A STUDY OF MECHANICAL ROBUSTNESS OF PORTABLE ELECTRONIC DEVICE SUBJECTED TO MECHANICAL DROP

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by

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Dissertation submitted in partial fulfillment of
the requirements for the
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CERTIFICATION OF APPROVAL

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

TAN YINN HOONG

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ABSTRACT

Mechanical drop is one of the main factors which cause damage to electronic devices especially to mobile phone. The effect of mechanical drop has caused electronic and material failure to mobile phones. The objectives of this project are to conduct simulation and physical drop tests in order to analyze the mechanical drop effects on the mobile phone. The constraints are the physical drop tests are high cost and the results can only be analyzed by visual inspection. The cost constraint has caused a limitation to only two drop test specimens which are two function-able mobile phones model Nokia 3310. The methodology of this project is to set up a drop test plan based on the ASTM Standard (D 5276-98), followed by conducting physical and simulation drop testing. One drop specimen is used for each type of drop: Flat Drop and Edge Drop. Both drops are static free fall from a height of 1.0m onto a concrete impact surface. Additional multiple dummy drops are conducted by using a dummy phone to obtain a more consistent drop procedure. This is because the drop specimens are allowed to be dropped once to prevent cumulative drop impact damage from affecting the results. The physical drop tests are recorded using a video camera and the video is split into multiple images using software. The physical drop tests show that edge drop sustains higher impact energy which causes material failure. As for simulation drop test, a solid model of the mobile phone is done using 3D Laser Digitizer and CATIA but the modeling file could not be open in ANSYS. Instead, a PDA ANSYS model is used as a replacement for the mobile phone model. The PDA model is then assigned elements and materials properties for the simulation drop test using the ANSYS LS-DYNA Drop Test Module (DTM). There were several problems occurred during the simulation which prevents it from completing. As a conclusion, all the objectives set are met except for the simulation drop test which is still under troubleshooting.

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CHAPTER 1

INTRODUCTION

1.1 Project Background

Drop impact damage has been an inevitable problem for all the portable electronic devices and drop impact reliability is a key issue. Besides the material behavior of the products, the packaging is also a very important factor as the devices might get damage during transportation. To ensure quality and reliability of the products, previously physical drop test is being carried out using prototype but the drop phenomenon is very difficult to obtain, especially the inside response, as the impact is of very short duration [1]. A physical drop test is the study of how well an object survives the impact resulting from being dropped in a gravitational field (1 g) from an elevated position onto a target surface .[2] The initial orientation of the object may impact the final results and the target surface is usually very rigid and flat. This is why proper parameters must be set prior to starting the physical or the simulation drop test as the equipment setup and the drop test procedures will obviously affect the final outcome. A product that manages to pass the drop test is a product that has the ability to function as designed after being subjected to this loading scenario. The drop may due to either standard use of the object or to an accidental event (probable misuse of the product) [2].

Physical drop tests are often performed on just a prototype of the final product design, since the cost of the product and that of the testing equipment required to conduct the physical drop test may be quite high [2]. In order to analyze the damage or failure, engineers can only the causes based on the final failure and come up with solutions to improve the design and to increase its reliability [1]. The only let down on this method is that it requires very experienced engineers to do multiple trial and error tests which are very time consuming. This causes production delay and uncertainty of product quality.

To replace the physical test, it is required that drop test simulation supplies reliable results and sufficient information. Thus, it is a vital step to set up the simulation model properly, which includes the geometry simplification, FE model, material model and boundary conditions, etc. Another challenging requirement is to detect the failure inside small components during the drop test simulation in product level [1]. The difficulty is to obtain the drop-induced response in the components, which needs very fine mesh for the tiny structures. The fine mesh may cause the simulation very expensive and even make the simulation impossible [1].

This is why in this project; drop test simulation by using software will be done in order to analyze the drop phenomenon on a cell phone (Model Nokia 3310). To do a drop test simulation, Finite Element Analysis (FEA) software such as the ANSYS LS-DYNA can be used to perform a virtual drop test analysis, saving both time and money [2]. This type of computer simulation should still be correlated with the results of an actual physical drop test to validate the material properties, allowable strains, loading scenario, boundary conditions, etc [2]. Conducting simulation drop test has many benefits:

- Drop test can be done in the early product design stages, therefore eliminating the cost associated with developing an inadequate product and last minute corrections to improvise the poor design.
- Different initial orientations, drop heights and parameters may easily be considered in the virtual/simulation world, but are usually cost-prohibitive in the real world.
- After an early design is analyzed, the proposed design modification can be evaluated before committing to the new design. This saves time and money building prototypes that are destined for failure [2].

Application of simulation drop test analysis on the market products is very important in order to determine whether the product is too fragile and is not likely to succeed in the competitive marketplace. Also, with the current environment of litigation, products must be designed to at least fail harmlessly when subjected to realistic accidental falls [2]. Some of the products being analyzed for drop test adequacy are as follows:

- Electronics: Cell phones, laptop, televisions, CD players, etc.
- Appliances: Refrigerators, washers, dryers, microwaves, etc.
- Industrial Containers: Toxic chemical storage drums, etc.

This project will contribute a lot to the electronic industry especially in the massive cell phone industry because various solutions can be proposed in order to reduce the damage done to the portable electronic devices due to mechanical drop by analyzing the results obtained from this project. This is because the results obtained from this project will provide an insight to what is happening to the device before, during, and after the drop impact and possible solutions can be proposed to prevent or reduce the damage caused.

1.2 Problem Statement

- Electronic devices are very vulnerable and fragile subjected to mechanical drop.
- The material strength of the electronic devices is ineffective in absorbing the drop impact.
- The casing/housing and packaging are unable to protect the devices from damage.
- Physical drop tests are high cost and time consuming.
- Physical drop tests are only able to analyze the final failure, not the inside response during the impact. Internal impact force changes are not known.
- Physical drop test requires only very experienced engineers to analyze the drop impact damage on the drop specimen.
- Simulation drop test can replace physical drop test as it is cost and time efficient, and it provides detail test results.

1.3 Objectives

- To identify the drop orientation, height, and angle for the simulation and physical drop test.
- To decide and produce a drop test plan in order to ensure the simulation and physical drop test are done according to plan and procedure.
- To build a solid model of the mobile phone using 3D Laser Digitizer and CATIA Digitized Shape Editor.
- To simulate the drop impact effect acting on the electronic device (mobile phone) with various parameters using drop test simulation software, ANSYS LS-DYNA.
- To conduct physical drop testing.
- To propose possible solutions to reduce the drop impact damage.

1.4 Scope of Study

Table 1: Job Scope for FYP

Final Year Project 1	**Final Year Project 2**
Data gathering and research on the respective topic.	Confirmation of the material properties and characteristics of the device.
Confirmation of electronic device design. (Mobile phone Nokia 3310)	Confirmation of the parameters involved in the drop test simulation.
Build solid model of the device by using 3D Laser Digitizer and transfer it into CATIA software for further alterations.	Drop test simulation by using ANSYS LS-DYNA. – Parametric study.
Research on the parameters involved in the drop test simulation.	Physical drop test by using the mobile phone.
Research on the material properties and characteristics of the device.	Analysis and discussion on the results obtained from simulation and physical test.

CHAPTER 2

LITERATURE REVIEW

2.1 Drop Test Simulation done using ANSYS LS-DYNA

The following figures are the drop test simulation done on a PDA by using LS-DYNA.

Figure 1: Example of simulation drop test done using ANSYS LS-DYNA

For the initial impact (left) was dropped from a height of 1,829 mm (~6ft). The secondary impact (middle) exhibits the PDA batteries separating from its housing [5]. The image (right) shows rebound of the secondary impact by the device in the simulation [5].

Table 2: Drop Test Module Specification by ANSYS LS-DYNA

Drop Test Module Specifications		
Loads & Conditions	**Result Evaluation**	**User Interface**
Angle of Incline	Animation output	Intuitive
Initial velocities	Stress & Strain	Single dialogue box
Frictional effects	Deflection	Drop test-specific documentation
Drop heights	Motion	
Gravity	Windows AVI output	
	Time history graphs	
	Displacement vs Time	
	Velocity	
	Acceleration	

The ANSYS LS-DYNA Drop Test Module (DTM) as shown in Table 2 is an optional add-on feature to the ANSYS LS-DYNA product. It greatly simplifies the tasks associated with conducting a drop test simulation [2]:

- Dropped objects easily oriented
- Gravitational field quickly established
- Rigid target surface automatically constructed and restrained.
- Entering drop height straightforward
- Impacting velocity conveniently calculated

The DTM was designed to allow inexperienced users to quickly set-up a complicated drop test simulation, solve it, and review the results. The DTM is essentially a streamlined GUI that guides you through the steps necessary to conduct a drop test simulation [2]. The ANSYS User Interface Design Language (UIDL) and the Tool Command Language and Toolkit (Tcl/Tk) were used to implement it into the GUI [2].

2.2 Simulation of Drop Impact Reliability for Electronic Devices

Consecutive drop of an electronic device with Al casing

According to drop test simulation which is done by Y.Y. Wang, C. Lu, J. Li, X.M. Tan and Y.C. Tse, 2004, in their research they did face drops; X+, X-, Y+, Y-, Z+, and Z- with two different heights (1.5 and 0.7 m) on the electronic device [1]. The drop ground is concrete and the material properties can be found in Table 3 [1]. The simulation outputs have been compared with the physical drop test results in order to verify the simulation model and results. In Table 4, the result comparisons are summarized.

Table 3: Material Properties of the Materials used in Drop Test

	Young's modulus (GPa)	Poission's ratio	Density (kg/mm^3)	Yield Strength (GPa)
Al casing	71.0	0.33	2.70×10^{-6}	0.16
Plastic housing	8.28	0.3	1.54×10^{-6}	-
Concrete floor	26.0	0.2	2.40×10^{-6}	-

Table 4: Maximum stress region during the impacts as comparison of *g* level

Drop height (m)	Physical Test Measurement σ (Pa)	ANSYS Simulation σ (Pa)	Direction
0.7	10,652	12,424	-*X*
1.5	14,519	16,372	
0.7	11,082	11,763	+*X*
1.5	16,576	17,686	
0.7	8316	8748	-*Y*
1.5	14,241	15,981	
0.7	8076	7789	+*Y*
1.5	13,316	11,327	
0.7	11,601	11,152	-*Z*
1.5	20,532	21,490	
0.7	7285	9720	+*Z*
1.5	10,880	14,532	

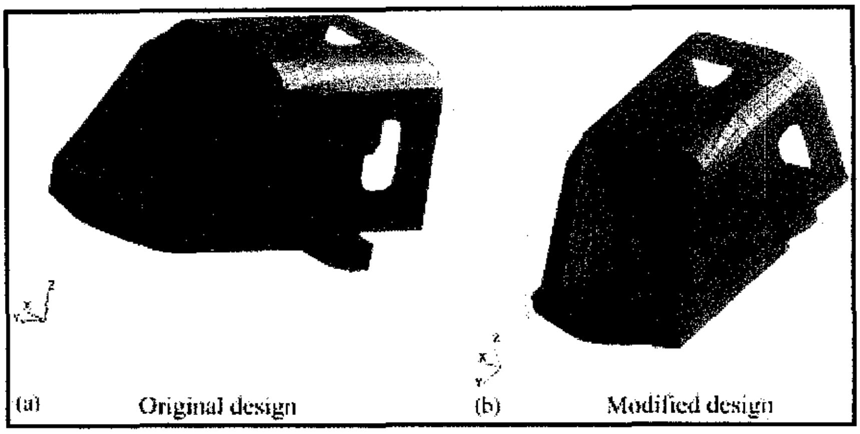


Figure 2: Finite element model of an electronic device with Al casing

The problem encountered after the results were analyzed was the *g* value impact was over the allowance in +*Y* direction, the stiffness in the tip portion of the product should be reduced so that the tip with low stiffness can absorb part of the drop impact and reducing the damage done by the drop [1]. A slot is inserted in the tip portion in order to improve the quality and reliability of the design [1]. The drop test simulation was done using ANSYS LS-DYNA where the LS-DYNA module is specialized in simulation drop testing. The results in Table 5, and Figure 2, and 3 shows the acceleration response of the structure is reduced greatly as the plastic deformation of the modified tip absorbed most of the impact energy [1].

The simulation results of the new design model in three consecutive drops are summarized in Table 5. The stress contours at the time of maximum stress occurring during the impacts and the residue stress contours after drops are presented in Figure 3. The acceleration responses at the given position during the impacts are shown in Figure 4. The results show that the slot spacing determines the acceleration response for the three consecutive drops [1]. The plastic deformation absorbed most of the impact energy; hence, the acceleration response of the structure is reduced greatly. The results also show that the plastic deformation and the acceleration response and for the first two impacts are almost the same [1]. While in the third drop, the slot spacing is insufficient for the plastic deformation (the slot closed during impact), and hence a rise of acceleration response and a drop of the value for plastic deformation are observed [1].

Table 5: Simulation results of newly designed model for three consecutive drops

	First drop	Second drop	Third drop
g value of impact (*g*)	**1760*g***	**1639*g***	**4387*g***
Accumulated deformation at tips (mm)	1.56	2.21	2.83
Accumulated plastic deformation at tips (mm)	0.95	1.91	2.55

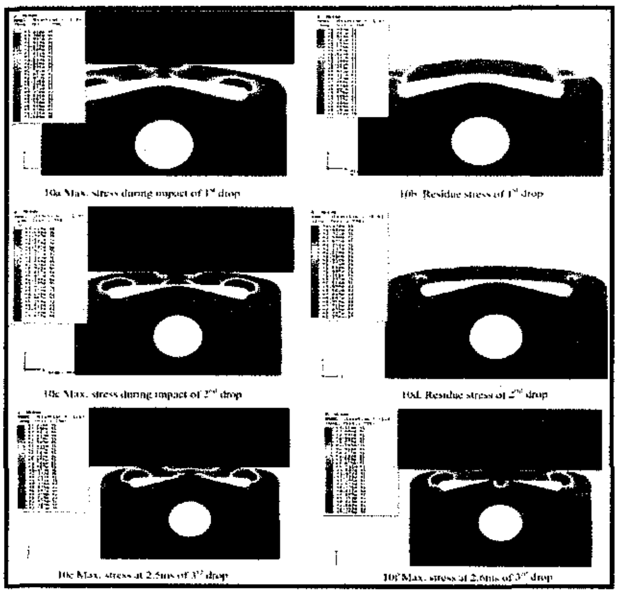


Figure 3: Stress contour and deformation of the three consecutive drops

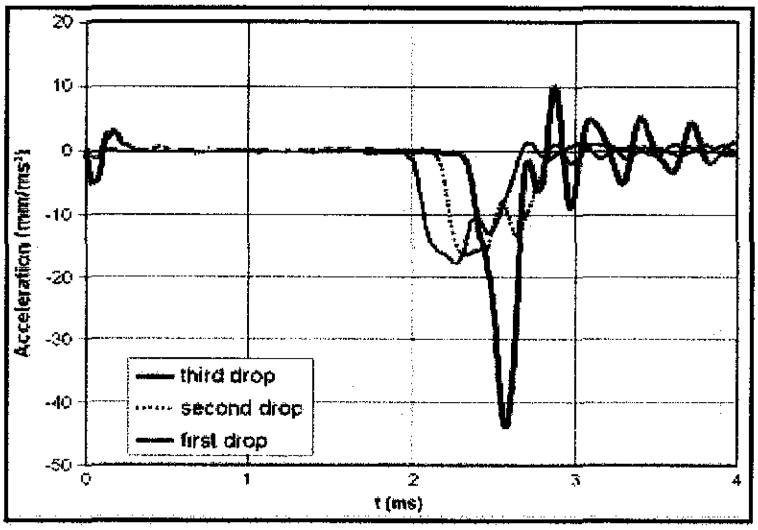


Figure 4: Acceleration responses of the three consecutive drops (with 3kHz filter)

2.3 ASTM Standard Test Method for Drop Test of Loaded Containers by Free Fall (D 5276 – 98)

This ASTM standard drop test standard of loaded containers by free fall is similar to this final year project topic as only the drop specimen is different which is a cell phone. All the standard procedures and parameters are applicable for this project. This standard drop test is done on containers not exceeding 110 lb (50 kg) and this test method fulfills the requirements of ISO Standards 2206:1987 and 2248:1985 [3]. This test method is meant for evaluating the capability of a container to withstand the sudden impact shock resulting from a free fall or to evaluate the capability of the container and its inner packing to protect its contents during sudden shock resulting from a free fall [3]. This test method is also used to compare the performance of different packaging designs. Besides that, this test method also permits observation of progressive failure of a container and the damage done to its contents [3]. This test method is particularly suitable for containers that are normally handled manually during some part of the distribution cycle.

The apparatus used for this standard drop test on containers by free fall is the Free-Fall Drop Test Equipment. Correct orientation of the container must be set prior to starting the drop test. It permits different kinds of drop orientation such as flat-face drops, edge drops, or corner drops [3].The equipment also permits accurate control of the drop from various heights and it provides a release mechanism that does not exert vertical, rotational, or sideways forces to the test specimen. A proper impact surface, horizontal and flat is provided to enable accurate drop impact results. The impact surface should be rigid enough and durable under the test conditions [3]. For instance, the impact surface should be concrete, stone or steel plate.

In order to prepare the container for the drop test, it must be setup similar to the actual condition. The container must be packed either with the actual content or dummy loads which are made similar to the actual loads in terms of shape, weight and sizes. The container must also be closed, sealed and coated with protective coatings similar to the actual condition before it is being sent for shipment [3].

There are several drop orientations that can be used for this drop test:

Table 6: Drop Orientation of Standard Drop Test on a Container by Free Fall

Drop Orientation	***Explanation***
Flat Drop	Position drop specimen so that upon impact, there is no more than a 2 degrees angle between the plane of this face and the impact surface [3].
Edge Drop	Position drop specimen so that upon impact, this edge makes no more than a 2 degrees angle with the impact surface and the plane containing this edge and the center of gravity of the container makes no more than a 5 degrees angle with the vertical [3].
Corner Drop	Position drop specimen so that upon impact, the line containing this corner and the center of gravity of the container makes no more than a 5 degrees angle with the vertical [3].
Cylindrical Container Drop	If dropped on either a chime or a circumferential edge, position specimen so that upon impact, a plane containing this edge and the center of gravity of the container makes no more than a 5 degrees angle with the vertical plane perpendicular to the drop surface [3].

In order to determine the *Drop Height*, proper planning and measurements must be done prior to the drop test. Drop height can be measured from the *bottom surface, edge, or corner of the container to the impact surface* [3]. Besides that, we must also label the sides of the containers with numbers to enable easier identification and analysis of the drop face.

The drop test method must include a detail *test plan* which considers the type of information desired from the testing; a statement whether or not pre established acceptance criteria was obtained; qualification of damage, determination of the drop height to failure; the number of drops to failure, etc [3].

As a part of the test plan, Drop Height Procedure is also very important in order to produce a successful drop test. This is to set a standard for the drop test to enable easier drop test analysis that is needed to be done [3]. Examples of drop height procedures are as follows:

- Constant Drop Height Procedure

These procedures consist of single or multiple drops from a constant drop height [3]. Replicate samples should be subjected to identical procedures for comparison and for statistical analysis [3]. Typical types of drop cycles are such as single drop, ten drop cycle, four drop cycle, twenty six drop cycle, etc.

- Progressive Drop Height Procedure

The test specimen is dropped from an initial drop orientation chosen to be unlikely to cause predefined damage to the drop specimen [3]. This is because the impact damage from the previous drop will be accumulated affecting the outcome of the following drop. The cumulative effects of all previous drops will cause the drop results of the subsequent drops to be inconsistent and inaccurate. This will be in a prescribed orientation of a prescribed cycle of drops [3]. If there is no damage occurs on the specimen at the initial drop height, the subsequent drop height will be increased as per planned. The drop cycle is repeated until there is a significant damage occurred to the specimen. In order to estimate the critical drop height, the midpoint between the height of the last successful test and the height of the test which caused damage to the specimen is taken. Replicate samples are subjected to identical procedures to determine the consistency of the failure point [3]. Occasionally, single drop or drop cycle from a height which caused relative damage of this procedure will not cause similar damage to the drop specimen [3].

- Up and Down Procedure

This procedure varies the drop height for each drop cycle with a new test specimen for each [3]. The number of specimens depends on the purpose of the tests but will usually require eleven or more replicate test specimens; the use of larger sample sizes will result in higher confidence of result statistics [3]. Different drop height is used for each drop specimen and the result of each drop no matter it fails or a success will be carefully recorded. The drop height increment is a constant. Estimation is done on the average or median drop height to failure by counting the number of passes and failures. If there are more passes than failures, the arithmetic mean of the height of the failures is computed and half of the drop height increment is subtracted from there [3]. If failure is more than passes, the height is averaged and added with half of the drop height increment.

The drop height procedure must be set prior to each physical or simulation drop test in order to create a consistent drop test procedure to ensure reliable drop test results. This procedure will also enable easier data gathering n documentation of the results. The physical drop test results are evaluated by analyzing the final outcome of the drop through observations according to the drop orientation and procedure.

In this project, *Constant Drop Height Procedure* is chosen as the drop specimen, cell phone will be simulation and physically dropped at a constant height of 1.0m in order to gain a set of results for further analysis. The simulation and the physical drop test results can be compared against each other to gain better understanding of the drop specimen reliability can characteristics. Drop height of 1.0m is chosen as it equivalent to the possible height of a cell phone dropping from a table or from a person's hand. As for further testing of the cell phone's reliability and strength, drop testing is also done at a constant height of 1.5m in order to see the reaction of the structure of the cell phone towards drop impact.

CHAPTER 3

METHODOLOGY

3.1 Procedure Identification

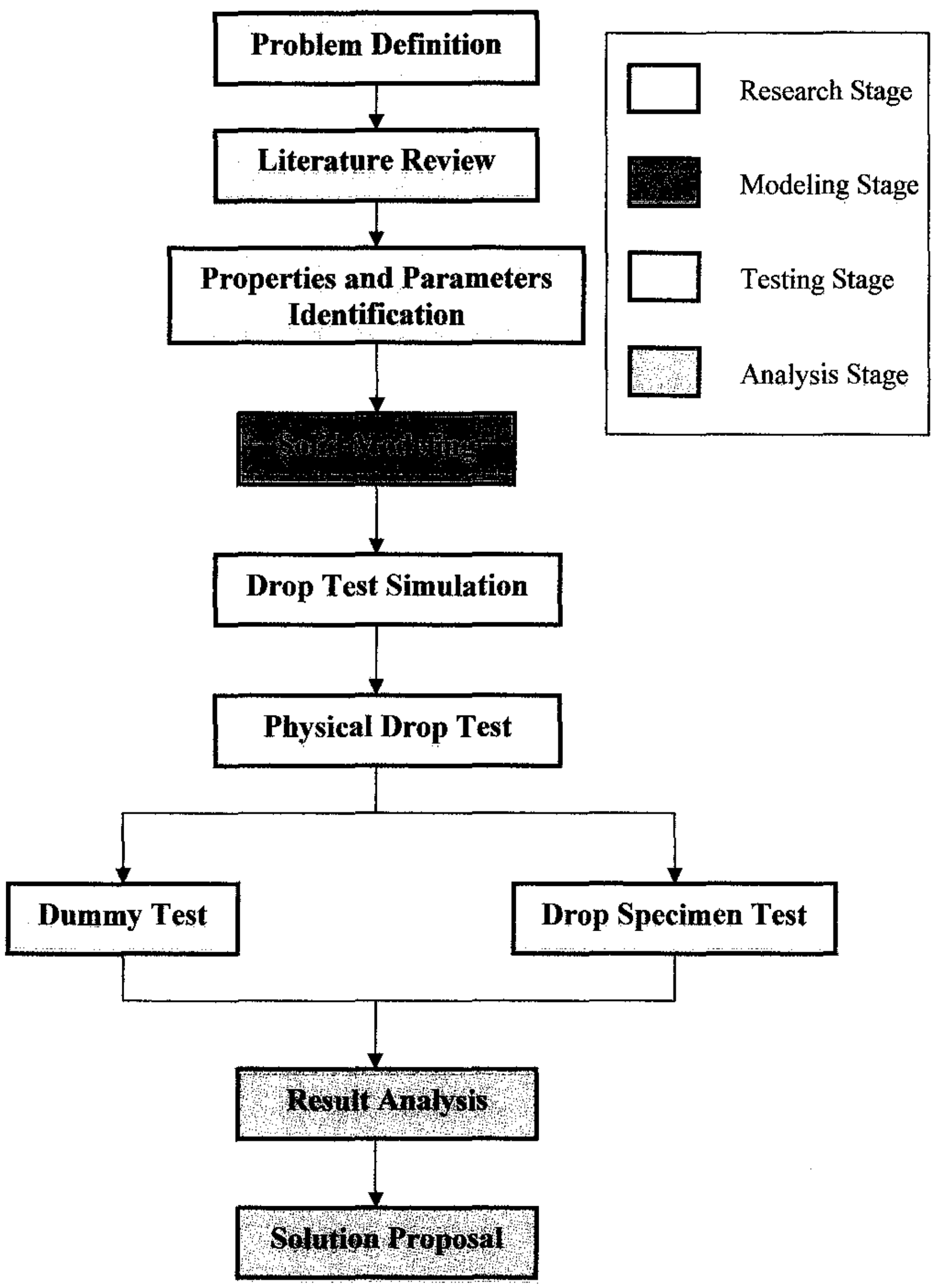


Figure 5: Project Work Flow

In order to start this project on the topic of "a study of mechanical robustness of portable electronic device", research must be done to gain further understanding of the project background, problems related to this project, and the objectives that needed to be fulfilled at end of this whole project. To archive this, research is done on various journals, websites, ASTM standards, etc in order to find the existing information related to this final year project so that further planning can be done. After the research is done, all the information about this project such as the types of impact surfaces, drop specimen, orientation, angle, height, procedure and repetition are set based on the existing information from the standards and journals. A test plan will also be set in order to ensure that the physical and simulation drop tests done are according to plan. The material properties of the drop specimen and the drop surface must be identified before the simulation is done as the parameters for the simulation drop test must be fulfilled. All the above steps are included in the **Research Stage**.

As for the **Modeling Stage and Testing Stage**, the modeling of the drop specimen is done by using the Renishaw 3D Laser Digitizer. By using a probe, it can scan the surface of the cell phone which is hard surface and come out with a solid model in its software which is compatible to other modeling and stimulation software. After the modeling is done, the solid model can be transferred to CATIA for further alterations and then send to ANYSY LS-DYNA for drop test simulation. For the physical test, a proper set of apparatus or equipment must be used in order to produce a flawless drop test on the cell phone. This is because the drop specimen is too costly to get multiple specimens. A dummy drop specimen is used to ensure that the apparatus is prefect to produce a flawless physical drop test before the real drop specimen which is the cell phone is used. Various aspects must be taken into account in order to produce a perfect drop because problems such as faulty release mechanism, uneven drop surface, inappropriate drop apparatus, unbalanced starting point of the drop, etc will seriously affect the orientation, speed, angle, and height of the drop. This will consequently affect outcome of the physical drop test.

For the **Analysis Stage**, after the simulation results based on the result evaluation column in Table 1 and the physical drop test results are obtained, comparison can be made within both tests. After analysis and comparison are done, possible solutions can be proposed in order to curb with these problems related to portable electronic devices caused by drop impact damage.

3.2 Drop Test Parameters

Drop test parameters are very important in simulation and physical drop testing as they act as a guideline to ensure consistent drop testing procedures for accurate results. Table 7 shows the information of the drop specimens used for the drop tests and Table 8 shows the drop test plan proposed for this project which is based on the ASTM standard (D5276-98) as reference.

Table 7: Drop Specimen Information	
Drop Specimen	Cell phone
Model	Nokia 3310
Dimensions (W x D x H)	(4.8cm x 2.2cm x 11.3cm)
Weight	133g
Material	Plastic & Electronic components
Components	Front casing Back casing Keypad Electronic component board and display Battery

Table 8: Proposed Drop Test Plan	
Parameters	***Information***
Impact Surface	Concrete
No. of Specimen	Two
Test Plan	Constant Drop Height Procedure
Initial Velocity, Vo	Nil (Static drop)
Drop Height	Simulation: 1.0m & 1.5m Physical : 1.0m
Drop Orientation	Simulation: Edge drop & Flat drop (Refer to Table 5) Physical : Edge drop & Flat drop
Total no. of Drops	Simulation: Four Physical : Two actual tests & multiple dummy tests

According to Table 7, it includes the drop specimen information which is the cell phone modeled Nokia 3310. In the table, it includes the information of the model name, dimensions, weight, material and the components of the cell phone. As for in Table 8, it provides the information about the proposed drop test plan which includes the procedure on how the simulation and physical drop test will be done. The impact surface of the cell phone will be a concrete surface. Besides that, two functional cell phones are used in the physical drop test because at the height of 1.0m, two types of drop orientation will be done. This is to prevent cumulative impact damage in the cell phone which will affect the final result. As for the simulation drop test, there will be two type of drop height, 1.0m and 1.5m with two drop orientations each, which are edge drop and flat drop. As a summary, the total no. of drops for simulation consists of four whereas for the physical test, there are two actual and multiple dummy tests.

Figure 6: Drop test specimen (Nokia 3310)

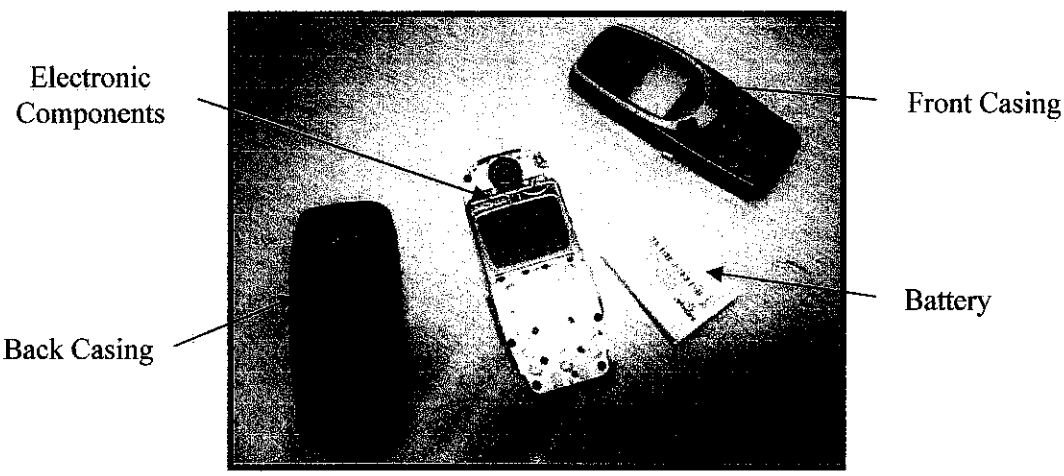


Figure 7: Different components of the drop specimen (Front view)

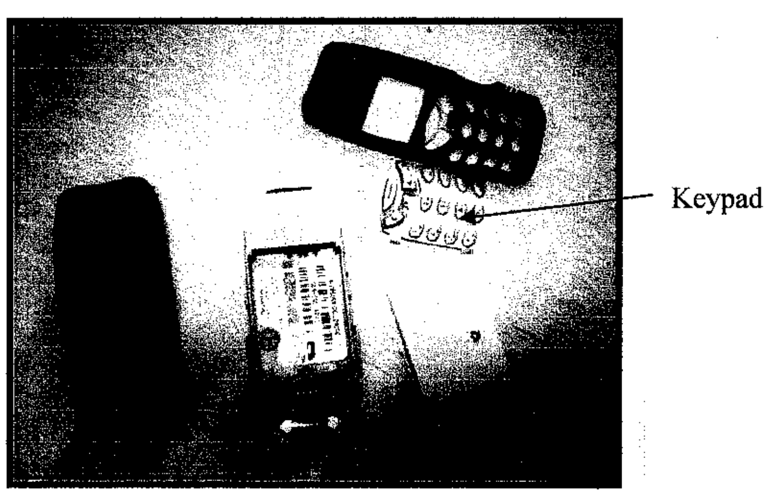


Figure 8: Different components of the drop specimen (Back view)

3.3 Simulation using ANSYS LS-DYNA

Based on the ANSYS Training Manual, Chapter 12 on Drop Test Module (DTM); the following steps are used in a typical DTM session:

1. Import or Create the Model
2. Enter the DTM and Initialize the Model
3. Complete the Basic Tab Information
4. Complete the Velocity Tab Information
5. Complete the Target Tab Information
6. Check the Status Tab and Run the Solution
7. Postprocess the Results

The DTM is designed to be used in one continuous session. When entering the DTM, we are required to always start with the original database [2]. It will not be a limitation as the DTM is very user friendly and it will not be a hassle to reenter the previous settings [2].

1. Import or Create the Model

After the drop specimen model is being drawn using modeling software such as CATIA, the model is needed to be transferred into ANSYS LS-DYNA for drop test simulations. The file names and modeling requirements must be followed in order to ensure perfect transition of the finite element model from the modeling software to the simulation software.

2. Enter the DTM and Initialize the Model

This step is to initialize all the required information regarding the model so that the simulation will be done according to the parameter set.

3. Complete the Basic Tab Information

This step is to key in all the specific parameters such as the common gravity value, the drop height, reference point used to measure the drop height, orientation of the drop specimen, the frequency of output data being recorded, and how long the analysis needed to be done. All units of measurements must be consistent in order to ensure successful drop test analysis.

4. Complete the Velocity Tab Information

This step is to specify the translational velocity and the angular velocity so that it can be used for the calculation of the drop test analysis and this velocity largely affects the CPU processing time.

5. Complete the Target Tab Information

This step is to create a virtual impact surface for the drop specimen by specifying the length, thickness, material properties, static and dynamic coefficient of the drop surface. This will simulate the actual impact surface in order the make the drop test simulation as real as possible.

6. Check the Status Tab and Run the Solution

The status tab includes the summary of all the parameters set and to confirm all the parameters are set correctly according to the software requirements before the drop test can be done. It is advisable that the drop test is started near the impact time in order to reduce the CPU time as lesser processing capacity and time will be needed.

7. Postprocess the Results

After the drop test simulation, the results will be obtained. We can view the final results in order to proceed with further analysis of the drop test or to do comparison with the physical drop test.

3.4 Specimen modeling using 3D Laser Digitizer by Renishaw

Since building a solid model of the cell phone is very difficult due to lack of measurement details, 3D Laser Digitizer is used to make a full dimension measurement of the cell phone by using a special probe, as laser is used for soft materials only. 3D Laser Digitizer by Renishaw is a complete and fast scanning system for reverse engineering of unknown surfaces [6]. It requires non-contact laser and contact scanning probe to scan the surface of the specimens in order to produce a solid model in its software [6].

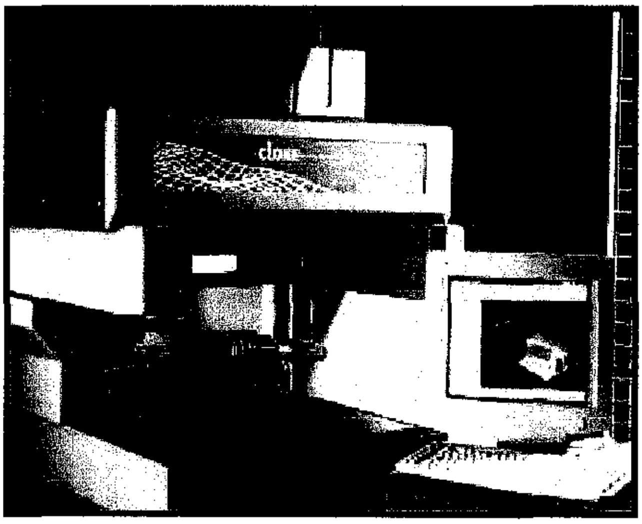


Figure 9: 3D Laser Digitizer by Renishaw

Non-contact laser is for soft objects whereas the contact scanning probe is for hard surfaces [6]. Besides that, it saves a lot of time and energy by able to do solid modeling of the prototype by just scanning the prototype. It directly eliminates the need of measuring and manual 3D drawing of the prototype which consumes a lot of time and energy. The output files from the 3D Laser Digitizer by Renishaw are compatible with modeling software such as CATIA and can be used for simulation purposes in ANSYS LS-DYNA. This allows the simulation to be done immediately after the modeling is done by the digitizer without having much trouble with the modeling difficulties.

The procedures of digitizing the test specimen components are as follows:

- Firstly, for 2D digitizing purposes, place the component that will be digitized on the digitizer platform.
- Install the contact probe with the size that suites the contact surface onto the digitizer.
- By using the TraceCut software for the digitizer, initialize the probe so that the probe positioning settings are reset back to default settings.
- Set Z datum by touching the probe on to the surface of the digitizer platform for 3 times. This is to determine the height where the component is placed on.
- Move the probe near the component and start scanning.
- After it is finished, a circumference of the phone casing will be displayed on the screen.
- For 3D digitizing purposes, maintain the component at the same location and spray a type of chemical on it to enhance laser reflectivity from the casing.
- Change the probe into the laser probe and calibrate the probe to gain default setting of the probe position on a steel reflective silver coloured ball.
- Move the laser probe near the component and set several parameters.
- Start the surface profile scanning using the laser probe.
- Save the file into .igs format by generating IGES points so that the file can be opened in CATIA for further modification.

Figure 10: Laser probe scanning the profile of the inner part of the front casing

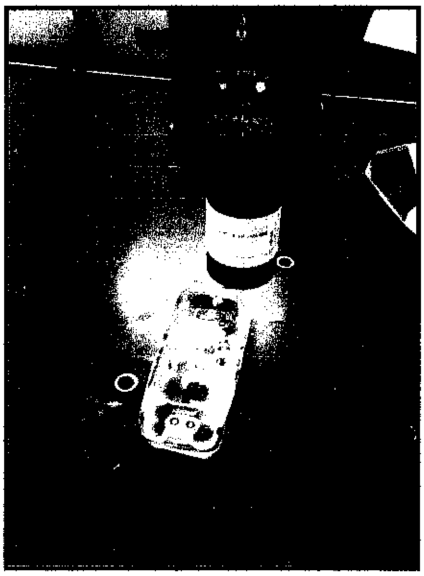


Figure 11: Laser probe scanning the profile of the inner part of the back casing

3.5 Tools and Equipment

- Workstation with CATIA software license.
- Workstation with ANSYS LS-DYNA with add-on Drop Test Module (DTM).
- 3D Laser Digitizer by Renishaw
- Equipment for physical drop test.
- Video Camera

3.6 Project Gantt Charts

Suggested Milestone for the 1st Semester of Final Year Project (Mechanical Engineering)																	
No.	Details / Week	1	2	3	4	5	6	7	MID SEMESTER BREAK	8	9	10	11	12	13	14
1.	Selection of Project Topic	■	■	■	■											
2.	Data gathering and research on topic	■	■	■	■											
3.	Submission of Preliminary Report				■											
4.	Confirmation of electronic device design					■										
5.	Build finite element model of the device					■	■	■		■	■	■	■	■		
6.	Seminar 1 (optional)					■	■	■								
7.	Submission of Progress Report									■						
8.	Research on the parameters involved in the drop test simulation.											■	■	■		
9.	Research on the material properties and characteristics of the device.											■	■	■		
10.	Seminar 2 (compulsory)											■	■	■		
11.	Submission of Interim Report Final Draft														■ 26/10	
12.	Oral Presentation															■

Suggested Milestone for the 2nd Semester of Final Year Project (Mechanical Engineering)																
No.	Details / Week	1	2	3	4	5	6	7	MID SEMESTER BREAK	8	9	10	11	12	13	14
1.	Solid modeling using CATIA															
2.	Preparation & Physical Drop Testing															
3.	Submission of Progress Report 1															
4.	Simulation Drop Testing															
5.	Submission of Progress Report 2															
6.	Seminar (compulsory)															
7.	Data compilation and Analysis															
8.	Poster Exhibition															
9.	Submission of Dissertation (soft bound)															
10.	Oral Presentation															
11.	Submission of Project Dissertation (Hard Bound)															

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Potential Hazards involved during Physical Drop Test

During the physical drop test, there will surely be a lot of potential hazards as it involves drop impact damage. The potential hazards being identified are as follows:

- Debris and particle from the drop specimen upon impact may cause injury to eyes and skin.
- The drop specimen may cause foot injury if the drop test is not being handled attentively.
- Impact surface must be rigid enough to sustain the drop, Eg. glass is not being recommended to be used as the impact surface as it will cause serious injuries if broken.
- Proper physical drop test equipment must be used to ensure accurate and precise drop results.

In order to prevent the hazards stated above from happening, the following prevention measures must be taken:

- Wear proper PPE such as safety glasses, safety boots and lab coats during the physical drop test is being done.
- Make sure the drop test equipments are in good condition before they are being used.
- Make sure the impact surface is rigid and solid instead of fragile.
- Barricade the drop test area so that other people will not interfere with the test which may cause test failure or injury.

4.2 Physical Drop Testing

For the physical drop testing, two mobile phones (drop test specimens) are included. Based on Table 8, the Proposed Drop Test Plan, one drop height and two drop orientations are set, which are 1m for drop height and flat drop and edge drop for drop orientation. This physical drop testing will be done in a natural manner whereby the drop will be done manually by human being. This is because most of the mobile phone drops which cause damages are caused by human error. In order to simulate a more realistic and practical physical drop, human aspect must be taken into account as it plays a big role in the outcome of this project.

The setup for this physical test will consist of concrete floor as impact surface, the drop height which will be carefully measured prior to drop and drop mechanism which will be done manually. Before the drop test begins, a similar dummy test specimen will be used repeatedly to make sure that the drop is perfect before the real physical drop test is done. This will reduce the margin of error to occur.

Since high speed camera will not be available to capture the physical drop motion of the phone, another alternative solution is to capture the drop motion by using the video camera and then convert the video into multiple images by using software called Advance X Video Converter. It is a comprehensive Windows video tool that makes it easy to convert, split and join video clips among a variety of major formats as well as many of the operations a user want to do, like extracting the audio and join/split video files [7]. This software enables us to convert continuous and lengthy video into multiple images by splitting a second of video into multiple static images. Besides that, this software can determine how many static images to extract from a second of video and the time frame for the splitting to occur can also be adjusted. The output static image files obtained will be in JPEG file which will consume a very little amount of disk space. This process takes very short period and it is very convenient. By having the static images, the effect of the drop on the phone can be monitored accurately and in detail.

The setup for the physical drop test is consists of a concrete impact surface with an area of (90cm X 70cm) and a measurement scale of more than 100cm ≈ 1.0m.

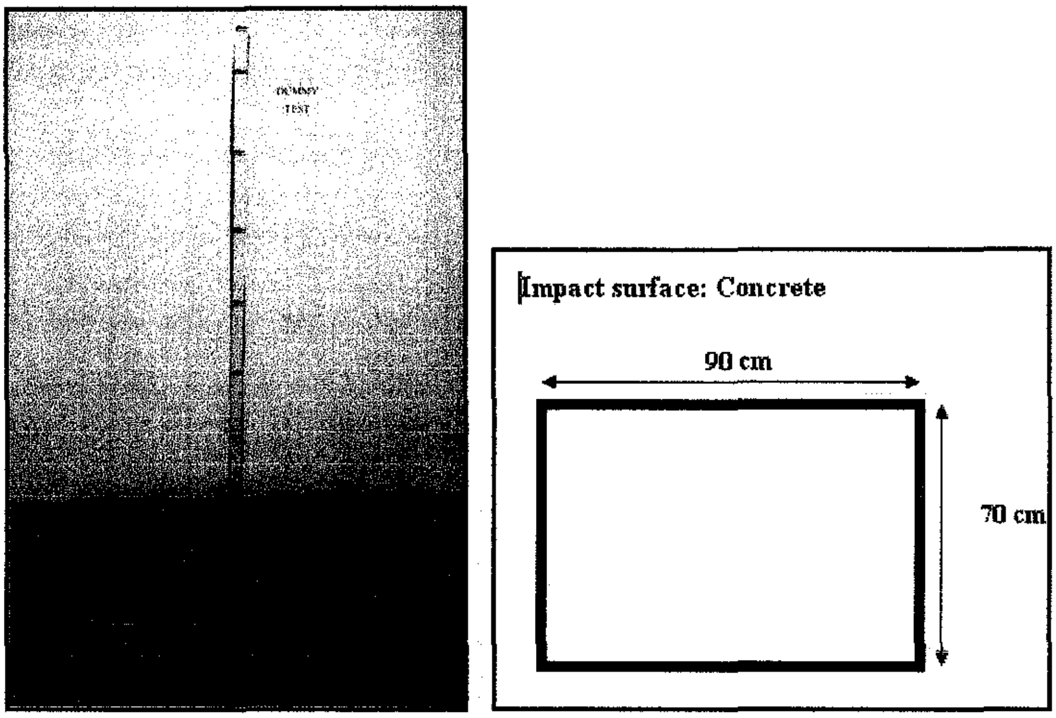


Figure 12: Setup for Physical Drop Testing

4.2.1 Dummy Drop Test

Before starting the physical drop test, multiple **dummy tests** are done in order to produce a consistent type of drop for the test. The dummy phone is tested with Flat Drop and Edge Drop whereby for flat drop, the phone is dropped with the back of the phone parallel to the impact surface, whereas for edge drop, the phone is dropped with the side of the phone parallel to the impact surface; both at the height of 1.0m.

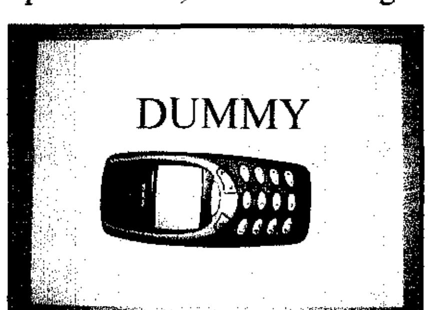


Figure 13: Dummy Test Specimen

Furthermore, due to the accumulated drop impact damage on the dummy drop specimen from multiple drops, there was several material failures observed at the casing of the phones. Obvious cracking, dents and scratches can be seen on the dummy phone casing due to the cumulative drop impact; refer to Figure 14 and 15.

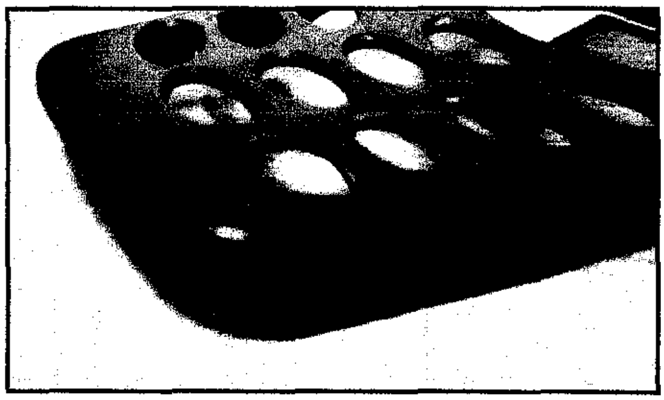


Figure 14: Cracking on the Dummy test specimen casing

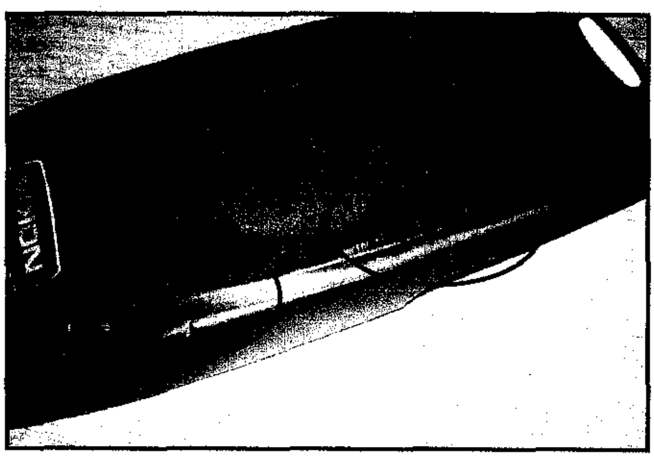


Figure 15: Scratches and Dents on Dummy test specimen casing

4.2.2 Flat Drop

After multiple dummy tests, **Flat Drop** physical drop test was done. The flat drop test specimen is labeled as Specimen A to avoid confusion between the phones as they look alike. Both test specimen for flat and edge drop are function-able phones in order to see how the drop impact force will affect its robustness.

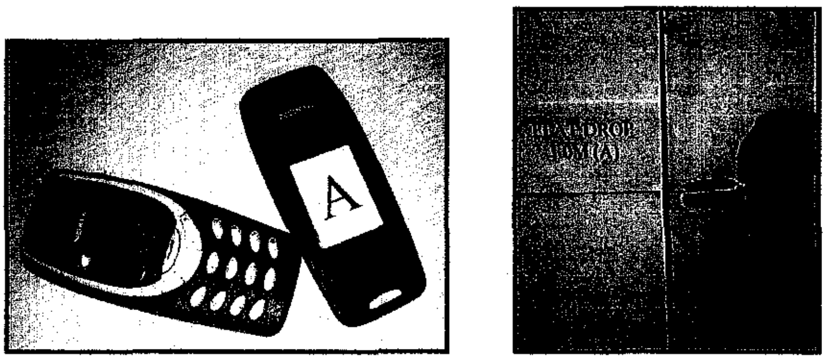


Figure 16: Flat Drop Specimen A

By referring to **Appendix A,** the images are the sequence of the physical flat drop testing of the mobile phone specimen dropped from the height of 1.0m onto the concrete impact surface. The images are spilt from a video of 8 seconds with the parameter of 20 images per second. Figure 17 shows the result generated from the flat drop with the impact point and the distance of each component differ from the impact point is properly labeled.

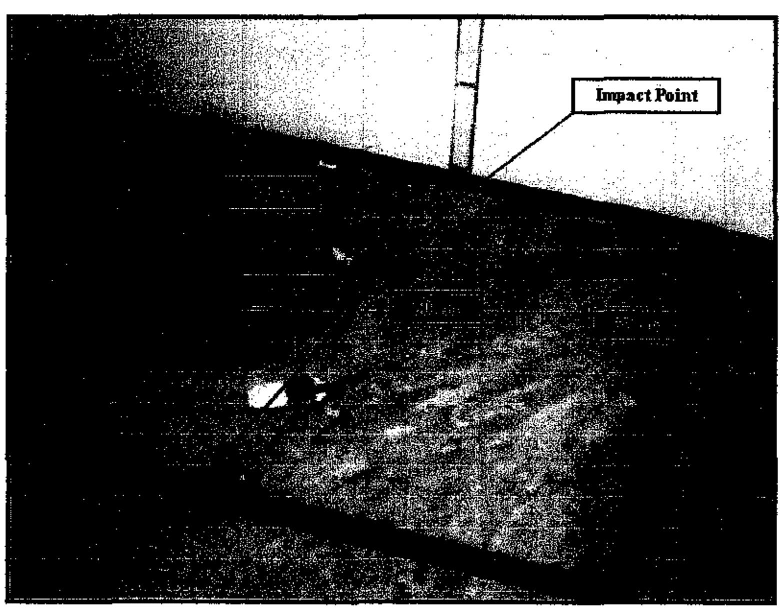


Figure 17: Physical Flat Drop Outcome

4.2.3 Edge Drop

After the Flat Drop was done, it was followed by the **Edge Drop** which means the test specimen will be dropped with its side parallel to the impact surface from the height of 1.0m. The test specimen for this edge drop was labeled as Specimen B.

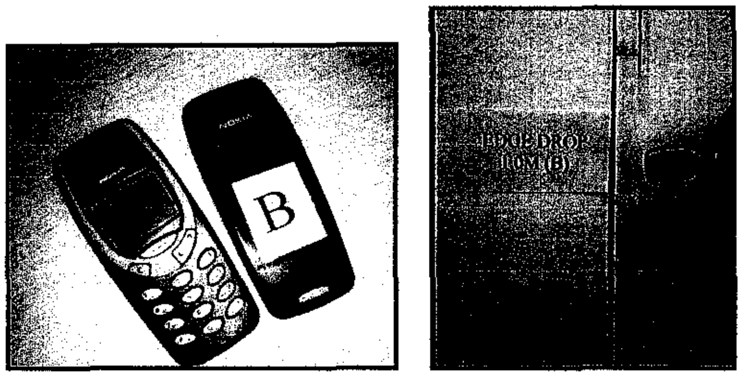


Figure 18: Edge Drop Specimen B

By referring to **Appendix B**, the images are the sequence of the physical edge drop testing of the mobile phone specimen dropped from the height of 1.0m onto the concrete impact surface. The images were spilt from a video of 9 seconds with the parameter of 20 images per second. Figure 19 shows the result generated from the edge drop with the impact point and the distance of each component differ from the impact point is properly labeled.

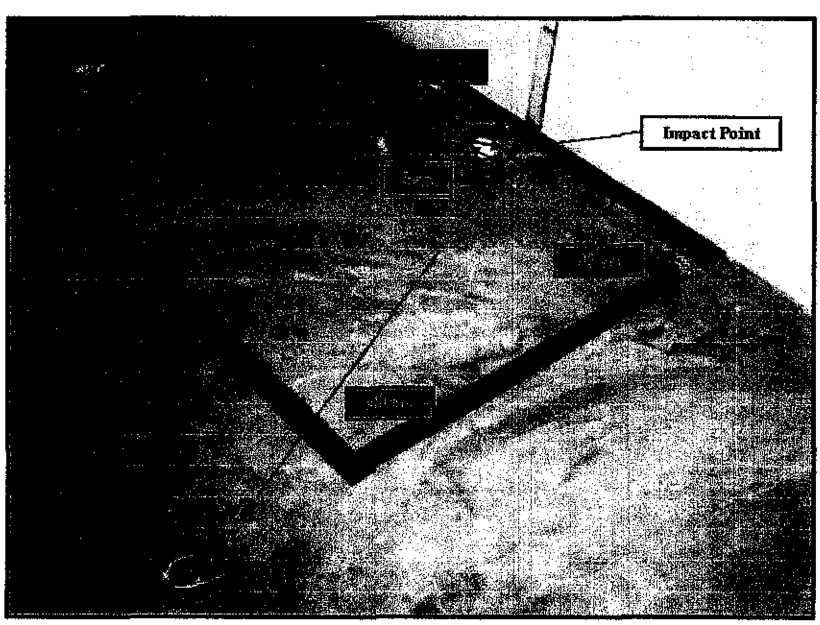


Figure 19: Physical Edge Drop Outcome

After visual inspection on the edge drop specimen, one of the plastic pins from the back casing was broken; refer to Figure 20. This material failure results also proves that Edge Drop specimen sustain a much bigger impact compared to Flat Drop specimen resulting in material failure such as the broken plastic pin.

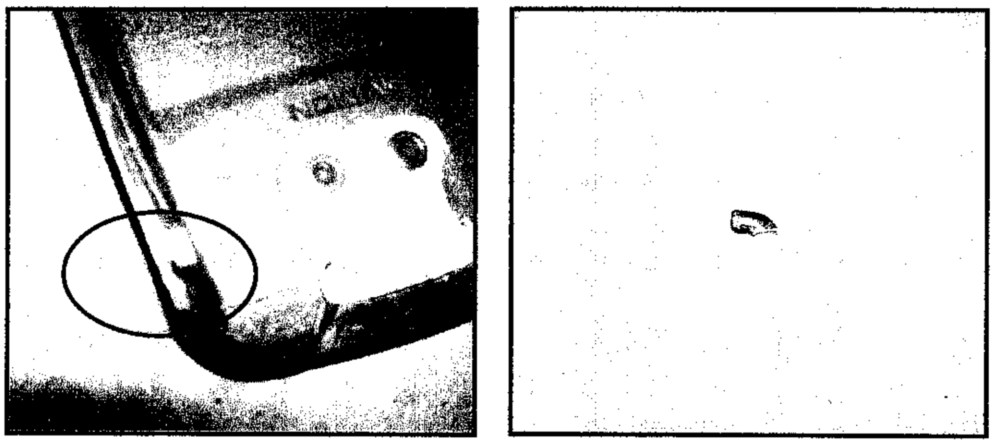


Figure 20: Broken plastic pin from the back casing of the Edge Drop specimen

4.2.4 Results Discussion

Table 9: Summary of Physical Drop Test Results

Drop Test	Height	No. of Drop	Distance from Impact Point					Visual Inspections	Function-ability
			Front Casing	Back Casing	Middle	Keypad	Battery		
Dummy	100cm	Multiple	-	-	-	-	-	Front Casing Crack; Scratches on back casing	Good
Flat	100cm	One	57cm	64cm	50cm	38cm	Intact	Nil	Good
Edge	100cm	One	93cm	9cm	3cm	43cm	Intact	Back Casing Pin Fracture	Good

According to Table 9, from both Flat Drop and Edge Drop what we can discuss about the outcomes are that both drops are dropped from the same height which is 1.0m and the impact forces causes the test specimen phone to break apart into pieces whereby the casings and the components are scattered around the impact surface. Besides that, from the results that we obtained from the physical drop; for flat drop, the distance of the components scattered away from the impact point are almost equally distributed. But, as for the edge drop, the components are scattered in an unevenly distributed manner. This means that the phone sustains more distributed impact force acting on it during the flat drop, whereas for the edge drop, the impact force is more concentrated at the edge of the phone which causes the force to be unevenly distributed throughout the body of the phone, resulting in some components are scatter far away and some are not. This is because based on the impact energy per unit area= E/A, whereby E = mgh; E is constant as the mass of the phone, gravitational force and the height is similar for both drops, the impact energy for edge drop is found to be higher compared to flat drop. The following is the calculation of the impact energy for both drops.

Impact Energy Calculation

Impact energy per unit area= E/A,

E = mgh (Joule); whereby

m = mass of test specimen = 133 g

g = gravitational force = 9.81 m/s^2

h = drop height = 1.0m

Thus, E = (0.133 kg) x (9.81 m/s^2) x (1.0m)

= 1.3047 J (E is constant for both drops as same type of specimen is used)

For Flat Drop;

Assume that the contact surface area of the phone is a rectangle,

A = (11.3 cm) x (4.8 cm)

= 54.24 cm^2

= 0.005424 m^2

Impact energy per unit area = $\frac{E}{A} = \frac{1.3047J}{0.005424m^2}$

= <u>240.54 J/m^2</u>

For Edge Drop;

A = (11.3 cm) x (2.2 cm)

= 24.86cm^2

= 0.002486 m^2

Impact energy per unit area = $\frac{E}{A} = \frac{1.3047J}{0.002486m^2}$

= <u>524.82 J/m^2</u>

From the calculation, we can see that the impact energy for edge drop is approximately 2 times higher than the impact energy for flat drop. This is because for Flat Drop, the contact area for impact is bigger than the contact surface area for edge drop. So, the higher impact energy of Edge Drop specimen caused the Edge Drop specimen components to scatter further and caused material failure.

After both physical drop tests are done, both the test specimen mobile phones are still function-able, as in both phones can still be switched on and by putting a proper sim card, it can still make outgoing and receiving incoming calls.

4.3 Digitized Components of the Test Specimen using Renishaw 3D Laser Digitizer

According to the procedures stated at the methodology section about digitizing the component, a surface profile for the specific mobile phone component such as the front casing will be generated. This file can be saved in different file extension to provide conveniences when people want to import the file into different type of modeling software. In this case, the digitized surface profile file using TraceCut digitizing software is saved in .igs form which is in IGES format which allows the file to be opened in CATIA for further modification such as combining all the separated components into one solid profile. The examples of digitized images of the components are shown in Figure 21, 22, and 23.

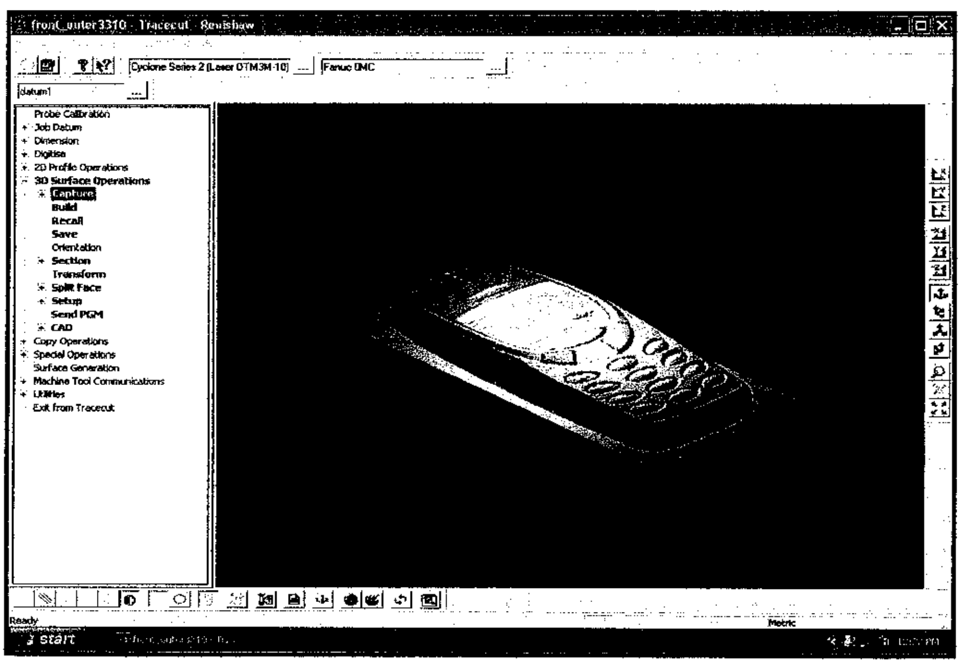


Figure 21: Digitized profile generated on the front casing

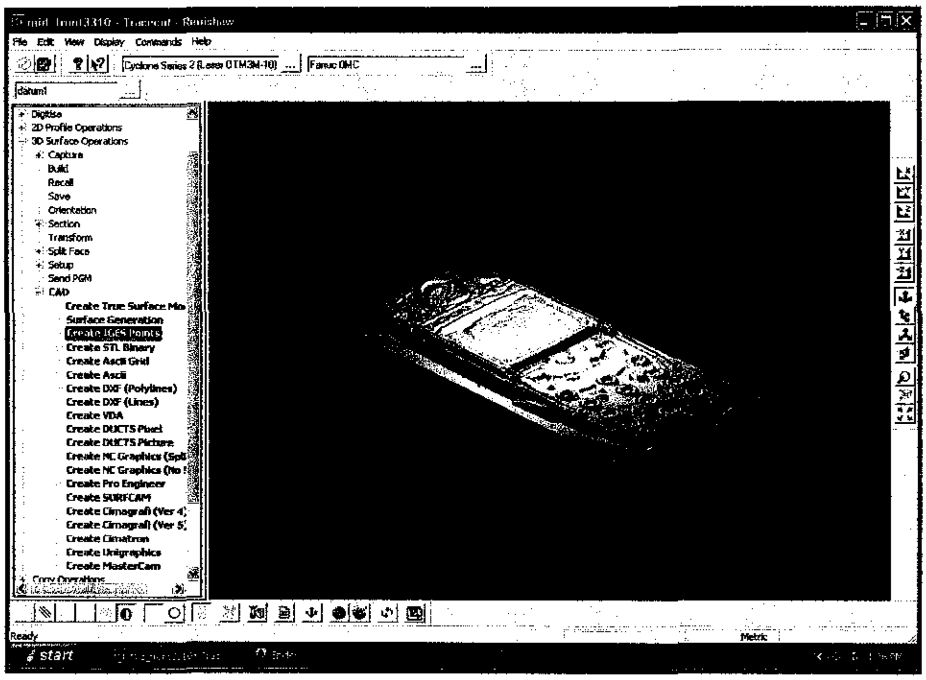


Figure 22: Digitized profile generated on the middle electronic console

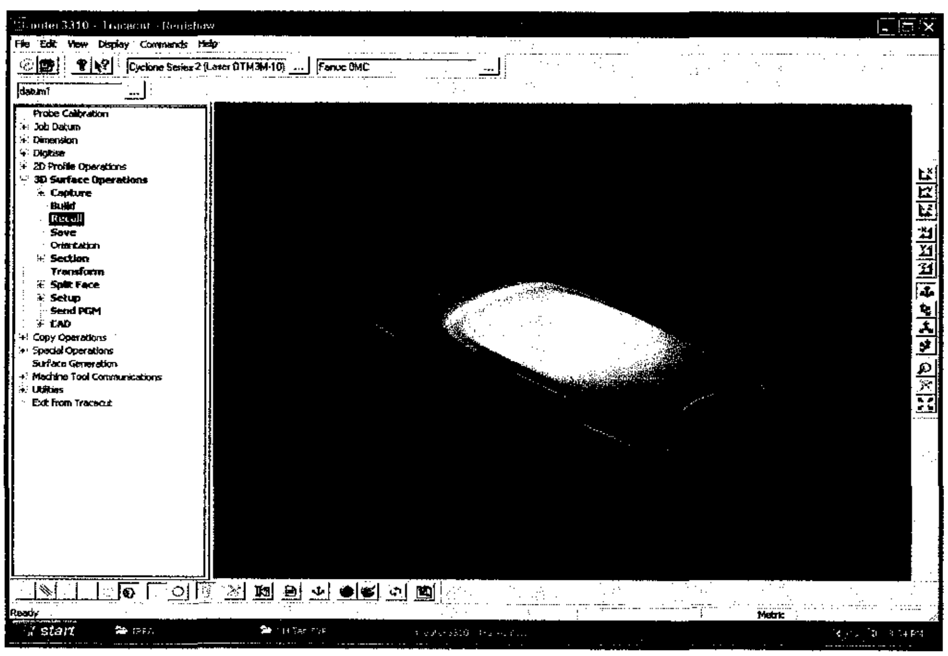
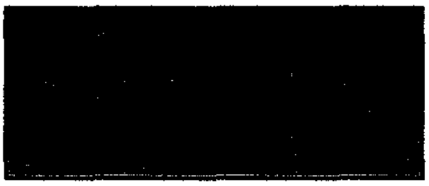
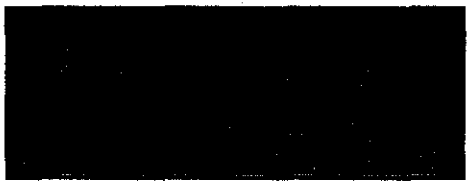
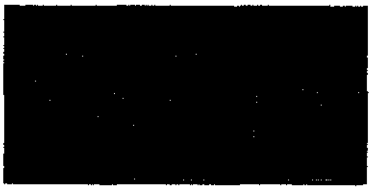


Figure 23: Digitized profile generated on the back casing

4.4 Merging the digitized components using CATIA

After the components are being digitized, the IGES files generated are imported into CATIA for further modification. For this project, the function used in CATIA is the *Digitized Shape Editor.* We can open this function by clicking (Start-✍ Shape -✍ Digitized Shape Editor). In the editor, we then import the IGES format file into CATIA using the import file command. We must make sure that the file extension selection in the CATIA is correct so that the import output can be done. After the file is being imported, the digitized component profiles can then be combined together to get a solid mobile phone profile for simulation purposes. Table 10 shows the output of the digitizer's IGES file after being imported into CATIA.

Table 10: Digitizer File Output in CATIA

Outer Front Casing	Inner Front Casing
	
Front View Middle Component	Back View Middle Component
	
Outer Back Casing	Inner Back Casing
	

The clouds from the digitized components are filtered to have lesser points to enable faster processing. Then, they are meshed and surfaced generated to produce orange colour surface as we can see in the figure below. After surface generation, the excessive and unwanted clouds are removed using the cloud remove function. The following is the image of the front mobile phone casing after being filtered, meshed and surface generated by using the Digitized Shape Editor before merging.

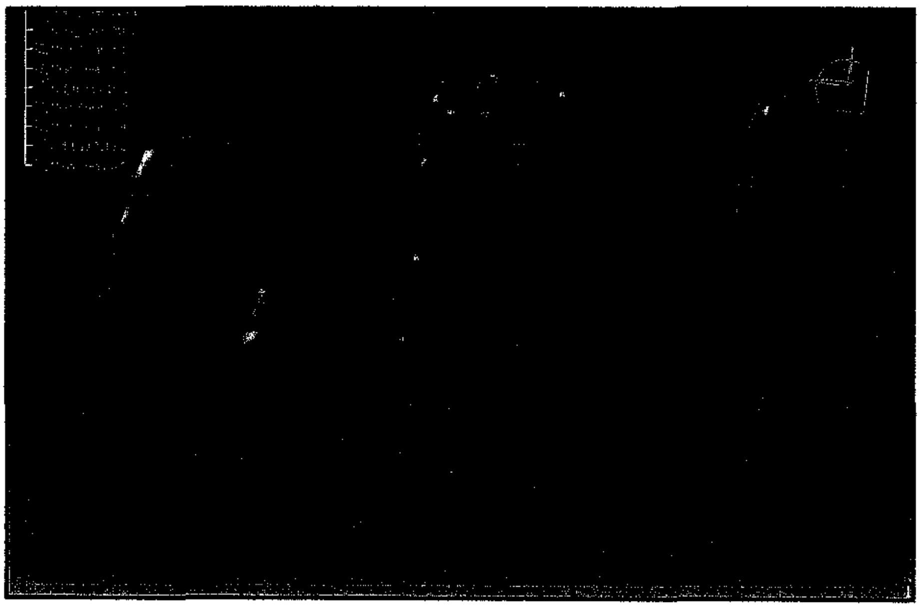


Figure 24: Front view of the front casing and middle components

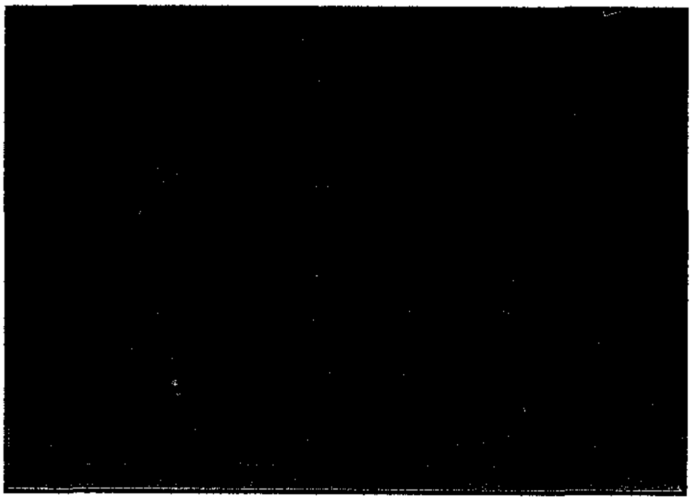


Figure 25: Back view of the front casing and middle components

After the components are altered and surface generated, the front and back surfaces (mesh creation) of the middle component are merged using the *Align with Compass* function where by the surfaces are arranged and fitted to one another by using the compass which aligns the surfaces by axis. After both middle mesh creations are perfectly aligned, the *Merge* function is used to merge both surfaces together into one merge creation called the *Cloud Union 1*.

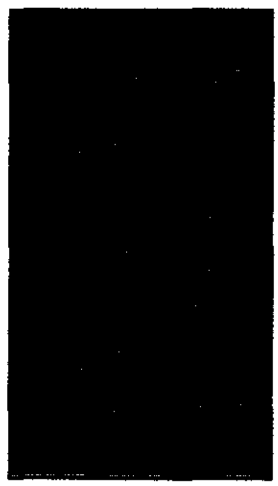


Figure 26: Cloud Union 1

The Cloud Union 1 which consist of front and back surfaces of the middle component is merged with mesh of the front casing by aligning both merged and mesh with the *align with compass* function. Both of them are then merged together after they are aligned properly according to axis. Cloud Union 2 is then produced.

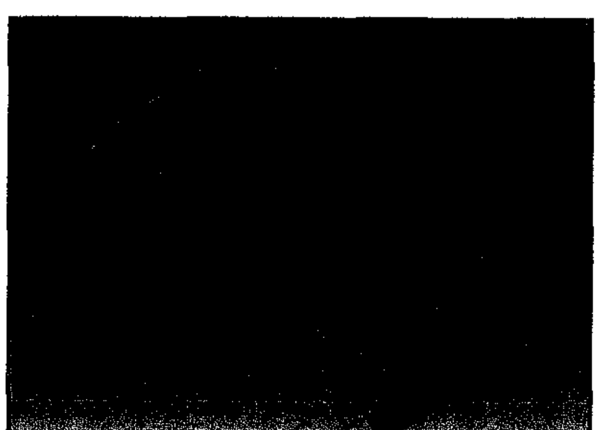
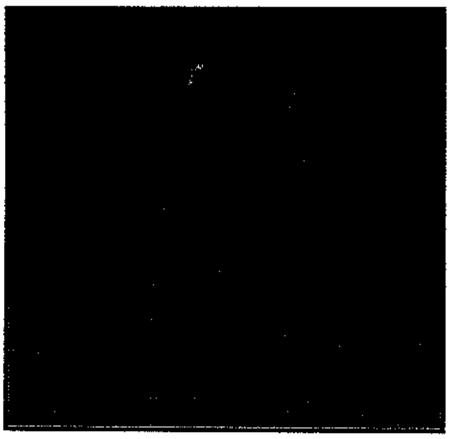


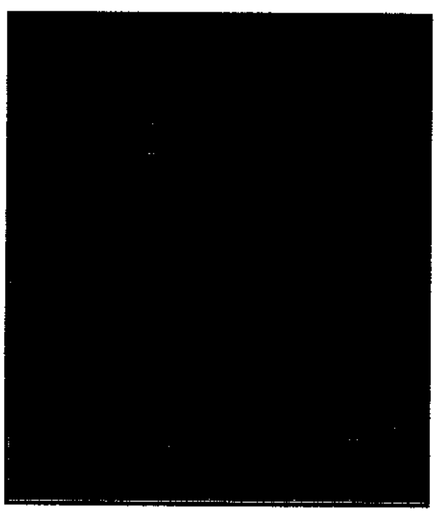
Figure 27: Cloud Union 2

After obtaining Cloud Union 2, it is followed by merging the back casing with the merged component to form a completely merged modeling of the Nokia 3310 mobile phone by using digitized surfaces from the mobile phone. The following are the images of the completely merged surfaces of the mobile phone test specimen which is labeled as the *Cloud Union 3.*

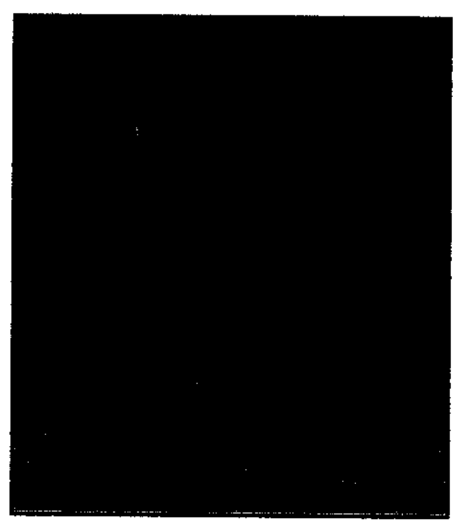


Front View

Side View



Back View

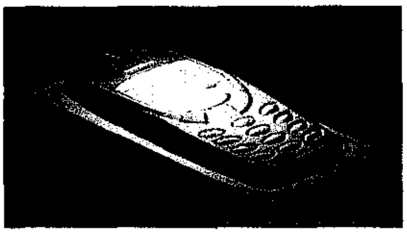
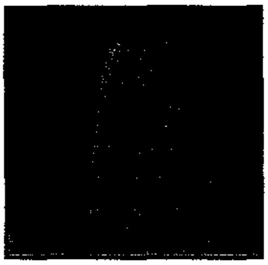
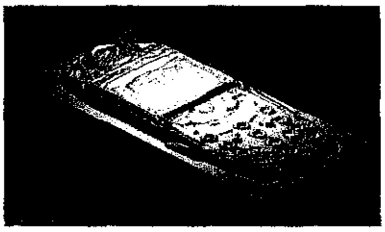


Complete View

Figure 28: Cloud Union 3

Table 11 shows the comparison between the digitized surface images generated using the Tracecut software in the Digitizer and the images after being meshed, altered, and surface generated in CATIA Digitized Shape Editor.

Table 11: Comparison between Digitizer and CATIA output

Digitizer	**CATIA**
 Front Casing	
 Middle Component	
 Back Casing	

4.5 Simulation Drop Test using ANSYS LS-DYNA with Drop Test Module (DTM)

For this simulation drop test, initially the test should be done using the solid model of the mobile phone. But due to the solid modeling file from CATIA Digitized Shape Editor failed to open in ANSYS due to unforeseen circumstances, the simulation is done using a PDA modeled ANSYS file. Then, the drop test is done on the PDA based on the drop test plan preset for the mobile phone. By referring to Table 8, the parameters involved are drop height, drop velocity, impact surface, drop orientations, etc.

Before starting the drop test simulation, the discipline options, elements of the PDA, the material model, and the components meshing must be done. Kindly refer to **Appendix C** for further understanding of the element parameters set for the PDA. Figure 29 shows the PDA after its elements are being defined and meshed.

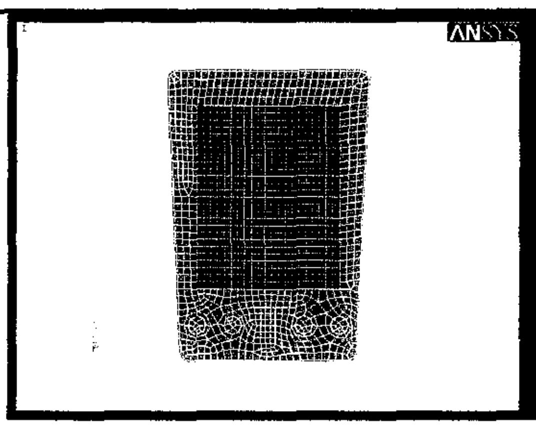
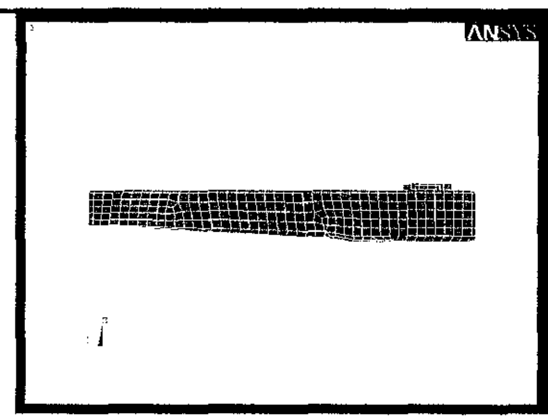
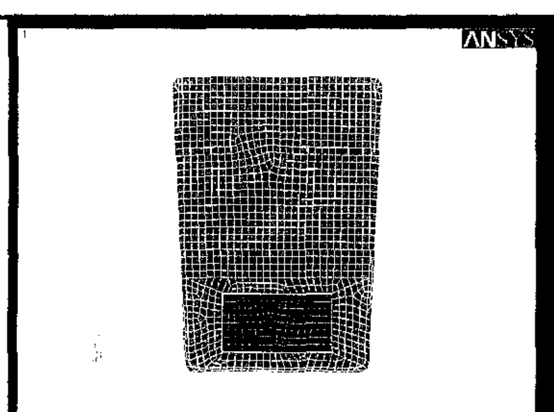
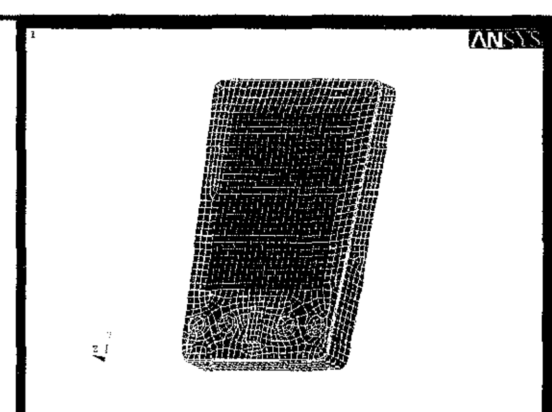
Front View	**Side View**
	
Back View	**Complete View**
	

Figure 29: PDA after elements defined and meshed

After the elements are being defined and meshed, the PDA model is saved and drop test is started by using the Drop Test Module (DTM). First, the drop test setup which allows us to key in the drop test parameters such as the gravity value, drop velocity, type of drop, run time after impact, number of results output, translational and angular velocity, etc is initialized. The following figures show the step-by-step methods of initializing the values in the drop test setup.

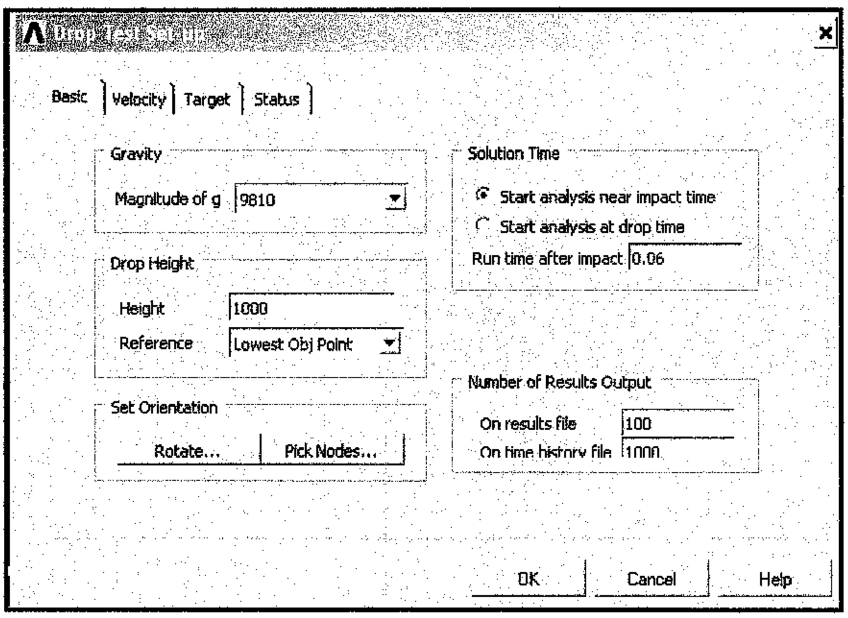


Figure 30: Basic setup values for drop test

For the basic setup values, for this PDA, the gravity magnitude, g is set as 9810mm/s^2 because the model is built in unit of millimeters. Then, the drop height is set to 1000mm according to the drop test plan. The solution time is set to start the analysis near impact time to cut down processing time and the run time after impact is 0.06s. The number of results output is to set how often the output date should be written in the result files. To set the drop orientation, the PDA can be rotated or by picking the nodes.

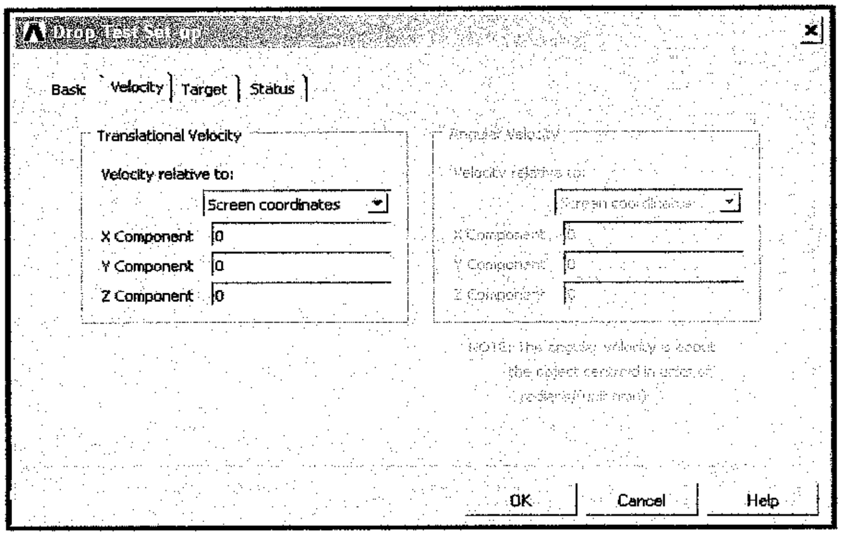


Figure 31: Velocity setup for drop test

For the velocity tab, the translational velocity relative to X, Y, and Z are set to 0 because both flat and edge drops are static drops. The angular velocity tab is greyed out because since the drop analysis is set to start at near impact time. Specifying an angular velocity greatly increases the CPU time.

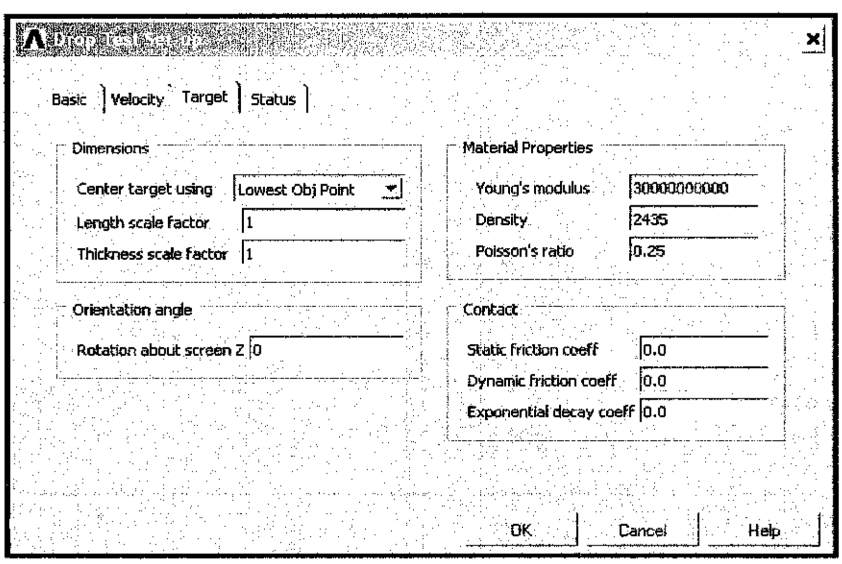


Figure 32: The drop target (impact surface) setup for drop test

For impact surface setup, the orientation angle is set as 0 because the impact surface is a concrete floor. The material properties of the concrete floor (eg. Portland cement) is set with the Young's modulus of 30GPa, Density of 2435 kg/m^3 and Poisson ratio of approximately 0.25.

After setting the basic, velocity and target values for the drop test setup, the images of the PDA model on ANSYS LS-DYNA screen for flat drop and edge drop are shown in Figure 33.

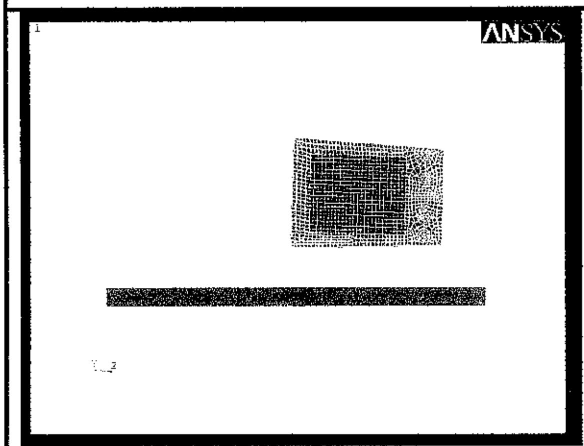
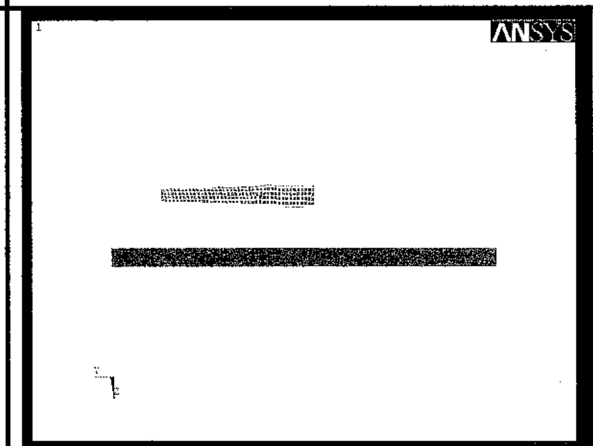
Edge Drop	**Flat Drop**
	

Figure 33: Drop test Setup for Edge Drop and Flat Drop

The status of the drop test setup can be confirmed by clicking on the status tab. The summary information can be review to ensure that the data are entered correctly. The termination time will be the sum of times before and after impact. If "start analysis near impact time" is selected, the CPU time require to run it will be much lower. The status tab must indicate "Successful Set-Up. Ready to drop" before the drop test simulation is carried on.

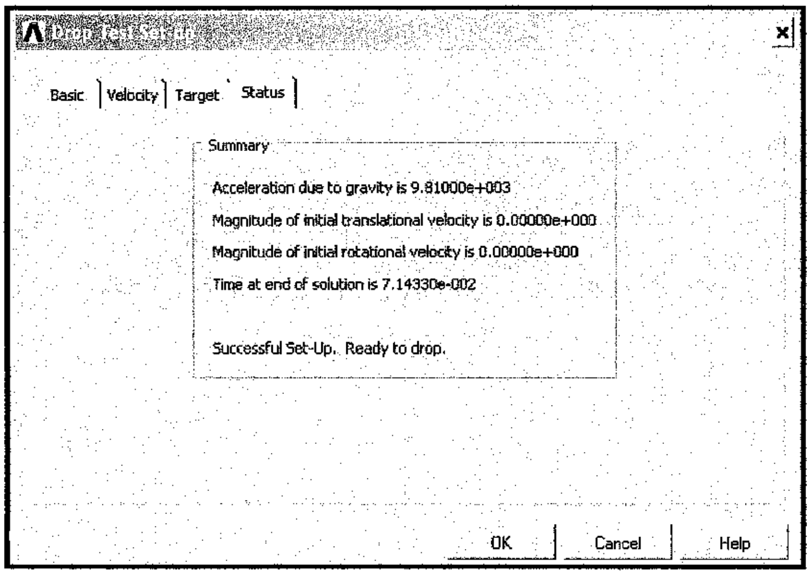


Figure 34: Status of Drop Test Setup

After initializing the drop test setup, since the status tab indicates that the setup is successful and ready to drop, so the drop test can then be started. But there were several errors and 19 warnings appeared during the run and the drop test simulation failed to run. Figure 35, 36, and 37 are the screen shots of error messages appeared during the drop test was being run. "There are no translational and rotational displacement boundary conditions set", "no data set on file", and "load set not found on file file.rst". Various steps are taken to solve this problem such as by reading through the ANSYS help files, ANSYS Forum search, going through all the ANSYS function tabs, and multiple trial-and-error attempts but none of the method was successful. The drop test simulation is unable to complete due to time constraint and inability to solve the error and warning messages.

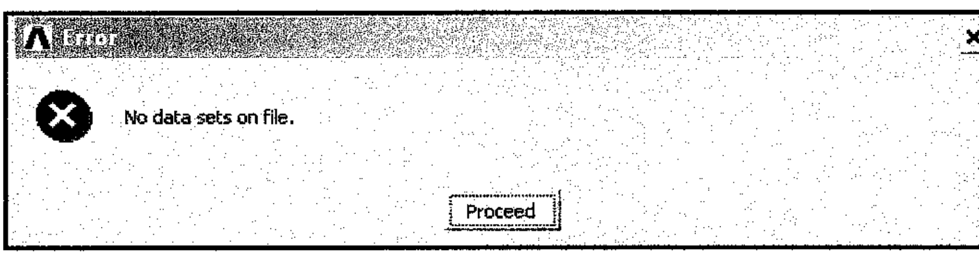


Figure 35: Drop Test Module Error Message 1

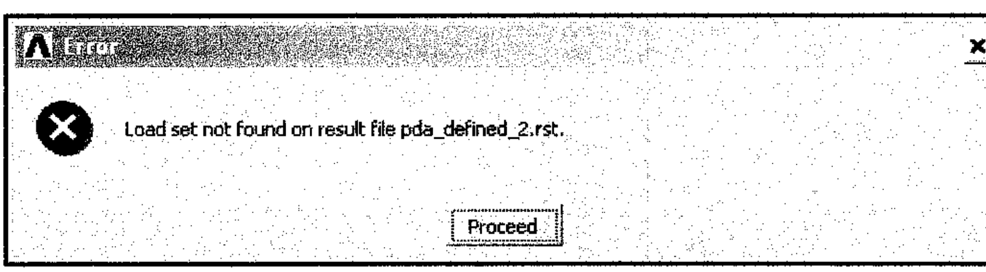


Figure 36: Drop Test Module Error Message 2

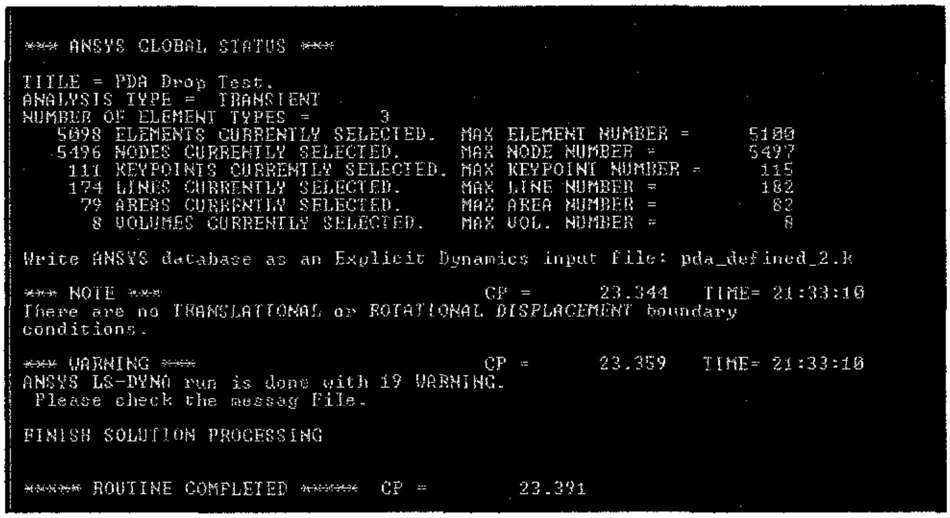


Figure 37: Drop Test Module Error Message 3

4.6 Problems Faced

During the project is being done, there were various problems to be faced. For example, there were difficulties searching for relevant information about simulation drop testing because it is considered a new technology applied in the electronic industries. This is because prior to simulation drop testing, physical drop testing is done to various products. Since the physical drop testing is progressively being obsolete and replaced by the simulation by using software recently, the information available about the simulation drop test is quite rare. A journal regarding simulation drop testing on an electronic device aluminum casing written by Y.Y. Wang et al with the title "Simulation of drop/impact reliability for electronic devices" [1] was found.

Besides that, the determination of the drop orientation is also a major problem because it was difficult to search for standards which done physical drop test on electronic devices. This problem is solved when a few ASTM standards regarding physical drop testing done on various products including loaded containers, bottles, etc were found. The most suitable ASTM standard for this final project title is the ASTM Standard Test Method for Drop Test of Loaded Containers by Free Fall (D 5276 – 98). This is because the drop orientation which includes drop height, angle, repetition, procedures and the drop plan are related to this project. These drop parameters is very crucial and must be included in the drop plan to ensure successful drop testing for both simulation and physical drop tests.

During the digitizing process of the mobile phone components, there were problems where I had no idea on how to operate the digitizer and it was running out time for me to keep up with the FYP schedule. This is because the 3D Laser Digitizer is totally new for me and it takes a very long time for self-learning. This problem was solved when a senior FYP student was willing to help me out by giving me tutorial on how to operate the digitizer. This cut down the time taken from figuring out the method to operate and to digitize the components from 3 weeks to approximately 1 week.

Furthermore, after digitizing the components, it is a big challenge to combine all the separate components into a perfect solid profile for simulation purposes. The simulation cannot be done until a perfect solid profile of the phone is created because the meshing needs a perfect solid. Besides that, the surfaces generated in CATIA by using the Digitized Shape Editor on the components are very poor compared to the surfaces digitized from the digitizer. This is because when the files from the digitizer are converted into IGES form, a lot of information has been lost and this causes the surface generation to be unsmooth and not clear. This problem is solved by referring to the help files available and trial-and error.

Furthermore, there are more problems arose when the application for approval to use the high speed camera for physical drop test was declined. This causes the motion capture of the drop cannot be done as there are no other cameras in UTP which can be used to capture motion in static images. But there is a solution whereby with the use of Advance X Video Converter, the specimen drop can be recorded by using a video camera and then the video can be split into multiple static images per second using the software to generate a series of images that shows the drop motion of the mobile phone. The output of this method is similar to the one obtained using the high speed camera.

Finally, for the simulation drop test, the merged component file from CATIA Digitized Shape Editor failed to open in ANSYS LS-DYNA. To carry on with the simulation, a PDA model ANSYS file is used to replace the mobile phone in simulation drop testing. The drop test is done on the PDA based on the drop test plan parameters preset for the mobile phone. After defining the elements, complete meshing, and initialization of the drop test setup of the PDA model is done; during solving the model, multiple errors and warnings were detected. Various methods were used to solve this problem such as by reading through the ANSYS help files, ANSYS Forum search, going through all the ANSYS function tabs, and multiple trial-and-error attempts but unfortunately none of the method was successful. In the end, I was unable to proceed with the simulation drop testing due to time constraint and unsolvable errors and warnings from the software during running the simulation solver.

4.7 Solution Proposal to Improve the Reliability of the Mobile Phone

From the physical drop test, we see that the casing material fails due to single mechanical drop. In order to protect the mobile phone from drop impact damage due to multiple drops especially the electronic components, various modifications must be done to the mobile phone. The types of modification that can be done are as follows:

a. Modify the casing design of the phone in such a way that the drop impact can be distributed evenly throughout the casing to reduce impact damage. For example, produce a 2 layer casing with small empty space between the two layers. This enables the drop impact to disperse or reduce through the empty space before reaching the phone components. This will largely reduce the impact damage sustained by the phone due to drops.
b. Increase the strength of the casing material. This will protect the mobile phone components from drop impact as stronger casing material can absorb more impact damage.

The modification done to improve the reliability of the mobile phone can only sustain drops to a particular extend only. Excessive or extreme drops will still cause damages to the mobile phone due to accumulated drop impact or the impact is too high for the material to sustain such as drop from a very high position.

4.8 Significance of this Project to the Market of Electronic Products

The significance of this project to the electronic products market especially cell phone market is that damage done to cell phones especially due to accidental or intentional drop impact can be properly analyzed. Stress concentration of the drop impact on the cell phone also can be analyzed. By using simulation drop testing, it will be very cost effective and time saving to conduct drop test with various drop orientation and procedure in order to obtain sufficient data for further analysis. After the analysis, various solutions to the problem such as by improving the cell phone design or material characteristics and extra protective accessories can be proposed. By doing this project, a clearer picture of the drop impact damage behind each cell phone drop can be obtained.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Referring the project objectives stated in this report which are as follows:

- To identify the drop orientation, height, and angle for the simulation and physical drop test.
- To decide and produce a drop test plan in order to ensure the simulation and physical drop test are done according to plan and procedure.
- To build a solid model of the mobile phone using 3D Laser Digitizer and CATIA Digitized Shape Editor.
- To simulate the drop impact effect acting on the electronic device (mobile phone) with various parameters using drop test simulation software, ANSYS LS-DYNA.
- To conduct physical drop testing.
- To propose possible solutions to reduce the drop impact damage.

All the information regarding solid modeling, drop parameters, drop test simulation, physical drop test, etc are obtained. The drop test plan including the drop orientation, drop height, impact surface and types of drops for the simulation and physical drop testing are set (refer to Table 8). The digitizing process of the mobile phone components using 3D Laser Digitizer and the merging of all the components surface profiles by using CATIA Digitized Shape Editor are already done. The simulation drop testing using ANSYS LS-DYNA Drop Test Module done on alternative PDA model can only be completed half way until finished defining elements, meshing and initializing the drop test setup due to time constraint and various unforeseen problems. On the other hand, the physical drop testing of Flat Drop and Edge Drop is completed. Finally, solutions are proposed to improve the reliability of the mobile phone subjected to mechanical drop.

5.2 Recommendations

For future research purposes, since this final year project is to analyze the effect of the drop impact to the mechanical side of the electronic device which is the cell phone, further analysis to the electronic components such as the circuit board can also be done. This is because besides mechanical failure, after the portable electronic devices are dropped, the major damage occurs at the electronic components, and this causes major malfunction of the electronic device itself. The drop impact badly damages the micro components inside the circuit boards, for instance, the soldering, broken microchips, cracked circuit boards, etc. If the circuit board is broken, there will be no cure for the damage instead of having to replace the whole circuit board. This is not cost effective and time consuming as the replacement parts might not be available upon ordering and the price for electronic components are very expensive especially for the high end electronic devices such as the cell phone.

In the future, simulation drop testing can be done to the circuit boards to identify the stress concentration point, strain, impact stress distribution, etc. The combination of mechanical and electronic part of drop testing analysis on the cell phone will bring a lot of benefits to the electrical and electronic industries can this will help them to improve their products by referring to the results obtained from this two types of projects. This will indeed helps the cell phone companies to produce a cell phone which is more reliable and more resistance to drop impact damages. Consumers will benefit from it because the cell phone that they use will be more drop resistant and last longer. They will not have to chip in a lot of money to buy cell phones as the cell phones will be more reliable. Furthermore, further studies based on this two aspects; mechanical and electronic failure can be done in order to come out with more ideas to improve the design, structure, material characteristics, reliability, and practicality of electronic devices. The outcome will not only benefit the cell phone industry but all the other electrical and electronic industries.

REFERENCES

[1] Y.Y. Wang, C. Lu, J. Li, X.M. Tan and Y.C. Tse, 2004, "Simulation of drop/impact reliability for electronic devices". *Finite Elements in Analysis and Design, Volume 41, Issue 6, March 2005, Pages 667-680*

[2] ANSYS, "Drop Test Module (DTM)". *ANSYS Training Manual, Chapter 12, June 4, 2003.*

[3] ASTM Standard Test Method for Drop Test of Loaded Containers by Free Fall (D 5276 – 98)

[4] K.G.Budinski, M.K. Budinski, 2004, "Properties and Selection", *Engineering Materials*, 8th Edition, Pearson Prentice Hall.

[5] http://www.ansys.com/products/drop-test.asp

[6] http://www.renishaw.com

[7] http://www.aoamedia.com/extract_images.htm

[8] http://www.catiav5forum.de/

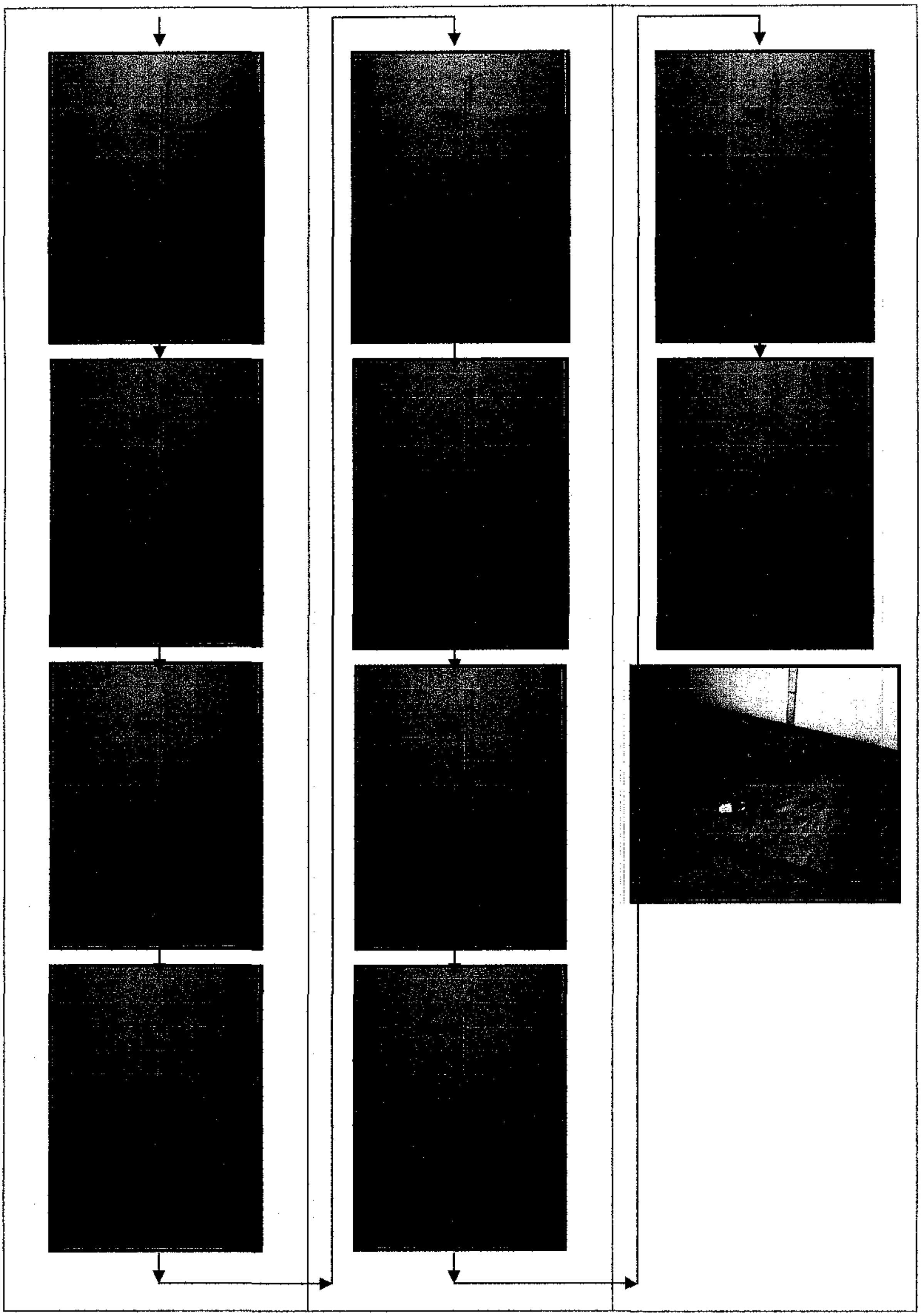
[9] http://www.**catia**world.com/lang1/mem/comm/cw.htm

APPENDIX A

FLAT DROP PHYSICAL TEST

Physical Drop Test – Flat Drop

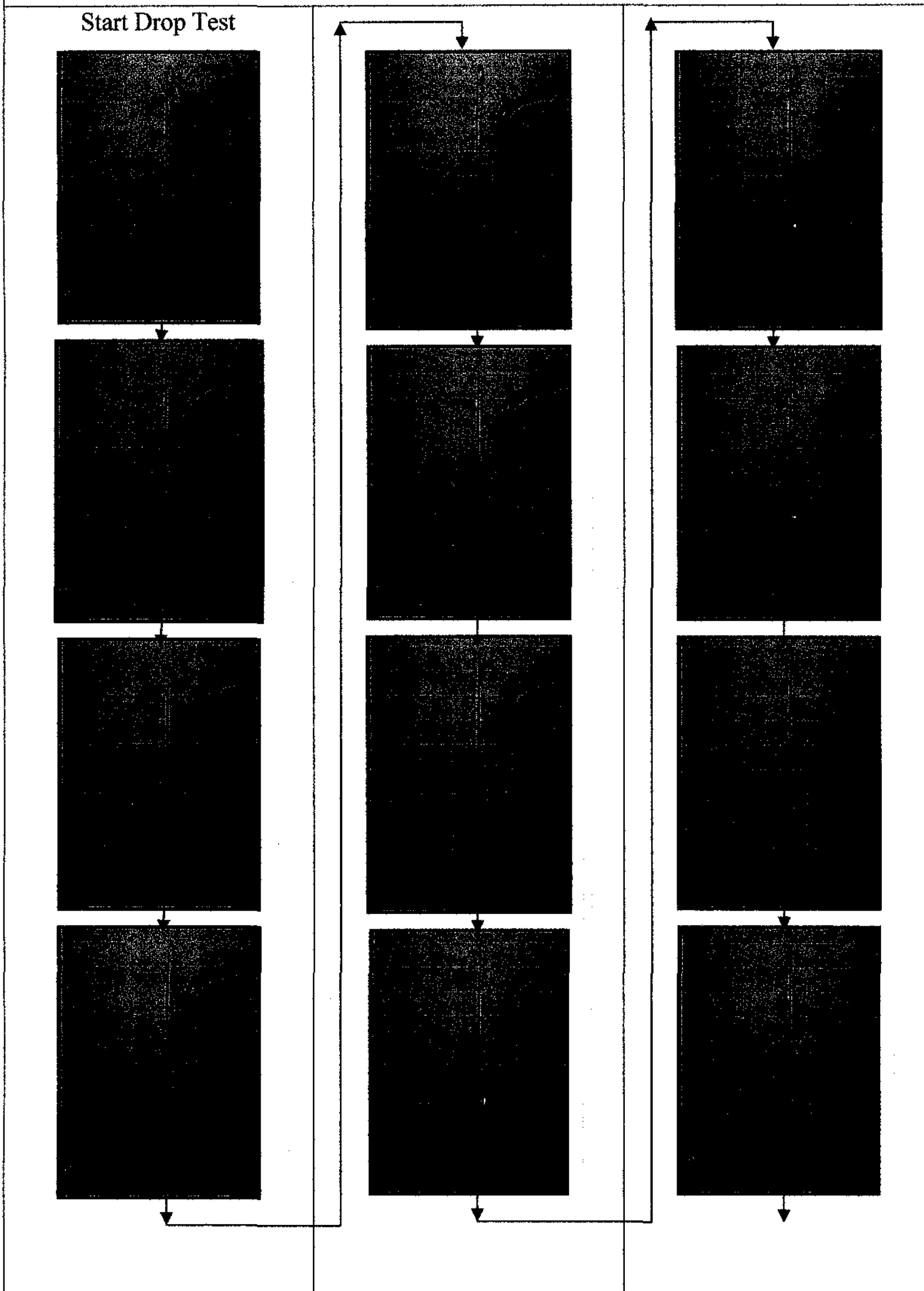
Start drop test

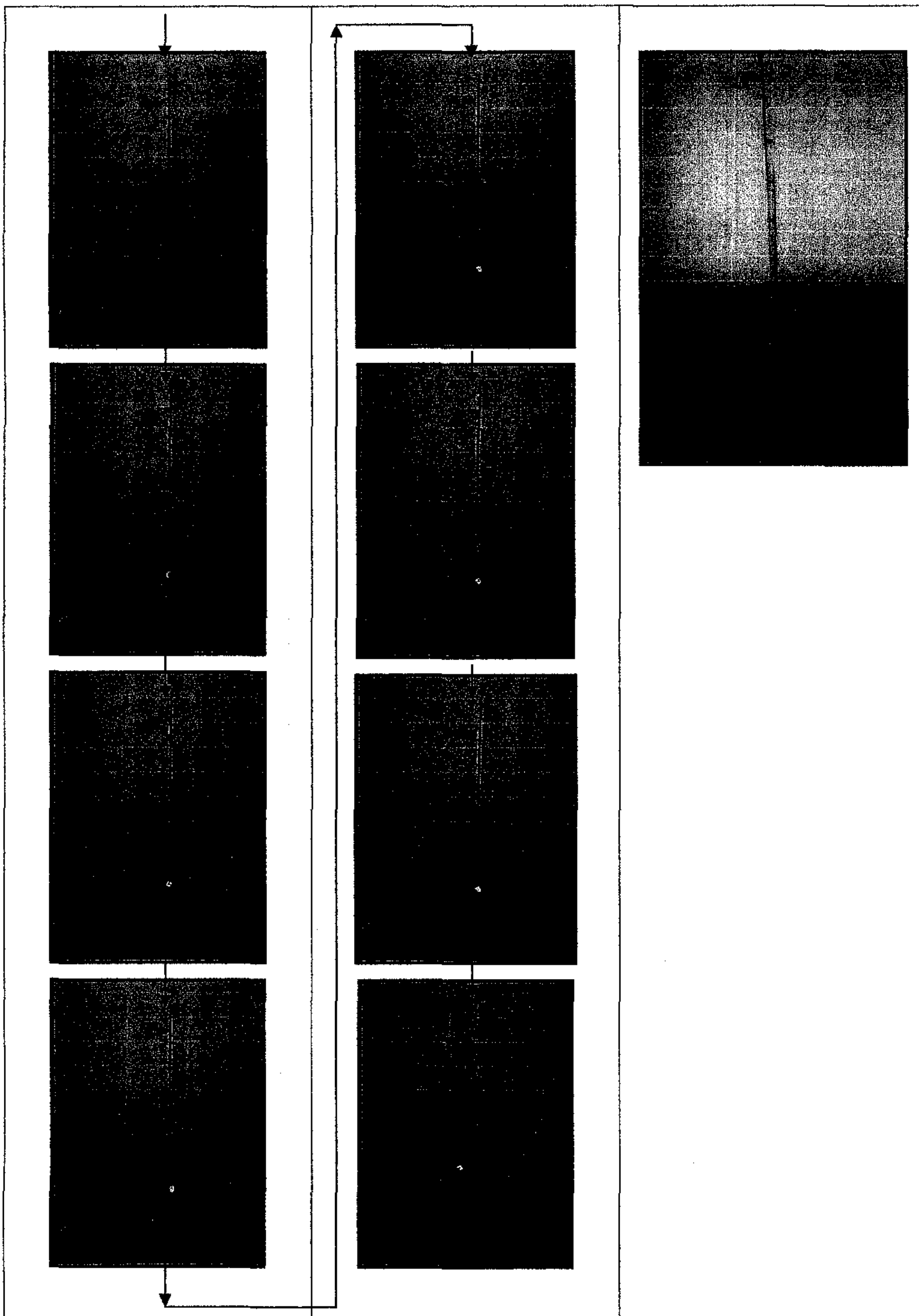


APPENDIX B

EDGE DROP PHYSICAL TEST

Physical Drop Test – Edge Drop





APPENDIX C

ANSYS LS-DYNA ELEMENT PARAMETERS SET FOR PDA MODEL

Table: Summary of ANSYS LS-DYNA Element Parameters Set for PDA		
Parameters	**Values**	
Preferences> Discipline Options	LS-Dyna Explicit	
Elements>	(1) Thin Shell 163 (2) 3D Solid 164	
Real Constant> Shell 163> Set 1	Shear Factor	0.833
	No. of Integration Pts.	3
	Thickness at Node 1	0.5
Real Constant> Shell 163> Set 2	Shear Factor	0.833
	No. of Integration Pts.	3
	Thickness at Node 1	0.75
Real Constant> Shell 163> Set 3	Shear Factor	0.833
	No. of Integration Pts.	3
	Thickness at Node 1	0.5
Material Model 1> Bilinear Kinematic	Density	1.71E-09
	Young's Modulus	17200
	Poisson Ratio	0.35
	Yield Stress	228
	Tangent Modulus	5000
Material Model 2> Bilinear Kinematic	Density	1.64E-09
	Young's Modulus	10500
	Poisson Ratio	0.3
	Yield Stress	125
	Tangent Modulus	1000
Material Model 3> Elastic Isotropic	Density	6.10E-09
	Young's Modulus	70000
	Poisson Ratio	0.29
Define Attributes> All Areas	Material model	1
	Real const. set no.	1
	Element type	Shell 163
Define Attributes> LCD Screen	Material model	2
	Real const. set no.	2
	Element type	Shell 163
Define Attributes> Battery Cover	Material model	1
	Real const. set no.	3
	Element type	Shell 163
Define Attributes> Batteries	Material model	3
	Real const. set no.	1
	Element type	Solid 164
Meshing	Element size	5 mm
Define Contact	Contact Type	General (NTS)
	Static Friction Coeff.	0.2
	Dynamic Friction Coeff.	0.1
	Viscous Damping Coeff.	0.1