1.0 INTRODUCTION

The objective of a tensile test is to determine the mechanical properties of the material. The test carried out with a load applied uniaxially along the long axis or a cross section of a specimen until it deformed. When a specimen is loaded beyond its' ultimate tensile strength (UTS), a particular cross-sectional area begins to decrease, this deformation is known as *necking*, which it is the point of the specimen which subject to the greatest stress during testing. The necking will grow with the continue loading and finally break the specimen into two part.

For the tensile test, the shapes of the specimen have to be standard in accordance with ASTM D638 or ISO527 for standardization. During testing, deformation is confined to the narrow centre region of the sample, which has a uniform cross section along its length. Figure below shows the stress-strain behavior of any plastic polymers, and from the curve we can determined several useful properties of the material, and it helps in making selection of type of material for application purpose.

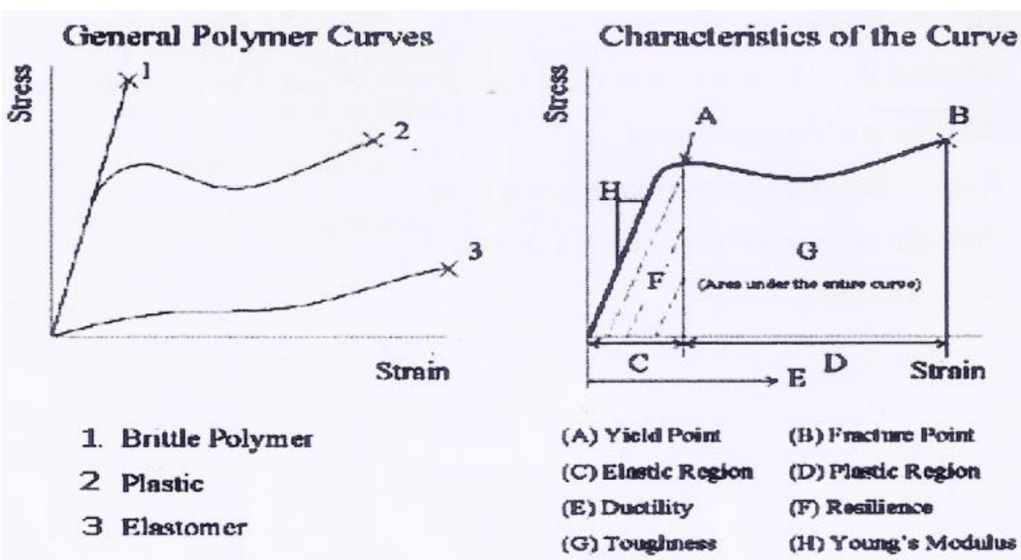

Figure 1: Stress-strain curve

The descriptions for several characteristic of the curve are simplified as below:

1. **Yield point**: A point which marks the elastic limit of a material. In another word, it shows the end of elastic behavior and the beginning of plastic behavior. When the specimen is removed at a point less than yield point, it will returns to its original shape but this does not occur for a specimen which removed after the yield point.

2. **Fracture point**: It is the point at which the specimen exceeds its stretching limit and break into two pieces.

3. **Elastic region**: It is the region before the yield point of the material in which the material able to return to its original shape IF removed under this region.

4. **Plastic region**: It is the region after the yield point of the material in which the material will not able to return to its original shape IF removed under this region.

5. **Ductility**: It is a measure of how much strain a material can take before rupturing. A material with high ductility will able to be drawn into long, thin wires without breaking. But for a material with low ductility, although it is strong but it will simply rupture once deformed, which named as a brittle material.

6. **Resilience**: It is the ability of a material to absorb energy when it is deformed elastically, and release that energy upon unloading. The modulus of resilience is defined as the maximum energy that can be absorbed per unit volume without distortion. It can be calculated by integrating the stress-strain curve from zero to elastic limit.

$$Modulus\ of\ resilience, U_r = \frac{\sigma_y^2}{2E}$$

7. **Toughness**: It is the amount of energy per volume that a material can absorb before rupturing. It can be determined by measuring the area underneath the stress-strain curve. The mathematical expression is:

$$\frac{Volume}{Energy} = \int_0^{E_f} \sigma\, dE$$

8. **Young's Modulus**: It is also known as tensile modulus which is a measure of the stiffness of elastic. It is defined as the ratio of the uniaxial stress over the uniaxial strain in the range of stress in which Hooke's Law holds, in another word, the reading for Young's Modulus must take before the Yield point.

$$Young\ Modulus, E = \frac{\Delta Stress}{\Delta Strain}$$

There are differences between the properties of Low Density Polyethylene (LDPE) and High Density Polyethylene (HDPE) which is LDPE was the first PE to be developed. It has low-density levels and only a small amount of branching. It is very flexible and easy to clean. On other hand, HDPE has higher density levels. It is also characterized by a linear structure consisting of no branching. That makes HDPE stronger and more resistant to chemicals. While ABS is a plastic which has impact resistance and toughness, however, its ductility is comparatively low.

2.0 EXPERIMENTAL OBJECTIVES

The objective of this experiment is to study the behavior of mechanical or tensile properties of different polymeric materials which is High Density Polyethylene (HDPE), Lower Density Polyethylene (LDPE), and ABS.

3.0 SPECIMEN AND EQUIPMENTS

1. Universal testing machine - Instron Series 8500 (10kN).
2. Vernier caliper.
3. Tensile specimens: High Density Polyethylene (HDPE), Lower Density Polyethylene (LDPE), and ABS.

4.0 EXPERIMENTAL PROCEDURE

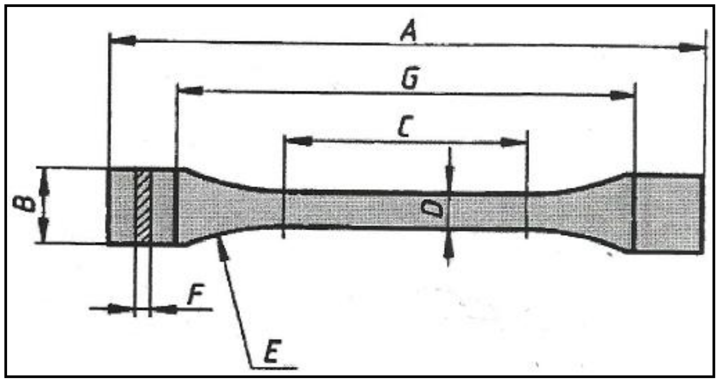

Figure 2: 7 measurements of specimen

1. Refer to figure above, a vernier caliper was used to measure the parameter of the specimen. An average value of the three measurements was taken.
2. The specimen was secured in the machine.
3. The required parameters were set on the control panel.
4. The load recorder was adjusted on the front panel controller to zero.
5. The tensile test started.
6. The sample and note was monitored when the constriction begins. The force then tended to decrease until the fracture of the specimen occurred.
7. The tested specimen was removed from gripping head.
8. The stress strain curve and the results were printed.
9. A technical report was written.

5.0 DATA AND RESULTS

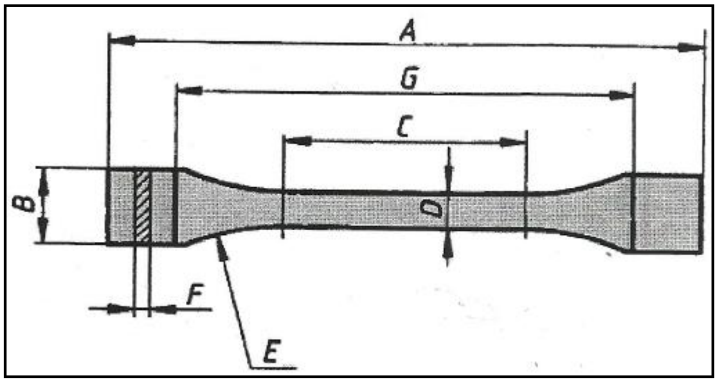

Figure 3: Measurements of specimen

Referring to the figure above, the average measurements (average value of 3 measurements) of the specimens are written as below:

Type of Specimen	LDPE (Red)	HDPE (White)	ABS(Yellowish)
A	164.42 mm	159.64 mm	165.32 mm
B	18.84 mm	18.78 mm	19.00 mm
C	63.70 mm	63.80 mm	65.20 mm
D	12.90 mm	12.80 mm	12.90 mm
F	3.20 mm	3.16 mm	3.18 mm
G	97.26m	96.0mm	99.12 mm

Table 1: Measurements of specimen

*Measurement E is not taken due to the lack of radius gauge

The calculation of stress, strain and Young Modulus, E of specimens applies formula as below:

$$Stress = \frac{Force\ (N)}{Area\ (m^2)}$$

In which Area = Length (m) x Thickness (m) of the specimen

$$Strain = \frac{Tensile\ extension\ (m)}{Original\ length\ of\ specimen\ (m)}$$

$$Young\ Modulus, E = \frac{\Delta Stress}{\Delta Strain}$$

Specimen 1: Low Density Polyethylene (LDPE)

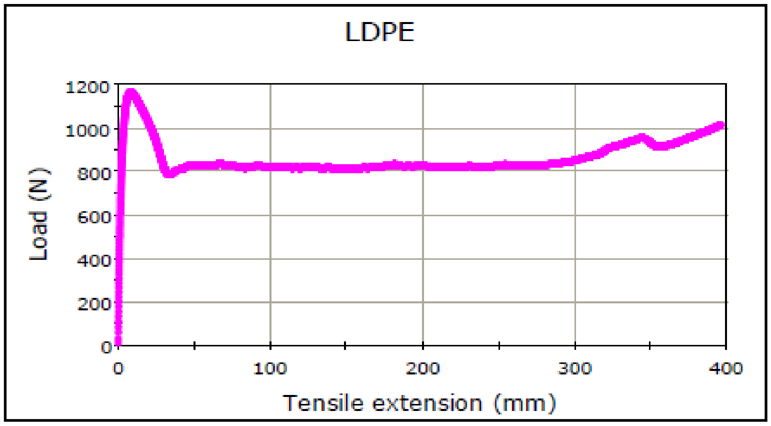

Figure 4: Load Vs Tensile extension of LDPE

The cross-sectional area and original length of specimen is calculated as below:

Area $= 0.0129\text{m} \times 0.0032\text{m} = 4.128 \times 10^{-5}\ \text{m}^2$

Original length of specimen = 0.09726m

Stress and strain data calculated for LDPE:

Tensile Extension (m)	Load (N)	Stress (MPa)	Strain
0.00	0	0	0
0.01	1100	26.6473	0.1028
0.02	1000	24.2248	0.2056
0.03	800	19.3798	0.3085
0.04	810	19.6221	0.4113
0.05	820	19.8643	0.5141
0.06	820	19.8643	0.6169

0.07	820	19.8643	0.7197
0.08	800	19.3798	0.8225
0.09	810	19.6221	0.9254
0.10	800	19.3798	1.0282
0.20	800	19.3798	2.0563
0.30	830	20.1066	3.0845
0.40	1010	24.4671	4.1127

Table 2: LDPE stress-strain data

Stress-Strain graph of LDPE is constructed based on calculated data:

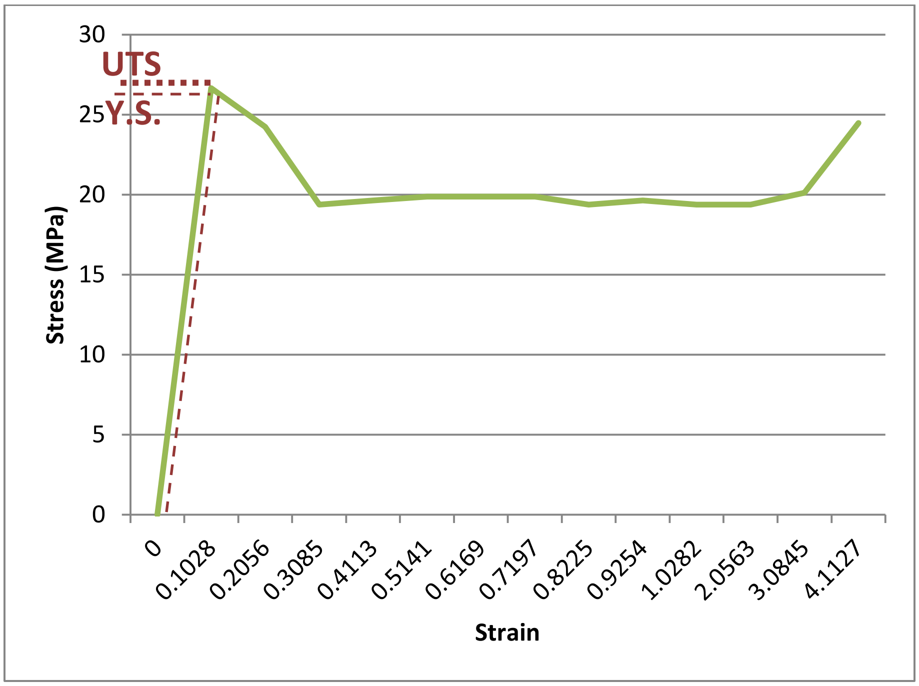

Figure 5: Stress-strain graph of LDPE

From the graph, we can found that:

i. Ultimate Tensile Strength (UTS) = 27MPa
ii. Yield strength, σ_y = 26.5MPa (with 0.002 offset)
iii. Fracture Stress = undefined (The specimen do not break with the extension limit of stress-strain machine)
iv. $Young\ Modulus, E = \frac{\Delta Stress}{\Delta Strain} = \frac{24.2248-26.6473}{0.2056-0.1028} = 23.5652\ MPa$

Specimen 2: High Density Polyethylene (HDPE)

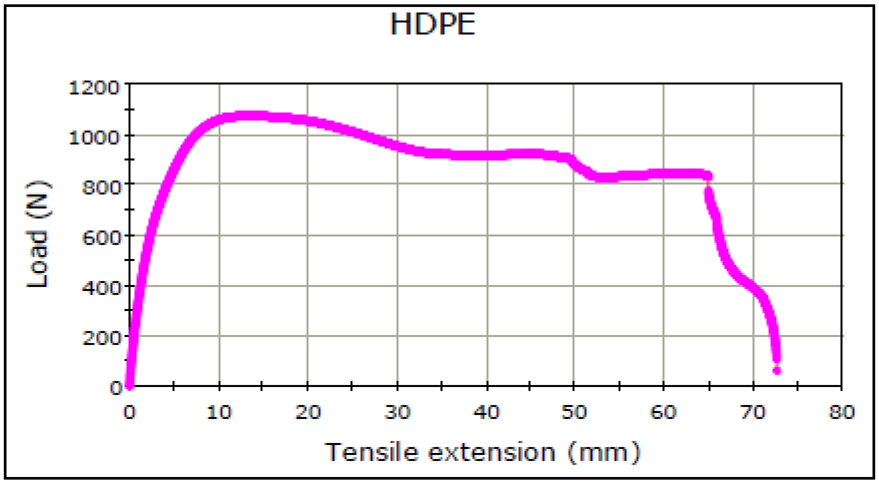

Figure 6: Load Vs Tensile extension of HDPE

The cross-sectional area and original length of specimen is calculated as below:

Area $= 0.0128\text{m} \times 0.00315\text{m} = 4.032 \times 10^{-5}\ \text{m}^2$

Original length of specimen = 0.096m

Stress and strain data calculated for HDPE:

Tensile Extension (m)	Load (N)	Stress (MPa)	Strain
0.000	0	0	0
0.005	870	21.5774	0.0521
0.010	1050	26.0417	0.1042
0.015	1040	25.7937	0.1563
0.020	1040	25.7937	0.2083
0.025	1000	24.8016	0.2604
0.030	950	23.5615	0.3125
0.035	900	22.3214	0.3646
0.040	900	22.3214	0.4167
0.045	900	22.3214	0.4688
0.050	860	21.3294	0.5208
0.055	820	20.3373	0.5729
0.060	820	20.3373	0.6250
0.065	780	19.3452	0.6771

0.070	400	9.9206	0.7292

Table 3: HDPE stress-strain data

Stress-Strain graph of HDPE is constructed based on calculated data:

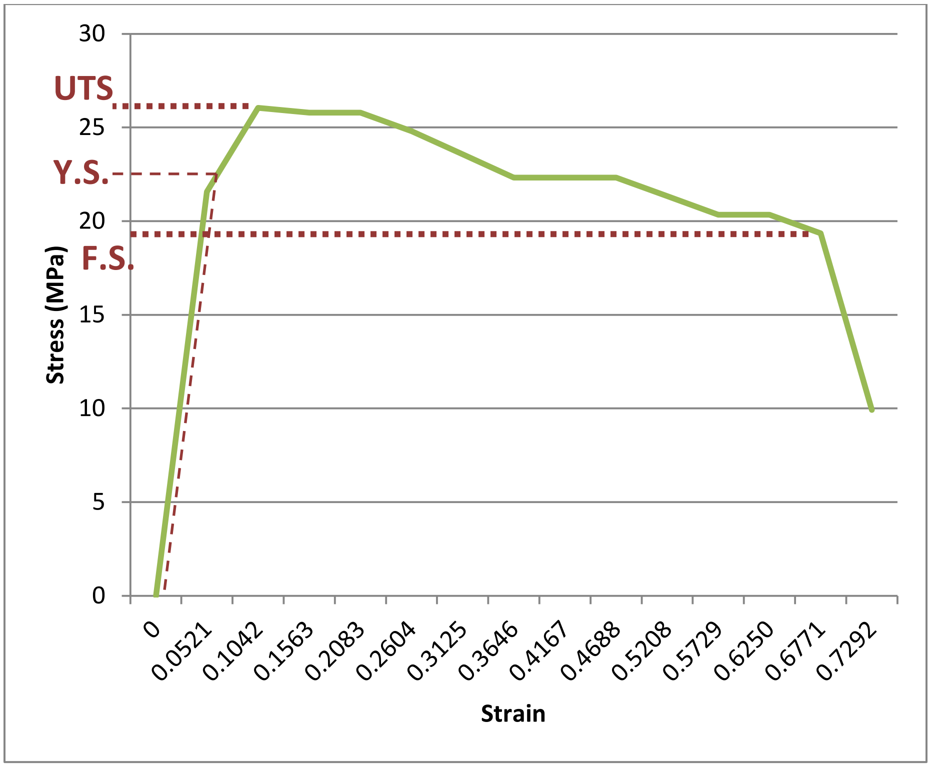

Figure 7: Stress-strain graph of HDPE

From the graph, we can found that:

i. Ultimate Tensile Strength (UTS) = 26MPa
ii. Yield strength, σ_y = 22.5MPa (with 0.002 offset)
iii. Fracture Stress = 19MPa
iv. $Young\ Modulus, E = \frac{\Delta Stress}{\Delta Strain} = \frac{26.0417-21.5774}{0.1042-0.0521} = 85.6871\ MPa$

Specimen 3: ABS

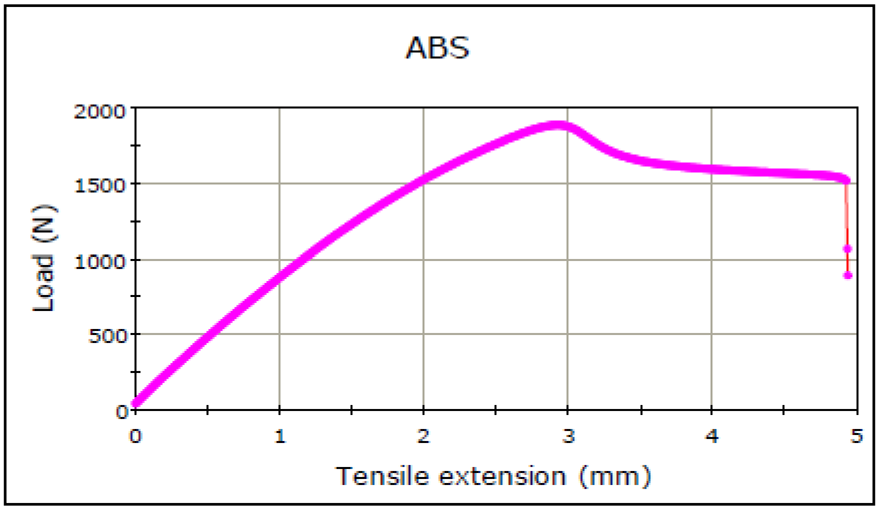

Figure 8: Load Vs Tensile extension of ABS

The cross-sectional area and original length of specimen is calculated as below:

Area $= 0.0129\text{m} \times 0.00318\text{m} = 4.1022 \times 10^{-5}\ \text{m}^2$

Original length of specimen = 0.09912m

Stress and strain data calculated for ABS:

Tensile Extension (m)	Load (N)	Stress (MPa)	Strain
0.0000	0	0	0
0.0005	500	12.1886	0.0050
0.0010	875	21.3300	0.0101
0.0015	1250	30.4715	0.0151
0.0020	1500	36.5657	0.0202
0.0025	1750	42.6600	0.0252
0.0030	1875	45.7072	0.0303
0.0035	1625	39.6129	0.0353
0.0040	1560	38.0284	0.0404
0.0045	1540	37.5408	0.0454
0.0050	1500	36.5657	0.0504

Table 4: ABS stress-strain data

Stress-Strain graph of ABS is constructed based on calculated data:

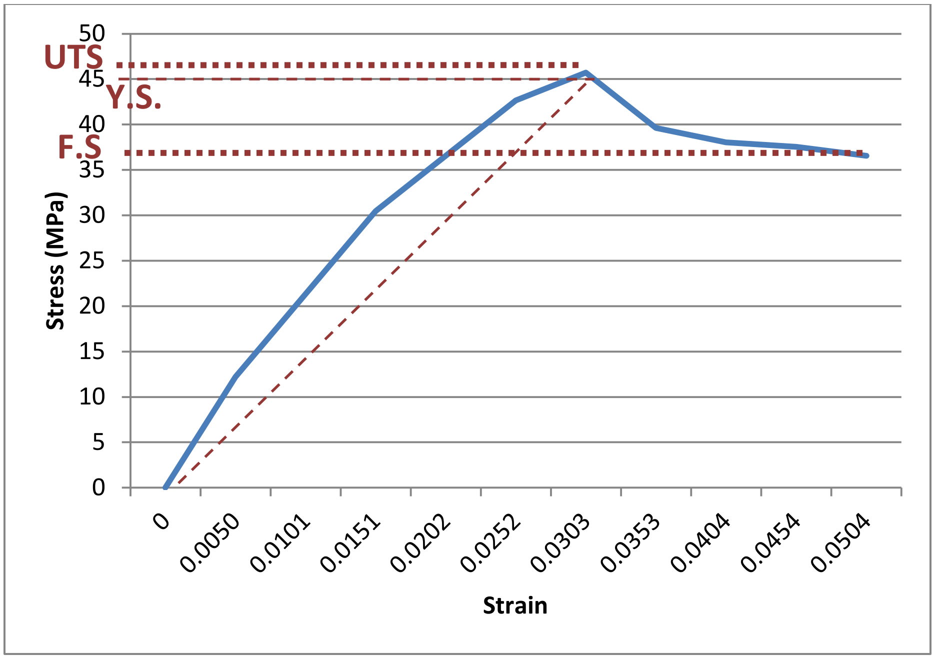

Figure 9: Stress-strain graph of ABS

From the graph, we can found that:

i. Ultimate Tensile Strength (UTS) = 46.5MPa
ii. Yield strength, σ_y = 45MPa (with 0.002 offset)
iii. Fracture Stress = 37MPa
iv. $Young\ Modulus, E = \frac{\Delta Stress}{\Delta Strain} = \frac{45.7072-12.1886}{0.0303-0.0050} = 1234.846\ MPa$

6.0 DISCUSSION

1. Discuss the mechanical properties obtained from the tensile test for each sample.

ABS is an amorphous blend consisting of three monomers which are acrylonitrile, butadiene and styrene. The addition of acrylonitrile helps in the increasing of the chemical and thermal enhancement. Butadiene contributes in the increasing of toughness and strength to the plastic. Lastly, the styrene will add the sleek and glossy to the plastic. In other words, ABS has good rigidity, toughness, low creep, low weight, good dimensional stability and good resistance to acid and alkali. Finally, ABS also has a high abrasion resistance as its mechanical properties.

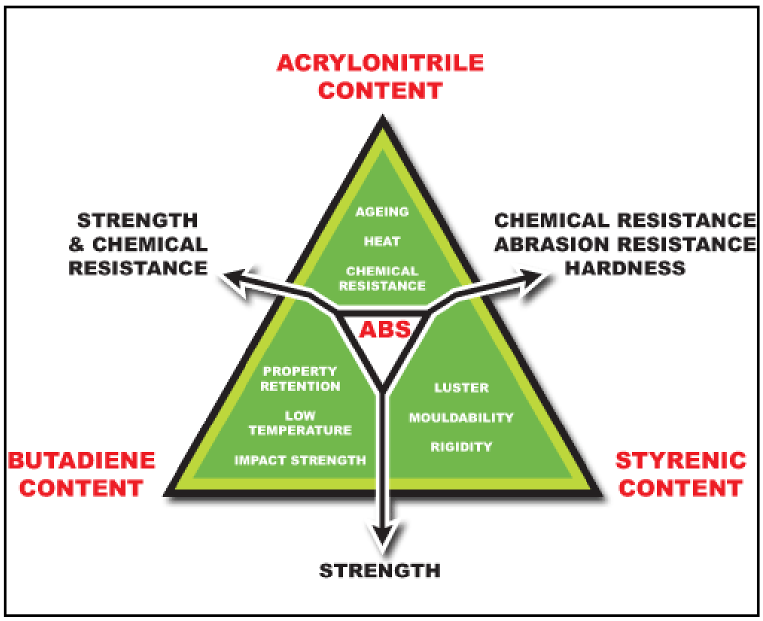

Figure 10: Properties of ABS

The mechanical properties of HDPE are that it has a good resistance to chemicals and impact. The difference in strength exceeds the difference in density, giving HDPE a higher specific strength. It is also harder and more opaque and can withstand higher temperatures.

LDPE has mechanical properties such as that it can be elongated very long before it fractured. LDPE is made in translucent or opaque variations, it is quite flexible and tough but it is easily breakable. In addition, LDPE also has high impact strength at low temperatures.

From the tensile test, LDPE has the highest ductility, followed by HDPE and ABS, regarding to the specimens' elongation before fracture. Besides, ABS is the strongest material regarding to the maximum load before yield point, followed by LDPE and HDPE.

2. **Which stress-strain curve shows brittle property and which curve shows the ductile property?**

   The stress-strain curve that shows the material with the most brittle properties is the ABS stress-strain curve (refer to attachments). This is because the stress-strain curve shows that it takes only 5mm of the tensile extension before the sample completely fractures. In addition, its maximum load is less than 2000N. It proves that the ABS sample to have the most brittle property compares to the other samples.

   The stress-strain curve that shows the material with the most ductile properties is the LDPE stress-strain curve (refer to attachment). As illustrated on the graph, it shows that the tensile extension is stretched to its maximum although the load is less than 1200N. However, the sample did not fracture even when it was stretched to the maximum.

3. **Discuss any possible error occurred during experiment.**

   Error which may be occurred during this experiment includes parallax error during reading of measurement. We are advice to measure the test specimen parameters more than twice using vernier caliper to ascertain the reading. Besides, zero error may also occur due to the lack of vernier caliper calibration. In order to avoid this to happens, we are advice to check the vernier caliper before measuring. If the vernier caliper is not showing absolute zero reading when it is totally closed, we have to minus or add the particular value in each of the measurements. Moreover, the consideration of putting the test specimen on the universal testing machine –Instron Series is also important. We have to make sure the test specimen is tied orderly at grips for holding test specimen firmly at fixed head in order to avoid the specimen became loosen from that machine during the experiment.

7.0 CONCLUSION

Tensile testing is a way of determining how something will react when it is pulled apart when a force is applied to it in tension. Tensile testing is one of the simplest and most widely used mechanical tests. By measuring the force required to elongate a specimen to breaking point, material properties can be determined that will allow designers and quality managers to predict how materials and products will behave in their intended applications.

During this tensile test, the most brittle specimen is Acrylonitrile Butadiene Styrene (ABS). It's has been notice that the fracture surface has turned white. This is due to the chemical stress cracking which is a typical example of brittle fracture. In such a case, there are no undulations on the fracture surface and it takes on a smooth appearance. Brittle fracture is caused by a combination of a force or stress which is less than the material strength and some other factor (i.e., chemical agents, temperature, paint, plating, state of external force application, etc.). Whereas, the most ductile specimen is the Low Density Polyethylene (LDPE). This has less hardness, stiffness and strength compared to HDPE, but better ductility.

ABS is a light weight material and has the ability to be an injection molded and extruded which makes it useful in manufacturing products such as drain-waste-vent piping systems, musical instruments such as recorders, plastic clarinets, and piano movements. Other than that, it is used to make golf club heads due to its good shock absorbance, automotive trim components, automotive bumper bars, medical devices for blood access, enclosures for electrical and electronic assemblies, protective headgear, whitewater canoes, buffer edging for furniture and joinery panels, luggage and protective carrying cases, small kitchen appliances, and toys, including Lego bricks. The limitations of ABS are such that ABS will crack and craze when subjected to petroleum-based cutting and tapping oils, it is flammable and under UV exposure, it will eventually cause the parts to become very brittle. However, this cannot be avoided by coating or painting on the ABS.

HDPE is commonly used to make toys, utensils, film, pipe and processing equipment. It is also used to make wire and cable insulations. However, its limitations are such as a high thermal expansion. It also has poor weathering resistance and subject to poor cracking. Subsequently, it is very difficult to bond with, flammable as well as poor temperature capability.

LDPE can be used to make variety of type of applications. It can be used to make packaging, transportations and protection such as shrink film for books, bundling and pallets, overwrap film for towels, tissues, and film for bakery goods, meat, coffee, frozen foods, liquid packaging, liners, bags and shoppers. Next, it can also be used to make agricultural applications such as greenhouse and tunnel as well as the silage. Finally, it is used to make electrical cables which are the insulators, semiconductor layers, coax and HFFR cables. LDPE has the limitations such as low strength, stiffness and maximum operating temperature. It is also flammable, poor UV resistance and has high gas permeability particularly toward CO_2. Lastly, it is susceptible to environmental stress cracking.

8.0 **APPENDIX**

Figure 11: Initial shape of LDPE

Figure 12: Final shape of LDPE

Figure 13: Initial shape of HDPE

Figure 14: Final shape of HDPE

Figure 15: Initial shape of ABS

Figure 16: Final shape of ABS