Chapter 14
Fixture Design and Analysis for Multi-axis Mechanical Shock Testing

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Abstract Resonant plate shock testing techniques have been used for mechanical shock testing at Sandia for several decades. A mechanical shock qualification test is often done by performing three separate uniaxial tests on a resonant plate to simulate one shock event. Multi-axis mechanical shock activities, in which shock specifications are simultaneously met in different directions during a single shock test event performed in the lab, are not always repeatable and greatly depend on the fixture used during testing. This chapter provides insights into various designs of a concept fixture that includes both resonant plate and angle bracket used for multi-axis shock testing from a modeling and simulation point of view based on the results of finite element modal analysis. Initial model validation and testing performed show substantial excitation of the system under test as the fundamental modes drive the response in all three directions. The response also shows that higher order modes are influencing the system, the axial and transverse response are highly coupled, and tunability is difficult to achieve. By varying the material properties, changing thicknesses, adding masses, and moving the location of the fixture on the resonant plate, the response can be changed significantly. The goal of this work is to identify the parameters that have the greatest influence on the response of the system when using the angle bracket fixture for a mechanical shock test for the intent of tunability of the system.

Keywords Mechanical shock · Fixture design · Resonant plate · Modal analysis

14.1 Introduction

Simulations of pyroshock events have been performed in the laboratory for many years using resonant structures. Resonant structure techniques using plates or beams are an accepted method for simulating high-frequency pyroshock-type environments at the component and assembly level. For resonant plate shock testing, a test article is attached to the front side of a tuned resonant plate with free boundary conditions while a projectile is fired into the back of the plate using an air gun. The impact of the projectile against the plate causes the plate to respond, consequently exciting the test article. Many factors are considered when planning a pyroshock test, including the size of the resonant plate, type of test fixture, location of the unit under test, and location of impact by the projectile, to name a few. Figure 14.1 depicts a typical resonant plate shock test machine in the laboratory. If the unit under test or the location of impact by the projectile is at an off-center location, a larger multi-axis response can be achieved by a single-axis input in one direction, but significant component over-test in one direction may occur. Multi-axis response during mechanical shock testing has been studied recently by investigating the response of the system when the component under test was positioned at the plate's center and the impact was located offset toward one corner of the plate [1, 2]. The measured responses indicated generally good agreement with the test specifications

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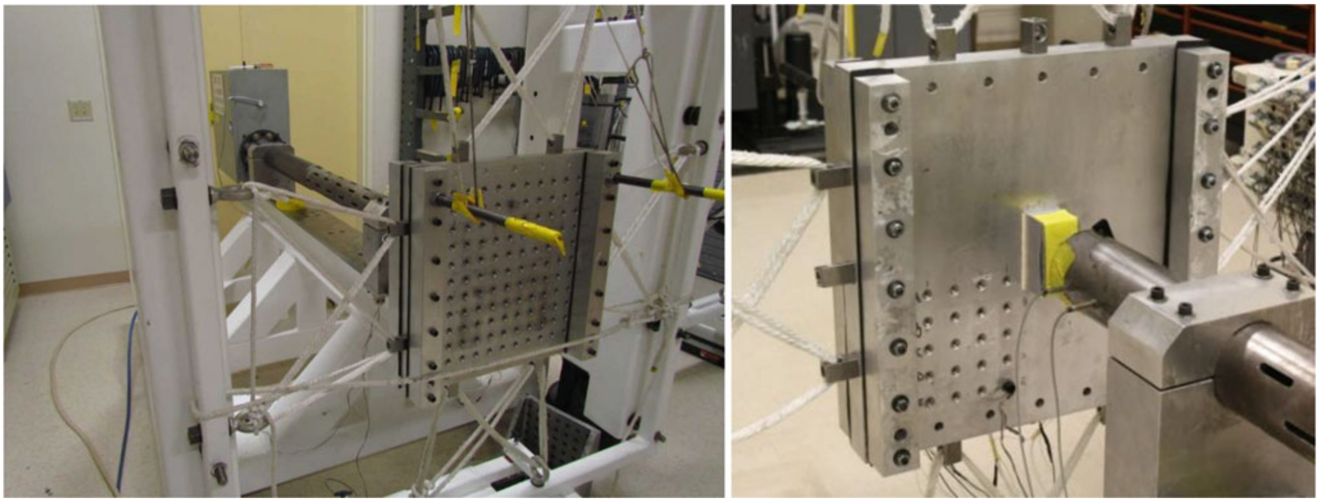


Fig. 14.1 Typical resonant plate test setup

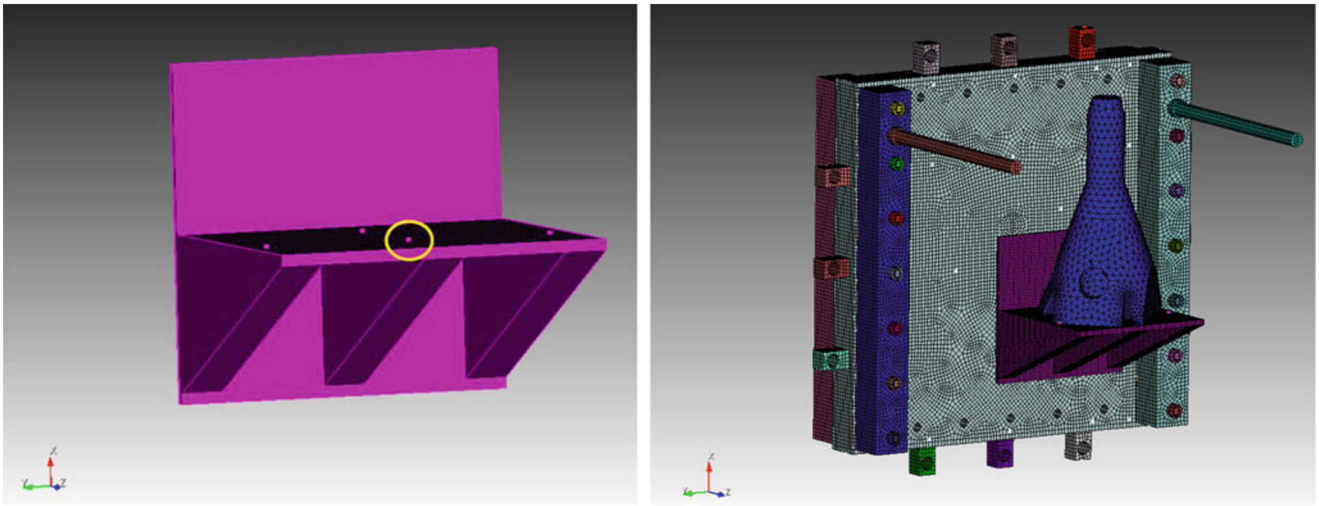
in two directions and slightly high inputs to the component in the third axis. Although this study by Hopkins and Sisemore [1] was considered a success, further tests are needed to bring the off-axis responses into closer agreement with test specification. The output response is a coupled response of the transverse plate vibration and the rotational motion of the component on the plate. Recent efforts in modeling and simulation as well as testing of the resonant plate with and without a component under test have been able to provide insight into the mode shapes of the plate itself and help understand the true test environment [3, 4]. Model-driven test design should be developed and validated for a single test that excites the multi-axis environment simultaneously without over-testing in a single direction. This report aims to use the model-driven test design method to design an angle bracket test fixture for multi-axis mechanical shock testing.

14.2 Angle Bracket Fixture Design

For this study, an angle bracket fixture is used. The fixture consists of an 8 × 8 inch platform with 0.5-inch-thick ribs along the bottom for support normal to the angle bracket. The base and angle plates each have a thickness of 0.25 inches. Only the mounting location of the fixture, along with the impact location, is varied for this study. This angle bracket design is seen in Fig. 14.2, both by itself and mounted off-center on the resonant plate with a test mass, including the response axes as well. The configurations for the location of the angle bracket fixture and test mass are seen in Table 14.1, where the impact location changes from the middle of the plate to one of the corners, and the fixture location changes from the middle of the plate to the opposite corner of the impact location. The impact force used for these simulations is based on previous multi-axis pyroshock test data with similar configurations [4].

14.3 Simulation Results

The following results are based on the configurations of Table 14.1, where a comparison is made between response of the angle bracket fixture when changing the impact and mounting locations on the resonant plate. Figures 14.3, 14.4, and 14.5 show the frequency response and shock response spectra and are based on a tri-axis measurement point located on the platform of the angle bracket as highlighted in Fig. 14.2a. From Fig. 14.3, the response normal to the plate (z-direction) is much higher than the off-axis (x- and y-direction) responses. When the impact location is moved off-center, the off-axis responses are considerably increased, as seen in Fig. 14.4. Figure 14.5 shows that moving the impact location and the fixture opposite of each other increases the off-axis responses even more, with results similar to the response normal to the resonant plate.

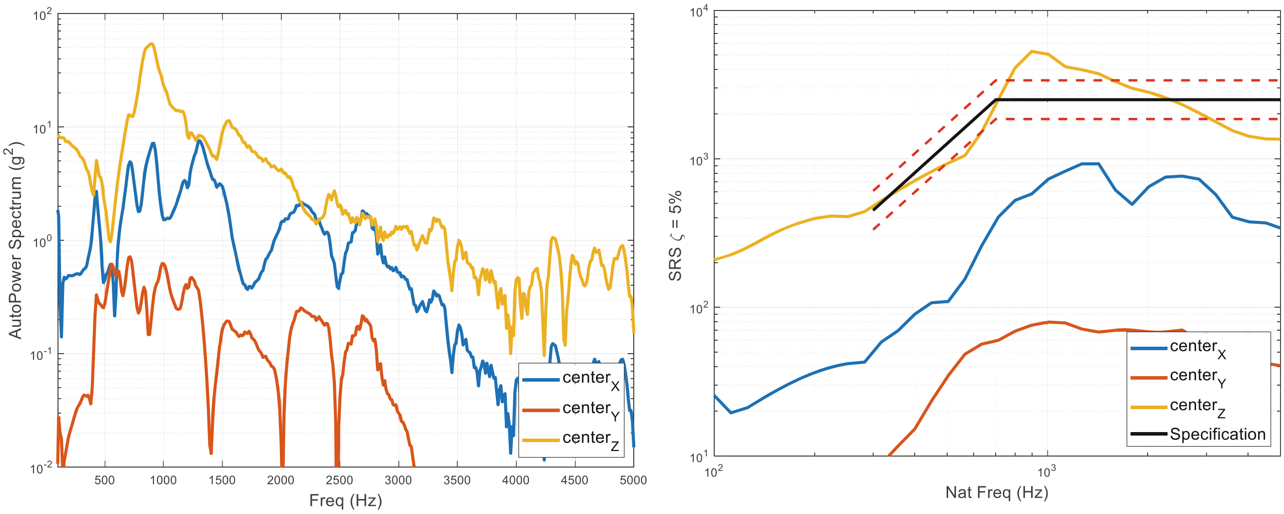


(a) (b)

Fig. 14.2 (**a**) Angle bracket design and (**b**) angle bracket mounted on the resonant plate along with testing mass

Table 14.1 Configurations for the angle bracket for resonant plate testing

Configuration type	Impact and fixture location (inches)	Case #
3 rib configuration	(0, 0) & (0, 0)	1
	(3.0, 3.0) & (0, 0)	2
	(3.0, 3.0) & (−3.0, −3.0)	3

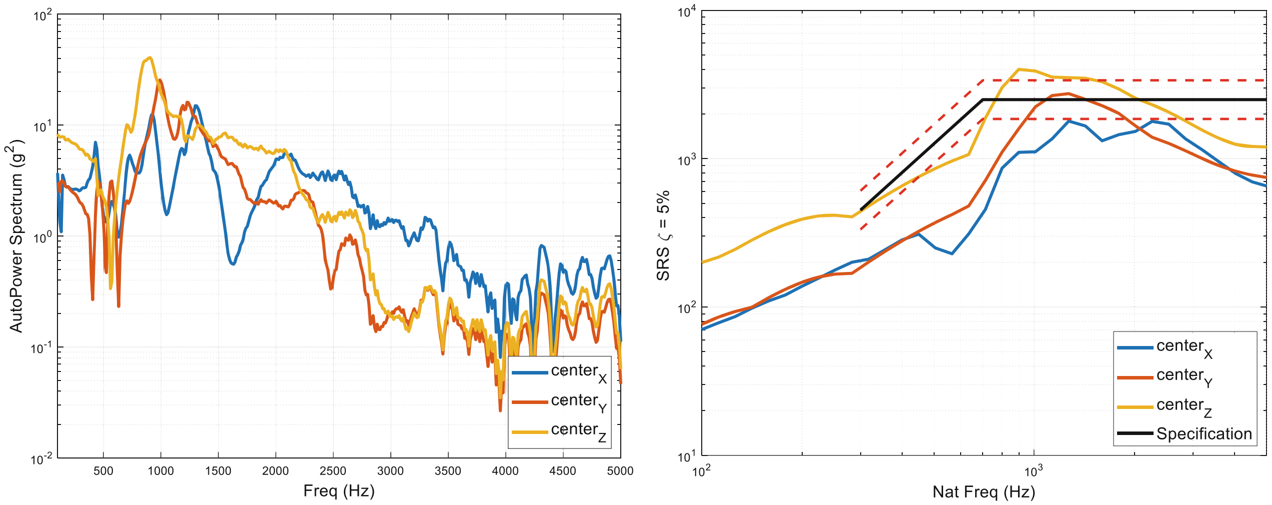


(a) (b)

Fig. 14.3 (**a**) Frequency response spectra and (**b**) shock response spectra of the angle bracket for case 1

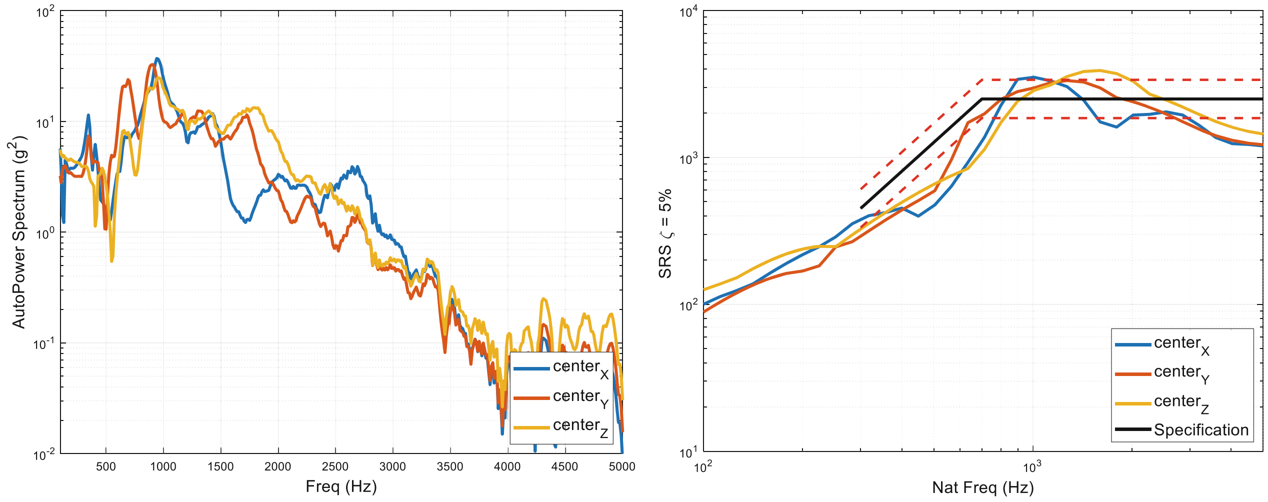
14.4 Conclusions

This chapter presents results of simulations of an angle bracket fixture for multi-axis pyroshock testing. Model-driven test design is a valuable tool for understanding the preliminary response of fixtures before using them in the laboratory in an actual test. The results presented show that the off-axis responses will increase to levels similar to the response normal to the plate when moving the impact and fixture location opposite of each other. Further work should be pursued to develop an angle bracket that provides a true multi-axis response from a single-axis input in a laboratory environment.



(a) (b)

Fig. 14.4 (**a**) Frequency response spectra and (**b**) shock response spectra of the angle bracket for case 2



(a) (b)

Fig. 14.5 (**a**) Frequency response spectra and (**b**) shock response spectra of the angle bracket for case 3

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