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Vibroacoustic Response Data of Stiffened Panels and Cylinders

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ABSTRACT

NASA has collected vibroacoustic response data on a variety of complex, aerospace structures to support research into numerical modeling of such structures. This data is being made available to the modeling community to promote the development and validation of analysis methods for these types of structures. Existing data from two structures is described, as well as plans for a data set from a third structure. The first structure is a 1.22 m by 1.22 m stiffened aluminum panel, typical of a commercial aircraft sidewall section. The second is an enclosed, stiffened aluminum cylinder, approximately 3.66 m long and 1.22 m in diameter, constructed to resemble a small aircraft fuselage with no windows and a periodic structure. The third structure is a filament-wound composite cylinder with composite stiffeners. Numerous combinations of excitation and response variables were measured on the structures, including: shaker excitation; diffuse acoustic field; velocity response from a laser vibrometer; intensity scans; and point acceleration.

1. INTRODUCTION

NASA has an interest in promoting the development of analysis tools for the vibroacoustic response of aerospace structures. This includes the perspective of an end user, as in the space program, where tools are used to predict vibration and interior acoustic levels during liftoff. It also includes research interests, as in the Fundamental Aeronautics program, where tool maturation and propagation of best-practices can improve the passenger experience in civil aeronautical vehicles. Tools for middle and high frequencies are of particular interest, where the modal density of acoustic spaces and structural components is so high as to require excessively fine finite element grids, or the uncertainty in boundary conditions makes it difficult to generalize conclusions based on the output of deterministic modeling tools [1, 2].

The goal of the present work is to give an overview of publicly available high quality vibroacoustic data sets that have been acquired or will be acquired on three test structures at NASA

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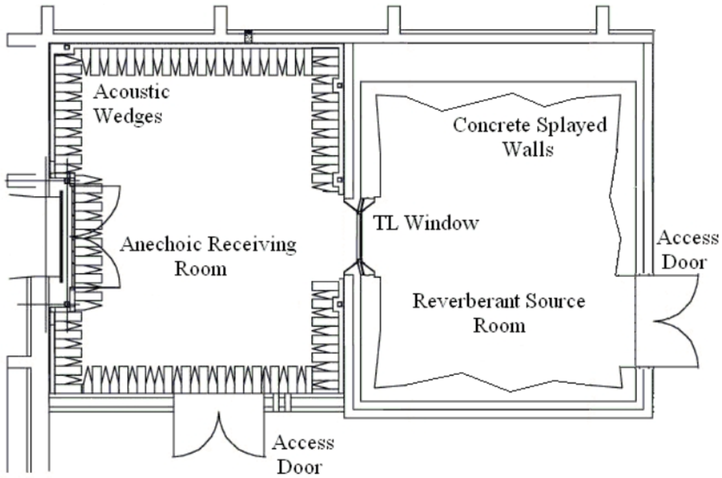


Figure 1: SALT Facility.

Langley. These data sets will hopefully complement other efforts to further the development and validation of modeling tools [3]. The test structures discussed here consist of a stiffened aluminum panel, representative of the sidewall of an aircraft fuselage; a stiffened aluminum cylinder capable of being pressurized, representative of a small aircraft fuselage with no windows; and a stiffened composite cylinder, also representative of a small aircraft fuselage without windows. Multiple tests have been conducted on the stiffened panel and aluminum cylinder, and data from six of those tests is described here. Data that will be acquired in a future test on the composite cylinder will also be described. Finite element models of each structure are also available.

Each dataset is briefly described here, and more details are available to persons interested in the data. It is hoped that these data sets will encourage additional research, the development of training tools, or tool maturation for middle and high frequency vibroacoustic analyses. Persons interested in the datasets should contact the authors of this paper by email for more information.

2. FACILITY AND INSTRUMENTATION

Vibroacoustic measurements on the structures discussed in this paper were typically conducted in the Structural Acoustic Loads and Transmission (SALT) facility at NASA Langley Research Center. The SALT facility is a transmission loss suite with a window between a reverberant source room and an anechoic receiver room. Depending on the test requirements, the facility can be used either as a TL facility, an anechoic room, hemi-anechoic room, or a reverberation test chamber. The facility and associated instrumentation are briefly described here. The test structures and more detailed documentation of the tests performed on these structures are discussed in Section 3.

A schematic of the SALT facility is shown in fig. 1. The facility consists of a 278 m^3 reverberation room and a 337 m^3 anechoic room connected by a transmission loss window with a 1.37 m by 1.37 m opening. The facility is qualified down to the 100 Hz one-third octave band [4]. Below this frequency band, the modal density of the reverberation room is not sufficient to approximate a diffuse sound field and the free field assumption for the anechoic room begins to break down.

Two primary sources were used for exciting structures studied in this facility. For experiments requiring point force excitation, shakers combined with impedance heads at the drive point were used. This allowed identification of the excitation force and input power applied to the structure. For tests requiring a diffuse acoustic excitation, a large number of acoustic sources were driven incoherently inside the reverberation room. For either excitation, a wide variety of transducers were used to measure the vibroacoustic response of a test structure, depending on the test requirements. These transducers included:

- a large number of accelerometers
- various types of microphones
- impedance heads
- a scanning laser vibrometer
- two-microphone intensity probes

The accelerometers and microphones were used to measure the response of the test structure at fixed points on or near the surface. Microphones were also used inside the reverberation room to characterize the diffuse acoustic excitation. Impedance heads were used to quantify the force and power applied to a structure at the shaker drive point. The scanning laser vibrometer was used to make non-contact measurements of the velocity response of the surface of a structure at a user defined mesh of points. Several two-microphone intensity probes, mounted to a traverse mechanism on the anechoic side of the transmission loss window [5], were used to measure the spatial intensity distribution radiated by a structure.

Transducer responses for tests on the stiffened panel and aluminum cylinder were acquired using either a 16-bit data acquisition system, the laser vibrometer control computer, or some combination of the two. A newer, 24-bit data acquisition system, in addition to the laser vibrometer control computer, will be used to acquire responses on the composite cylinder test. For all of the acquired data, care was taken to ensure that the measured signals were within the dynamic range of the acquisition hardware being used. All experimental data described in this paper are available in engineering units.

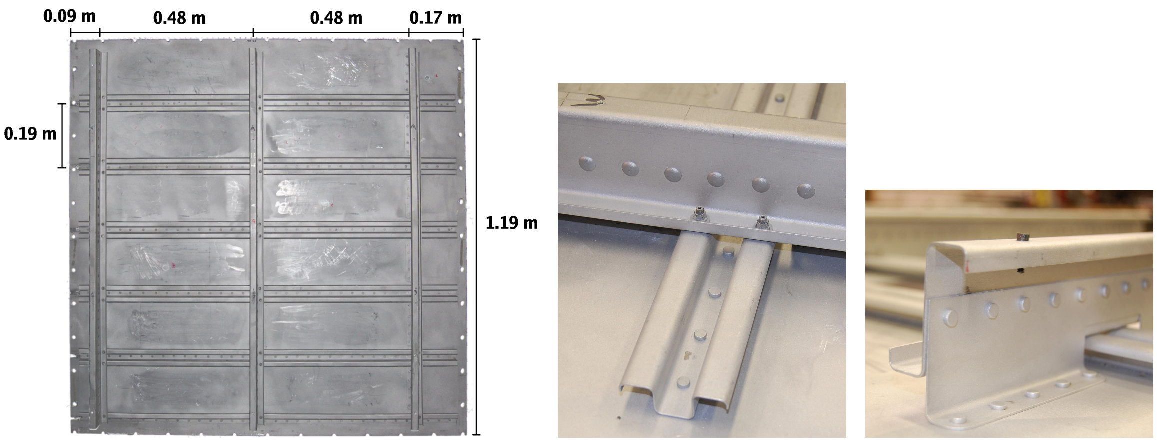
The particular transducers used in each test are listed in Section 3. For brevity, the signal conditioning used for the specific transducers is not documented here.

3. TEST ARTICLES AND TEST CONFIGURATIONS

Details of the three test articles are described here. For each test article, a table is included that lists the types of excitations and the transducers that were used.

A. Stiffened Aluminum Panel

Several tests have been conducted on a stiffened aluminum panel that has a 1.27 mm thick skin. This panel was originally constructed to represent the sidewall of an aircraft fuselage without curvature [6]. The stiffened side of the panel is shown in fig. 2(a). Six horizontal stiffeners, or stringers, and three vertical stiffeners, or ring frames, are attached to the panel along single rivet lines. Photos of the inverted hat-section stringer and ring frame are shown in figs. 2(b) and 2(c). Cutouts in the shear tie (the L-shaped member connecting the Z-section ring frame to the panel) where the ring frame passes over a stringer are evident in fig. 2(c). The bottom flange of the Z-section is bolted to the top flange of the stringer, as seen in fig. 2(b). The stringers are made from 1.02 mm thick aluminum; the ring frames from 1.27 mm thick aluminum.



(a) Panel dimensions and shaker locations.

(b) Stringer.

(c) Ring frame and shear tie.

Figure 2: Test structure.

Test Id.	**Configuration**	**Excitation**	**Response Transducers**
A	bare panel	diffuse field	intensity, laser
”	panel+trim	”	intensity, laser, accelerometer
”	panel+trim+isolators	”	”
”	panel+fiberglass	”	intensity, laser
”	panel+fiberglass+trim	”	intensity, laser, accelerometer
”	panel+fiberglass+trim+isolator	”	”
B	bare panel	diffuse field	intensity scans
”	”	shaker	intensity scans
C	bare panel	shaker	laser vibrometer
”	panel + damping	shaker	laser vibrometer

Table 1: Data sets for stiffened aluminum panel

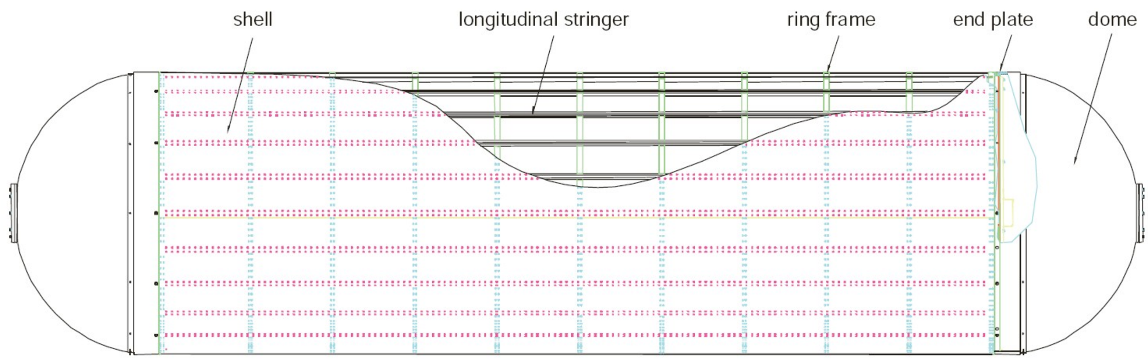


Figure 3: Aluminum Testbed Cylinder, cutaway view.

Data from three tests on the stiffened panel are being made available; excitations and response measurements from each test are listed in Table 1. The three tests are labeled **A**, **B**, and **C** in the far left column of the table. For all of these tests, the panel was clamped in the test window of the SALT facility.

For the **A** tests, the stiffened panel was configured with combinations of a trim panel, a bulk absorber, and vibration isolators between the trim panel and the stiffened panel. The stiffened side of the panel faced the anechoic room in SALT. The trim panel was a square aluminum panel, 1.22 m on each side, and 0.81 mm thick. A diffuse field was used to excite the stiffened panel, and intensity probes were used to measure sound radiation in the anechoic room. The laser vibrometer was used to measure the velocity of the stiffened panel in the reverberant room. When the trim panel was part of the test configuration, four accelerometers were mounted on that panel. For test configurations with the trim panel but no isolators, there was no mechanical connection between the trim panel and the stiffened panel.

The **B** tests on the stiffened panel used the intensity probes to measure sound radiation from the panel, with either a diffuse field or shaker exciting the panel. The data with the diffuse field excitation is a repeat of the first configuration in the **A** test.

In the **C** tests, a single shaker was used to excite the panel and the laser vibrometer was used to measure the panel's response. Data was collected for four different shaker locations; three of the locations were on the aluminum skin and one location was on the flange of a vertical stiffener. More detail on this test can be found in [7]. In the second of the two **C** configurations, two subpanels of the structure were covered with a stand-off constrained layer damping material with a bi-directional graphite composite constraining layer.

B. Aluminum Testbed Cylinder

Data is available from tests conducted on the Aluminum Testbed Cylinder (ATC). The ATC is an all-aluminum cylinder that was constructed to represent a scaled version of a typical metallic aircraft fuselage [8]. The cylinder is 3.66 m long and has a diameter of 1.22 m. The skin of the cylinder is 1.02 mm thick, and is stiffened by 11 ring frames and 24 equally spaced longitudinal stringers (see fig. 3). Double lines of rivets and epoxy were used to attach the skin to the frames and stringers. The ends are capped with airtight, 6.4 mm thick, fiberglass composite domes. These domes allow pressurization of the cylinder interior to 48 kPa to simulate flight conditions at altitudes up to 11000 m. Flat, particleboard end plates are located at either end of the cylinder's

Test Id.	Excitation	Response
D	single shaker	laser vibrometer and accelerometers
E	diffuse acoustic field	laser vibrometer
F	four shakers, incoherently driven	laser vibrometer

Table 2: Data sets for Aluminum Testbed Cylinder

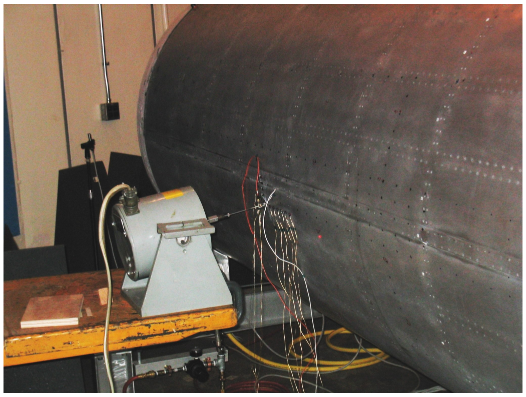


Figure 4: Single shaker excitation of ATC.

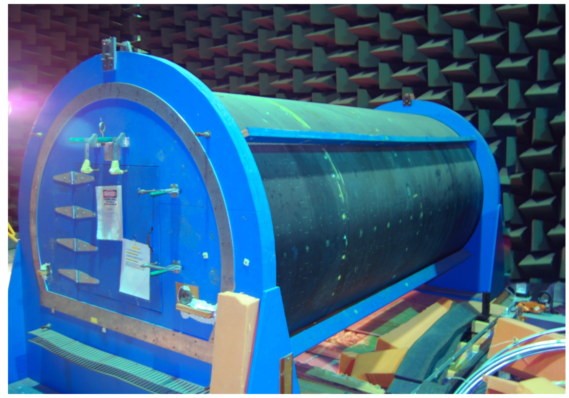


Figure 5: Exterior of composite cylinder.

interior to provide acoustically reflective terminations. The end plates contain several 1.27 cm diameter holes to allow the pressure on each side of the plate to equalize during pressurized tests.

Data from three tests on the ATC are being made available and are described in Table 2. For the first two tests, the ATC was located in the reverberant room of the SALT facility. For the third test, the ATC was located in the anechoic side of SALT, configured as a hemi-anechoic room. In all tests, measurements of the normal velocity response of the skin were made using the laser vibrometer. Impedance heads were used to characterize the shaker excitations. In addition, for the test with the single shaker excitation, accelerometers were placed on the excited bay to sense the response of this bay, which could not be measured using the laser vibrometer. For the diffuse acoustic excitation, the acoustic field was characterized using several microphones in the reverberant room.

C. Filament-wound, Stiffened, Composite Cylinder

Data will also be available from vibroacoustic tests on a stiffened, composite cylinder, shown in fig. 5. This data will be collected in the late spring and early summer of 2008. The test structure is a filament wound stiffened cylinder, 3.66 m long, with a 1.68 m diameter [9, 10]. The shell composite material consists of carbon fibers embedded in an epoxy resin. The ply sequence for the skin fibers is ± 45, ± 32, 90, ∓ 32, ∓ 45, for a total thickness of 1.7 mm. The skin is stiffened with 10 J-section ring frames and 22 evenly spaced hat-section stringers, riveted and bonded to the skin. The cylinder contains a 1.27 cm thick plywood floor, 0.544 m above the bottom of the cylinder. The cylinder is supported between two hard-walled rigid baffles, made from three layers of 32 mm thick particleboard. The cylinder's skin rests within grooves in the particleboard baffles.

In contrast to the ATC and stiffened panel, the cylinder will not be tested in the SALT facility at Langley. Instead, testing will be done in a large room with acoustically treated walls.

A single shaker will be used to excite the cylinder at various points on the cylinder's exterior, as indicated by the red circles in fig. 6. These locations include subpanels of the skin, stringers, and

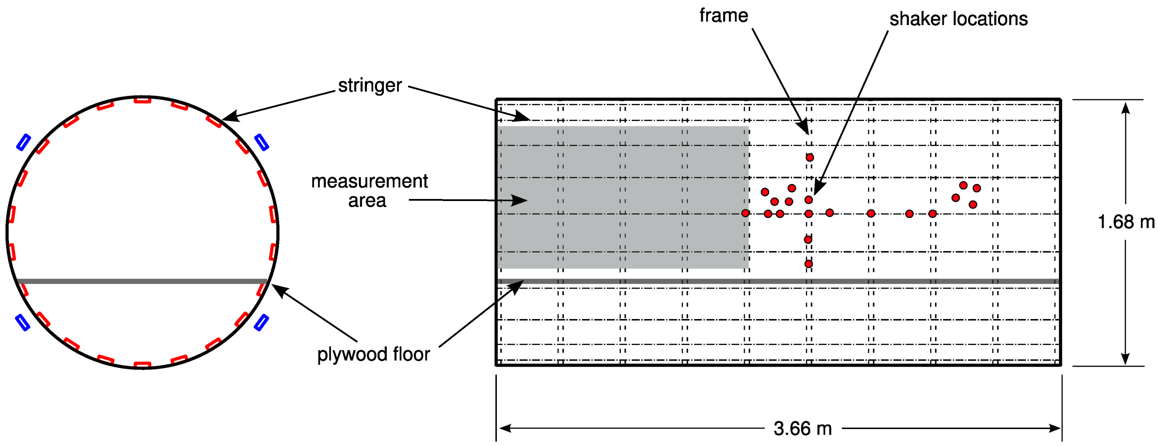


Figure 6: Composite cylinder excitation and response locations.

Test Id.	**Excitation**	**Response**
G	shaker on subpanel	laser vibrometer, interior mics, accelerometers
”	shaker on stringer (exterior)	”
”	shaker on ring frame (exterior)	”

Table 3: Planned data sets for composite cylinder

ring frames, as listed in Table 3. At each type of excitation location (skin, stringer, or ring frame), data will be collected from multiple shaker attachment points to study measurement variance and repeatability. A scanning laser vibrometer will be used to measure the velocity response of a portion of the cylinder's skin, as indicated by the shaded area in fig. 6. Accelerometers will be used to collect response data near the shaker drive point. Additional measurements will be taken to characterize loss factors of components of the structure, including the cylinder walls, the plywood floor, and the acoustic cavities above and below the plywood floor.

4. CONCLUSIONS

Publicly available data sets from vibroacoustic tests on three aerospace structures are described. Data are available from tests on a stiffened aluminum panel, a stiffened aluminum cylinder, and a stiffened composite cylinder. Excitations and response variables for the different tests are described. Excitations include single and multiple shakers, and a diffuse acoustic field. Response measurements include impedance head measurements, accelerometers, laser vibrometer velocity scans, and two-microphone intensity probe scans. Persons interested in the data sets are encouraged to contact the authors of this paper.

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