Design and Development of Drop Test Rig & Test Analysis of Handheld Electronic Devices

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Abstract- **Portable electronic devices suffer from impact-induced failure in usage. These products must pass drop or impact tests before shipment, so that there are no grievances at the customer end due to poor life of the product. Hence, drop or impact performance is one of the important concerns in product design. Because of the small size of these kind of electronics products, it is very expensive, time-consuming, and difficult to conduct drop tests to detect the failure mechanism and identify their drop behaviors. A large number of sensors are required in the extremely small space of the electronic device, so as to obtain sufficient data for failure analysis. To overcome this hurdle, a combination of only a few sensors, a rudimentary test rig, and finite element analysis with the help of software can be used to study device behavior during impact. Recent work has shown that due to the multiple impacts that result during an accidental drop of a portable electronic product, the propensity for damage to the product can be significantly higher than in a single impact. When viewed in light of these findings, conventional methods for drop-testing of portable products, either constrained or free, suffer from drawbacks. In the former, the object being tested is not allowed to move naturally during impact, and in the latter, it is difficult to control the orientation of the object at impact and to instrument it. In this project, a new method of drop-testing has been designed, that combines the advantages of the constrained and free methods, without their drawbacks. It is proposed that the object being tested be suspended onto a guided drop-table in the precise desired impact orientation. The test device, drop test and correlation of analysis to test data are illustrated in the report.**

Index Terms- Analysis, Design, Drop, Handheld electronic devices, Impact, Test Rig.

I. INTRODUCTION

With many products, it is not a specific technological feature any more that will guarantee a competitive advantage, but more often success is based on other product attributes such as the selected feature set, total quality, design and usability of the product. Besides for these product specific features, the company's skills in different business operations and strategies, such as in R&D, product development, manufacturing and logistics, play a major role in overall business success. Hence, we come to what has become one of the most important factors in product development; which is functionality. A device must function properly and offer the customer the same services throughout its life cycle. Now that we have established the importance of product functionality in deciding its success in the market, it is important to look at the ways in which said functionality can be tested or verified before the product is launched into the market. This may be related to its physical attributes; which is mainly studied and discussed in this report, or it may be related to its software attributes. The physical attributes of a handheld electronic device include the device housing, its electronic circuits and display screen. Our testing and analysis has been focused on the housing level analysis of the device- the reason being, the first point of contact for transmission of damaging forces is always the housing. How well the housing of the device handles external forces decides whether or not the internal electronic circuits, or external feedback devices will continue to function.

II. LITERATURE REVIEW

Constrained Drop Testing

Constrained drop testing is by far the most common, and it is based on sound fundamentals, and is part of many standardized test protocols. In constrained drop testing, the object being tested is clamped rigidly to a heavy table that is guided along vertical rods (or horizontal rails) to have a single impact against the ground (or a vertical barrier). Constrained drop testing has several advantages,

- Shock pulse amplitude and duration can be controlled fairly easily through drop height and using elastomeric pads, deformable metal cones or pneumatic actuators between the drop table and the ground.
- Since the object being tested is clamped to the drop table rigidly, the orientation of impact of the object can be fixed.
- The tests are repeatable and instrumentable.
- Permanent magnet brush type motors

The main disadvantage of constrained drop-testing is that it does not allow the object to execute its natural dynamics during impact, which usually results in multiple impacts. Recent work has shown that such multiple impacts, explained further in the following section, can significantly alter damage potential. Another drawback with constrained drop-testing is that it is difficult to subject the object to impacts on its vertices and edges since it has to be clamped to the drop-table. In contrast, during free drop-testing, as implied by the classification, the object is dropped freely, without any constraint. Constrained drop testing may also be in the form of a stationary impact test. In this, a spherical metal ball is dropped from a specified height onto the device or product. This however is not indicative of an actual drop during usage, and is more closely related to impacts due to other packages or parts during product handling in warehouses or factories.

Free Drop Testing

Free drop testing best replicates the abuse of portable product in the field. As implied by the classification, the object is dropped freely, without any constraints. The main advantage being, the object is allowed to execute its natural dynamics, which usually results in multiple impacts. The main disadvantage with this technique is that it is difficult to control the orientation of the object at impact and hence the tests are hard to instrument or repeat. For instance, it is difficult to guarantee that a desired vertex will strike the ground first. Since impact-orientation cannot be determined precisely, there is greater likelihood that a sensor, for example, an accelerometer wire may get entrapped between the object and the ground and get severed. Free drop testing is also not very suitable for individual components (such as a liquid crystal display) that are meant to be part of a larger system (such as a cellular phone) since in the field they experience shocks mitigated by their suspensions and the outer housing of the system. Finally, it is difficult to automate free drops which is desirable for tests requiring many repetitions.

Types of Drop Test Standards

Most drop test items must be able to withstand impact such as that which would be experienced when impact testing the item from the average height of a table (approximately 30 inches) or more. However, drop test procedures vary by product type and industry. There are two different drop test procedures that companies routinely perform:

1.Telecommunications Equipment —

Telecommunications equipment covered under the GR-63-CORE standard must meet the drop methods and shock (height) criteria for containerized and unpackaged equipment. The drop testing methods include free fall, corner drops, and edge drops.

2. Military Equipment — MIL-STD-810 is a United States Military standard specifying environmental test conditions to determine the durability of equipment. Procedure IV of that standard specifies criteria for examining material outside of or within the transit case as it is being loaded, unloaded, moved from a rack, placed within a transit case, or removed from a transit case. During the process, the test simulates an accidental drop or bump shock requiring a free fall from 18 to 48 inches depending on package weight and size. This testing methodology involves 5 to 26 drops and utilizes either a quick release tester or a fixture that elevates and drops one side of the package.

III. DESIGN AND MODELLING

Proposed Method of Drop Testing

The objective is to devise a method that allows realistic, precise and repeatable drop testing of the object. These goals may be met by controlling the orientation of the object till just before impact using a soft suspension. The object is released from suspension just before impact allowing it to execute its natural dynamics during and after the impact, while also giving the control over orientation of first impact. Hence in this method the disadvantages of constrained type and free drop testing are avoided, giving a realistic reproduction of an actual object drop.

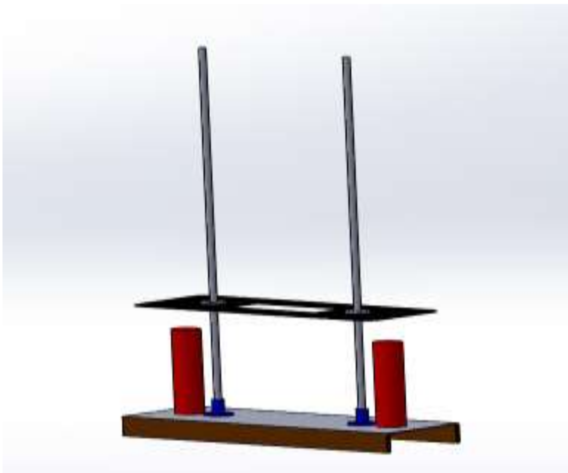


Fig.1: Final CAD Design

Final Rig Design

The final rig has the following construction.

1. Base Plate: It is made of MS 8mm thick C section. The selection of materials enables to consider the base surface as hard for the drop.
2. Rod Housing: The Rod Housings are bolted on the base plate.
3. Guide Rods: The guide rods with 12mm diameter are used. This makes the assembly light weight and portable.
4. Linear Bearings: SMF12 linear ball bearings are used which minimize the friction and enable free fall.
5. Drop Plate: The drop plate is 3mm thick Mild Steel. It is lasercut for suitable dimensioning and tolerances. A mesh is attached to the drop plate from which strings and threads can be passed. The threads can be attached to the mobile phone test samples. By changing the lengths and position of the threads, any desired orientation of the test sample can be achieved.
6. Damping Rods: The damping rods are made of Polyurethane which serve the purpose of stopping the drop plate after free wall with damping.
7. Electronic Circuit: Accelerometer sensors are mounted on the test sample and the readings are sampled in Ardiuno Uno board.

It is to be noted that while preparing the test sample for drop test the length of the threads or strings attached should be greater than the length of the damping rods. This is necessary to ensure that the sample is impacted on the base plate before the drop plate hits the damping rods.

Fig.3: Actual Test Rig

Impact Dynamic Analysis

Initial impact dynamic analysis was done using software ANSYS.

- Part Detail- The mobile phone selected for analysis has weight of 148 grams. Outer body is of Aluminum and screen made of hardened glass is fitted in housing.
- Type of analysis- In drop test simulation impact loading is applied on mobile phone hence Explicit dynamics analysis system is chosen and AUTODYN solver is used.
- Meshing- Meshing is done on ANSYS. 3-D tetra mesh elements is used.
  No. of nodes- 9139
  No. of elements- 30917

- Load conditions- Impact velocity of 4.5 m/s is given to mobile phone. Base plate is considered as rigid and fixed support is given to it.

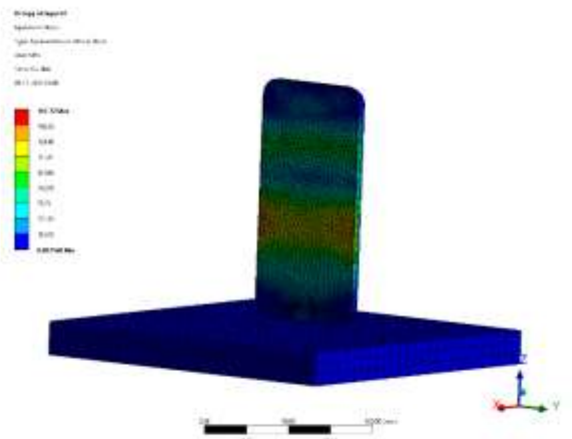


Fig.2: FEA Model

IV. TESTING AND ANALYSIS

The test setup was done using nylon strings and adhesive to hang the mobile device. The nylon strings were suspended and tied at the perforated metal plate. The orientation was fine-tuned using the strings and measured with the angle measuring device. The drop plate is raised at height of 1m

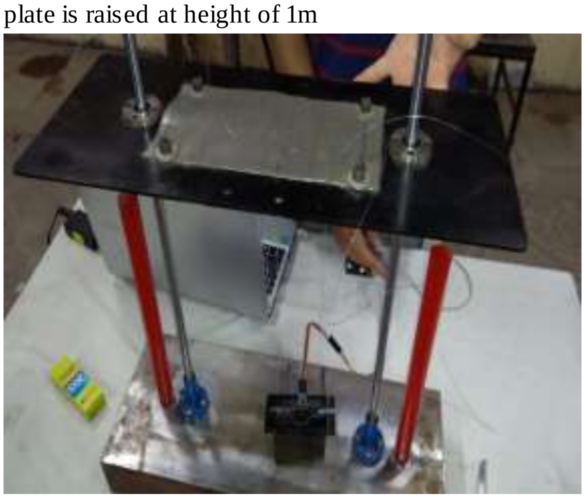
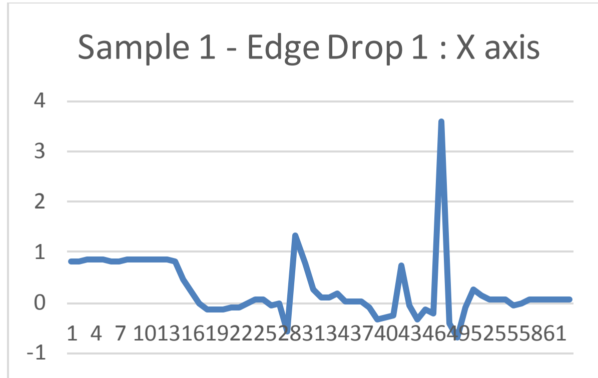
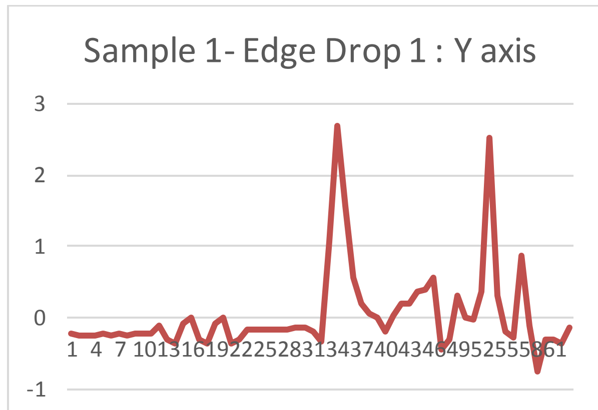


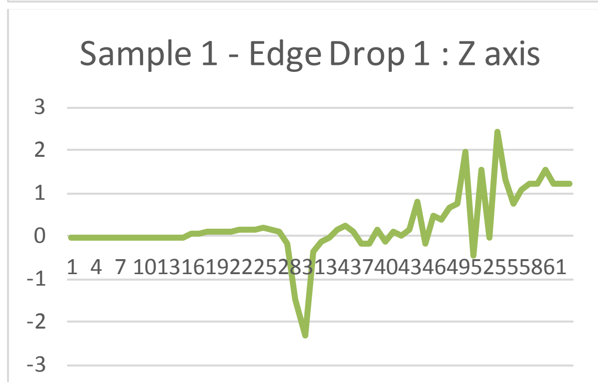
Fig.4 Drop Setup

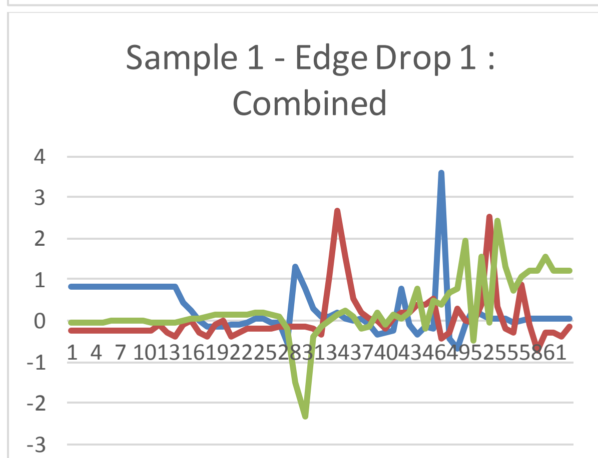
Test Accelerometer Results

The readings were recorded using Arduino Uno board and ADXL 335 accelerometer sensor. Using Arduino software the readings were recorded in X, Y and Z axes. Graphs for acceleration versus time were plotted for each test for all orientations to observe pattern.



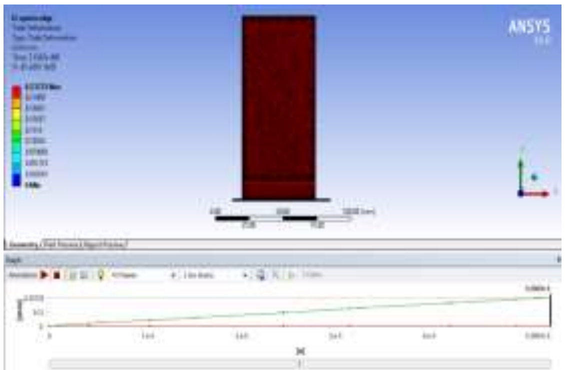


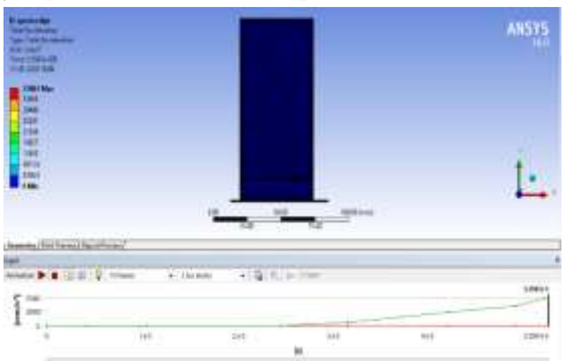


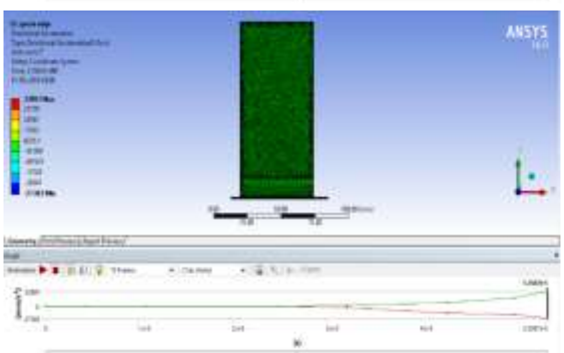


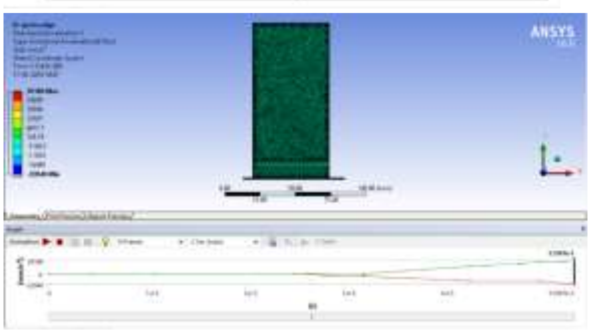
V. SIMULATION

Simulation on ANSYS for Sample 1: sample load case was performed. Values on the software are compared with the experimental values. For the simulation, analytical value was calculated for the velocity of the model right before impact, and then simulation was done with those input values.









V. RESULTS

Model	Orientation	Maximum acceleration-Experimental (in g)
Sample 1	Edge	X axis 4.42
	Face	Z axis 5.1
Sample 2	Edge	X axis 4.42
	Face	Z axis 5.1
Sample 3	Edge	Y axis 4.66
	Face	Z axis 3.89

Correlation of Analytical and Experimental Value

Model	Orientation	Maximum acceleration-Experimental (in g)	Corresponding numerical solution value (in g)
Sample 1	Edge	4.42	3.4693

VI. CONCLUSION

The developed test rig successfully gave us the maximum acceleration values at the point of impact. The behavior during the whole impact time period was recorded and analyzed.

Simulation on ANSYS for Sample 1: sample load case was performed. Values on the software are compared with the experimental values. A difference can be seen between the simulation and the actual experimental values. This is due to the fact that we consider fixed orientation in the simulation, however it can be seen that an actual drop, the components of reaction force from first impact are in all three axes. A correlation factor can be found out which relates the experimental to analytical value, which signifies that the actual acceleration values in the axes are greater than the analytically determined values.

From the graphs, the actual drop can be imagined and forces in all 3 directions can be found out, which can be used as input values for a more accurate simulation- which would give more realistic stress and strain values. Further, studying the rebound and clatter behavior of the device after first impact becomes easier, since consecutive peaks can be observed for all three directions from the experimental graphs. The same is difficult to do in a simulation alone.

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