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Research paper

Study Measuring Characteristic of the High Intensity Reverberation Acoustic Chamber Performance

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Abstract

Reverberation Acoustic Test Facility (RATF) is a one of the mechanical satellite testing facility in the Assembly, Integration and Test Centre at National Space Agency (ANGKASA). This is the reverberation type of chamber with external volume at 999.5m3, has the capability to regenerate high intensity acoustic noise ambiance that will be experienced during the launching stage. This paper will describe on reverberation chamber characteristics, the noise generating system and capabilities, and the chamber configuration for high intensity acoustic testing in empty chamber condition. This paper recommends the measurement setting for three variant spectrum levels in generating high-intensity acoustic noise from 130dB to 155dB with center frequencies from range 31.5Hz to 1250Hz.

Keywords: *Composite; High intensity acoustic; reverberation chamber; noise generation system*

1. Introduction

High intensity noise causes structures to vibrate or move in response to the applied force. The extent of the motion or vibration depends upon the stiffness and damping of the structure. Flexible, lightly damped structures may readily develop large stresses in a high intensity acoustic field. The purpose of high intensity acoustic testing is to disclose a test component to a measured acoustic environment. This environment is capable in stimulating the actual flight surrounding to ensure the test component functionality is not impaired by severe launch or landing environments. Reverberation Acoustic Test Facility (RATF) is a latest facility in Assembly Integration and Test (AIT), In National Space Agency (ANGKASA). There are six (6) equipment for satellite testing at AIT that will provides testing conditions for the spacecraft and its payload. The AIT facility is able to simulate the actual launch and space environment as experienced by a satellite, spacecraft and its components during lift-off, separation stage and in orbit as well as able to be used to conduct testing and measurement for other field such as electronics and automotive.

The RATF building construction was completed in Jun 2014. RATF serve as a reverberation chamber which rebound the sound wave to entire points by highly reflective surfaces and the sound cannot propagate. A reverberant sounds field does not decay with increased distance from the source, but build up in inverse proportion to absorptive properties of the bounding surfaces [1]. The RATF, will simulate spacecraft launch and ascent acoustic environments reaching an overall sound pressure level at maximum 155dB and minimum 130dB. The test article is placed in a reverberant chamber and high intensity acoustic energy is generated to excite the test article to ensure and verify that electronic and mechanical component durability and tolerance which acoustic segment in launch profile [2]. The capability of test component to meet specified performance in a simulated environment during the launch period or in orbit entry can be demonstrated in acoustic test which a part of environmental test.

1.1 The Need of High Intensity Acoustic Testing

In satellite launch environment, a loud noise and strong acoustic pressure spread to the entire launch vehicle structure which produced by the propulsion system. Acoustic pressure from the engines exhaust propagates to the nose of the launch vehicle which leads to vibration occurrence that impacted a whole launch vehicle body. Satellite commonly has numerous components which are sensitive to sound and vibration.

Exposure to the high intensity noise by spacecraft component may cause problems as; failure of joints in structures from composite materials, crack on printed circuit boards, vibration of optical elements, failure of electronic component and chafing of wires [3]. Observation and failure mode show as described in Table 1 as below:

Table 1: Failure mode in high-intensity acoustic test

Failure mode	Observation of failure
Fatigue	Cracks
Wear and crystallization	Metal erosion, deformation
Malfunction	Electronic noise, Inverted actuation , Distortion, Erroneous signals

Elimination of premature failure and component fault during orbit operation can be achieved by exposing test article to the controlled and simulated field. Meanwhile, it's also assist in improving reliability of spacecraft components. RATF is a new facility at Assembly Integration and Test (AIT), investigation on facility performance is beneficial to support in conducting acoustic test effectively. Next section in this paper will explain on reverberation chamber characteristic, noise generation system, test configuration for high intensity acoustic and present the measurement results for low, medium and high level test.

2. Reverberation Chamber Characteristic

ANGKASA's acoustic chamber has an internal volume chamber at 999.5m3 with the size of 7.54m length (L) x 9.79m width (W) x 13.54m height (H). The 450mm chamber wall thickness was made from reinforced concrete wall which constructed to isolate it from adjacent facilities to avoid any effect from vibration coupling [4]. In reverberant acoustic field, the sound is bounded on all sides by highly reflective surface and the sound cannot propagate.

Main segment of RATF system include nitrogen (N_2) vaporization system, nitrogen gas (GN_2) distribution system, boiler system and close-loop acoustic control system. The system operation starts with conversion of liquid nitrogen (LN_2) using warm water in the vaporizer to produce nitrogen gas (GN_2). The warm water in vaporizer generated using propane gas delivery system and boiler system. Figure 1 shows the general segment of the RATF noise generation system. High-intensity acoustic noise for RATF produced by GN_2 which transferred into noise source modulators. High-intensity noise in the RATF chamber is measured, controlled and recorded by close-loop acoustic control system.

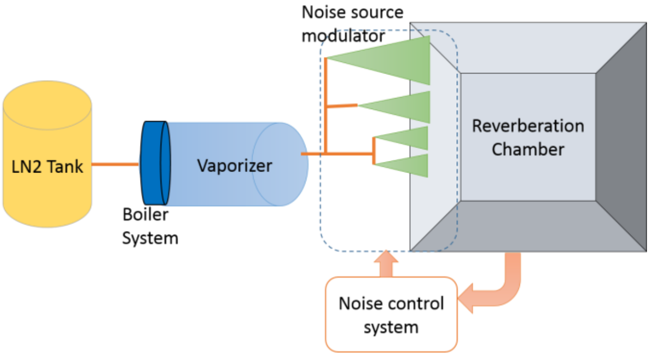


Figure 1: Configuration of RATF noise generation

RATF chamber had been installed four (4) unit electro-pneumatic gas stream modulators form Wyle Acoustic Source (WAS) as summarizes in the Table 2 as below. This chamber was designed to generate the maximum overall sound pressure level (OASPL) of 155 dB through exponential horns. RATF noise source comprising of WAS-3000 and WAS-5000 modulator, amplifiers and three (3) type of horns.

Table 2: RATF noise Equipment

No. of unit	*Equipment*	*Modulator Type*
1	25Hz Horn	WAS-3000
1	50Hz Horn	WAS-3000
2	200Hz Horn	WAS-5000

The signal generation and shaping system used in acoustic performance test to drive signal for both modulator, produce and control noise generated in the chamber and amplifies the signal to reach specific OASPL.

Spectrum analyser, the shaper and the noise controller are functions of closed loop Acoustic Control System (ACS). The significant function of ACS is to create known values of sound pressure level (SPL) per 1/3 Octave Band (OB) in the reverberation chamber [5]. ACS will control the generated signal, shape, split and amplify the noise source into different frequency bands and drive generated spectrum to the output which required for the acoustic test.

An acoustic power generated in the chamber was captured using an array of microphones which set up inside the reverberation chamber, used as input for the closed loop acoustic control system. The random noise signal generated by the acoustic controller, radiated to drive the acoustic power generators. Microphones feedback signals in the chamber are used as input to adjust the drive signal to achieve desired acoustic levels in controlled frequency field. The empty chamber test configuration of RATF close loop acoustic control system is shown in Figure 2.

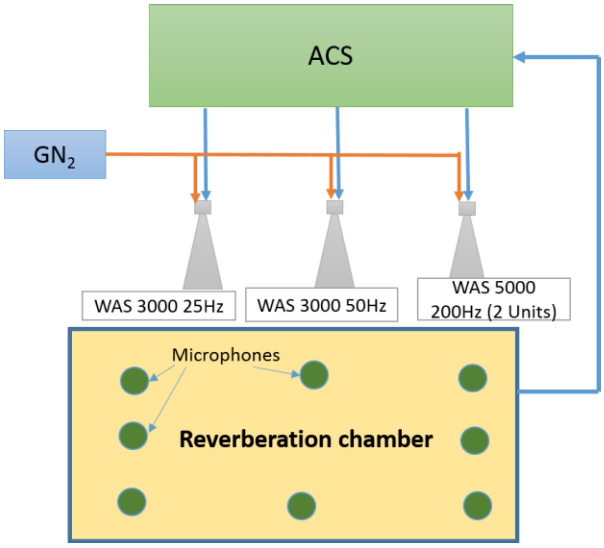


Figure 2: Configuration of RATF Close Loop Acoustic Control System

The ACS is combination of PAK software version 5.6 and hardware such as input module with digital processor and VXI mainframe that allowed fast output and input channels, and the control algorithm to automatically shape the desired test spectrum. The ACS output channel carries the command spectrum, which is pre-amplified, passed through a crossover filter, and finally amplified to drive the noise sources [5]. For this measurement, one-third OB with center frequencies from 31.5Hz – 1250 Hz is controlled by ACS. All sound pressure levels for this measurement are referenced to 20 micro Pascal. (20µPa = 0.000020 Pa).

3. Chamber Configuration for High Intensity Acoustic Testing

For high intensity empty chamber testing, the sound pressure level result was measured by maximum of eight (8) microphones which position at different locations inside the chamber as shown in Figure 2. The microphone position had been set up at least 750mm from the nearest reflecting surface such as wall and supporting equipment and the microphone stand height need to be configured at a minimum of three (3) elevations. A distance from any surface of at least 1/4 of the wavelength of the lowest frequency of interest is recommended [6].

Reflecting surfaces likes floor, ceilings and walls give higher acoustic pressure. The sound field quality which created around the test article can affected by the position of the microphones and testing probe in the chamber. Besides, oxygen level in the reverberation chamber had an effect on absorption of high frequency noise. A low oxygen level can be archived by supplying GN2 during test setup and help in reducing noise absorption for high frequency. Pure nitrogen environment conducts reverberation sound more efficiently than air and also reduces the possibility of device under test contamination.

3.1 High Intensity Acoustic Measurement Setting for High, Medium, Low Level Testing

For low level test measurement at 130dB, the measurement directly starts at the desired OASPL. Measurement parameters for 130 dB test had been set up and maintain within the range as in the Table 3. GN_2 pressure for modulator WAS 3000 had been controlled in range 22 to 25 psi. GN_2 temperature needs to be monitor along the experiment to maintain the GN_2 condition at 25C. For low level test, modulator WAS5000 is required to control the frequency up to 1.25 KHz. GN_2 pressure for this modulator need to be regulated in range 31 to 33 psi. Figure 3 presented the results for OASPL 130dB spectrum profiling.

Table 3: RATF pressure modulator setting for low, medium and high level test

Equipment / condition	Measurement setting		
	Low level test	Medium level Test	High level Test
WAS 3000	22 – 25 psi	24 - 26 psi	27 – 29 psi
WAS 5000	31 – 33 psi	32 - 34 psi	34 – 36 psi
GN2 Temp	25C	25C	25C

The medium level test had been set up for OASPL at 148 dB, precautionary step to avoid electrical equipment failure need to be taken by starting the test at -3dB stage (145dB), and then gradually increased to desired decibel at 148dB. The modulators setting for medium level test are slightly higher compare to low level test as shown in the Table 3.

Meanwhile, for target spectrum high level test at 155dB, the measurement starts at -6dB, then increased by -3dB before achieves the intention OASPL of high level decibel. The WAS3000 modulator pressure was setup, maintain and control within the range of 27 to 29 psi. Meanwhile, WAS5000 modulator was regulated in the range 34 to 36 psi. GN2 pressure had been controlled in the range 80 to 100 psi throughout the experiment and close monitoring of GN2 temperature to regulate at 25°C.

For medium and high level test, the GN2 temperature and modulator pressure has been set up and control within the measurement setting range shown in Table 3. By precise regulator of noise generation system, Figure 4 and Figure 5 presents the medium and high level test spectrum profiling at 148dB and 155dB respectively. The acoustic spectrum measurement reading shows in Table 4 as below. For RATF, the frequency range of interest includes the one-third OB with centre frequencies from 31.5 Hz to 1250 Hz.

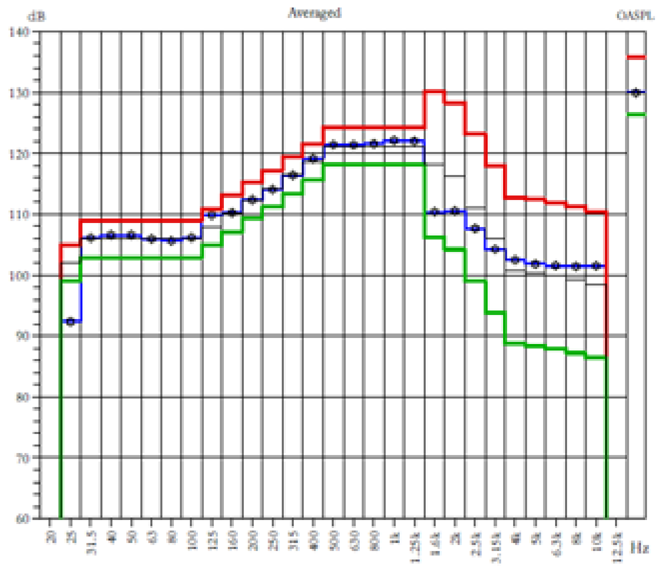
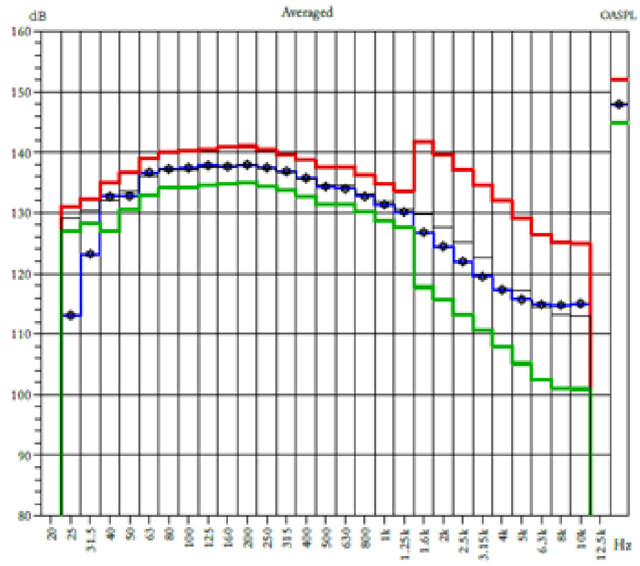


Figure 3: The result for 130dB spectrum profiling for low level test



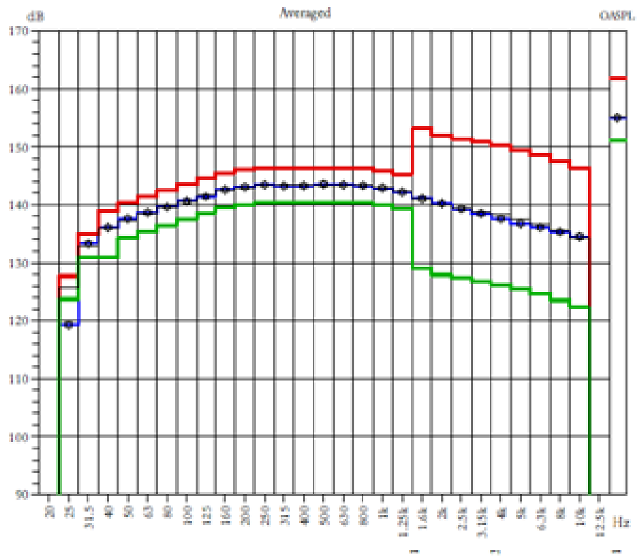


Figure 5: The result for 155dB spectrum profiling for low level test

Table 4: Acoustic Spectrum Measurement For The Low, Medium And High Level Test Spectrum

Center Frequency 1/3 OB (Hz)	*SPL Measured 1/3 OB (dB)*		
	Low Level	*Medium Level*	*High Level*
25	92.3	113.1	119.3
31.5	106.1	123.2	133.3
40	106.6	132.7	136.1
50	106.6	132.8	137.6
63	105.9	136.7	138.7
80	105.7	137.2	139.6
100	106.2	137.4	140.6
125	109.9	137.8	141.4
160	110.2	137.6	142.6
200	112.3	137.9	143.0
250	114.0	137.5	143.4
315	116.4	136.9	143.2
400	119.1	135.8	143.3
500	121.4	134.4	143.5
630	121.4	134.0	143.4
800	121.5	132.7	143.3
1000	122.1	131.4	142.9
1250	122.0	130.1	142.2
OASPL	130dB	148dB	155dB

4. Discussion

For low level test in Figure 3, 130dB of spectrum profiling has been obtained within tolerable value. The 130dB spectrum in the frequency range from 31.5Hz to 1.25k Hz surpasses to be regulated to match the desired acoustic emission by precise modulator pressure and temperature setting. From previous experiments, improper setting will affect low level test result to be overshot for more than 2 band of control spectra frequency less than 500Hz.

Based on prior experiment for medium and high level test, inappropriate setting will cause the overall test result not achieve desired acoustic emission with OASPL tolerance more than +-1dB. Pressure setting in each modulator's must be precise to regulate every control spectra running in the acceptable acoustic tolerance. For medium and high level, test plan must be set up ahead to avoid equipment failure and effectively the noise power source and consumable substances. Medium and high level test are conducted to perform at low decibel stage and increased by adding 3 dB for each stage until meets the desired decibel. For example, high level test at 155dB was started at 149dB, followed by 152dB before meets the desired acoustic emission. This is importance as a precaution step to avoid any unwanted electrical failure by monitoring closely on voltages and current value changes during testing stage transition.

The cost effective element is another crucial factor that reflect by precise setting of modulator and temperature control. Noise source for this chamber required LN2 as a main consumable element besides propane and other substances. The precise setting in controlling nitrogen driven horns gas pressure for each modulator is benefited in saving testing time and effectively consumes the noise source.

5. Conclusion

ANGKASA's RATF noise spectrum in the reverberation chamber manage been controlled and shaped to match desired acoustic emissions at low, medium and high level test and meets requirement of ANGKASA's chamber performance. Precise setting in modulators pressure and temperature is important to control acoustic emission to match the desired test spectrum besides adding value in cost effective element and saving testing time.

6. Way Forward

RATF is capable of stimulating experimental of high intensity acoustic condition to support aero-acoustic activities for aircraft structural, composite material, aerospace engine and others related. This facility also capable in supporting private sector related activities. For satellite mission, acoustic test is required as qualification of spacecraft components for structural and flight model to recognise the durability in acoustic environment of a launch vehicle. The acoustic test for the RazakSat Satellite structural model will be performing for familiarization with the actual satellite testing condition as an effort in supporting the RazakSat-2 Satellite testing during the development period in the near future.

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