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Automotive module is durability tested with both multi-axis vibration and climatics

(details, see page 5)

Life cycle evaluation of automotive cockpit modules

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Buzz, Squeak and Rattle (BSR) testing is an essential part of the evaluation of automotive cockpit modules. In automotive noise terms, a buzz is a noise from a part excited at its resonance frequency, squeaks are frictional noises caused by rubbing contact of adjacent parts, and rattles are impacts when adjacent parts come in contact.

BSR testing is done to identify these irritating noises inside the passenger compartment of an automobile. Often the presence or absence of these irritating noises is a direct influence on the perception of the build quality in a vehicle. Reduction of noise due to other sources such as the engine and powertrain has made cockpit noise a larger issue in the overall noise envelope inside the vehicle.

BSR testing is often done on new vehicle components, but what is the impact of years of usage of the vehicle on BSR generated by cockpit modules? At Calsonic Kansei in Shelbyville, Tennessee, new cockpit module designs can be tested and then subjected to years and thousands of miles of use in the laboratory. The BSR evaluation is conducted periodically during a durability test to determine the effect this use has had on BSRs generated by the cockpit module.

Overview of cockpit module life cycle test facility

The cockpit module life cycle test facility at Calsonic is comprised of a six-degree-of-freedom shaker system inside a large thermal chamber. Inside this thermal chamber there are lights to simulate the effects of radiation from the sun on cockpit module materials.

The Cube, from Team Corporation, Burlington, Washington, is the six-degree-of-freedom hydraulic shaker system used in the facility. The Cube has a force rating of up to 62 kN and a frequency range of 0–250 Hz. Figure 1 is a cutaway view of the Cube showing the orientation of the six actuators and the hydrostatic bearings that allow vibration in all six degrees of freedom.

The Cube shaker system is controlled by a SignalStar Matrix multi-shaker multi-axis vibration control system from Data Physics, San Jose, California. The SignalStar Matrix vibration controller at Calsonic is capable of multi-shaker random, sine, and time-waveform replication control. Surrounding the Cube is an environmental chamber made by Espec, Hudsonville, Michigan, with internal dimensions of 12 x 12 x 8 feet. It is capable of temperatures from -65 to 150°C (2°C/minute average transition rate), and has the capacity to control humidity from 20 to 95 percent relative humidity. Inside the chamber there is also an infrared light array for simulating the effects of solar radiation on the cockpit module components.

The Espec chamber has a controller that is capable of communicating with the vibration controller to monitor vibration status and initiate specific vibration profiles once the chamber has reached the desired temperature levels. It is also capable of com-

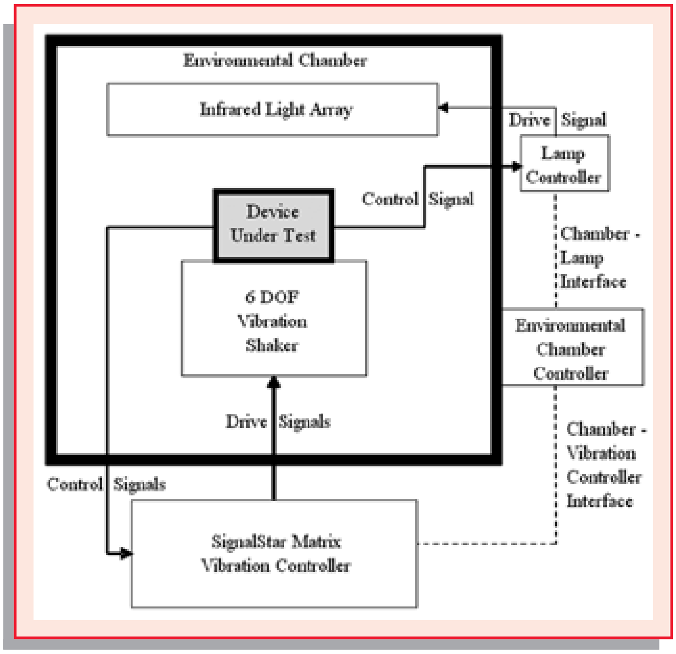

FIG. 2—Integration of temperature, vibration, and radiation testing.

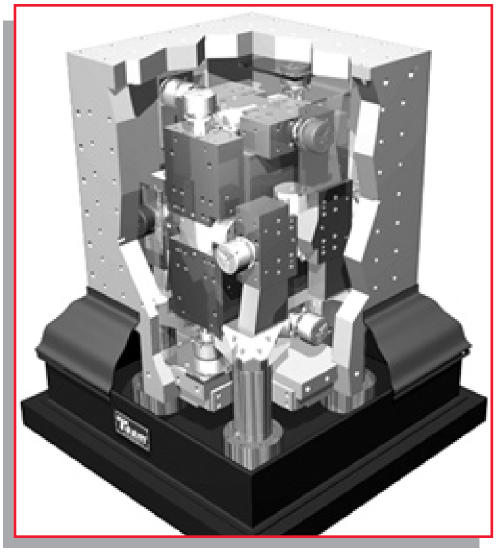

FIG. 1—Team Cube 6DOF actuator system.

FIG. 3—Vibration time data replication.

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FIG. 5—Environmental chamber with cockpit module on 6DOF actuator system.

municating with the light array controller.

Life cycle vibration testing—multi DOF time replication

To acquire cockpit module vibration data, a vehicle with the cockpit module installed is brought to the test track and acceleration data is acquired while driving over different road surfaces.

When making field measurements for six-degree-of-freedom time waveform replication, there are two important criteria that must be met. First, the sensors must be placed so that all six degrees of freedom (X, Y, Z, RX, RY, RZ) can be measured, and second the sensor placement should allow for the exact same placement during the laboratory simulation. For automotive cockpit module vibration testing, triaxial acceleration measurements are typically made at right and left A pillars, at the base of the center console below dash, and at the rear of the center console. This provides 12 acceleration measurements that ensure we can clearly measure all six degrees of freedom of vibration. These same accelerometer locations are used when simulating the vibration in the laboratory.

The basis of multi-axis time waveform replication control is convolution of reference time histories with the multiple-input/multiple-output (MIMO) transfer function between the drive signals sent to the actuators, and the control signals measured by the accelerometers on the cockpit module. This convolution is done by a matrix multiplication in the frequency domain of the inverse of the MIMO frequency response function (FRF) and the FFT of the reference time history.

Controlling six-degree-of-freedom vibration requires at least six control response locations. It is often desirable to have more than six control locations to accurately reproduce the required six degrees of freedom motion. This results in a non-square, or over-determined transfer function matrix. An over-determined matrix requires a pseudo inverse technique for matrix inversion. The computational method of the pseudo inverse technique is based on singular value decomposition of the matrix. The singular value decomposition technique also has the additional benefit of dealing well with singularities that may exist in the transfer function matrix.

In the case of the automotive cockpit module there are 12 reference time history signals available for control and six actuators in the Team Cube. This provides a 6 x 12 frequency response function matrix that must be inverted.

SignalStar Matrix Time Data Replication offers both frequency-domain and time-domain control. Both techniques follow the same general procedure:

1. Pretest system characterization
2. Iteration (to reduce error)
3. Test

Pretest

The first step for both the time-domain and frequency-domain techniques is a pretest system identification. This is a MIMO FRF measurement using all the drives as inputs and all the control channels as output. This is performed using band-limited uncorrelated random noise because any correlation, present in many reference time signals, can affect accuracy of results. To help with obtaining a good initial estimate of the system FRF during pretest, the excitation may be shaped to provide sufficient signal to noise discrimination at all frequencies.

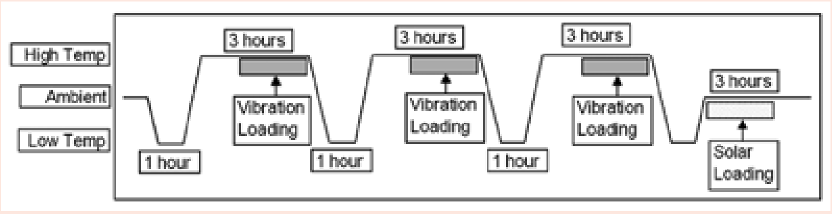


FIG. 4—Example system test profile.

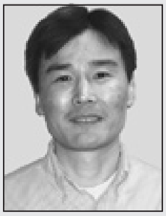
Test

There are two methods for conducting the test—the frequency-domain method or the time-domain method. If using the time-domain method there is a necessary iteration phase before test phase to derive the drive waveforms. If using the frequency-domain method there is a choice between using iteration or direct real-time control.

During iteration the controller initially outputs drive signals generated with the reference time histories and the inverse FRF from pretest. It then compares the resulting control time histories with the reference time histories. This is typically done with a scaled reference value and the reference level is increased as the iteration continues.

The time-domain technique calculates the error (control-reference) in the time domain and uses the inverse FRF matrix to produce a delta drive value in the time domain that can be added to the drive of the previous iteration to create the drive signal for the next iteration.

The frequency-domain technique updates →



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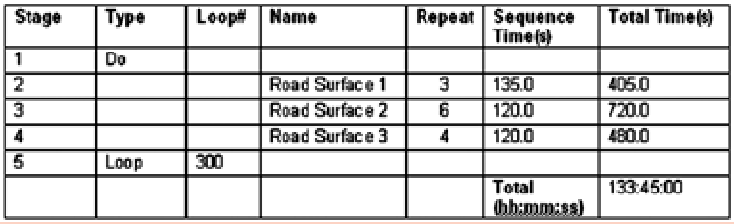
the inverse FRF matrix with each iteration, to reduce the error be-tween the control and reference time histories. Once acceptable error is reached in the iteration phase, the test is ready to begin.

When using the frequency-domain technique with the "real-time" control option, the inverse FRF is updated in real time during the test. This eliminates the need for the iteration stage and also corrects for changes in the system dynamic response that may occur during the test.

Vibration profiles are typically made up of shorter segments of different road surfaces that are arranged in a sequence of repeats and loops to create a composite time-history profile that simulates the desired duration of typical vehicle usage. The example in Table 1 shows three different road surfaces combined to create a single road-vibration profile of the desired duration. Figure 3 shows operation of the SignalStar Matrix MDOF Time Waveform Replication software to reproduce a 6DOF vibration profile on the Team Cube actuator system.



Stage	Type	Loop#	Name	Repeat	Sequence Time(s)	Total Time(s)
1	Do					
2			Road Surface 1	3	135.0	405.0
3			Road Surface 2	6	120.0	720.0
4			Road Surface 3	4	120.0	480.0
5	Loop	300				
					Total (hh:mm:ss)	133:45:00

TABLE 1—Example 6DOF vibration run schedule.

Combined temperature, radiation, and 6DOF vibration testing

The cockpit life cycle evaluation combines temperature and humidity cycling, radiation, and 6DOF vibration testing. The chamber controller acts as a supervisory system, initiating vibration and radiation after temperature/humidity levels are reached. Figure 4 is an example profile showing temperature cycling profile and the vibration testing at prescribed points in the temperature cycle. The infrared light array is also controlled by the chamber controller. The chamber controller can also detect the status of the vibration system (controller and actuators) and IR light array, and can initiate a test shutdown if any error condition occurs.

Cockpit module life cycle evaluation process

The typical test sequence for cockpit module life cycle evaluation involves an inspection of the cockpit module and BSR test prior to the 6DOF vibration durability testing. Durability testing is followed by another BSR test and inspection to evaluate the effect of the durability testing on the cockpit module.

Typical test sequence:

- Pre 3D laser measurement inspection scan of cockpit module;
- Pre durability BSR test;
- Six DOF vibration durability test;
- Post durability BSR test;
- Post 3D laser measurement inspection scan of cockpit module.

BSR testing combines a number of techniques to identify noises inside the cockpit that may be encountered during operation of the vehicle. These techniques include swept- and fixed-sine vibration testing; random testing using Power Spectral Density (PSD) profiles derived from road load data; and subjective and objective rating of components and systems.

Laboratory simulation of the life cycle improves efficiency and repeatability when evaluating automotive cockpit modules. It helps ensure that cockpit module designs exhibit excellent buzz, squeak, and rattle performance throughout the expected life of the automobile, improving customer satisfaction and reducing warranty costs.

For more info about Calsonic Kensei's testing,
CIRCLE #135 or go to
www.testmagazine.biz/info.php/8dj135

For more info about Data Physics' controllers,
CIRCLE #126 or go to
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For more info about Team's shaker systems,
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