# Process Automation for LS-DYNA Based Shock and Impact Studies (Drop Testing) in eta/VPG Environment

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## Abstract

*Consumer products are many times used under extreme use conditions which have the potential to damage a device in a manner such that the internal components become damaged, and non-functioning.*

*Designing engineers must consider these shock, impact and vibration conditions when designing products, as well as the shipping containers or packaging of the product for transport to the end user. In addition, there are many different variations of the impact condition, including height, and angle of impact.*

*Drop Tests are performed to test physical prototypes for such inputs. LS-DYNA analyses can be used to simulate these tests, thereby reducing the number of tests and improving the product design prior to prototype construction.*

*A case study of how process automation within eta/VPG has enabled engineers to consider many different drop test simulation scenarios in an efficient manner will be presented.*

## Introduction

Consumer products have undergone a significant change over the past 15 years; transforming from products which, though portable, were operated in a stationary manner to completely portable products which "go with" the user. This transformation of products to ever more portable designs have been driven by advances in the electronic components and their packaging. However, this has caused new challenges for the mechanical design engineer, who must design products that will withstand sometimes severe environments, with the product expected operate in an proper manner.

Primary abuse loads that consumer products must withstand are due to transporting the product to the consumer, and user abuse such as dropping the product.

Engineers have developed testing procedures that allow them to study the durability of products to such drop tests. These tests are used to evaluate the design of a product and the packaging materials used to ship the product. The tests allow engineers to better design energy absorbing

materials into their products and provide adequate strength to products so that they may withstand impacts.

In order to make more efficient use of the time available to design and test a consumer product, simulations using LS-DYNA have also been developed, which simulate the testing process.

Results of these simulations are in the form of deformations, stresses and acceleration histories. In the test, these are obtained by accelerometer measurements, strain gage measurements and high-speed video. The simulation data is obtained through results files specified in the simulation model(s).

Since there are many possible variations of a drop test, both the testing and simulation process can be time consuming.  As simulations of drop events have become more and more reliable and predictive in nature, there has been a need to implement automation into the process of creating drop test simulation models.

In order to automate this process a Drop Test Module has been developed, allowing the engineer to quickly define all necessary parameters used in a drop test, and by allowing the engineer to create a series of drop test simulations, representing multiple test configurations.

## Drop Test Parameters

In order to identify which parameters could be automated in the pre-processing of drop test simulation models, a series of drop tests was observed. Testing is usually conducted by dropping the product from a specific height onto a rigid surface. The drop height may vary depending on the type of product and the desired severity of the impact. Another variable that is found in most drop tests is the angle at which the product is dropped.  For instance a product may be dropped at a 0 degree angle with respect to the rigid surface, or it may be dropped at a 30 degree angle with respect to the surface. The impact may be performed at many different angles, to identify the critical angle at which the product may have a failure.

Another parameter that is necessary to define is the measurement points in the test specimen. This is usually where an accelerometer is placed on the specimen for the test to collect deceleration data.

In summary, the parameters that need to be identified for each individual drop test are:

- Drop Height
- Drop Angle
- Data Output Requirements

## Process Automation Implementation

The VPG software includes a Drop Test Module (DTM), which implements a series of menus, allowing the user to specify all of the parameters which are used in defining the physical testing of the product.

The user accesses the DTM through the main menu, by selecting DTM. Upon entering the Drop Test Module, VPG executes a command to calculate the center of gravity and the mass and inertias of the current model.
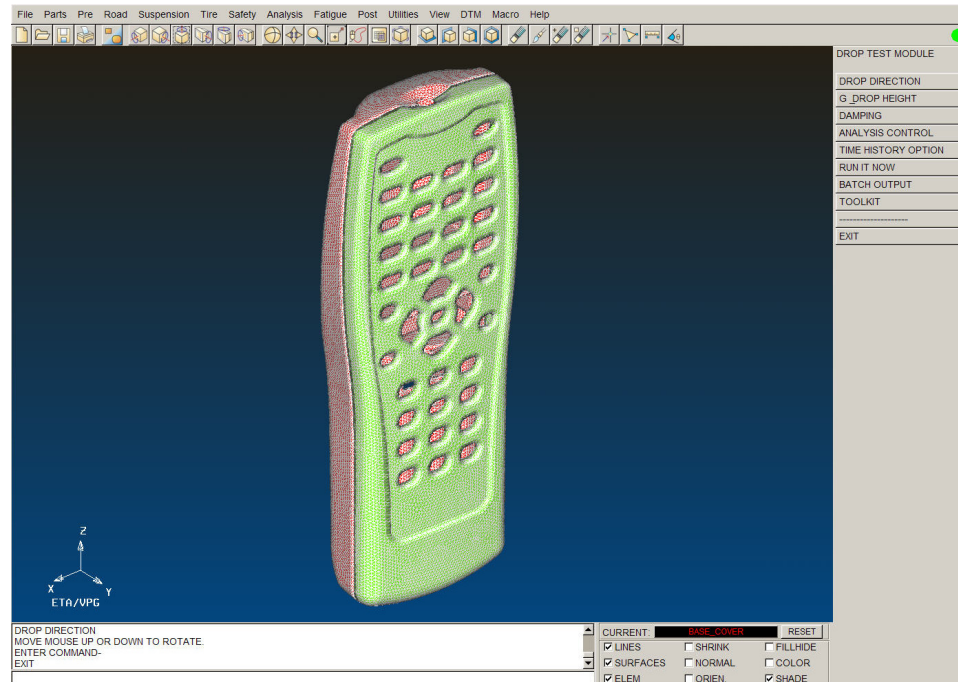


Figure 1: Drop Test Menu

The menu provides additional sub-menus which allow the user to specify various parameters.

The DROP DIRECTION menu provides a means to define the direction of the drop. A local coordinate system can be defined from the calculated CG point to another specified node on the model. Another method of creating a local coordinate system is to define a direction between two nodes. VECTOR command allows the user to define a vector which will serve as the direction of the drop.

The user may make use of the global coordinate system of the model, to define the drop axis.
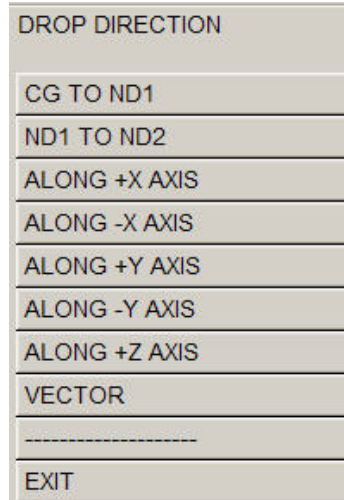
Figure 2: Drop Direction Menu

The G and DROP HEIGHT command allows users to define the drop height parameter and the gravity constant used in the model. The sub-menu is shown in Figure X.
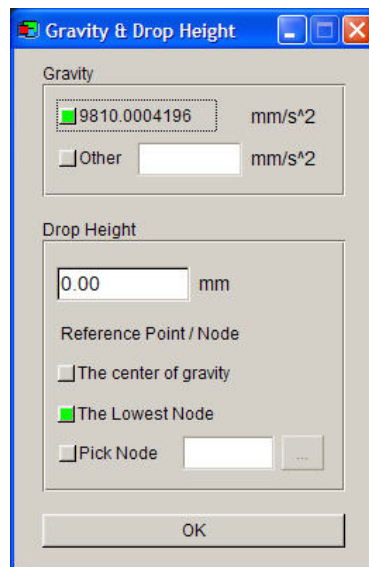

Figure 3: Gravity and Drop Height Definition Menu

The gravity constant can be adjusted to meet the users mass and distance units. A common default value is provided for the user. Definition of this parameter results in the creation of a *LOAD_BODY_Z in the LS-DYNA input file.

The Drop Height parameter specifies the distance above the surface the model should be drop from. VPG calculates an initial velocity based on the gravity constant and drop height, and applies this velocity to all nodes in the model through and *INITIAL_VELOCITY definition.

Definition of the model DAMPING parameter is necessary to provide an accurate response of the drop model. The damping is defined by creating a *DAMPING_GLOBAL definition in the model. If necessary, a nonlinear damping may be defined by means of a Load Curve.



Figure 4: Damping Parameter Definition

The ANALYSIS CONTROL sub-menu allows the user to control the simulation height at which the model will be defined. This definition places the rigid impact surface the specified distance from the model. Since in the physical test, the specimen must be dropped from the actual height, definition of the parameter at a distance close to the model (lower number), reduces the required simulation time. By default, the drop height is used as the start height for the simulation.
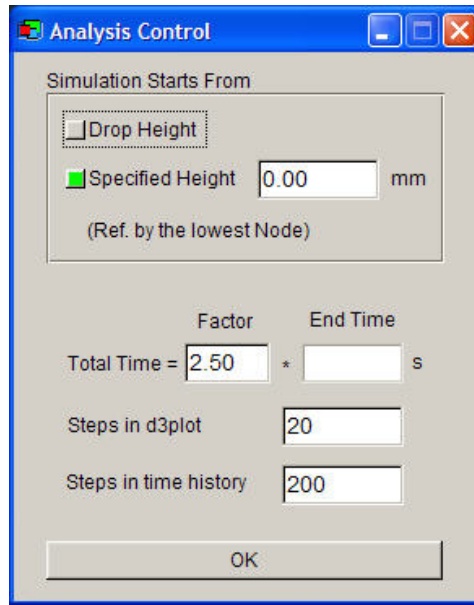
Figure 5: Analysis Parameter Definition

The ANALYSIS CONTROL sub-menu also allows the user to define the simulation duration and the number of output steps that the analysis will output.
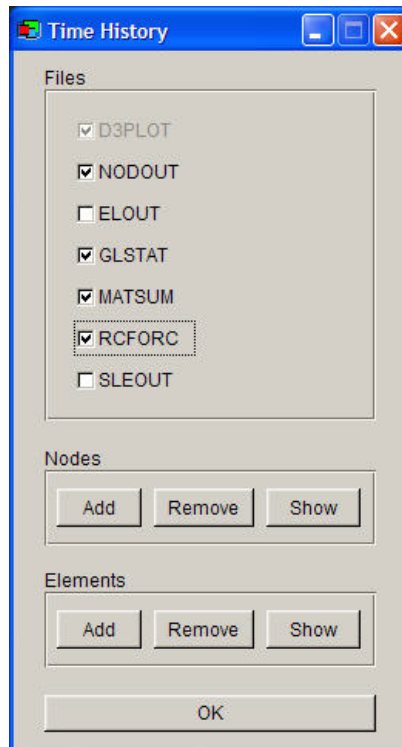
Figure 6: Time History Parameter Definition

Additional output data can be obtained from the analysis. This data, such as material energies, contact energies, global response data, and node response data can be obtained by selecting the

options from the TIME HISTORY sub-menu. Since these results are provided via the SET definition in LS-DYNA, VPG allows the users to define nodes and elements to be added to sets for the output of this data.
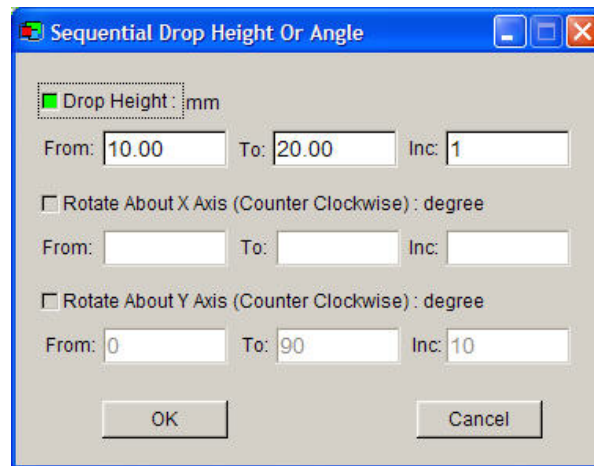

Figure 7: Batch Model Creation Options

A typical series of tests used to evaluate a design may consists of many different drop angles and heights. VPG Drop Test Module allows the user to define a series of angles and drop heights which are to be simulated. By defining the range of angles and drop heights, and the increment between each configuration, the user can automatically generate a series of models which can be evaluated.

The result of this definition is the creation of models named DTMdeck001.dyn, DTMdeck002.dyn, etc. Up to 999 input files may be created in this manner.

Additional tools for set up of the model are found in the TOOLKIT menu. This provides tools such as a recalculation of the model center of gravity, in the event that the model was modified. It also allows the user to remove the damping definition and control which version of LS-DYNA is executed and the amount of memory requested for each simulation.
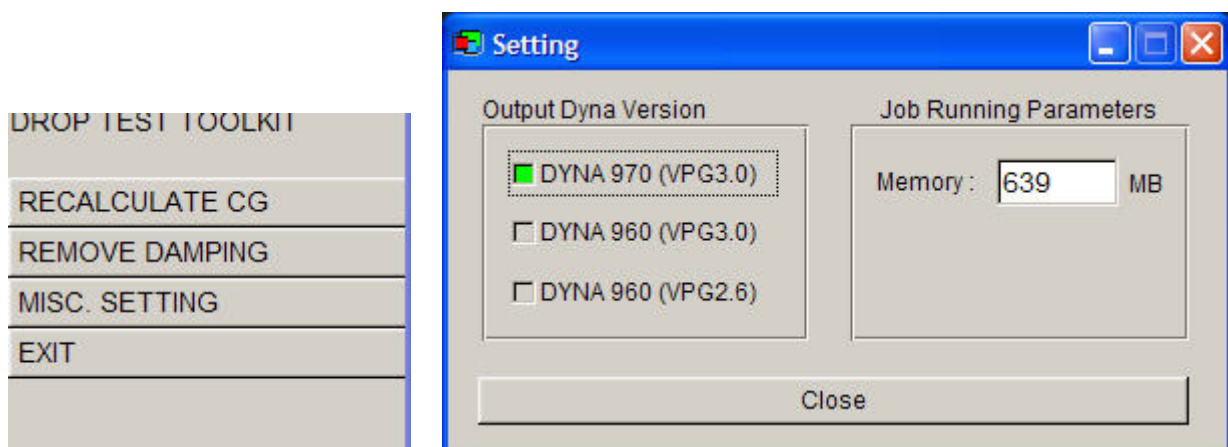

Figure 8: Toolkit Options

## Example of Drop Test Module Implementation

The usefulness of these tools can best be demonstrated on a typical drop test model. The model used in this demonstration will be a typical television remote control unit. The goal of this study will be to evaluate the remote control response for stress and deceleration pulse for 3 different drop angles; 0 degrees, 15 degrees and 30 degrees.
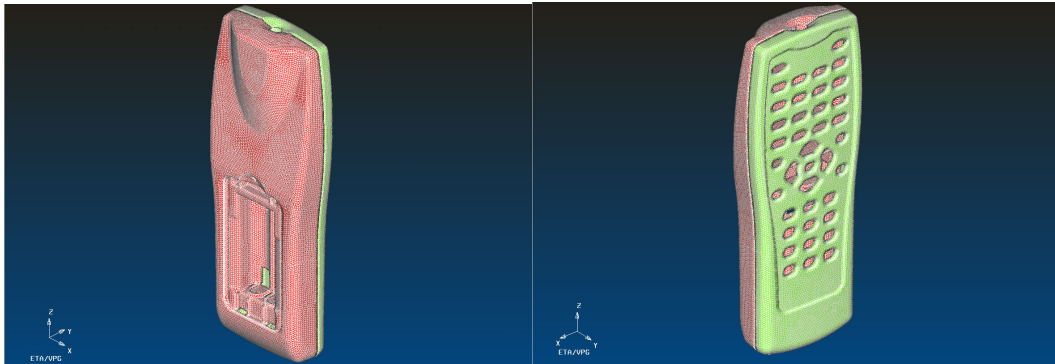


Figure 9: Remote Control Unit Drop Test Model

This unit is made from a plastic material, and is composed of two components. These components are attached via a contact (Automatic Single Surface) of a tab and a receiver. The complete model is shown in Figure 9. The model was meshed in eta/VPG using the Topology Automesh option to create a skin mesh, and then filling it using the Tetra Meshing commands.

The appropriate materials were defined and applied to the components, using a *MAT_PLASTIC_KINEMATIC definition in LS-DYNA.

After the modeling was completed, the Drop Test Module was used to complete the model and prepare it for drop testing simulation.

Since the goal of the process was to create a series of simulation models, the first command used was the BATCH MODEL creation menu. In this menu, the definition of the drop height remained constant, but the angle was changed from 0 to 30 degrees, with an increment of 15 degrees. Since the model is symmetrical, there was no difference if the model was rotated clockwise or anti-clockwise.

The next step in the preparation was to specify a height at which the simulation started, using the ANALYSIS CONTROL menu. On this menu, the model was specified to start the simulation at a height of 10 mm above the rigid contact surface, in order to minimize the time required for the calculation. This command resulted in the creation of a *RIGIDWALL_PLANAR_FINITE positioned 10mm from the model. This also created an *INITIAL_VELOCITY_GENERATION definition for the model, using the drop height and analysis start height to calculate a proper velocity value.
The ANALYSIS CONTROL menu was also used to define the stop time for this simulation, and the number of output steps desired. In this case, the end time of the simulation was 0.003 seconds, with a output step of 0.0001 seconds, resulting in 30 output steps.

Upon exiting the DTM, three input files were generated, DTMdeck001.dyn, DTMdeck002.dyn and DTMdeck003.dyn. These files were then directly submitted for analysis.

Stress Contour results for the 0 degree drop condition are shown in Figure 10. The localized results in the tab areas are shown in Figure 11. The simulations predicted that a local yielding of the tabs would occur in the 0 degree drop, prompting a design change.
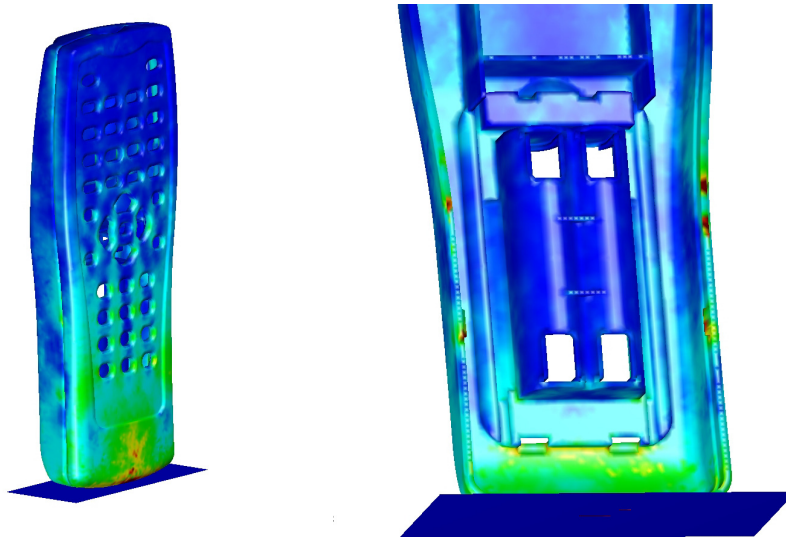


Figure 10: Stress Results for 0 degree Drop Test Configuration
Figure 11: Detailed View Showing Tab Stresses

## Summary

Drop Testing Simulation can be made more efficient by implementing a process automation, which allows the creation of specialized models meeting the requirements of drop test simulation, and allows for the simultaneous creation of multiple models.