Environmental and Vibration Testing of Hard Disk Drives for Automotive Applications

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Introduction

Information technology for today's system of automotive applications demands that a central computer system controls and manages a large number of electrical interface connections related to the operation of the engine and other electrical items. The car's computer becomes so large that small to medium sized hard disk drives are necessary to store all the data that is streaming across the car's electrical bus system. The complexity of automobiles increases due to the workload and performance applications that are necessary to implement current and future engine/power plant technologies (gas, electric and hybrid) as the number of items that are accessed increases. In addition, communication, entertainment and navigational assist demands by the consumer are requiring GPS positioning, satellite radio, DVD movies and MP3 audio as standard equipment in every car that's being sold. The hard disk drive is being pushed to its limits in data storage capabilities to satisfy the storage demands for all these applications. To design better hard disk drives, environmental concerns are also necessary to ensure the reliability of these disk drives for these and future applications.

The main environmental concerns are temperature and vibration. How these two environmental parameters affect the data integrity of the fragile hard disk drive is paramount to maintain the reliability of the steady stream of information in harsh environments of the Sahara desert to the top of the Rocky Mountains. Initially, the hard disk drive was designed and built to standards for the Information Technology field that housed computers and disk drives in 19-inch racks. These hard disk drive designs were designed for conservative environments where air-conditioned computer rooms and labs didn't vary by more than a few degrees Centigrade. However, once these drives transitioned to consumer-oriented products, i.e. car drives, TV set-top boxes, game players, phones etc, the environmental designs became much more severe. This article will describe the common environmental testing that is currently being designed for the future automotive hard disk drives.

Results and Discussion

A hard disk drive that could be used for automotive applications was tested in an environmental chamber with a special custom-made rotary vibration machine. The environmental chamber was programmed to allow constant temperature and humidity environments such as the standard "4 corner" specifications: cold humid, cold dry, hot humid and hot dry. The high and low temperature are set between -20 C and 80 C temperature excursions. The high and low humidity is set at 5% for dry and 95% for humid conditions.

The custom-made rotary vibration machine was obtained from GHI Systems, Inc. It has the following frequency and acceleration specifications:

Model RVM-1 with Labworks random and sine vibration controller.
Frequency: 6-2000 Hz one channel control; 2-500 Hz two channel control.
Acceleration: 4.95 g RMS @ 4 in radius = 475 rad/s^2 - blower on.

To meet the environmental requirements of the planned test program, the RVM-I had to be extensively modified. Ceramic magnets within the actuator de-rate rapidly with temperature. The upper 4-corner specification of 85C would result in a loss of over 50% of available actuator power, rendering the system incapable of performing the tests. For this reason, the actuator was sealed with an air-conditioned enclosure exchanging cooling air to the outside of the thermal chamber. The enclosure mandated a new coupling for the stinger to allow the degree of required motion. While not a part of this test, the actuator was also modified to allow operation at reduced air pressure to simulate high altitudes.

Figure 1 shows the RVM-1 machine inside the environmental chamber in photo 1. The drive is placed in an XY orientation. Other orientations tested were YX, ZX and ZY. In any one of these orientations the drive may be susceptible to resonant frequencies and accelerations due to sensitivity of the actuator, arm, suspension or head. During rotary table frequency ramping from 6 through 200 Hz, a resonance may develop in any portion of the drive which would affect the head/disk interface. Depending on the orientation of the drive the head could sway from side to side or up and down. If the head sways up and down then data integrity is lost since the head will not read or write properly. If the head sways side to side then the servo will not respond adequately to keep the head on track for reading the data from that particular sector of the disk. These effects can be easily monitored by tracking the data transferred from head to the electronics. These signals are necessary to keep the head positioned on-track (servo signals) and for reading/writing the data (read back signals).

Figure 1. Environmental chamber with RVM-1 rotary table with hard disk drive mounted in the XY orientation.

The automotive hard disk signals monitored were RRO, NRRO and PES. The RRO and NRRO are the repeatable and non-repeatable run out of the disk, respectively. Excessive RRO and NRRO signals show how far the head/suspension system will have to move to maintain constant compliance with the disk surface at the pre-determine flying height. If the flying height is 15 nm and the RRO shows 100 nm of run out movement then the entire suspension system holding the head would have to maintain a constant 100 nm displacement to allow the head to fly at 15 nm. If there is too much RRO and NRRO movement then the suspension system will not be able to follow the large disk excursions and as a result the head will not be able to sustain the small flying height of 15 nm above the surface of the disk. As a result, it will be impossible to read data from the track.

For monitoring the PES, or position error signal, excessive large results show that the servo system lacks the robustness to maintain the head sitting on a single track with successful track-following. Again, excess PES means that the head is swaying too far from side to side and will not be able to read the entire track. Typically, for small 2.5” disk drives with capacities of 20 to 30 Gigabytes there are approximately 40,000 tracks in the drive from ID to OD positions. The ID position is defined as the innermost diameter area of the disk. The OD position is just the opposite. It is the outermost diameter area of the disk. The ID and OD represent the minimum and maximum head excursions of the data and servo area of the disk.

Figure 2 shows a typical acceleration versus frequency profile for the RVM-1 table. For this test, sine sweep frequency starts at 6 Hz and maximizes at 500 Hz. The first dotted line starting with a low acceleration value of 0.05 G at 6 Hz which then finishes with a constant slope of 1.0 G to the right hand side of the graph is indicative of a typical frequency profile across this region. The corresponding vertical axis for the acceleration is on the left hand side of this graph. The other dotted line with the non-constant slope displays the velocity profile and its corresponding vertical axis on the right hand side of the graph. The large dot and vertical line shows where in the linear sweep the table was being controlled at the time of the printout. The four dialog boxes on the left-hand side of the diagram indicate the instantaneous acceleration, velocity, displacement and frequency at the indicated frequency of the sine sweep.

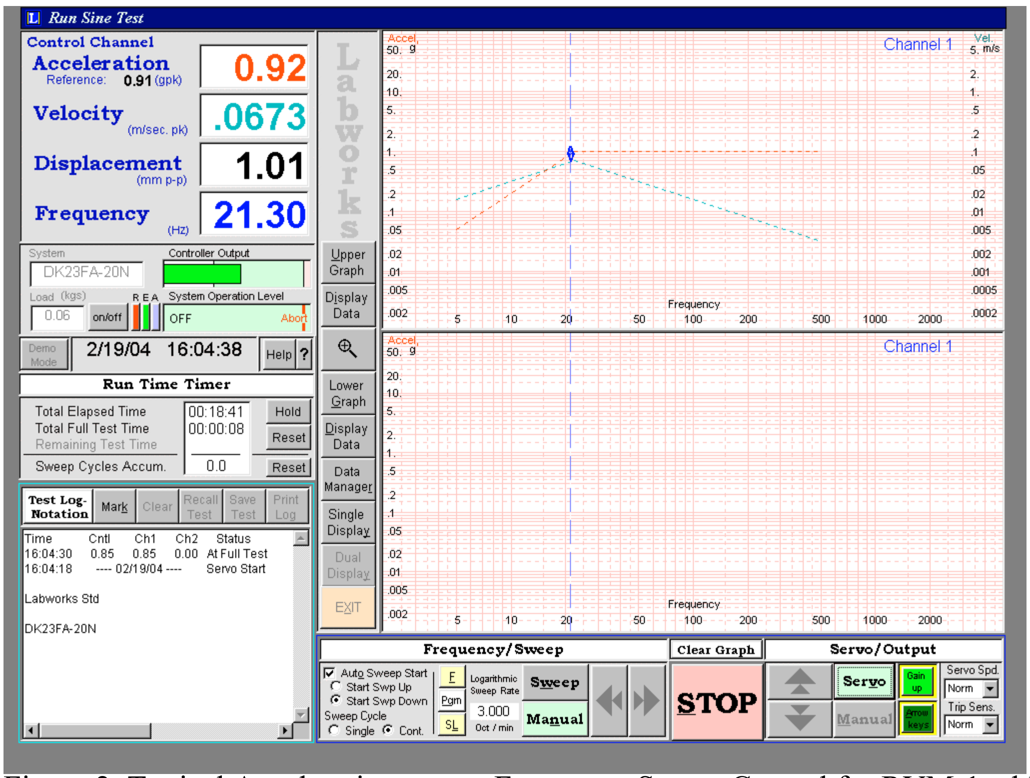

Figure 2. Typical Acceleration versus Frequency Sweep Control for RVM-1 table.

The RRO signal was monitored for the hard disk drive mounted on the shaker in the environmental chamber between the temperatures of -20C to 80C and from rotational frequencies between 6 Hz and 500 Hz. The RRO data for these ranges for head 0 at the OD track of the disk are shown in a 3D plot in Figure 3. For this test the drive was positioned in the XY plane. A quick inspection of the data shows that the most severe case for the drive is at low temperatures. A large amplitude for the RRO is shown at the low temperatures region at -20C and for the rotational table frequency of about 300 Hz. The maximum RRO is shown to be 24 nm. At this large RRO the suspension was still able to be compliant enough to follow the peaks and troughs of the disk and all the heads to maintain a constant flying height of 15 nm.

The minimum RRO is shown for room temperature of 25C for the rotational frequency of 300 Hz. Temperatures above and below 25C show modest gains in the amplitude of the RRO signal.

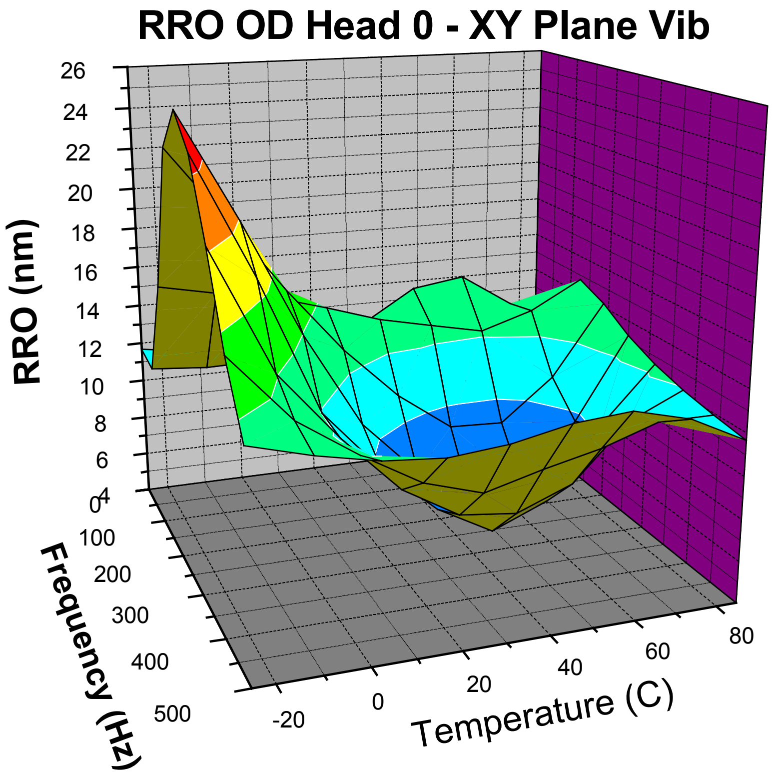

Figure 3. RRO data for Head 0 at the OD area of the disk and the drive in the XY plane.

Conclusion

A 2.5" hard disk drive was investigated using a small GHI Systems rotational vibration table. The table was positioned in an environmental chamber where four corner environments of hot/cold, dry/humid conditions were established and maintained for long periods of time. The RVM-1 rotational table was ramped between 6 and 500 Hz while measuring the RRO signals from the hard disk drive through high and low temperature extremes and low and high rotational frequencies. A large hard disk drive resonance was found at the -20C, 300 Hz operating point which allowed the RRO signal to become 8 times larger than obtained at room temperature of 25C, i.e., RRO of 6 nm increased to 24 nm. By uncovering this large resonance, suitable solutions may be obtained to decrease the RRO signal and allow for better performance at the cold and hot temperature extremes. The ability to measure the performance of these small hard disk drives will allow more robust system designs that will allow good performance in especially harsh environmental conditions.

This study verified the practicality of using small rotary shakers installed in environmental chambers. Modifications to the shaker were made by GHI Systems, Inc. to meet or exceed the required temperature and altitude test parameters of the study.

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About Hitachi Global Storage Technologies:
The company was founded in 2003 and was formed as a result of the strategic combination of IBM and Hitachi's storage technology businesses. Hitachi Global Storage Technologies is positioned to immediately advance the role of hard disk drives beyond traditional computing
environments to consumer electronics and other emerging applications.

GHI Systems, Inc., producer of specialized shock and vibration equipment for the hard disk market as well as other high technology products is located at 916 N. Western Ave, Suite 201, San Pedro, CA 90732 and maintains a web site www.ghisys.com.