# A Parametric Study of Drop Test for Hard Disk Drives Packaging using Finite Element Analysis

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***Abstract***

Design a package for logistic hard disk drives concerning considerable parameters. Mostly the loadings are confined to fulfill with ASTM D4169 and company restriction, however, the cushion performance can be varied. In this work, simulations employing finite element analysis are performed to investigate the performance of cushion having various cushion spacers from 3 millimeters to 9 millimeters. Six positions of impact (6 sides of corrugated box) were examined and compared with the actual drop test. The results indicated that changes in cushion spacer have significant influence on the longitudinal of corrugated box. For the most hazard drop side, impact acceleration is reduced dramatically when the spacer is increased to a certain distance.

## 1. Introduction

Safe logistic is crucial for fragile product such as Hard Disk Drive. The performance of container box must be ensures to provide the designer confident. Standard drop test (ASTM D4169) is mostly required prior to the production. Numerous of researcher [1-3] have conducted experimental examinations for packaging design. These destructive activities raise the product cost noticeably. Finite element analysis is a numerical technique employed by researchers [4,5] to accelerate the design process and reduce the cost of making models. In 2002 K.H. Low [4] has studied and analysed drop test model of Hi-Fi Audio comparing between model with cushion and model without cushion. This study concluded that the cushion can reduce the displacement, shock and acceleration occurred at the components of the Hi-Fi Audio. In 2004 Y.Y. Wang, et al [5], had studied the reliability of the drop test for electronic devices using finite element methods and simplifying the model to reduce the calculation time. The techniques employed shortening the design process and confirmed that drop test could be simulate using computer code to reduce the number of required physical tests.

In this work, the simulation of drop test for 2.5" hard disk drive packaging, as shown in

Fig. 1, is undertaken using finite element analysis. The ASTM D4169 [6] is followed. The packaging, consists of top cushion, bottom cushion, corrugated box and 20 items of 2.5 inches hard disk drives, is allowed to drop from 900 mm height. The acceleration at a particular position is examined to compare with the experimental investigation [7]. Furthermore, a parametric study, using finite element analysis, is conducted on the cushion spacer from 3 to 9 millimeters in order to observe the effects of the change in cushion spacer on the packaging's impact acceleration, and provide design suggestion.

## 2. Packaging Drop Test

In this study, five major items of hard disk drive packaging, consist of top cushion, bottom cushion, corrugated box, 4 hard disk drives and 16 dummies, were examined. Two hard disk drives (number 1 and 4) are positioned at the end of each row of the packaging and the other two (number 2 and 3) are placed in the middle columns, as shown in Fig. 2.

A tri-axis accelerometer is installed at the spindle motor of hard disk drive number 1 for typical packaging drop tests from 900

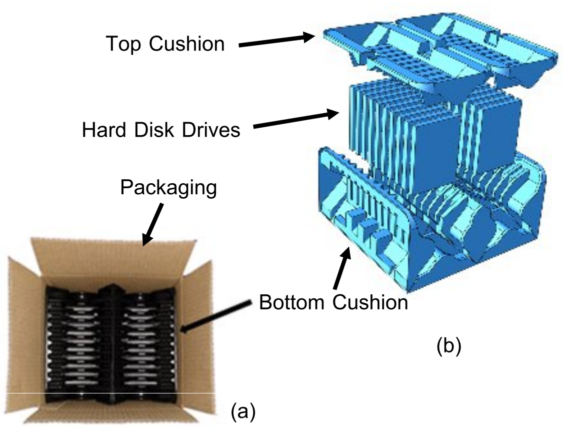



Fig. 1 Corrugated box and the packaging

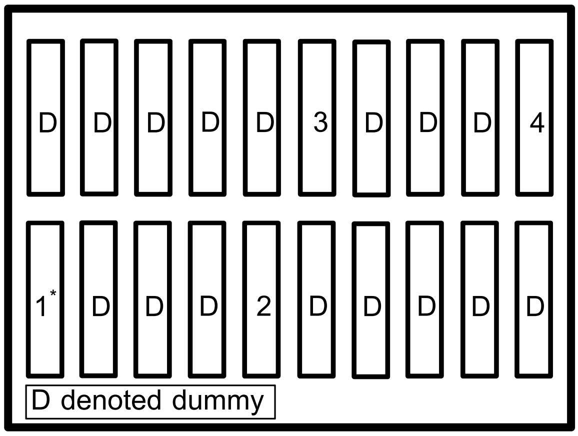



Fig. 2 Positions of hard disk drives (1-4) and dummies (D)

millimetres above the reference plane, as shown in Fig. 3. Ten consecutive drops for a packaging are performed according to the referred drop test procedure. Dropping positions of the corrugated box, indicated in Fig. 4, are given. A parametric study of drop test performed for only six sides (seq 5 to 10) of the corrugated box. Cushion spacer is the preliminary parametric studied in this work based on the simulation of drop impact on the six sides of the packaging.

## 3. Finite Element Models

Six positions (seq 5 to 10) of impact were tested continuously for the actual drop test. However, doing this in the simulation, a huge storage is required to collect the results from previous processing as the initial condition for the consecutive run. To simplify the pre-processing for each impact position an undeformed model is used for each simulation. The finite element software, ABAQUS, is employed in this study using explicit solver. The following steps are used to construct the finite element model.

### 3.1 Creating parts and assembly

Three-dimensional model of hard disk drive packaging composes of top cushion and

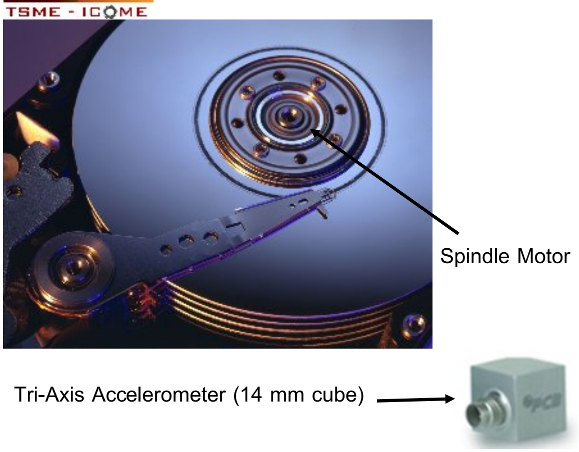



Fig. 3 Tri-axis accelerometer installed at spindle motor

bottom cushion which represent by 3 nodes shell element, corrugated box utilized 4 nodes shell element, whereas, hard disk drive and dummy are considered as rigid bodies, as shown in Fig 1 (b). All components are assembled together using contact pair. And the floor is represented by a rigid body.

**3.2 Material properties**

The materials of both top and bottom cushion are Low Density Polyethylene (LDPE) which specified as elastic perfectly plastic material. Other properties are specified for density of 880 kg/m$^3$, elastic modulus of 0.541 GPa and Poisson's ratio of 0.3. The corrugated box has orthotropic property which consists of

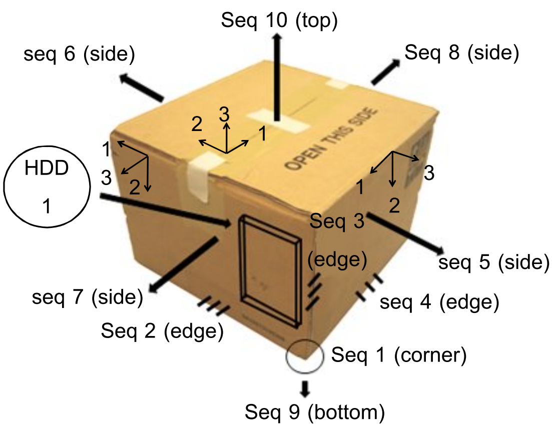



Fig. 4 Sequences and local directions of drop test (First hard disk drive shown)

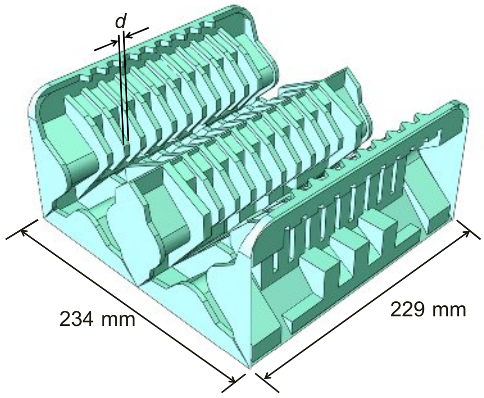



Fig. 5 Bottom cushion (*d* represents the cushion spacer)

three unequal values: machine direction (direction -1), cross machine direction (direction -2) and out-of-plane direction (direction -3). The elastic modulus were examined according to the NFQ 03-002 standard [8] for both machine direction and cross machine direction. The out-of-plane elastic modulus is calculated using 250 [9] to divide the elastic modulus in machine direction. These mentioned values are given in table 1. The shear modulus are approximated according to the following formula [10-12]

$$G_{12} = 0.387\sqrt{E_{11} \times E_{22}} \tag{1}$$

$$G_{13} = E_{11} / 55 \tag{2}$$

$$G_{23} = E_{22} / 35 \tag{3}$$

where $G_{12}$, $G_{13}$, and $G_{23}$ are shear modulus in the 1-2 plane, 1-3 plane and 2-3 plane,

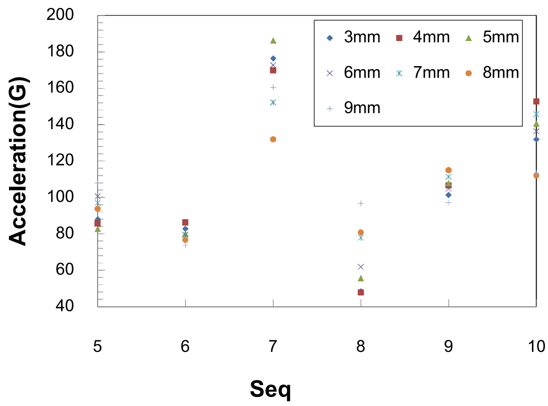



Fig. 6 Acceleration on HDD position 1 for various cushion spacing (*d*)

respectively. Due to the orthotropic properties, the local directions specified for each side of the packaging model are given in Fig. 4.

Table. 1 Material properties of corrugated box

| Direction | Elastic Modulus | Poisson' ratio |
|---|---|---|
| Machine Direction | 5.5 GPa | 0.34 |
| Cross Machine Direction | 2.76 GPa | 0.01 |
| Out-of-plane Direction | 2.2 kPa | 0.01 |

**3.3 Contact properties**

Finite element model for drop test consists of 20 hard disk drives, corrugated box, top cushion and bottom cushion. Contact pair is used between these parts: hard disk drive and bottom cushion, hard disk drive and top cushion, bottom cushion and top cushion, corrugated box and top cushion, and corrugated box and bottom cushion. In addition, self contact is also specified for bottom cushion and top cushion. Frictionless is assumed to reduce the calculation time.

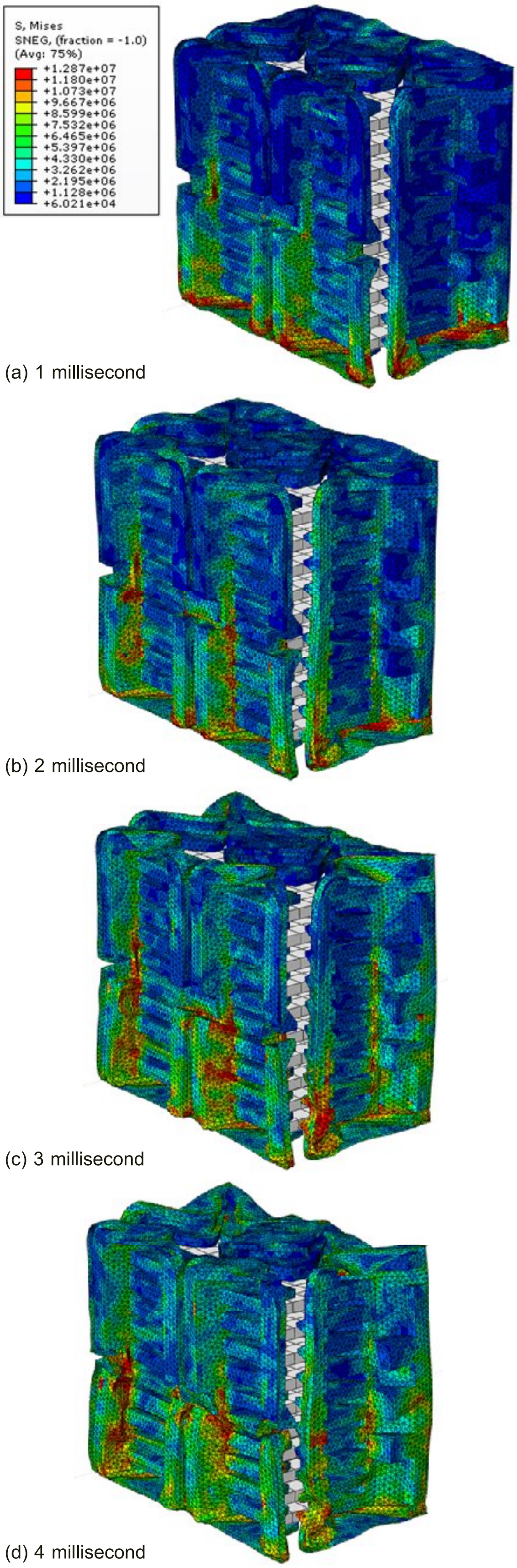
**3.4 Initial and boundary conditions**

Since the drop test is letting the packaging fall free at a specified height, it is time consuming to calculate the model. Therefore, the velocity of the packaging is calculated for the instance of impact and used as the initial velocity for the simulation to reduce the analysis time.

For free fall of packaging from a specified height, the impact velocity is determined from the following equation:

$$v = \sqrt{2gh} \tag{4}$$

According to ASTM D4169 and Eq. (4), the calculated initial velocity just before impact is 4.2 m/s for the whole packaging. Floor is specified to be constrained from both




(a) 1 millisecond

(b) 2 millisecond

(c) 3 millisecond

(d) 4 millisecond

Fig. 7 Stress distribution on the cushions at 1 to 4 milliseconds of seq 7 translational and rotational motions at the reference point.

### 4. Parametric Study

In packaging design process, the cushion's outer dimensions are confined to conform with the limitation for packaging in the container. The cushion performance is varying with cushion spacers. Three millimeters is the minimum requirement to avoid adjacent drives collision, whereas, over nine millimeters is not feasible to product. A parametric studied in this work is examined by alter the cushion spacer of top and bottom cushion from 3 to 9 millimeters. Nevertheless, the major configurations of the packaging are resemble, as indicated in Fig. 5.

### 5. Results and Discussions

The sampling rate of the acceleration for drop test is taken every 0.1 millisecond until the end of event at 4 ms for hard disk drive position 1 (refer to Fig. 2). In order to avoid the data distortion, antialiasing filter is used during ABAQUS analysis and Butterworth filter with a cut off frequency at 500 Hz is utilized for the post processing. The comparison of peak acceleration obtained from the analysis of dropped impact on the packaging sides (seq 5-10) for different values of *d* are showed in Fig. 6.

In general, the acceleration amplitudes for various values of cushion spacer at a particular dropped position are comparable. The peak accelerations of seq 5, seq 6 and seq 9 deviate less than those of seq 7, seq 8 and seq 10. The acceleration of seq 8 is increased when *d* is increased from 3 millimeters to 9 millimeters due to the flexural rigidity of the cushion increased, and vice versa for seq 10.

For the most aggressive dropped size, seq 7, the peak acceleration is decreased dramatically when the spacer is increased to 8 millimeters. However, increase the spacer to 9 millimeters would raise the acceleration amplitude due to the nonlinearity and instability of the structure.

Typical impact stress distribution on cushion at 1 to 4 milliseconds of seq 7 having 8 millimeter cushion spacers are showed in Fig. 7. Clearly, high stress areas are occurred adjacent to the dropped side in the collision (Fig. 7 (a)). These stresses are consequently transported upward to the other portions along with the impact period (Fig. 7 (b) – 7 (d)).

### 6. Conclusion

The intention of this work is to investigate the performance of cushion using finite element techniques for HDD packaging design process. In this work, only six sides of the corrugated box were conducted. The results indicated that changes in cushion spacer acquire significant influence on the longitudinal performance of corrugated box. The maximum acceleration occurred at seq 7 having value of 186.18 G.

### 7. Acknowledgement

This research is financially supported by Industry/University Cooperative Research Center in HDD Advanced Manufacturing and National Electronics and Computer Technology Center (NECTEC). Information and collaboration from Hitachi Global Storage Technologies (Thailand) Co., Ltd. is also acknowledged. Gratitude to the computational part facilitated by the Center of Operation for Computer Aided Research

Engineering (COCARE), King Mongkut's University of Technology Thonburi.

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