Utilizing High-Speed Imaging Technology, High-Speed Data Acquisition and Motion Analysis Software in the Drop Testing of Small Size Product Packaging Designs

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Benefits of High-Speed Imaging

Many of the performance characteristics of a product's package are clearly evident when evaluated using drop testing techniques. However, the speed with which the packaging designs advantages and shortcomings reveal themselves during a drop test in many cases is too fast for the human eye to discern. By employing high-speed imaging techniques, the test engineer is able to slow down the event, taking images at 5,000 frames/second and faster. This allows the test engineer to clearly identify, in a visual manner, all the characteristics of performance of a particular package (e.g. flex, deformation, durability, etc.).

Benefits of High-Speed Data Acquisition

By applying a transducer to a product during testing, data can be collected better describing the test environment. For instance, by attaching an accelerometer to a product being tested (e.g. a mobile phone); the test engineer can collect information relating to the test which compliments the imaging data collected using high-speed camera systems. In this case, acceleration data can be collected at rates of speed similar to and greater than the frame rate of the camera. This data can be reviewed in conjunction with the review of the image data and the test results can then be correlated.

Benefits of Motion Analysis Software

Prior to running the drop test, targets can be fixed to the product being tested. The points on the product that are of interest to the test engineer (e.g. points where the package may be expected to flex, etc.) can be identified using target markers. Using the digital video images created using the high-speed camera system; the motion analysis software can automatically track the position of these markers during a test. In addition to position, the software can automatically calculate displacement, velocity and acceleration, providing the test engineer with important data immediately following the test.

Important System Component Considerations

Other than the drop test tower itself, there are four main components that make up the complete system for high-speed image capture, high-speed data acquisition and motion analysis. These components are: 1) the high speed camera system, 2) the lighting system for the high-speed camera system, 3) the high speed data acquisition device and 4) the motion analysis system.

High-Speed Camera – There are three significant camera features that must be evaluated and defined. First, the camera must be able to capture images at a very high framing rate. Second, the camera must offer sufficient spatial resolution so that the test engineer is able to see sufficient detail in the test images. Third, the camera must be sufficiently light sensitive such that quality images can be captured with as little additional illumination as possible. The HotShot 512 sc provides a very balanced

solution for this high speed imaging application as it provides 512 X 512 pixel resolution up to 5000 fps with excellent light sensitivity.

Lighting System – Sufficient light must be applied to the test subject so that the high speed camera can provide images of sufficient brightness allowing the test engineer to properly analyze images. There are basically two choices for lights for a drop test application, tungsten lighting and HMI lighting. Both types of lighting can provide sufficient illumination, but HMI lights are more efficient in their use of power. They are able to convert more energy into light energy and less into heat. As a result, HMI lights operate much more effectively in an enclosed testing laboratory because they generate a lot less heat. To meet the needs of this application, the ARRI Pocket Par 125W HMI light kit (using two light heads) is utilized.

Data Acquisition System – The data acquisition system must sample information from the sensor (e.g. accelerometer) at speeds that equal or, more typically, exceed the speed of the high speed camera. Since these types of sensors are readily available and are easily integrated into the system, any data acquisition device can be used with the system.

Motion Analysis Software – Image analysis software performs automatic tracking of the targets identified in the image file. Since analysis results depend on the position of the various points in each image, and this information is compared frame to frame, the tracking algorithms used by the software must be proven. In addition, the motion analysis software should be able to take the information generated by the tracking algorithms and be able to perform meaningful analyses (e.g. velocity, acceleration, etc.). The software should also be capable of importing information from the data acquisition for analysis and display. Finally, the software should be able to display multiple graphical representations describing the results of its analysis and these results should be displayed simultaneously with test images, synchronized and played back. NAC's Standard Version MOVIAS, which has been in use worldwide for more than 20 years, meets all the requirements for the motion analysis software for drop testing applications.

Equipment Package Used for the Drop Test Application

A standard package used by many test engineers incorporates the HotShot 512 sc Digital High-Speed Video Camera system from NAC Image Technology (see Figure 1), NAC's MOVing Image Analysis Software (MOVIAS) (see Figure 2) and the Pocket Par 125W HMI lighting system from ARRI (see Figure 3).

- The HotShot 512 sc captures high resolution images at frame rates commonly used by product test engineers (between 5,000 fps and 10,000 fps). The HotShot 512 sc is offered in a variety of memory configurations. The configuration selected will depend on the number of images required by the test engineer.
- NAC's MOVIAS software performs auto-target tracking of multiple targets, automatically performs requested analysis and automatically calculates position, displacement, velocity and acceleration. In addition, MOVIAS imports transducer information and synchronizes and plays back simultaneously image data, transducer data and analysis results.
- The Pocket Par 125W HMI lighting system provides daylight quality light which allows the camera to capture brilliant color or monochrome images. Important for this application, the Pocket Par 125W HMI generates very little heat while generating a great deal of light. This is important when evaluating packages that might be adversely impacted by high heat generated by a lighting system.

Note: In the past, high-speed imaging packages with the capabilities of the described system were typically >$100,000. The described package is configured for the product testing marketplace with the total system priced below $35,000.

Figure 1

Figure 2

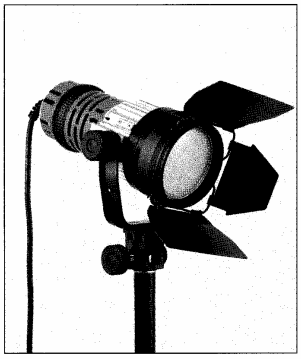

Figure 3

Application Environment

The main challenge was to perform repeatable tests for small packaged systems. The test facility needed to develop procedures for generating test results to analyze the performance of small packaged items. More specifically, they were tasked with evaluating the performance of items weighing less than 5kg (e.g. laptops, mobile phones, consumer products packaging, etc.).

Utilizing the high-speed imaging system described above (i.e. HotShot 512 sc, MOVIAS and ARRI 125W HMI lights), the test engineer integrated this system with his drop test fixture. Although the equipment configuration described above is capable of being integrated with a number of drop test fixtures in the lab, the test engineer selected the DT202 for testing the small items.

The DT202 drop tower is manufactured by Yoshida Seiki of Japan. The DT202 allows the test engineer to perform repeatable tests with products weighing 5kg and less. Using the DT202, the test engineer was able to set the test height and, using the capabilities of the drop tower, allow the test subject to drop free at a pre-determined height. This system was specifically designed for testing such products as notebook PC's, mobile phones, personal electronic devices (e.g. PDA's, entertainment devices, etc.), packaged foods, cosmetics, medicines, medical devices, etc.

The drop tower was set in a laboratory environment operated at room temperature. The HotShot 512 sc is placed perpendicular to the vertical arm of the drop tower such that the product being evaluated drops in the Y direction and the plane of the impact area is the X axis. Two ARRI Pocket Par 125W HMI light heads are placed at angles to the drop tower such that shadows are eliminated from the images. The HotShot 512 sc is connected to a laptop computer via USB2.0 and the MOVIAS software is loaded on the laptop computer.

Prior to running the test, the product package is prepared for testing. Specifically, targets for tracking and an accelerometer are fixed to the product package. In addition, vertical and horizontal distances are calibrated within the camera's field of view. In this way, the software will be able to equate displacement within the image to actual distances. The product package is mounted on the drop tower, the camera is placed in the ARM mode and the lights are switched on.

Test Procedure

Having fixed the test subject to the drop tower, the camera system is placed in the ARM mode and the lighting system is switched on. The test area is secured and a countdown is initiated. The drop tower is activated and the camera system is triggered (i.e. commanded to capture and store images). Using the DT202, the maximum vertical height of the drop is 200mm, so the test is completed very quickly.

There are a variety of ways in which the camera trigger can be integrated with the operation of the drop tower. The simplest (and quickest) method is to simply manually trigger the camera using a switch closure. The operator who activates the drop tower also presses a trigger switch commanding the camera to follow its pre-programmed routine for capturing images. At the completion of the test, the lights can be switched off while the test fixture is prepared for subsequent tests.

After completion of the test, the captured raw images are downloaded to the laptop computer from the camera via USB2.0. The images are then converted to a computer recognizable (e.g. AVI). In addition, the data acquired from the accelerometer is imported to the laptop computer.

The process of downloading and converting the images is accomplished in a matter of a few minutes (depending on the capabilities of the laptop computer employed). As a result, it is possible to perform multiple tests in a very short period of time. The pacing item which dictates the number of tests that can be run is the setup time with respect to preparing the test subject. Once in place, the camera and lights should not need to be adjusted.

After testing is complete, MOVIAS is started on the laptop computer. Each image file captured is opened and analysis performed on the image. First, the points of interest are identified and labeled. Then, the MOVIAS software is instructed to track the points. Once tracked, the software can be instructed to analyze the tracking results providing such standard 2-dimensional analysis results as position, displacement and acceleration. The analysis results are then displayed graphically and can be synchronized and viewed simultaneously with the image results. In addition to performing the desired analysis, MOVIAS is capable of importing the accelerometer data, displaying the data graphically, and synchronizing the data acquisition results with the images captured and the results of the analysis performed by MOVIAS.

Test Results

The following figures show sample drop test results for a notebook PC (Figure 4), a mobile phone (Figure 5) and a package for a liquid product (Figure 6). In each case, the subject was dropped from the DT202 and the images were captured and stored on the laptop computer. Points of interest were identified and labeled and graphical results were displayed. The test results from the notebook PC demonstrate how graphs can be overlayed to compare results for multiple points. The test results for the notebook PC and mobile phone demonstrate how transducer data can be imported and displayed using MOVIAS software. The test results for the notebook PC and the liquid package demonstrate how acceleration and/or velocity results can be graphically examined using MOVIAS software.

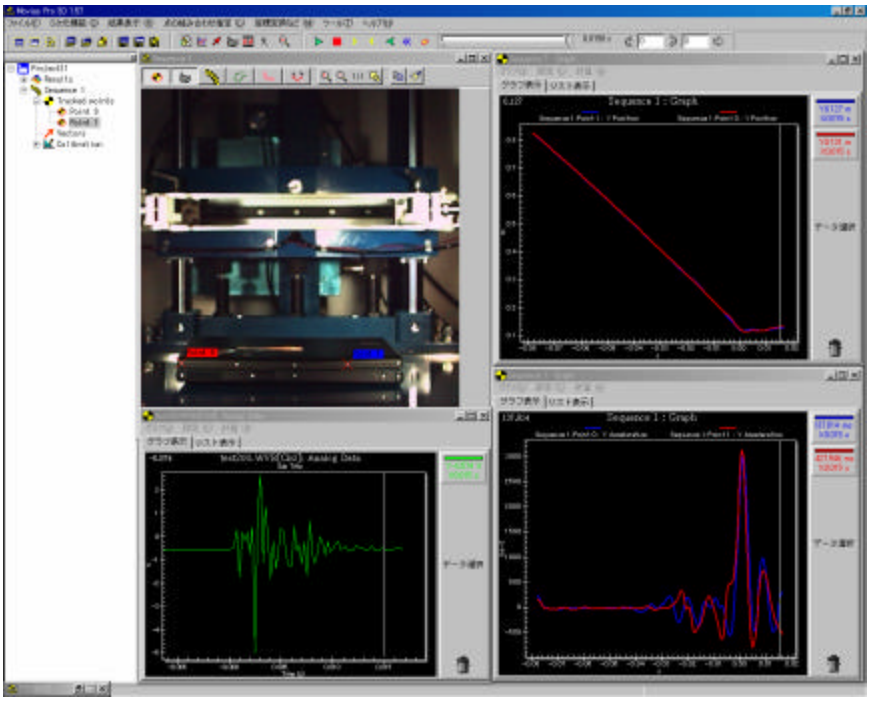

Figure 4 – Notebook PC drop test results

Test Results (continued)

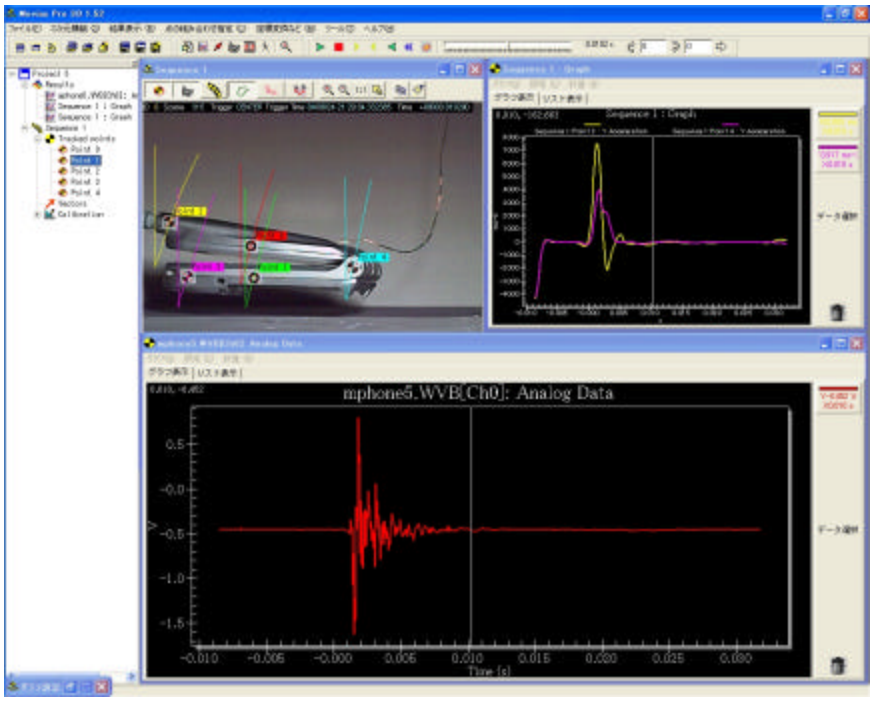

Figure 5 – Mobile Phone drop test results

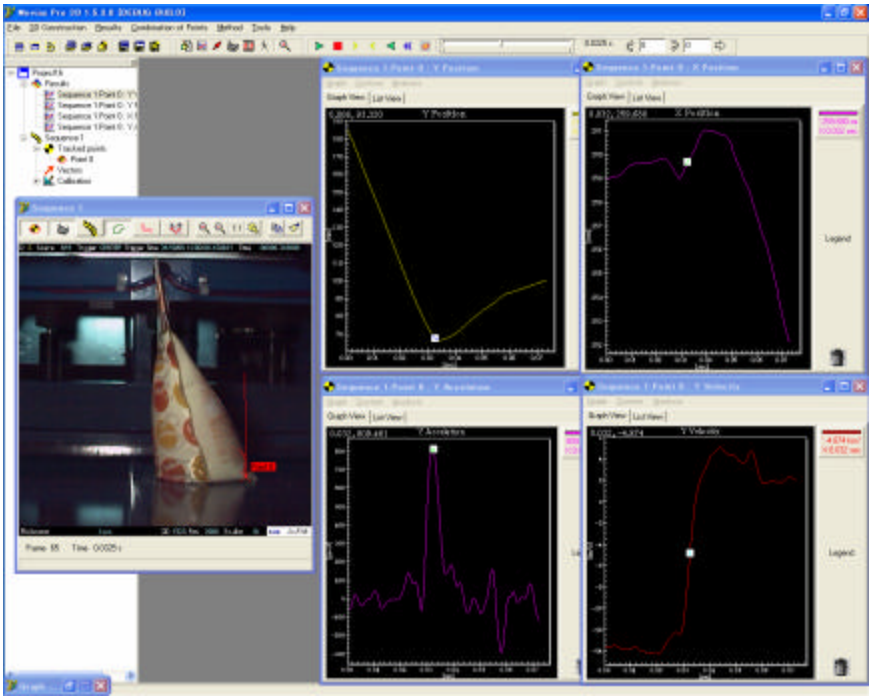

Figure 6 – Liquid Package drop test results

The Bottom Line

The HotShot 512 sc Digital High Speed Video System, the MOVIAS Motion Analysis Software and the Pocket Par 125W HMI Lighting system, taken together, offer a turn-key high-speed imaging and data analysis system that will integrate with any drop testing environment. It is an easy-to-use system that is extremely affordable.

Historically, the price of systems used to support drop testing activities have been in excess of $125K. Advances in camera and motion analysis software technology allow NAC Image Technology to offer this complete package for sale for less than $35,000. This complete package from NAC Image Technology puts high quality high-speed video capture, high-speed data acquisition and data analysis in the hands of more testing laboratories.