Multi-axis testing of Under Wing and Ground Vehicle Weapons Systems

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ABSTRACT

High frequency multi-axis testing - controlled vibrations in all six degrees of freedom at the same time - is the latest tool used by the U.S. military for problem solving. This type of testing provides the test engineer with the most realistic duplication of the vibration environment, resulting in the ability to reproduce field observations in the laboratory, quickly solving the specific problem.

INTRODUCTION

The U.S. Army Redstone Technical Test Center (RTTC) is interested in performance characteristics of various weapons systems during their life cycle. Some of the weapons tested are mounted under the wing of aircraft. Others are mounted on ground vehicles. In the past most testing programs called for sequential vibration testing in the three perpendicular axes X, Y, and Z. This type of testing is still the “accepted” protocol in many industries including military and defense. However, if you truly want to simulate real-world vibration environments you must test in all six degrees of freedom X, Y, and Z plus the rotations of those axes Roll, Pitch, and Yaw.

Simulation of these environments, which are very different from each other, is best achieved using multiple degrees of freedom to accurately replicate “real-world” conditions. For Under Wing Weapons Systems the life cycle conditions include a combined environment of multi-axis vibration with high intensity acoustic noise, shaped per Mil-Std 810D.

Although there are many different Military Standards for performing vibration tests on weapons systems, none are currently written to address multi-axis testing of the weapons systems and/or component sub-assemblies of the weapons. RTTC’s efforts are aimed at better understanding the “real-world” environment, and replicating that in the laboratory. With the actual field data and results from reproducing that data in the laboratory, perhaps RTTC can begin to develop new standards for quantifying and qualifying new products.

CHALLENGES IN TESTING WEAPONS SYSTEMS

The automotive industry has been testing vehicles using multi-axis vibration systems for several years. To best simulate the environment that ground vehicle weapons systems must tolerate RTTC must look to perform the same types of tests. As weapons are carried on military vehicles such as tanks or APCs they will see vibrations similar to typical off-road vehicles. There will be times when severe low frequency, large displacement motions occur along with the typical rough road motions. Another vibration that will be induced into the test article will happen during live firing of the weapons. The weapons system will see an intense momentary torsional vibration during live firing.

To simulate the real-world environment of under wing weapons systems one must first examine the environment that these systems will experience during their lifetimes. Weapons carried on military aircraft experience vibrations in all six degrees of freedom at varying acceleration intensities. They are also subjected to intense acoustic conditions. While an aircraft is performing evasive maneuvers near it’s performance envelope there exists a condition known as buffeting. While the aircraft is buffeting several modes of the aircraft structure are excited. These severe vibrations are transmitted to the weapons systems on the aircraft. In addition, severe acoustic noise/vibration is also transmitted simultaneously.

RTTC'S SOLUTIONS FOR WEAPONS SYSTEM TESTING

In order to replicate the vibrations seen in the field a ruggedized portable data acquisition system with a portable PC computer are used to obtain vibration (acceleration measurements) time histories from instrumented test vehicles that are operated over various road surfaces at the RTTC test track. This data is then analyzed, reduced, and digitized with a multi-axis test system controller. This data is then converted into actual time histories that allow test engineers to simulate in the laboratory the same conditions seen on the test track.

To perform multi-axis vibration replication RTTC selected the Team Corporation CUBE™ multi-axis vibration test system (see fig. 1 and fig. 2). The CUBE™ utilizes six dynamically controlled actuators that operate in pairs to control all six degrees of freedom. Using the CUBE™ the customer can go into the field and record the vibration conditions, return to the lab and replicate those same conditions repeatedly. Control is typically within 5-10% rms error (see fig. 3). Since the CUBE™ is located indoors; the customer can replicate the vibration conditions without external variables such as individual driver, speed, or weather conditions.

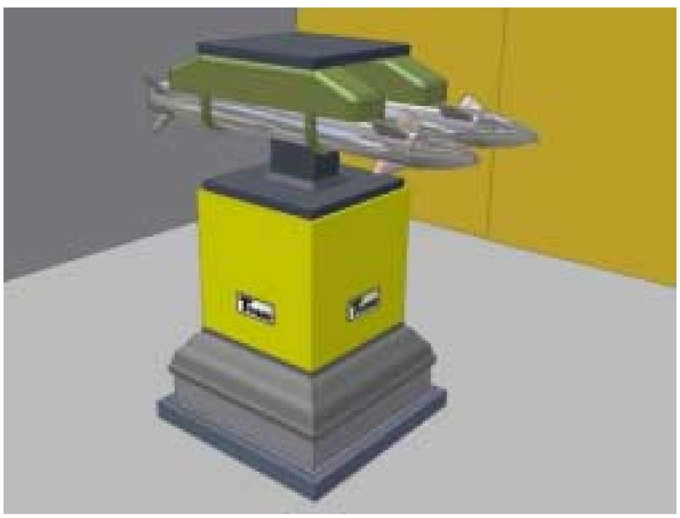

Figure 1: Team CUBE testing under-wing weapons.

To generate high intensity acoustic noise, RTTC chose the Team Corporation Mk VI.2 Acoustic Modulator. Team's Mk VI.2 generators have been installed at military and defense related test facilities throughout the world. In most cases the high intensity acoustic facilities are dedicate facilities for acoustic vibration and analysis exclusively. A few installations use the Mk VI.2 in a combined environment with single degree of freedom vibration test systems. However, the installation at RTTC is the first to combine the CUBE™ multi-axis vibration test system with the Mk VI.2 acoustic generator (see fig. 4). This combined environment allows the test engineers to more accurately simulate the in-flight conditions in the testing laboratory.

Figure 2: Team CUBE testing ground-vehilce weapons.

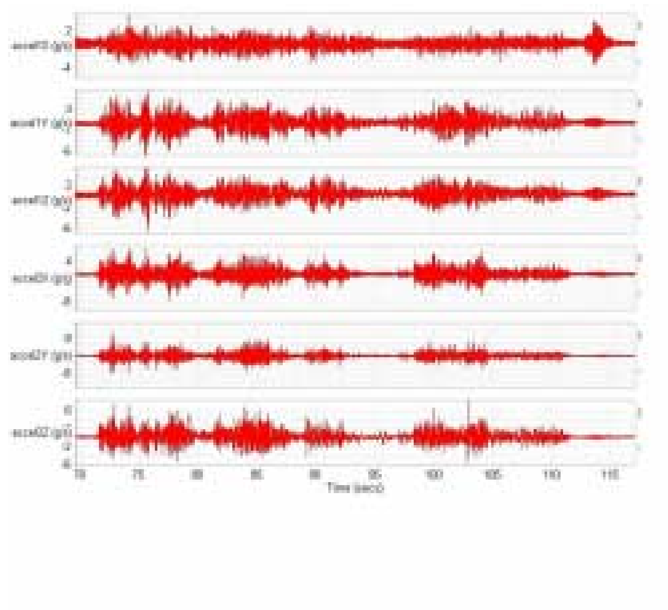

Figure 3: Measured vs. actual for typical weapons test.

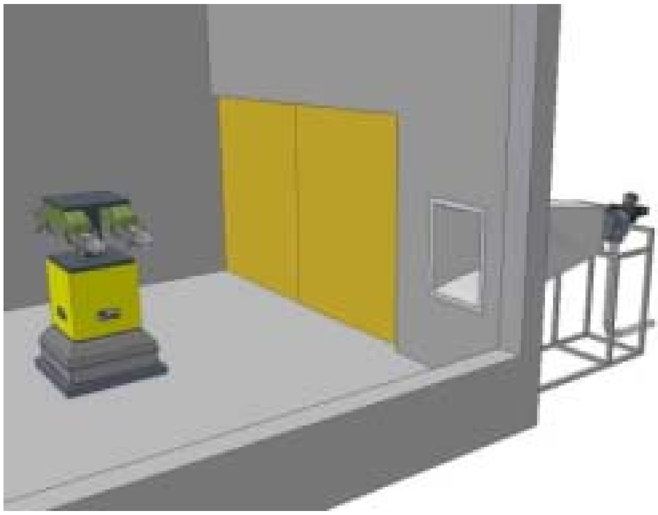

Figure 4: Combined vibration and high-intensity acoustic test facility.

THE CUBE™ MULTI-AXIS VIBRATION TEST SYSTEM *(FIG. 5)*

Figure 5: Team CUBE 6-degree-of-freedom vibration test system.

The actuator systems used within the CUBE® are very high response closed loop servohydraulic actuators. When the six degrees of freedom are accurately controlled the customer in the testing laboratory is better able to duplicate the time history of the actual motion.

KEY TECHNOLOGIES

The CUBE® incorporates three key design developments to increase frequency response, improve maintainability and reduce the dimensional envelope of multi-axis vibration test systems. These technologies are high response servo valves, hydrostatic bearings and the integrated shaker.

INTEGRATED SHAKER

Six degrees of freedom necessitates six axis of control. Within the structure of the CUBE®, six Integrated Shakers™ are arranged in pairs, one pair on each of the X, Y and Z axes. When each pair is operated in phase, pure linear motion parallel to the axis is created. When operated out of phase, a rotational component is produced.

HYDROSTATIC BEARING

TEAM uses hydrostatic bearings in lieu of conventional spherical rod end bearings in the CUBE®. Hydrostatic bearings utilize an extremely thin pressurized fluid film to separate the moving parts of the mechanism. This fluid film provides considerable advantages. All metal-to-metal contact is eliminated, resulting in long life and frictionless motion. The fluid film is very stiff which eliminates backlash and provides high transmissibility of force without introducing noise or distortion.

SERVO VALVE

TEAM pioneered the development of the voice coil servo valve that uses the electrical input signal to directly drive the valve spool, eliminating mechanical feedback limitations. Originally introduced in 1956, the design has proven its effectiveness in thousands of applications. It functions very much as a high fidelity loudspeaker, e.g. an extremely stiff voice coil is directly attached to the valve spool and, as the drive current is modulated, the voice coil alternately extends or retracts into or out of the magnetic field of the field coil. This force is directly proportional to the drive current, therefore, with a spring-centered spool; the spool position is directly proportional as well. The primary result of this design is an increase in frequency response. Measured in the same manner as conventional flapper-nozzle design, the frequency response of TEAM Model V-20 Voice Coil Servo Valve is approximately 2000 Hz.

CUBE PERFORMANCE SPECIFICATIONS

	Model 3	**Model 3LS**
Test Frequency Range	0-250 Hz.	0-250 Hz.
Maximum Specimen Mass	450 kg.	450 kg.
Translational Performance		
Vertical:		
Displacement	50 mm	101 mm
Velocity	.96 m/s	.96 m/s
Force-Dynamic	62 kN	62 kN
Lateral:		
Displacement	50 mm	50 mm
Velocity	.96 m/s	.96 m/s
Force-Dynamic	62 kN	62 kN
Longitudinal		
Displacement	50 mm	50 mm
Velocity	.96 m/s	.96 m/s
Force-Dynamic	62 kN	62 kN
Rotational Performance		
Pitch Displacement	± 6.0 deg	± 4.0 deg
Roll Displacement	± 6.0 deg	± 4.0 deg
Yaw Displacement	± 6.0 deg	± 6.0 deg

MK VI.2 ACOUSTIC MODULATOR *(SEE FIG. 6)*

Figure 6: Team Mark VI.2 High-intensity acoustic modulator.

During the 1970's through the 1990's Team Corporation worked with Northrop Aircraft Division to manufacture the Mk VI.2 Acoustic Modulator. The Mk VI.2 is capable of producing up to 150 KW of acoustic energy. Using a small servohydraulic shaker and a poppet-style air valve, the Mk VI.2 modulates the air stream to produce pressure fluctuations to generate high intensity sound.

The modulator input frequency is controllable to 500 Hz., and using the harmonic noise the output can be analyzed out to 10 KHz. With the Mk VI.2 coupled to the large reverberant chamber at RTTC, the system can produce overall sound pressure levels in excess of 160 dB. Using a "White Noise" generator and 1/3 octave spectrum filters the spectrum can be shaped according to MIL-STD 810D specifications (see fig 7 and 8).

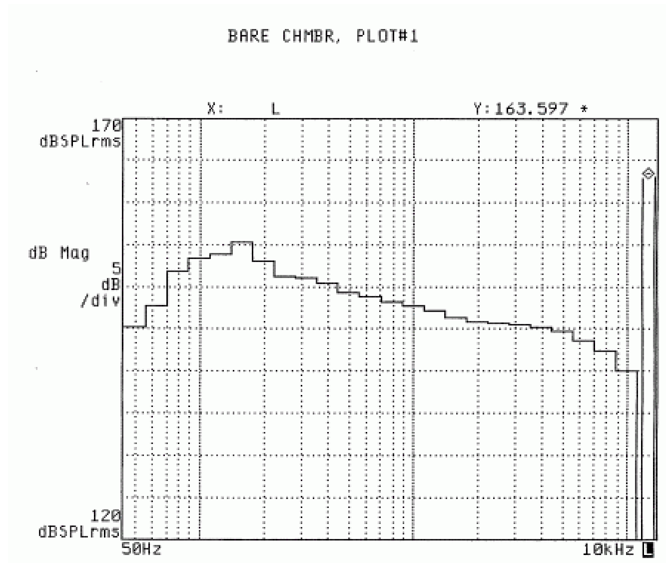

Figure 7: Shaped spectrum produced by Team acoustic modulator.

BARE CHMBR, PLOT#1

X: L Y:163.597 *

dB Mag

Entry Label	Hz	dBSPLrms
	L Bin	163.597
OCTAVE BAND	50	145.264
OCTAVE BAND	63	147.803
OCTAVE BAND	80	151.985
OCTAVE BAND	100	153.53
OCTAVE BAND	125	153.985
OCTAVE BAND	160	155.378
OCTAVE BAND	200	153.265
OCTAVE BAND	250	151.377
OCTAVE BAND	315	151.141
OCTAVE BAND	400	150.577
OCTAVE BAND	500	149.494
OCTAVE BAND	630	148.96
OCTAVE BAND	800	148.302
OCTAVE BAND	1 k	147.86
OCTAVE BAND	1.25 k	147.161
OCTAVE BAND	1.6 k	146.472
OCTAVE BAND	2 k	146.019
OCTAVE BAND	2.5 k	145.811
OCTAVE BAND	3.15 k	145.62
OCTAVE BAND	4 k	145.24
OCTAVE BAND	5 k	144.869
OCTAVE BAND	6.3 k	143.81
OCTAVE BAND	8 k	142.436
OCTAVE BAND	10 k	140.059

Figure 8: One-third octave spectrum produced by Team acoustic modulator.

CONCLUSION

With the commissioning of two Team Corporation high frequency CUBE™ multi-axis test systems and a MK VI.2 Acoustic Modulator, RTTC can now simulate real-world conditions on both Under Wing and Ground Based Weapons systems in the laboratory with greater accuracy. RTTC can begin to develop new multi-axis testing standards that will replicate the field data, thereby simulating the conditions that the weapons are subjected to on the ground or in-flight. The weapons can be subjected to the same environment as in operation, validating the robustness of the design.

If any design changes are made to the weapons, the enhancements can be tested and proven in the laboratory, again with accuracy and without varying environmental conditions.

ACKNOWLEDGMENTS

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