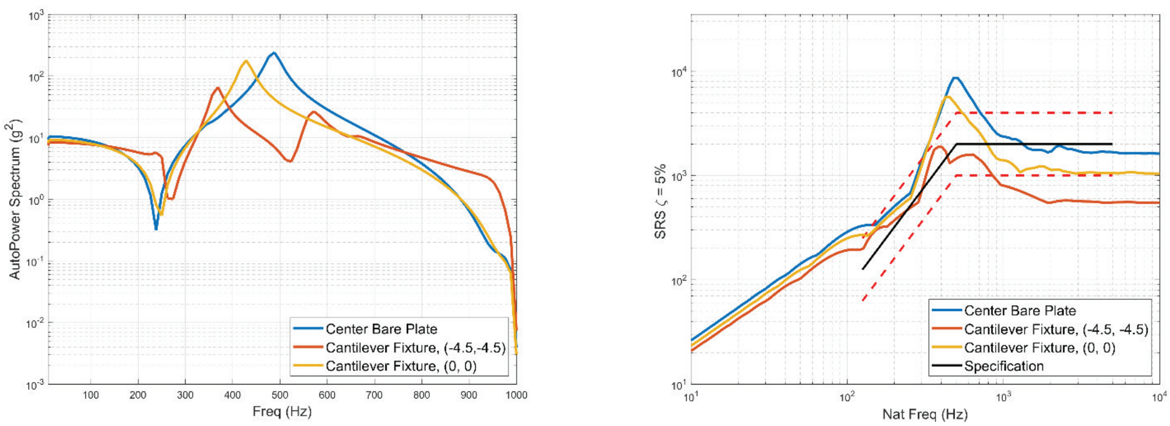
Simulation Results

The following results are based on comparisons made between the response of the resonant plate with a vibration absorber when changing the impact pulse and mounting locations on the resonant plate. By tuning the cantilever fixture to match the breathing mode of the resonant plate, the knee frequency is shifted to ∼410 Hz in the Shock Response Spectra (SRS), shown in Figure 5. Tuning the fixture to match the breathing mode of the resonant plate shifts the response again, but only slightly, and the frequency peaks in the FFT is slightly higher than the SRS due to 5% damping. When moving the cantilever fixture to the offset configuration, two new resonance peaks appear at approximately 369 Hz and 571 Hz. This is seen in Figure 6, and the knee frequency is now driven by the 369 Hz response, and the magnitude is much lower than when the tuned absorber is mounted in the center of the plate. Figure 7 shows the response of the fixture when changing the pulse duration of the input force. A shorter duration pulse excites higher frequency modes while a longer duration pulse excites lower frequency modes, which is seen particularly in the x (axial) response of the SRS. The knee frequency will change depending on the input force.



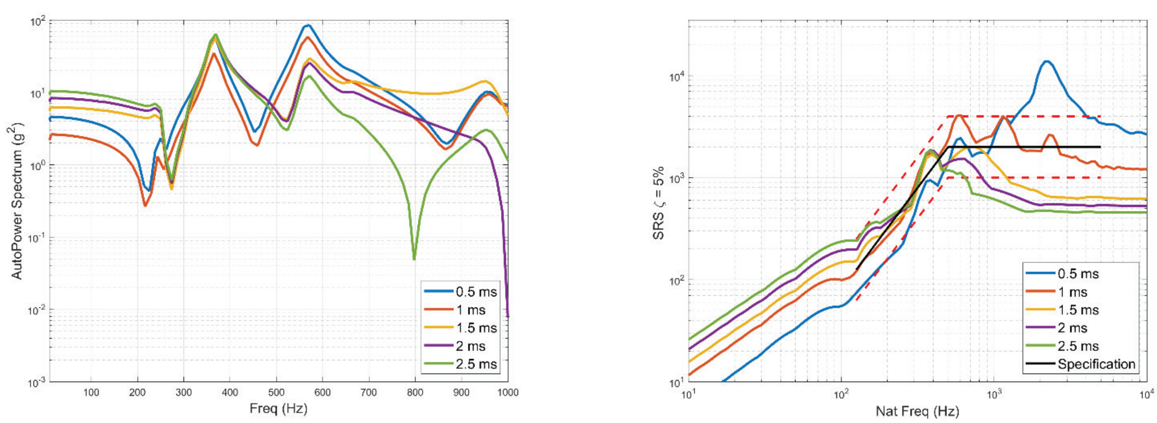
(a) (b)

Fig. 5 FFT and SRS of bare plate, untuned cantilever fixture, and tuned cantilever fixture with a center hit.



(a) (b)

Fig. 6 FFT and SRS of bare plate and cantilever fixture mounted in the center and offset configurations.



(a) (b)

Fig. 7 FFT and SRS of center hit with cantilever fixture mounted offset in configuration (-4.5, -4.5), comparing force input pulse duration.

Conclusions

The primary goal of this paper is to investigate the response of a resonant plate when adding a tuned vibration absorber. The bending mode of a cantilever fixture was tuned to the breathing mode of the resonant plate using point masses. The results presented show that the addition of the tuned vibration absorber will shift the knee frequency in the SRS, depending on the mounting location on the resonant plate. This is due to the tuned absorber creating two new resonant peaks, one lower and one higher than the breathing mode of the plate. Finally, the pulse duration will affect the response of the resonant plate and fixture. Further investigation should be pursued to optimize the design of a tuned vibration absorber for resonant plate shock simulation and testing.

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