Abstract
The theory of the packaging represents one of the most important parts of any manufacturing education. The main aim of paper is to obtain the knowledge of packaging, and to experience the actual behavior of the packaging materials. This paper will highlight the design and modeling of indentation test of blow moulded plastic bottles. Solid work was used to simulate the designed Solid work was also used to investigate the design behaviors when changing the settings of the parameters. This would allow using the developed modelling of the design without the need of a physical bottle. 

Keywords: Knowledge of packaging, using solid work to simulate the design, develops modelling of the design.

1. Introduction
The main aims and objectives of this project are to Design and modelling of Indentation test of blow moulded plastic bottles to help achieve this goal in the available time, various tasks were set. These include: To critically review the function, design, materials and manufacturing process of plastic bottles, to develop experimental method testing. The properties of plastic bottles, to develop an inverse method to predict the properties of the material (Elastic/plastic) through finite element modeling, to develop a top loading model of the bottle based on the materials properties measured.

2. The function, Design (assembly) of plastic Bottles
Packaging is a complex, dynamic, scientific, artistic and controversial business function, which in its most fundamental from contains, protects/preserves transports and informs/sells. The main functions of packaging are: Containment-Package can hold the contents and keep them secure until they are used. Protection- The protection function of the package has two aspects. First is the protection of the product from all hazards from the time it its packaged until the consumer of the product used it in its entirety. The second aspect of protection coequal with protection of the product- is protection of the environment surrounding the item in the package. This is true not only for people who may come in contact with the package product, but for storage and transportation as well.

3. The Packaging
Packaging plays a key role in maximizing the impact of brand names. Through design, decoration and process, packaging is best described is best as a coordinated system of preparing good for transport, distribution, storage, retailing and use of goods. Also, packaging may be defined in terms of its protective role as in “packaging is a mean of achieving safe delivery of product in sound condition to the final user at a minimum cost” or it can be defined in business term as “a techno-economic function for optimizing the cost of delivering goods whilst maximizing sales and profits” Packaging is the enclosure of products, items, or other packages in pouches, bag, boxes, cups, trays, cans, tubes, bottles, or other container forms to perform one or more of the following basic functions like Containment, Protection, Communication and Utility. The packaging function in the physical environment is subject to moisture, temperature extremes, mechanical shocks and vibration. No matter what environment conditions are encountered, the package is expected to
product, keeping it in the condition intended for use until the product is delivered to the ultimate consumer. Packaging is the enclosure of products, items, or other packages in pouches, bags, Boxes, cups, trays, cans, tubes, bottles, or other container forms to perform one or more of the following basic functions:

- Containment
- Protection
- Communication
- Utility

4. Uses of Plastic

Today, plastic are used in lots of different ways in everyday life, such as:

- Electrical switches
- Kettles
- Lawnmower part
- Drink bottle
- Carrier bags
- Paints and adhesives
- Plastic are strong, light and do not rust or biodegrade.

5. Plastic Bottles Productions

Plastic bottles are most made of polyethylene terephthalate which is a specific type of plastic in terms of fabrication there are two basic molding.

Methods one-step and tow steps. In two step molding, two separate machines are used. The first machine ejection molds the perform. The bottle-cap threads are already molded into place, and the body of the tube is significantly thicker, as it will be inflated into its final shape in the second step using stretch molding. In the second process, the performs are heated rapidly and then inflated against a two-part mold to form them into the final shape of the bottle. Performs (uninflected bottles) are now also used as containers for candy. In one-step machine, the entire process from raw material to finished container is conducted within one machine, making it especially suitable for molding non-standard shape (custom molding), including jars, flat oval, flask shapes etc. Its greatest merit is the reduction in space, product handling and energy and far higher visual quality than can be achieved by the two-step system [1].

6. Benefit of plastic and why we used plastic

The considerable growth in plastic use is due to the beneficial properties of plastics. These include:

- Extreme versatility and ability to be tailored to meet very specific technical needs.
- Lighter weight than competing materials, reducing fuel consumption during transportation.
- Extreme durability.
- Good safety and hygiene properties for food packaging.
- Excellent thermal and electrical insulation properties [2].

7. Availability

Plastic bottles are one of the biggest wastes in today’s packaging industry. So it’s possible to collect them and to use them without spending any money. It is even a big advantage to reuse the empty bottles since just 15% are going to be recycled in factories.

8. Plastic bottles Resin materials

Plastic bottles come in a variety of materials (resins). Plastic bottles produced from HDPE material are the most common and least expensive. Plastic bottles produced from PET material are crystal clear. Plastic jars produced from PP material are resilient and economical [4].

9. Physical Properties

The bottle design also plays an important role in providing performance in physical properties. The finish of the bottle should be thick enough to handle the forces placed upon it by the blow nozzle of amount of material so as to meet the top-load requirement.

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10. Type of plastic

There are about 50 different groups of plastics, with hundreds of different varieties. All types of plastic are recycled. To make sorting and thus recycling easier, the American Society of Plastic Industry developed a standard marking code to help consumers identify and sort the main types of plastic [5].

11. Finite element method and their Applications

The finite element method (FEM) is one of the most effective numeric methods for solving linear and non-linear multi-dimensional scientific and technical problems. It allows modelling of systems with a complex geometry and an irregular physical structure. One of the most time-consuming steps when solving three-dimensional problems using the FEM method is building adaptive mesh. The mesh should satisfy FEM requirements, allowance to represent a complex geometry of unknown parameter areas and describe the medium interface in detail. The creation of an automated generator of the spatial mesh with a user-friendly interface which is suitable for defining the calculation geometry, having visualization of incoming data and mesh quality control is a very complex and important problem. Such type generator is a critical constituent of any large scale specialized software complex based on FEM [6].

12. Elastic Deformations

For most materials, a stress-strain curve starts as a straight line. Over the straight-line region the stress is preoperational to strain. This is Hooke’s law. In this range of stresses the material undergoes elastic deformation. For small strain the whole process of extension and recovery is reversible, and can be repeated many times. This elastic behavior under loading is showing by most engineering materials up to a certain stress (the elastic limit). This contrasts with materials that are plastic under normal conditions such as putty and Plasticise. Note the term ‘elastic’ does not only apply rubber bands and other stretchy materials. It applies to all materials in the region of the stress-strain graph that in linear.

13. Results

LLOYD LR30K Tensile Testing Machine:

The equipment that has been used for the tensile machine that tests the plastic bottle pieces referred to as a LR30K testing machine. The Lloyd 30K is a universal materials testing machine which implies that it can perform both testing and compression tests. It operates using a hydraulic system where the load is applied by a ram moving in an oil filled cylinder. The machine has maximum loading capacity of 30KN. The machine is incorporated into a micro computer with graphical printouts, which allow the test to be obtained and stored.

The control console of the machine can either be operated manually or remotely. The test is conducted remotely, by utilizing a computer that has all the commands transmitted through the RS232 Link; the console displays the applied load and material extensions when the plastic pieces are being tested.

The test parameters were set using the computer, its parameters should in clued the “dimension size, maximum load, young’s modulus value, extension speed etc...” the plastic test pieces is loaded into a position and the machine jaws are henceforth tightened

Figure 1: Example for Element Meshes
with a pre-Load 400N. Once the test is completed, a graph of against extension is displayed in the monitor.

14. Thickness and measurements and the bottle used

The bottle was used the dimension of the bottle is not parallel and the thickness is different from top, middle and bottom and procedure of cutting the bottle into two pieces using sharp knife on the rigid flat table. In figure 2 show the way used to measure the thickness of the bottle using the micrometer which is measure from 0.5mm to 45mm.

Figure 2: Thickness Measurements

In figure 3 as shown the rig consist of two pieces the circular from cupper materials, hallow from inside to allow the indenter to go up and down, and Also consist of six screws to fix the sample materials from the bottle and prevent it from sliding.

In the figure 4 all graphs has been but together in order to compare and validate their different thickness results. Figure 7 show the FE model mimicking the experimental test. (a) FE model using the solid works and (b) the mesh used the solid works model.

Figure 8 (A) using the abaqus (B) the mesh used in abaqus.

The solid works model is straight forward test and the abaqus is good for choosing the materials properties.

Figure 9 show the pressure-displacement curves of thickness of (0.63mm) in different mesh sizes to study the effect of mesh in these curves and as can see the effect of mesh increase as the pressure and it doesn’t have much effect the pressure is small.

Figure (10) show the pressure-displacement curves of thickness of (0.75mm) in different mesh sizes to study the effect of mesh in these curves and as can see the effect of mesh increase as the pressure and it doesn’t have much effect the pressure is small.

Figure (11) show the pressure-displacement curves of thickness of (0.78mm) in different mesh sizes to study the effect of mesh in these curves and as can see the effect of mesh increase as the pressure and it doesn’t have much effect the pressure is small.

Figure (12, 13 and 14) shows the effect of materials properties change which young’s muddle in this study on the force – displacement curve. Which show that the displacement is increasing the young’s muddles decreasing and vice versa.

Figure (15) shows the compression between the experimental data with numerical one that gained from abaqus FE model. In this graph the experimental result is relatively agreed with the numerical one.

Fig 14 show the experimental set up of measuring the force – displacement of the materials sample which is the plastic taken from the bottle by using the tensile machine.

Figure 17 (A) FE model and Figure (17 (B) The model mesh FE model of the bottle for the top load tests

Figure 18 show the loading condition for the top load model.

Figure 19 effecting materials properties for the Bottle shows the experimental results taken from the solid work

Figure 20 Effects of the mesh sizes on the top load simulation results.
Figure 4: Design and making process of the indentation rig to test bottle wall plastic

Figure 5: The graph result from the intense machine force 4kn and thickness 0.78mm

Figure 6: Comparisons of the force displacement curves tested at different position on the bottle wall

Figure 7 (A): Figure FE models (B) Sold works mesh

Figure 8 (A): ABAQUS Models (B) ABAQUS mesh

Figure 9: Effecting mesh for thickness 0.63
The effect of mesh sizes on the pressure displacement data for two models with different thickness.

The effect of material properties on the pressure displacement data for FE models of three different thicknesses.

Comparison between the force displacement curve with fitted material data and the testing results.
Figure 15: Comparison of the Numerical and experimental results

Figure 16: Typical simulated force-displacement data

Figure 17 (A): FE model (B) The model mesh

Solid work and FE model of the bottle for the top load test.

Figure 18: loading conditions the loading condition for the top load model

Figure 19: Effecting materials properties for the Bottle
Figure 20: Effecting Mesh for the Bottle Typical results for the bottle

15. Discussion

The aims of this experiment were to investigate the effects of materials properties for the plastic bottle. To perform this experiment, three pieces of the plastic bottle were collected from the bottle, there were different thicknesses between all three pieces, the first piece was (0.63mm) the second piece was (0.75mm) the third piece was (0.78mm). By using the LIOYD LR 30K machine with the induction equipment indentation tests were performed on each of the three pieces of the bottle.

The first step was to place the piece of the plastic under the (8) mm indenter on the Lloyd machine. The machine was then programmed to apply a load of 400N to be put into one of the pieces of plastic bottles. The initial stage was to lower the indenter until it contact with the surface of the piece, the machine then applies the force of the piece, and will then shows the indentation depth of the plastic. The same technique was used on each piece shown on the Figure (3A).Typical raw force displacement data shows the result of the displacement (mm) and the force (N) that took place during the test on three areas of the plastic bottle the key areas of the plastic bottle being tested where the top and middle and the bottom of the bottle.

On the figure (4) Comparison of the force displacement curves tested at different position on the bottle wall. On the figures (7, 8 and 9) the solid work soft ware was used for the tests. And the test was to investigate the effect of mesh sizes on the pressure displacement data for two models with different thickness of a plastic bottle. From the figures it is clear that the 0.7 mesh size is the most appropriate to use. Figure (10, 11 and 12) shows the effect of material properties on the pressure displacement data for FE models of three different thicknesses. a big different between the Elastic used in this experiment for each pieces of plastic properties and the Elastics used in this experiment were (200, 400, 600,800, 1000 and 1200). The above experiment results indicates that the elastic 800 is the most suitable to use in this materials properties for the plastic bottle. Figure (13) show a comparison between the force displacement curves with fitted material data and the testing results. The 3D finite element model has been developed, using a commercial finite element software ABAQUS (6.4) mimicking the testing conditions, the indenter is modeled as a rigid body (analytical rigid) as the stiffness of stainless steel. The contact between the plastic and the indenter is defined by a contact pair option. To simulate the actual indentation bending test, fixed boundary condition was applied to the sides of the piece of the plastic. It clearly shows that the material has a large deformation from the center to the fixed edge. Figure (14) show a comparison between the force displacement curve with fitted material data and the testing results at different positions and thicknesses, and it also shows that the numerical result and experiment result is very typically in the graph so the result was as anticipated.

16. Conclusion

The project Aim was to design and modelling of indentation test of blow moulded plastic bottles.

From the mechanical testing and software testing which are solid work and ABAQUS procedure performers PET materials properties used for the design, and the materials differ so it is important a potential for packaging.

There is a large number of testing procedure available. The procedure used in this study was the force and
displacement figures. The plastic bottle material that makes the device was the main focus of the study. Materials chosen also played a huge part in the overall design and manufacturing of a plastic bottle. Test showed the resulted in less damage and can withstand a greater amount of force of the certain area of the plastic bottle.

The materials used for the design is PET materials Properties, because the chemist of PET is simple and its intrinsic properties do not rely on the present of the additive. It can be recyclable, and this is being done on an increasing scale. General toxicity and genotoxicity studies on PET and its monomers and typical intermediates indicate that this material does not pose a threat to human health. There is a significant body of evidence demonstrating that PET show no estrogenic activity.

As PET can be used in many packaging forms wrapping films to bottles, it constitutes valuable basic packaging materials. And also the PET materials lay its physical properties that allow for great freedom in design. Because of strength, thermo-stability and transparency of PET, it’s widely used in packaging industries. The other reasons for popularity of PET among consumer are it is lightweight, resalable, shatter, inexpensive and recyclable.

References