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# Experimental Study of Mechanical Properties of Type Linear Low Density Polyethylene and Mold Design

***Abstract-****In general, the manufacture of plastic materials is commonly in the world due to their applications. Plastic is light weight, cheap, and able to be used in different industries, for example parts of automotive and home tools. This research represents a challenge on how to design and manufacture a changeable mold. First, a mold was designed by the Auto CAD program and then manufactured in the workshop. The mold consists of three parts, the middle part has changeable cavity. The mold was cooled by worm net pipes embedded into the third part. All specimens were manufacture in this mold. The injection plastic flow is perpendicular on mold. The goals of this research are to design and manufacture a mold and to determine the mechanical properties of linear low density polyethylene. Three types of test were executed, tensile, impact and bending. The results of tensile test showed that the tensile strength value is 15 MPa, Young's modulus is 0.18 GPa, yield stress is 12 MPa, and Elongation to break is 70.88 mm. From impact test, the impact strength is about 193.75 KJ/m$^2$, while in bending test, the flexural strength is about 18 N/mm$^2$ and the shear stress is 1.5 N /mm$^2$.*

***Keywords****- Linear low density polyethylene, Tensile test, Impact test, Bending test, Mold*

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## 1. Introduction

The word polymer consists of two words, the first word (poly) means "many" and the other word (mer) means "parts". In last years, the use of polymer increased in automotive and medicine industry since it is light, formable, cheap, good resistant to corrosion, nontoxic, and flexible for all these characteristics in many applications replacing metal by polymer. Polymers are experiencing an increased use in load carrying components, and this is due to the low density and high-energy absorption skills of the polymer [1]. In this research we employed linear low-density polyethylene (LLDPE), density amount is 0.930 gm/cm^3 and melting temperature Tm (110-137) Celsius degree [2]. Plastic was obtained from the **Sabic** Company in Saudi Arabic this plastic illustrated in Figure 1. The advantages of injection molding include short cycle times, the ability to make complex components with good dimensional tolerances and high finish and design flexibility permits the elimination of finishing and assembly operations. The process allows full automation and is now largely computer controlled, together with peripherals such as robots. The main disadvantages compared with other plastics processing methods are: high investment costs, long lead times for production of molds, and the need to use complex machinery. Computer-aided engineering is reducing lead times considerably [3]. Injection molding is a manufacturing technique for making parts from both thermoplastic and thermosetting plastic materials in production. Molten plastic is injected at high pressure into a mold, which is the inverse of the product's shape. After a product is designed, usually by an industrial designer or an engineer, molds are made by a mold maker (or toolmaker) from metal, usually either steel or aluminum, and precision machined to form the features of the desired part. Injection molding is widely used for manufacturing a variety of parts, from the smallest component to entire body panels of cars [4]. Conventional machining operations such as drilling, sawing, milling or turning, and to a lesser extent grinding, are commonly used to produce prototype plastic parts. Cast, laminated or extruded plastic rod, sheet, or bar stock (i. e., semi-finished goods) can be machined to produce a plastic part or component. In many cases, these plastic parts are assembled, bonded, or in some way merged with other plastic, wood, or metal parts before they are decorated and finished to produce a final product assembly. Polyethylene has a very low glass transition temperature (Tg= -120°C) associated with a good retention of mechanical properties, including flexibility and impact resistance at low temperatures, which makes it a competitive material as a matrix [5]. Polyethylene (PE) is a thermoplastic polymer consisting of long chains produced by combination of the monomer molecules viz. ethylene. Depending on the mode of polymerization, three basic types of polyethylene are frequently used: linear high-density polyethylene (HDPE), branched low density Polyethylene (LDPE), and linear low-density polyethylene (LLDPE) [6]. The aims of this paper is to design and manufacture a plastic mold and then make tensile, bending and impact specimens due to study mechanical properties of linear low density polyethylene. In this research, an injection molding was employed to obtain the plastic product.

## 2. Experimental Work

In this part, the design and manufacturing of the mold, plastic plate and all the specimens and its preparing to test will be explained. A linear low density polyethylene (LLDPE) having density amount 0.930 gm/cm$^3$ and melting temperature (110-137$^0$C) [2], was used. Plastic was obtained from the **Sabic** Company in Saudi Arabia; this plastic is illustrated in Figure 2. An injection molding technique was employed, this method is characterized by short time, and the product has a good dimensional tolerance. The mold was designed by the Auto CAD program and then performed in workshop. The mold was designed by Auto CAD program. It consists of three parts as illustrated in Figure 3. The first part (upper part) is made from steel, and the second part has a cavity and is changeable in other to replace it easily. The second part is made from steel classified into two shape types, plastic sheet mold with dimension 200 mm x 160 mm as shown in Figure 4, and bending and impact specimen's mold as depicted in Figure 5. The third part (lower part) is made from aluminum; this part is employed to cool the specimens by water. This part consists of five internal holes allowing the water to flow through pipes, as manifested in Figure 6. The diameter of each hole is 6.5 mm, this piping net has two outer pipes, one for entering the cold water and the other pipe is for exiting the hot water, as displayed in Figure 7.

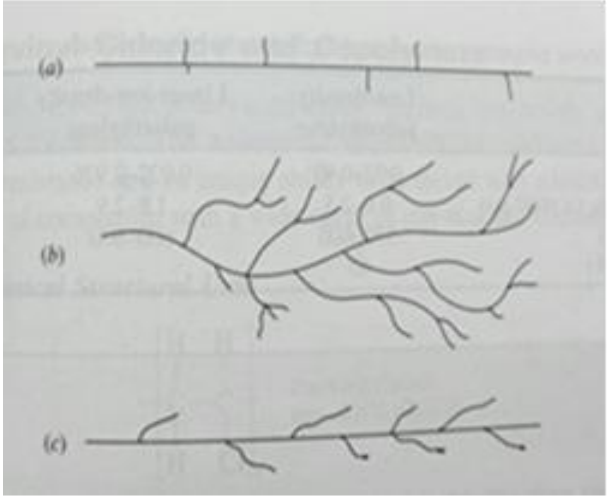


**Figure 1: Chain structure of different types of polyethylene: a) high density, b) low density, c) linear low density [2].**


**Figure 2: Linear low density polyethylene**

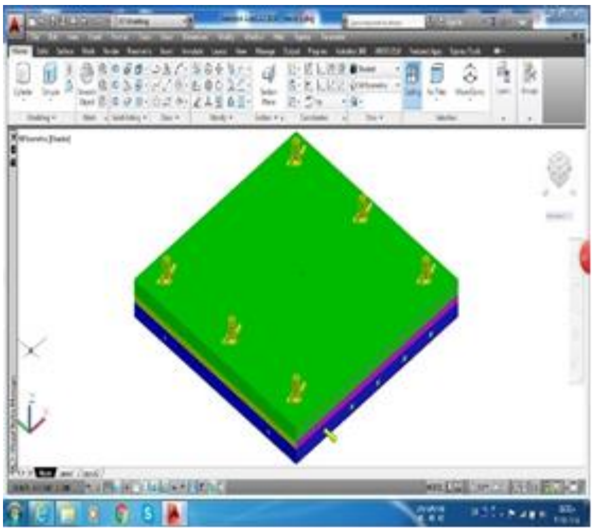

**Figure 3: Plastic changeable mold**

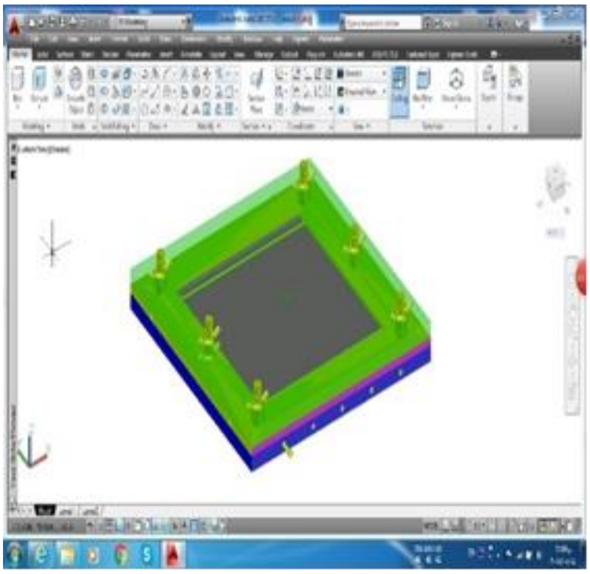

**Figure 4: Plastic sheet mold**

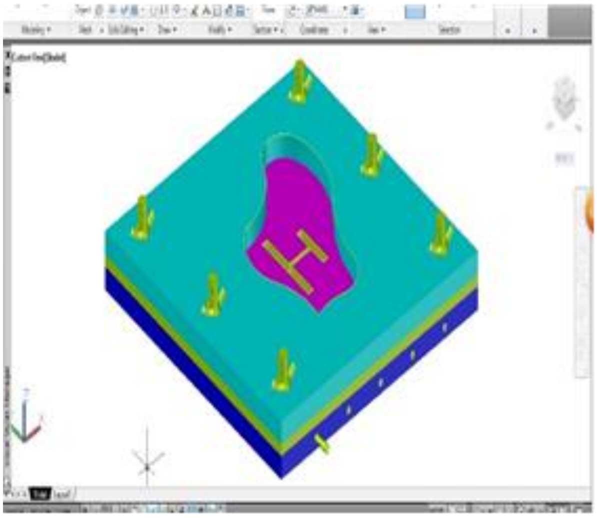

**Figure 5: Bending, impact specimen's mold**

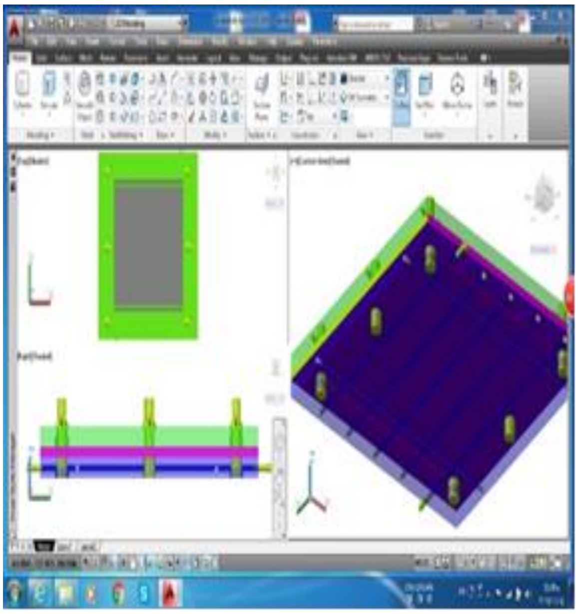

**Figure 6: Piping net cooling in three views**

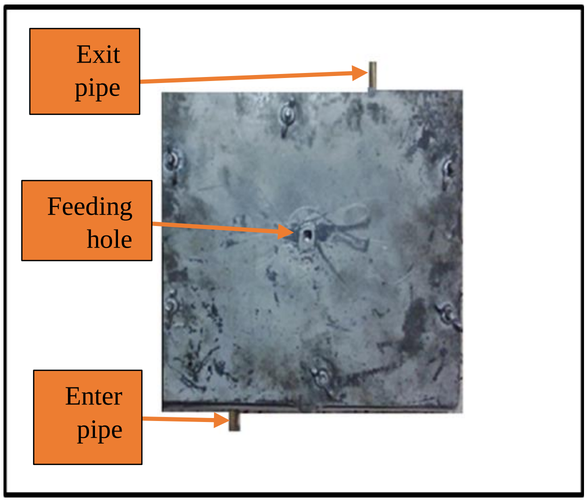


**Figure 7: Enter and exit water pipes**

*I. Preparation and manufacturing of specimen*

In this research, an injection mold technique was employed by using an injection machine illustrated in Figure 8. This machine gives a pressure injection about (1 MPa) and melting temperature value about 122°C. The mold was preheated at 40°C before injection; the injection time was two minute. After completing the injection, the cold water was pushed through the hole of mold to cool it and therefore cooling the specimen. The cooling time was one minute by using (5) liters of water, as revealed in Figure 9. After first injection, the sheet plate (LLDPE) was formed, as shown in Figure 10. Then, a CNC machine was used to cut the plastic sheet to produce the tensile specimens according to ASTM D638, as viewed in the Figure 11. The impact and bending specimens were injection molded and prepared, as exhibited in Figure 12. The impact specimens were manufactured according to ISO-179 illustrated in Figure 13, while the bending specimen were produced according to ASTM-D790, illustrated in Figure 14.

**Figure 8: Injection molding machine**

**Figure 9: Feeding water pump**

**Figure 10: Sheet plate plastic (LLDPE)**

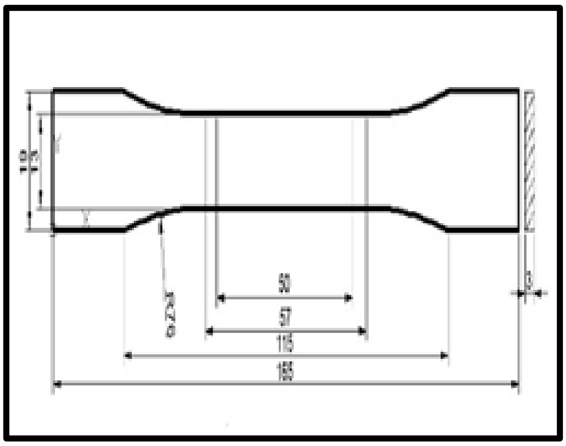

**Figure 11: Tensile test specimen**

**Figure 12: Impact and bending specimens**

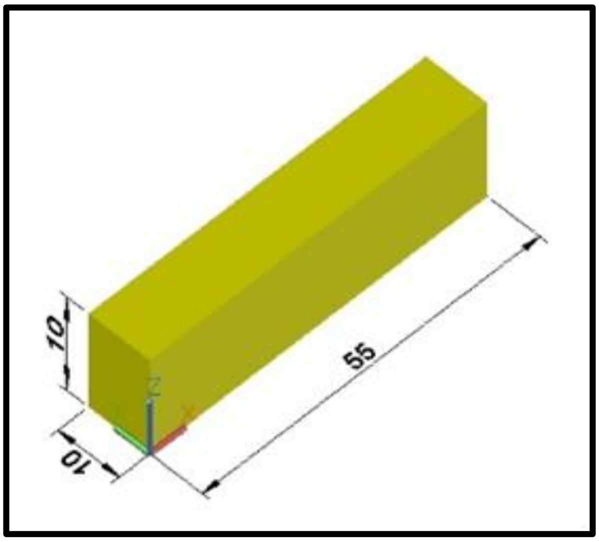


**Figure 13: Impact test specimen**

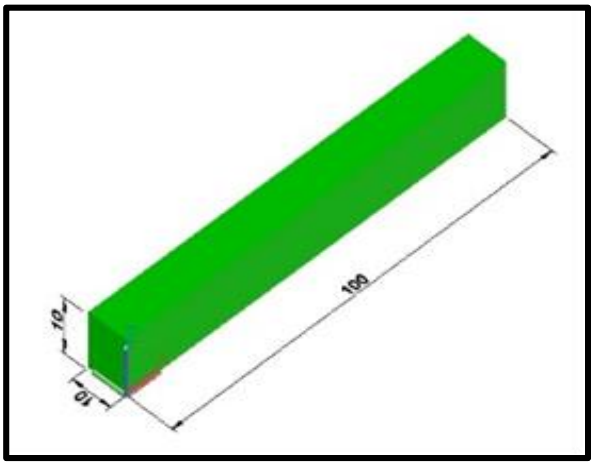


**Figure 14: Bending test specimen**

*II. Tensile Test*

In tensile test dimension specimen according ASTM-D638. Tensile testing machine type (WDW-200E) was used, as depicted in Figure 15. From this test, the force-extension curve was first plotted for each tensile specimen, and then the stress-strain diagram was drawn to determine the mechanical properties of linear low density polyethylene (LLDPE) plastic (tensile strength, Young's modulus, yield stress, elongation to break). The plastic (LLDEP) specimens after cutting in CNC machine are revealed in Figure 16.

*III. Impact Test*

The dimension of specimen according ASTM - D256. An impact testing machine type (Charpy-Izod Impact Test) was employed, as manifested in Figure 17. Three specimens were tested. In this test, one needs to obtain the value of impact strength measured in ($KJ/m^2$). The test speed is constant and its amount is (3.4 m/s).The specimens used in this test are displayed in Figure 18. Before starting test, the device should be reset, the amount of reset is (0.8) and the chosen hammer of tester has (30 J). The impact strength can be computed by the following equations (2) [7]:

$E_f$ = mg (H-h) (1)

I.S= $E_f$/A (2)

Where,

$E_f$ : Impact energy (KJ)

I.S: Impact strength (KJ/m$^2$)

A: Cross-sectional area (m$^2$)

m = Mass (kg)

g = Acceleration (m/s$^2$)

H=Height from the specimen before impact (m)

h = Height after impact (m)

ASTM: American society for testing and materials

**Figure 15: Tensile test machine type (WDW-200E)**

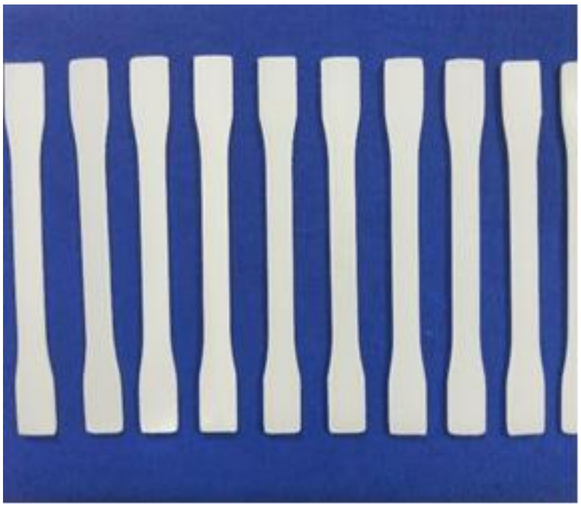

**Figure 16: Tensile specimens after cutting**


**Figure 17: Impact testing machine**

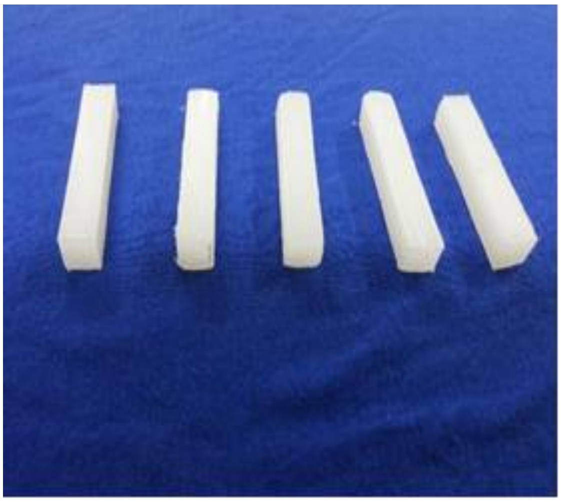

**Figure 18: Impact specimens**

### *IV. Bending test*

The purpose of this test is to calculate the flexural strength and shear stress, this test is called (three points test). The testing machine used is type (WDW-200E), as shown in Figure 19. The bending test was done according to ASTM-D790 specimens, as displayed in Figure 20.

The equations of flexural strength and shear stress are as follow [7]:

$$F.S = \frac{3PL}{2bd^2} \quad (3)$$

Where,

F.S: Flexural strength (N/mm$^2$)

P: Maximum load (N)

L: Length between subjected points (mm)

b: Width of specimen (mm)

d: Thickness of specimen (mm)

The equation of shear stress illustrated below:

$$\tau_{max} = \frac{3P}{4bd} \quad (4)$$

$\tau_{max}$: Maximum shear stress (N/mm$^2$)

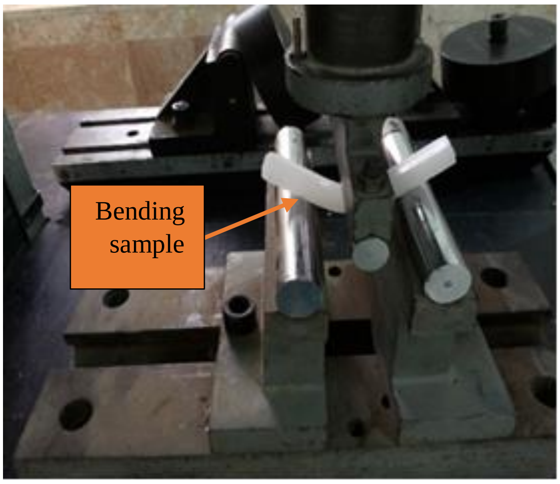


**Figure 19: Bending testing machine**

**Figure 20: Bending specimens**

## 3. Results and Discussion

### *I. Tensile Test Results*

The results of this test were obtained at the laboratory temperature (25°C) at the strain rate 3 mm/min. From the resulted force-extension curve shown in Figure 21, the engineering stress-strain curve was plotted, as depicted in Figure 22. The tensile strength value was taken as the average of testing three specimens. The specimen after break is demonstrated in Figure 23. In addition, the yield stress, Young's modulus, maximum strain and elongation at break were determined. All the results of this test are given in Table 1. These results were almost found close to previous results [8, 9].

### *II. Impact test results*

In this test, the calculated impact energy and impact strength were computed by equations (5) and (6), respectively. The result of impact strength is 193.75 KJ/$m^2$, and this value is the average of testing three specimens. The specimens after impact test didn't fracture, indicating that this plastic is flexible and dissipate energy; therefor this material withstood the impact load. Bernard Owusu [9] was found the value of impact test for (LLDPE) near to value obtained in this work.

### *III. Bending test results*

From the bending test diagram shown in Figure 24, the maximum load was obtained, which is about 200 N. This load was used to calculate the flexural strength and shear stress applying equations (7) and (8), respectively. The value of flexural strength is 18 N/$mm^2$ and shear stress is 1.5 N/$mm^2$. These values are the average of three bending test specimens. The specimen after the bending test is displayed in Figure 25. This result was almost found close to previous results [8, 9].

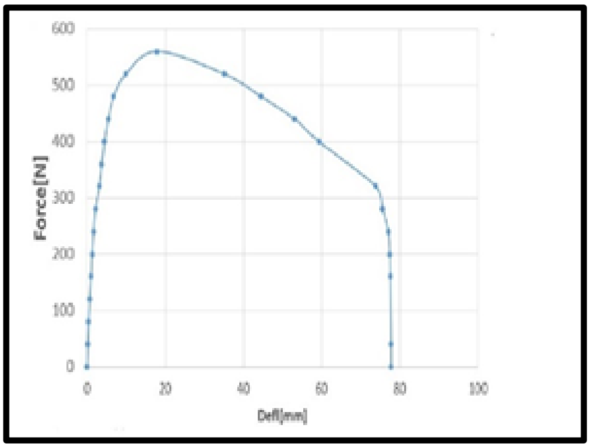


**Figure 21: Force-deflection diagram**

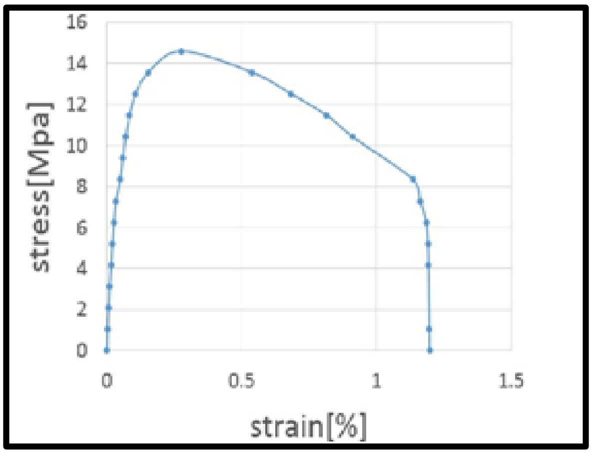


**Figure 22: Stress-strain diagram**

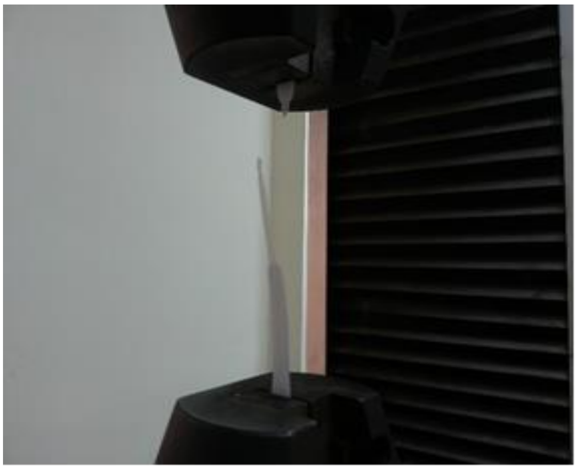

**Figure 23: Specimen after break**

**Table 1: Mechanical properties (LLDPE)**

| Property | Value |
|---|---|
| Tensile strength | 15 MPa |
| Yield stress | 12 MPa |
| Maximum strain | 1.2 % |
| Young's modulus | 0.18 GPa |
| Elongation to break | 70.88 mm |

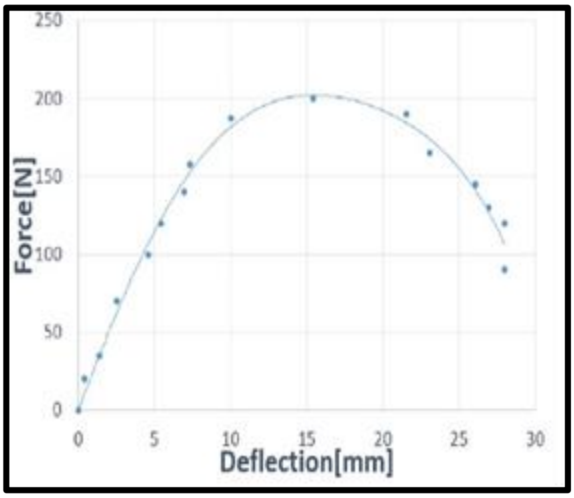


**Figure 24: Bending test diagram**

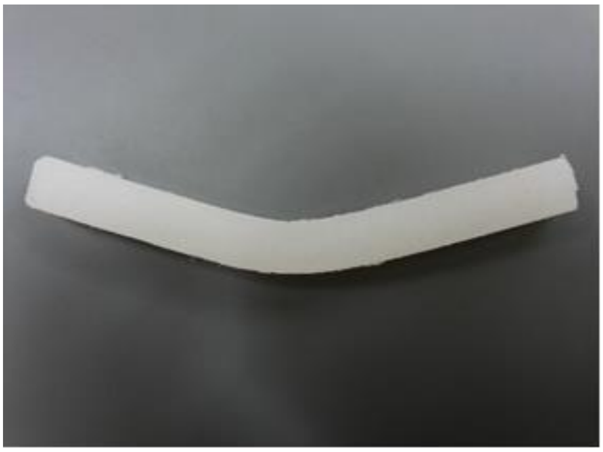

**Figure 25: Specimen after bending test**

## 4. Conclusions

1. LLDPE plastic was found strength.
2. This plastic was found a flexible material.
3. This material is able to dissipate the energy and withstand the dynamic load without braking.

### References

[1] R.T. Moura, A.H. Clausen, E. Fagerholt, M Alves and M Langseth, "Impact on =HDPE and PVC plates experimental tests and numerical simulations", International Journal of Impact engineering, 37, pp. 580-598, 2010.

[2] W.F. Smith and J. Hashemi, Handbook, "Foundations of materials science and engendering", fourth Edition. 2006, https://www.amazon.com/Foundations-aterials Science-Engineering-Professor/dp/0073529249

[3] Elsevier Advanced Technology, Handbook, "Automotive plastics and composites ", British Library Cataloguing, Second Edition, December 1999.

[4] M.N. Sudhindra Kumar and MSRSAS-Bangalore," Design for Injection Molding", Lecture delivered, M.S Ramaiah School of Advanced Studies – Bangalore.

[5] X. Li, "Development of flax fiber-reinforced polyethylene bio composites by injection molding", PhD Thesis, Department of Agricultural and Bioresource Engineering, University of Saskatchewan, March 2008.

[6] K. Myer; "Handbook of Materials Selection", John Wiley & Sons, 2002. New York. All rights re- served, Published simultaneously in Canada.

[7] D. Roylance, Handbook, "Mechanical properties of materials, Massachusetts institute 2008.

[8] V. Francis," modification of linear low density polyethylene for improved photo and biodegradation", PhD thesis, Cochin University of Science and Technology, Department of Polymer Science and Rubber Technology, November 2012.

[9] B. Owusu, "Tensile properties, water absorption and enzymatic degradation studies of polyethylene/starch filled hydroxyapatite blend for orthopedic applications", PhD thesis, Department of Physics Kwame Nkrumah University of Science, June 2016.

## Author's biography

Assistant professor Dr. Samir Ali Amin has a PhD degree in Engineering Metallurgy from University of Bradford, United Kingdom, 1985. He has published more than 40 papers concerning the MSc. and PhD students. He has been a member of the Iraqi Engineers Association Arab Engineers Federation, SME and ASME. His research field is in the properties of materials, powder metallurgy of HSS and manufacturing processes. Assistant professor Amin is currently supervising research works on creep property, FSW welding processes and shape memory alloys.

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