VIBRATION MAPPING OF HEAD EXPANDER FOR 9000 KGF SHAKER

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This paper is a case study on vibration mapping of Head Expander for 9000 Kgf Shaker as some of UUTs (Units Under Test) were qualifying the Random Vibration Test Level at 3500 Kgf Shaker System where as failed at 9000 Kgf Shaker System at the same Tests Level. The conceptual mechanism is to predict the effect of different control position of accelerometers on UUT and to develop a control strategy on Head Expander of Vibrator.

Finally this Experimental Case Study paper has been concluded by focusing on the need of mapping of Head Expander for 9000 Kgf Shaker System.

I. INTRODUCTION

Aerospace systems undergo a physically stressful journey throughout their life in the service. An adequate testing can help to ensure they survive the service life. The main source of vibration is noise generated by propulsion system at the time of take off that exert significant pressure on the system and is responsible for the vibration & another source of vibration is engine ignition, engine off and steady state operation.

A vibration test is an accelerated test. It simulates, in a short time, the effect of long duration field service. Test loads are derived from the field measurements. So, in theory there should be no difficulty designing a test that faithfully reproduces actual use in service.

But actually, things don't happen that way. The electro-dynamic shakers have got the feedback system which depends upon the mounting of the control accelerometers. Here our aim is to develop a control strategy for the mounting of the control accelerometer on the head expander. And also we have tried to understand how the position of control accelerometers on head expander affects the test results and UUTs.

HOW THE VIBRATION TEST IS DONE

Vibration test excite system by applying motion to the base. Most modern vibration test shakers incorporate automatic vibration level controls. This control is achieved by the use of feedback system. The accelerometers are used for this purpose and are known as control accelerometers. These accelerometers sense the level of vibration excitation and give the feed back to the controller which is connected to the Power amplifier as show in the figure below:

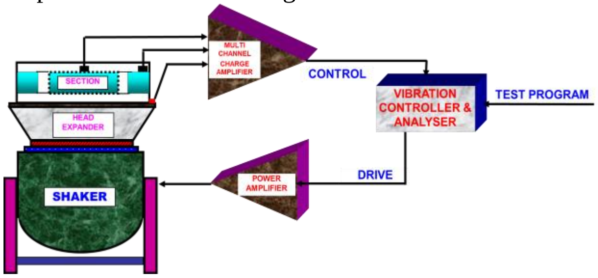

Figure1.Typical arrangement of an electro-dynamic shaker system.

II. ELECTRO-DYNAMIC SHAKER SYSTEM

This is an electro-mechanical convertor which converts the electrical energy applied to it to mechanical force. The design of an electro-dynamic vibration generator is based on the theory of electromagnetic induction. Please refer to the figure drawn below:

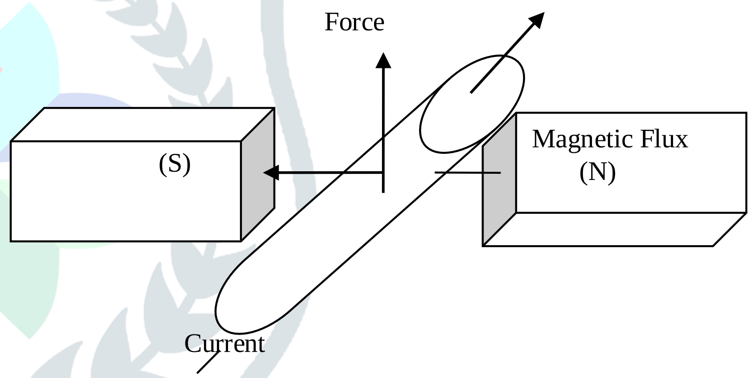

Figure2. Basic working principle of electro-dynamic shaker

From the above figure, it can be observed that when an electric current flow through a conductive wire (Drive Coil) and when a magnetic field (Generated by DC Field Coil) crosses the wire, a force is generated which tends to move the wire. This is called "Fleming's Left Hand Law".

The direction of the force is reversed when the direction of the current through the conductive wire is reversed. Thus, alternating characteristics of the current through the wire cause an reciprocal mechanical motion of the wire.

In accordance with the above principle, a vibration generator generates vibratory force when its drive coil (conductive wire) fed with an alternating current and is located in the high magnetic flex density created by DC field coils which are fed with DC power supply.

A sample illustration of construction of an electro-dynamic vibration generator is shown below:

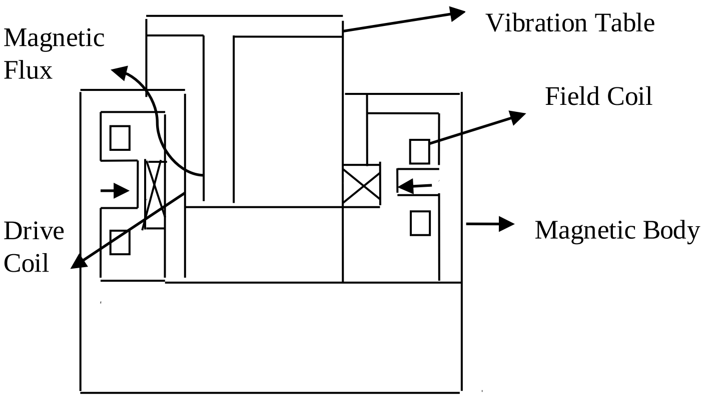

Figure 3. Construction of electro-dynamic Vibration Generator

III. Vibration Test Head Expander

Head Expander is component of electro-dynamic shaker used for vibration test in the vertical direction. A structure which is designed to couple the motion from the vibration source to the fixture or to the item to be tested without distortion. A Head Expander is generally required for testing of large size specimens which cannot be directly mounted on the shaker head or armature interface. It is essentially consists of magnesium cast work table surface which is bolted on to the shaker head. These are available in both round figural shapes and for any size of armature and with customized hole of patterns. But here round Head Expander has considered for study. When making the design of the Head Expander one should analyze its transmissibility and resonance frequencies. The vibration test head expander must have high stiffness and be able to transfer the vibratory energy generated by the vibrator to fixture or to UUT. In the other words, the vibratory energy in the head expander's output should be same in the head expander's input. Basically, head expander should be as light as possible, as stiff as possible, should have unitary transmissibility in the investigated frequency range and its resonance frequencies should be beyond the investigated frequency range.

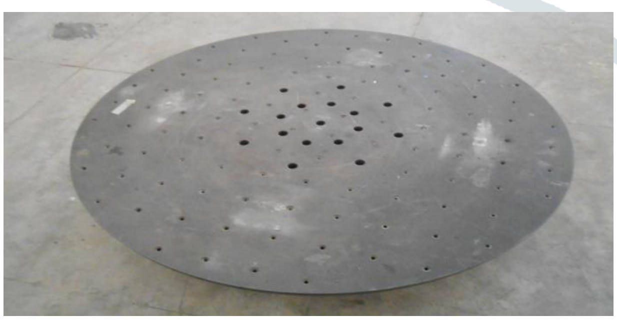

Figure4. A typical Photograph of Head Expander of 9000 Kgf Shaker System.

Table I. Head Expander's Characteristics.

Model	HE-120
Shape	Circular
Platform Size	1200 mm diameter
Dynamic Mass	285 kg
Mounting Holes	M10 SS Inserts with 100 mm matrix.
Useful frequency range	Up to 2000 Hz
Working Platform	Mg-alloy

IV. Case Study

The analyzed test head expander is shown in Fig.4 and characteristics are tabulated in table I. This head expander was developed specially for a LDS Dactron control vibrator, whose characteristics are described in Table II.

Figure5. 9000 Kgf Shaker System

Table II. LDS Dactron vibrator characteristics.

Model	SEW-500
Armature Diameter	500 mm
Rated Force	9000 Kgf peak sine and 9000 Kgf rms Random
Frequency Range	5 to 2000 Hz.
Maximum acceleration	100g
Velocity	1.6 m/s
Displacement (peak-peak)	50 mm
Effective mass of armature	90Kg
Armature resonance	>2000 Hz

V. Analyze by using different nos. of iteration

V.1 . Iteration 1.

A total 08 nos. of accelerometers were fixed on the head expander as shown in figure 6 at a radius of 550mm from center with channel 1,2,3,4,5,6,7,8. Out of eight accelerometers the channel 1,3,5,7 are made the control accelerometers and 2,4,6,8 were used as the output monitor. The input given to the system was 0.04g^2/Hz (PSD) in the frequency range 20-2000Hz.

Figure6.Control and Monitor accelerometers at 550mm radius from centre of head expander

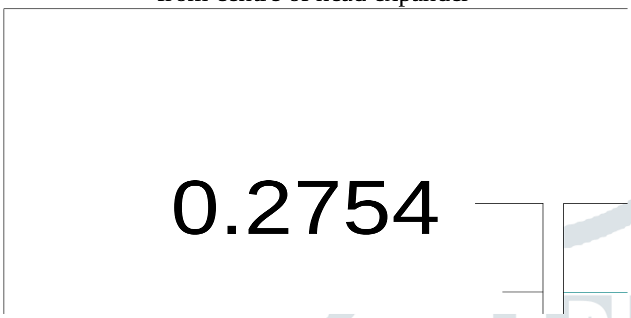

Figure7. Control 1,3,5,7 and Monitor 2,4,6,8

From the above test in figure 7 following results found:

Table III. Test results at the radius 550mm.

Channel No.	RMS Values (g)	Accelerometers Details
Control (f)	8.085	PCB Piezotronics Make
Input 1 (f)	8.023	Model No. 353B04
Input 2 (f)	8.182	Model No. 353B04
Input 3 (f)	7.991	Model No. 353B04
Input 4 (f)	8.196	Model No. 353B04
Input 5 (f)	8.241	Model No. 353B04
Input 6 (f)	8.468	Model No. 353B04
Input 7 (f)	8.082	Model No. 353B04
Input 8 (f)	8.468	Model No. 353B04
Profile (f)	8.034	Model No. 353B04

It is noted that Random Profile value is 8.034grms and the Control weighted value is 8.085grms which are almost same. The monitor accelerometers are also showing the vibration level equal to the input level. Therefore the UUT experience the same vibration input as mentioned in test.

V.2. Iteration 2.

In this case again the same eight accelerometers were fixed on the head expander as shown in the figure 8 at a radius of 450mm from the centre. Out of eight accelerometers the again channel 1,3,5,7 are made the control accelerometers and 2,4,6,8 were used as the monitor. The input given to the system was .04g2/Hz in frequency range 20-2000 Hz.

Figure8. Control and Monitor accelerometers at 450mm radius from the centre of the head expander

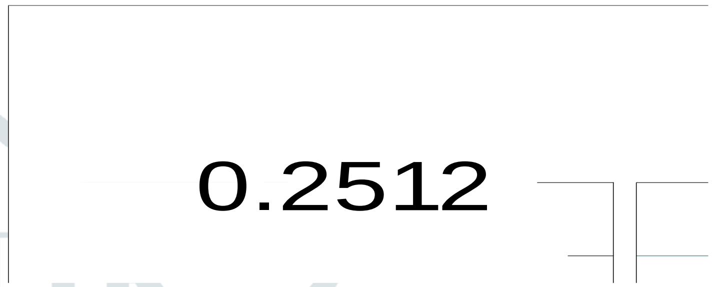

Figure9. Control 1,3,5,7 and monitor 2.

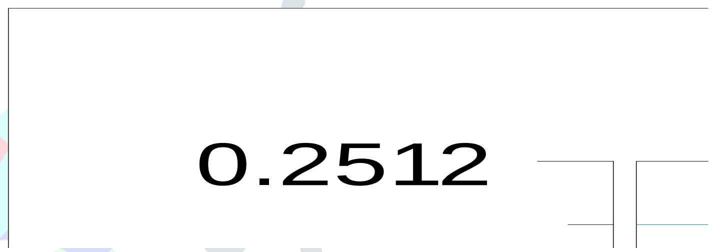

Figure10. Control 1,3,5,7 and monitor 4.

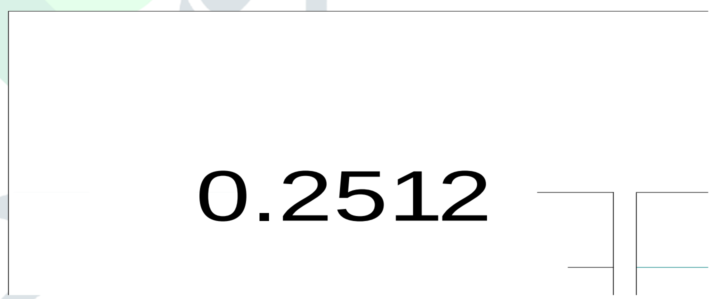

Figure11. Control 1,3,5,7 and monitor 6.

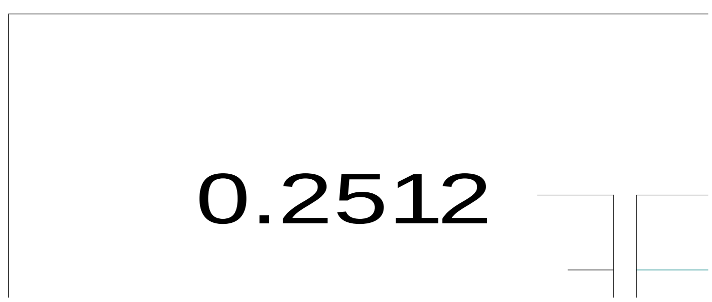

Figure12. Control 1,3,5,7 and monitor 8.

From the above test results, (shown in figure 9, 10, 11, and 12) again it is observed that the control and profile values are almost the same. Also the monitor accelerometers value is in agreement with control. Therefore if a UUT is mounted at 450mm from centre and controlled at same position. The UUT experience the same vibration input as mentioned in the test profile for unit.

V.3. Iteration 3.

In this case again the same eight accelerometers were mounted on the head expander as shown in figure13 at the radius of 350mm from the centre. Out of eight accelerometers the again 1,3,5,7 are made the control accelerometers and 2,4,6,8 were used as the monitor.

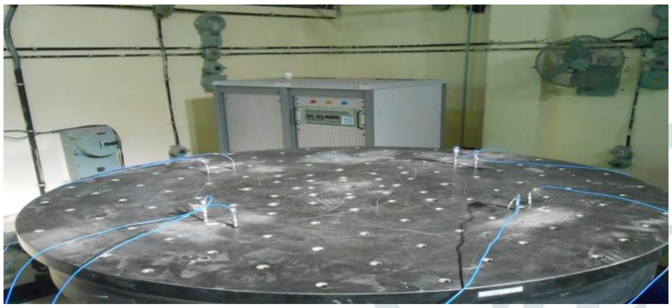

Figure13. Head Expander with 1200mm diameter with control and monitor accelerometers at 350mm radius from centre.

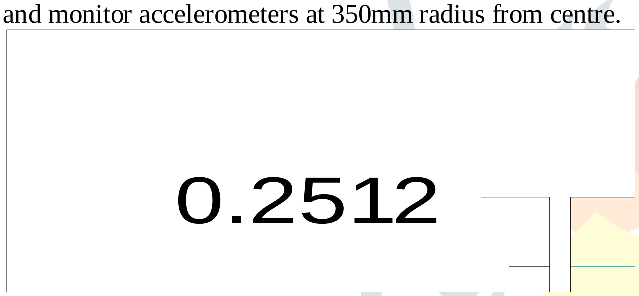

Figure14. Control 1,3,5,7 and Monitor 2.

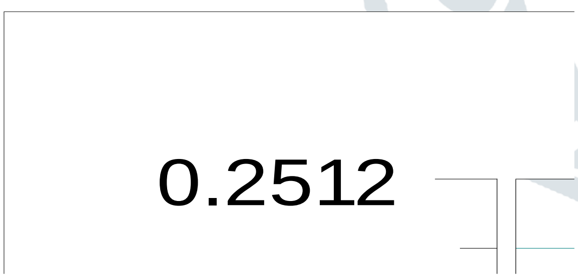

Figure15. Control 1,3,5,7 and Monitor 4.

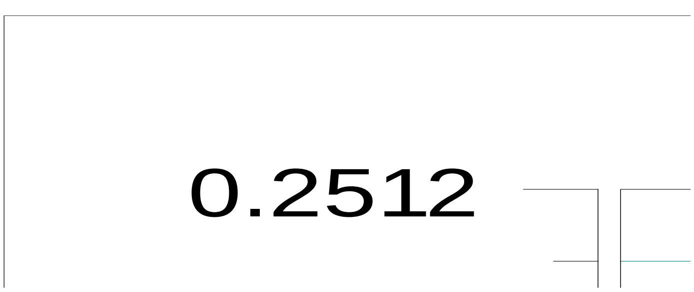

Figure16. Control 1,3,5,7 and Monitor 6.

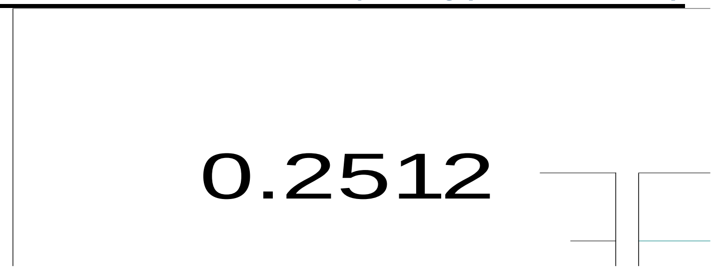

Figure17. Control 1,3,5,7 and monitor 8.

Again it is observed that control and profile values are almost same. Also the monitor accelerometers value is in agreement with control. Therefore, if a UUT is mounted at 350mm radius from the centre and controlled at same position. The UUT experience the same vibration input as mentioned in the test profile for UUT.

V.4. Iteration 4.

In this case the same eight accelerometers were mounted on head expander as shown in figure 18 at a radius of 250mm from the centre. Out of eight accelerometers the again 1,3,5,7 are made the control accelerometers and 2,4,6,8 were used as the monitor.

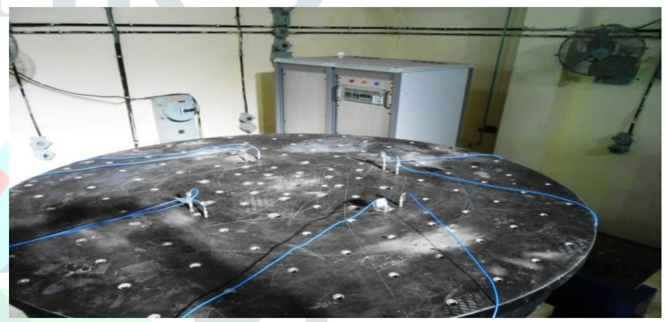

Figure18. Head Expander with 1200mm diameter with control and monitor accelerometers at 250mm radius from the centre.

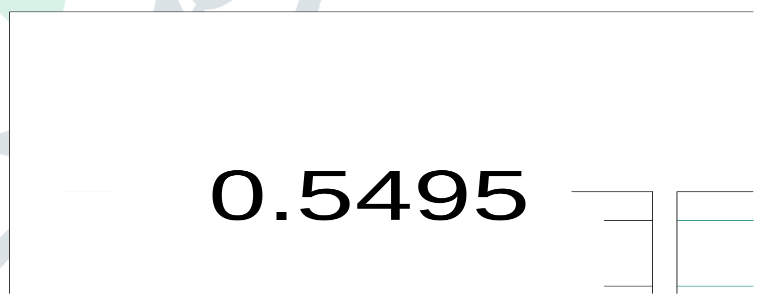

Figure19. Control 1,3,5,7 and monitor 2.

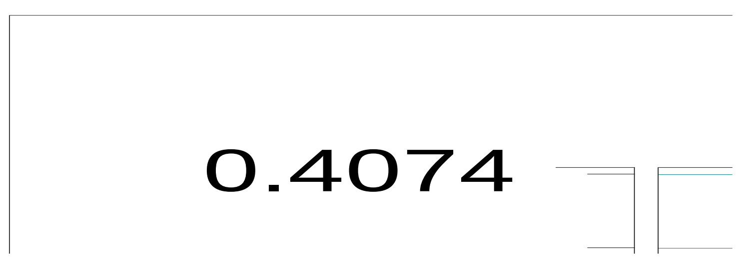

Figure20. Control 1,3,5,7 and monitor 4.

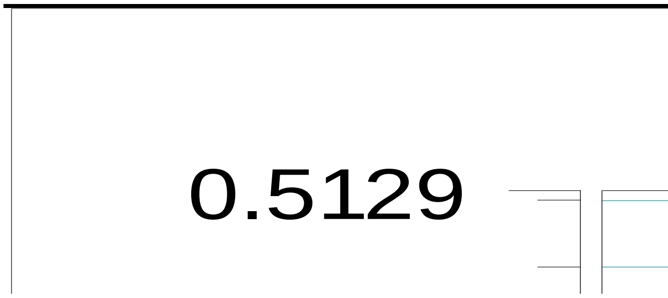

Figure 21. Control 1,3,5,7 and monitor 6.

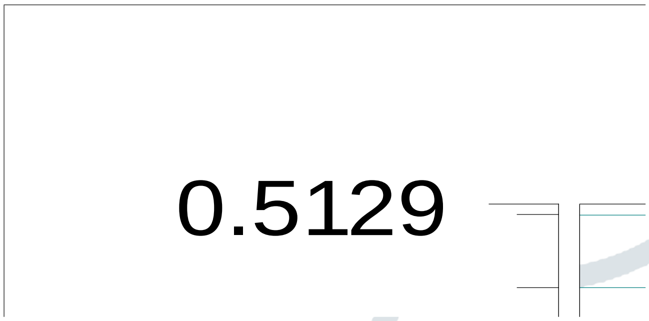

Figure22. Control 1,3,5,7 and monitor 8.

Results of iteration 4 are given in table below:

Table IV.

Frequency (Hz.)	PSD (g^2/Hz)
205	0.053
1372.500	0.2917
1572.500	0.229
1577.500	0.310 & 0.345
Profile value	0.04

It is observed that control value is different from profile value. Also it has been observed that control is not possible as per the graph at this location and when we tried to control at distance 250mm from the centre the Shaker System was tripping.

VI. Conclusion

Some conclusion about the useful area of the head expander and selection of vibration shaker:

1. Control of the test should be done from the point near to the UUT.
2. In case controlling is done at the outer most point and unit is mounted inside. The unit will experience low level i.e. unit will be under tested.
3. The head expander cannot be controlled at a point equal to or less than 250mm radius from centre. This is due to the reason that diameter of armature is 500mm. So, UUT less than or equal to 500mm diameter should not tested on 1200mm diameter expander of 9000 kgf shaker system.
4. The UUT was failing as it was mounted at 250mm radius from centre.
5. Selection of Shaker System according to the size of head expander and armature.

TABLE V

Units Used for Dynamic Environment (Short Title Here)

Symbol	Quantity
DC	Direct Current
g	Gravitational Acceleration
Hz	Frequency
PSD	Power Spectral Density (g^2/Hz)
RMS	Root Mean Square
0^0c	Temperature
m/s	Velocity
mm	Displacement or Distance
KgF	Kilogram Force
Kg	Kilogram (mass)

References

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[6] Clarance W. De Silva, Vibration, Damping, Control and Design, CRC Press, 2007.

[7] Douglas C. Montogomery, Design and Analysis of Experiments, John Wiley & Sons, 1976.