SCHOOL OF ENGINEERING
TAYLOR'S UNIVERSITY

ENG 60503
PROPERTIES AND APPLICATIONS OF MATERIALS

Creep Test Experiment

Lab Tutor: Ms. Norhabibah binti Mohamad

NAME	ID	SIGNATURE
Hong Jian Hua	0330534	
Lim Min Yee	0330907	
Yap Jin Teck	0326788	
Tan Jia Hao	0330881	

Due Date:
Date of Submission:

Return of student marked assessment tasks. Please check (√) the necessary column.

/	Electronically to the individual student via the University learning management system
	Collect during class, only by the student
	Collection from the school or a staff member upon presentation of their student ID card
	Collection from module coordinator, lecturer or tutor by prior arrangement

* For online assessment such as forum, quiz, test, survey and etc., return of students marked assessment tasks are published in TIMES.

Table of Contents

Date of Experiment:	
Report due date:	
Report submission date:	
Checked by:	
Item/marks	
Format/10	
Abstract and Introduction/10	
Figures and Diagrams/15	
Materials and Method/10	
Results Discussions/45	
References/10	
Total	

Abstract

The objective of this experiment was to discover the effect of temperature, material and stress on the creep rate of PDFE and Teflon specimens subjected to a static load. Another aim was to obtain a graph of stress against strain rate for different material under different temperatures.To accomplish this we used given 3 sets of samples of PDFE and Teflon for room temperature and another 3 sets for cold temperature. The apparatus we used was a gunt creep testing machine which featured a slot for the creep specimen, a weight holder where we used weights of 2N, 4N, and 6N, a meter for measuring the creep rate and there was also an ice box for the creep specimens of low temperature.

We started with weights of 2N, and by fixing the creep specimen into the slot. The weight was then slowly released to apply a static force on the specimen, while in the meantime, the experiment is recorded by using a smartphone camera for a duration of 3 minutes. The same was done for all the specimens, but the experiment for creep test at low temperature, the specimens were placed in an ice box before similar procedures was done to obtain the results. We then recorded the values of the elongation by intervals of 10 seconds from the video captured, and tabulated the data. Graphs of elongation against time were also plotted to show trends and for comparison of data.

Based on the data, we can conclude that Teflon (PTFE) elongates more compared to polyethylene (PDFE) in both high and low temperatures when a high stress in applied to the sample. This is due to the molecular structure of the samples, as the molecular structure of Teflon consist of carbon and fluorine, and has a weaker Van der Waals force due to its electronegativity whereas the molecular structure of polyethylene consist of carbon and hydrogen provides a much more stable structure and high resistance to creep.

1.0 Introduction

Creep testing is the measure of the tendency of a material to elongate or change in form after being subjected to a static load for long periods of time. Creep testing is also sometimes done to determine the effect of temperature on the rate of deformation. Generally, a creep testing device is used to generate data to show the rate of deformation of a creep specimen under a static load at constant temperature. Creep testing is important because it shows how much strain a material can handle under pressure or at specific temperatures, and to find out the rate of deformation of a material. This research allows engineers to understand and estimate the life expectancy of a specific material, and allows engineers to know whether a material will fail if subjected to a specific amount of load for long periods of time.

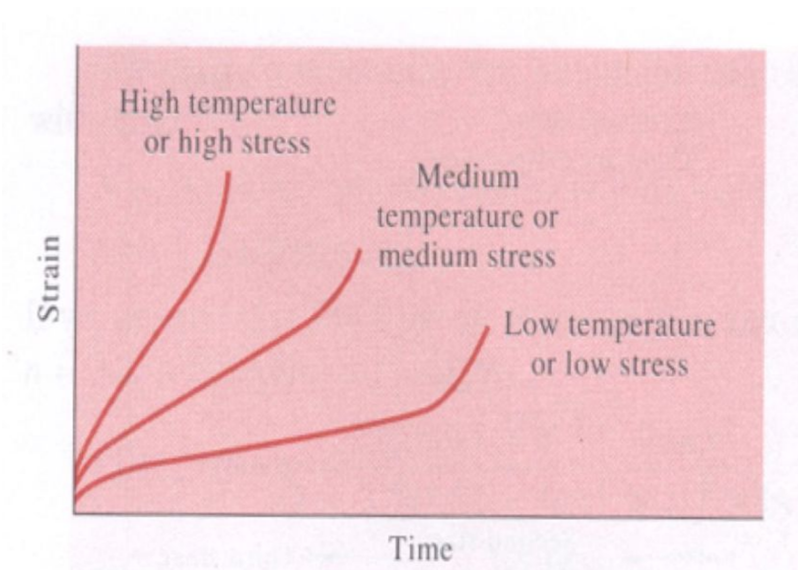


Figure 1. A general graph of strain against time in creep specimens exposed to different temperatures.

Creep is classified into three stages, where the first stage is primary creep, where the slope is rising rapidly in a short time (ASTM, 2011). This happens when the creep specimen is initially subjected to the load, and the slope will slowly decrease after a certain amount of time.

The second stage is the steady state creep, where the creep rate is constant and the curve turns into a straight line. The final stage is called the tertiary creep, where the material subjected to the strain is reaching breaking point. The object's creep continuously increases until the object breaks, and the slope of the graph is very steep in this state. However, how the object displays creep is still dependent on the material of the object (ASTM, 2011).

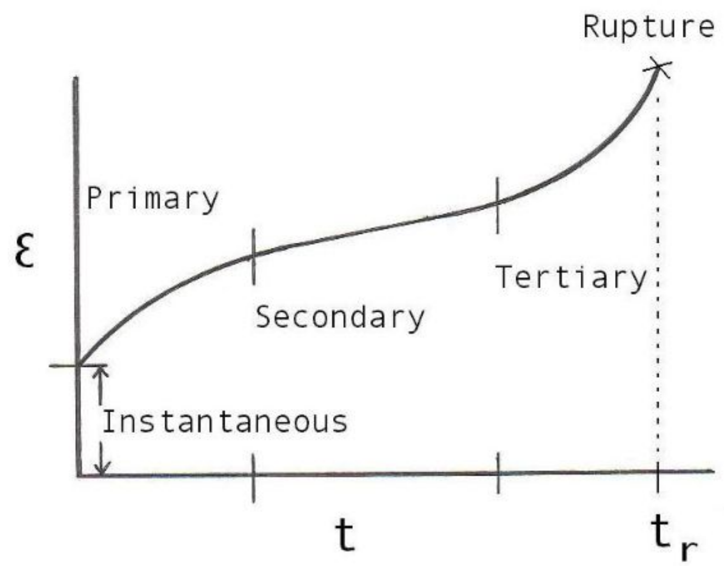


Figure 2. Illustration of the three stages of creep on a graph.

When the constant static load is applied on an object, we can plot a graph of elongation against time, as show in Diagram 2. The elongation of the object depends on various factors, which includes the dimensions of the object, the material, and also the extension property of the object (Clyne, 2018). However, to compare materials of different dimensions, we can plot a graph of stress against strain.

$$\text{Stress} = \sigma = F/A$$

A= cross sectional area of the object

F= Force applied

$$\text{Strain} = \varepsilon = \Delta l / l$$

Δl = Change in length or elongation of the specimen

l= Original Length of the specimen

After obtaining values for stress and strain, a graph can be plotted out to obtain the Young's modulus, which is a constant number that describes the elastic property of a solid undergoing tension or compression in one direction (Mather, 2018). Young's modulus measures the ability of a material to withstand changes in length when under tension or compression, and is equal to stress divided by strain.

$$\text{Young's modulus} = Fl/A\Delta l$$

On another note, all mechanisms of steady-state creep are in some way dependent on diffusion, and the creep rate will have this exponential dependence on temperature (Clyne, 2018).
Diffusion is governed by an Arrhenius equation, given as:

$$D=D_o e^{-Q/RT}$$

2.0 Experimental Design

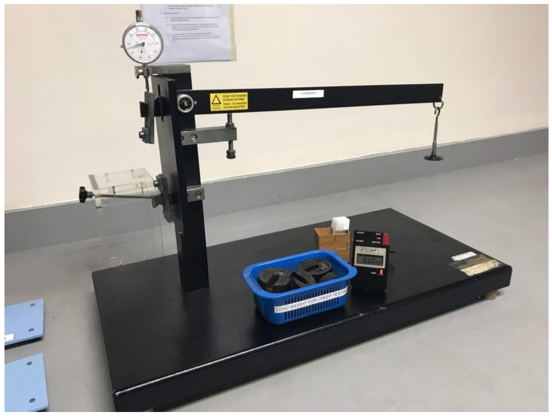


Figure 3. The set up of the creep testing machine

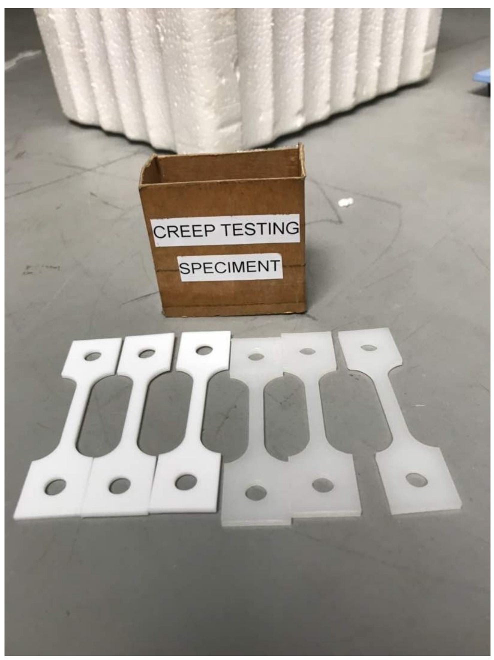


Figure 4. The teflon and PDFE specimens for the experiment

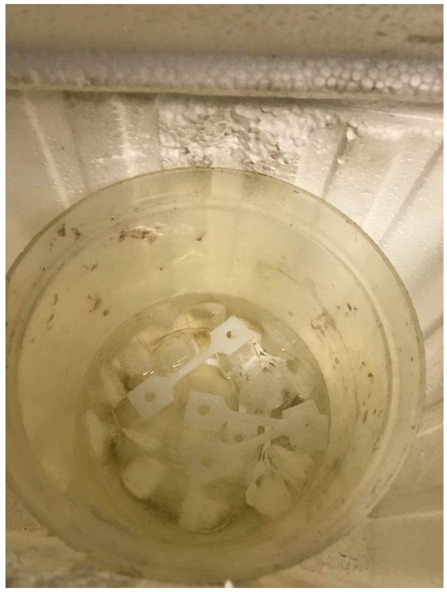


Figure 5. The specimens placed in ice water

2.1 Apparatus

1) 6 pcs PDFE specimens
2) 6pcs Teflon specimens
3) Ice Water
4) Thermometer
5) Load Weights - 2N, 4N and 6N
6) Gunt Creep Testing Machine
7) Video camera
8) Stopwatch

2.2 Objectives

To determine the effect of temperature, material and stress on the creep test

2.3 Experimental Procedures

1) The gunt creep testing machine is set up as shown.
2) 6 samples of teflon and PDFE specimens each are prepared.
3) 3 samples of teflon and PDFE specimens each are placed in a box filled with ice water
4) The teflon specimen is placed in a sample holder.
5) The sample holder is then placed onto the creep test machine.
6) The dial gage is adjusted to read zero before releasing the weight form the holder.
7) The reading of the specimen is recorded with a camera and the readings a recorded every 10 seconds for 3 minutes.
8) The experiment is repeated with weight of 4N and 6N.
9) The experiment is also repeated with PDFE samples and also the samples that have been placed in the ice water.

2.4 Methodology

Samples of teflon and PDFE have been placed in the creep testing machine and put under load with weights of 2N, 4N and 6N with some of the samples tested in room temperature and other samples chilled with ice water. The extension of the sample was recorded and the strain vs stress graph is plotted. The variables of the experiments are listed as follow:

Constant Variable: The size of the sample

Manipulated Variable: The temperature of the sample

Responding Variable: The extension of the sample.

3.0 Experimental Results and Discussion

3.1 Tabulation of Data

Teflon			
	Extension (mm)		
Time(Seconds)	2N	4N	6N
10	0.75	1.205	2.71
20	0.8	1.38	3.19
30	0.83	1.48	3.51
40	0.855	1.565	3.73
50	0.87	1.625	3.91
60	0.89	1.68	4.09
70	0.9	1.73	4.205
80	0.91	1.77	4.335
90	0.92	1.808	4.45
100	0.93	1.84	4.555
110	0.935	1.87	4.641
120	0.945	1.9	4.71
130	0.95	1.93	4.79
140	0.96	1.95	4.855
150	0.965	1.975	4.91
160	0.97	1.995	4.96
170	0.975	2.015	5.02
180	0.98	2.035	5.07

Table 1.0 Table showing the data of time and extension teflon in room temperature

PDFE			
	Extension (mm)		
Time(Seconds)	**2N**	**4N**	**6N**
10	0.215	0.355	0.56
20	0.25	0.395	0.63
30	0.26	0.43	0.67
40	0.28	0.46	0.71
50	0.29	0.47	0.725
60	0.3	0.475	0.75
70	0.305	0.49	0.77
80	0.31	0.505	0.785
90	0.315	0.51	0.795
100	0.32	0.525	0.805
110	0.321	0.53	0.82
120	0.323	0.545	0.829
130	0.325	0.55	0.839
140	0.327	0.557	0.848
150	0.33	0.561	0.858
160	0.331	0.565	0.865
170	0.332	0.575	0.875
180	0.335	0.579	0.88

Table 2.0 Table showing the data of time and extension of PDFE in room temperature

Teflon			
	Extension (mm)		
Time(Seconds)	2N	4N	6N
10	0.575	0.78	1.79
20	0.64	0.885	2.004
30	0.685	0.95	2.172
40	0.715	1.005	2.33
50	0.74	1.05	2.46
60	0.76	1.087	2.6
70	0.78	1.126	2.713
80	0.8	1.16	2.817
90	0.812	1.196	2.92
100	0.83	1.232	3.01
110	0.849	1.27	3.106
120	0.867	1.312	3.208
130	0.88	1.347	3.31
140	0.898	1.383	3.395
150	0.915	1.42	3.48
160	0.93	1.45	3.57
170	0.943	1.49	3.66

Table 3.0 Table showing the data of time and extension of Teflon after submerging in ice water.

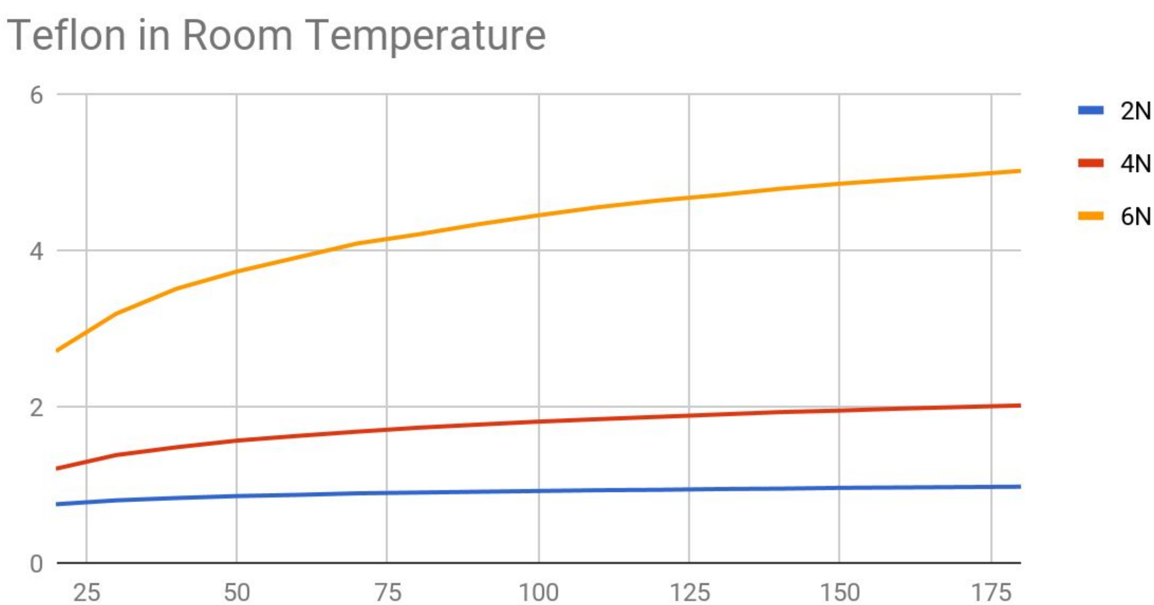
PDFE			
	Extension (mm)		
Time(Seconds)	2N	4N	6N
10	0.41	0.615	0.9
20	0.447	0.66	0.97
30	0.465	0.685	1.026
40	0.486	0.71	1.067
50	0.504	0.725	1.105
60	0.515	0.74	1.13
70	0.53	0.754	1.161
80	0.54	0.765	1.183
90	0.552	0.77	1.205
100	0.559	0.78	1.225
110	0.57	0.792	1.245
120	0.575	0.797	1.27
130	0.582	0.805	1.282
140	0.59	0.812	1.302
150	0.598	0.82	1.317
160	0.603	0.825	1.33
170	0.606	0.831	1.342
180	0.611	0.839	1.36

Table 4.0 Table showing the data of time and extension of PDFE after submerging in ice water.

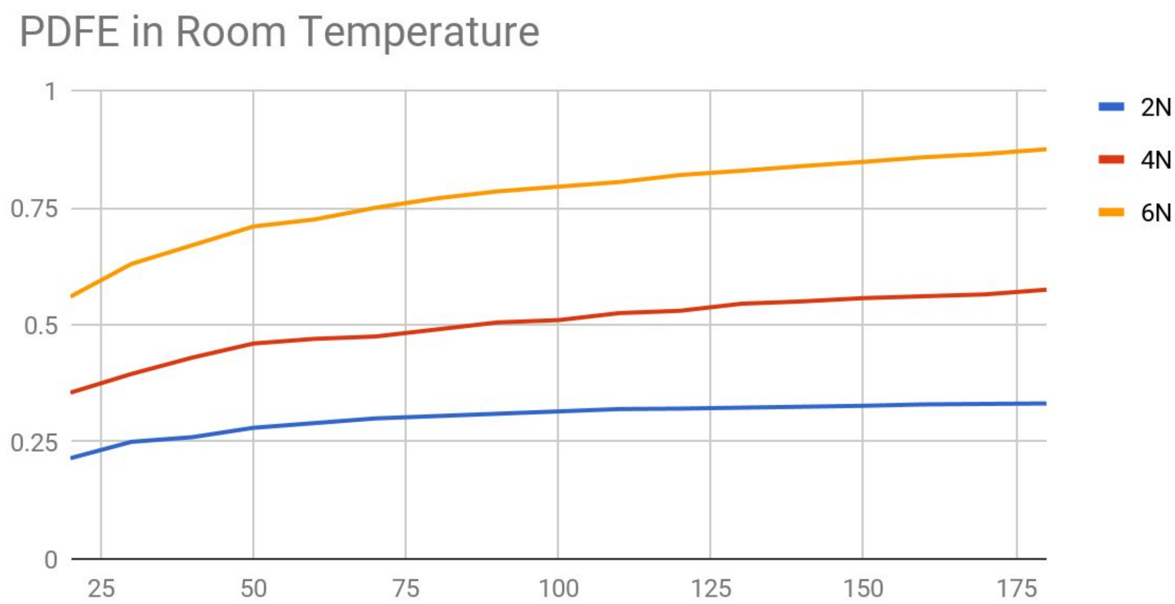
Stress	Teflon	PDFE	Teflon (Cold)	PDFE(Cold)
0.2MPa	0.0382	0.0134	0.0382	0.02444
0.4MPa	0.0814	0.02316	0.0608	0.03356
0.6MPa	0.2028	0.0352	0.1492	0.0544

Table 5.0 Table showing the relation of stress and strain.

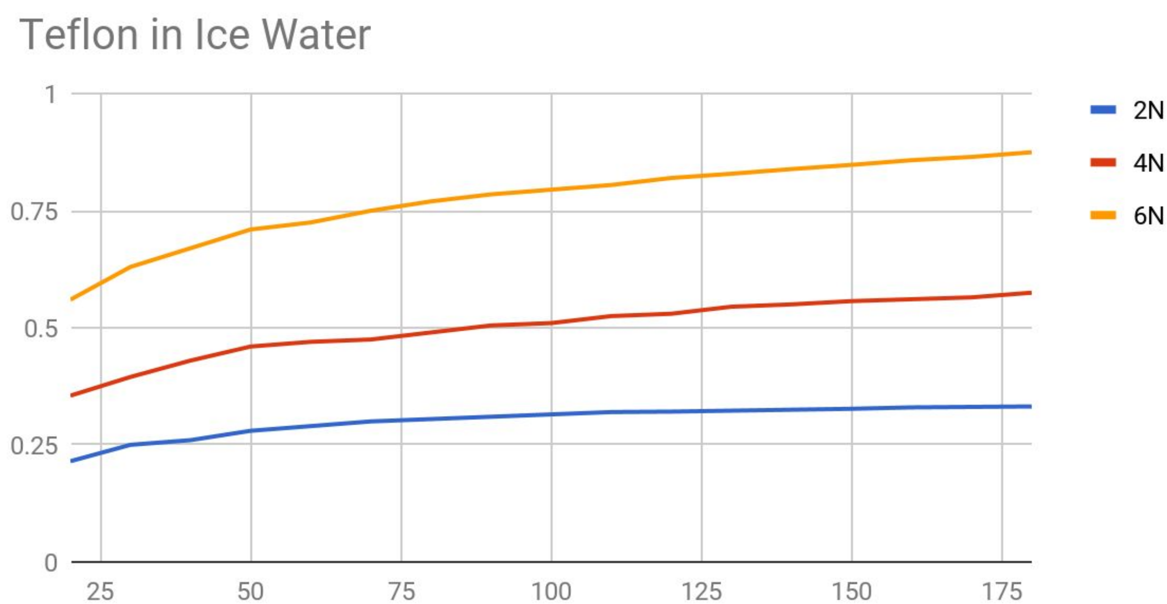
3.2 Graphs



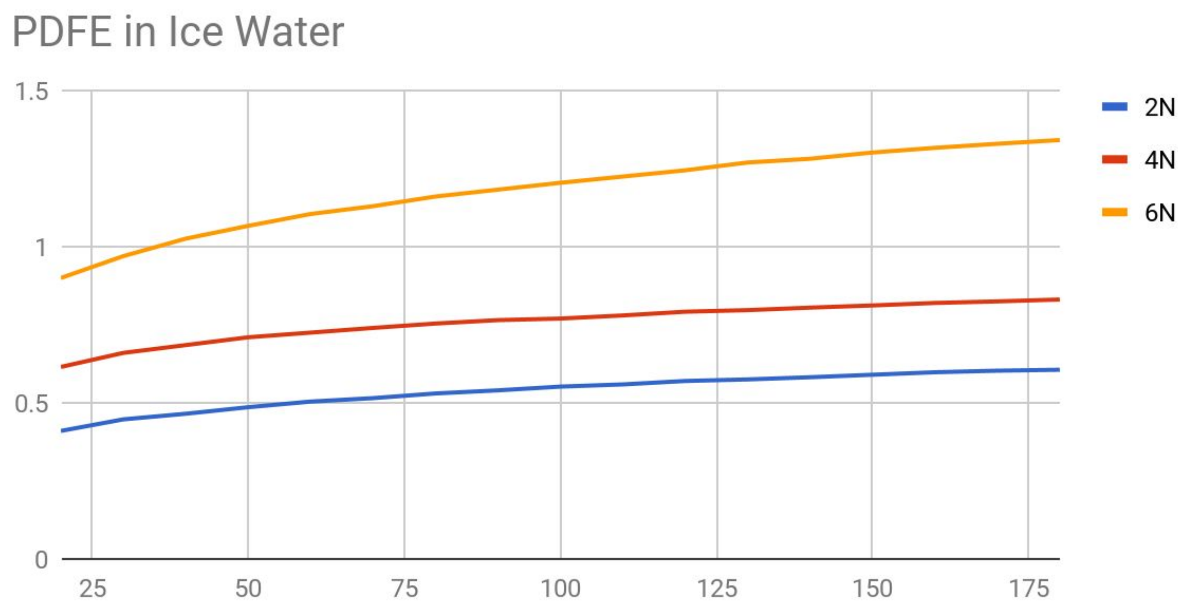
Graph 1.0 Graph shows the extension of the teflon sample over time in room temperature



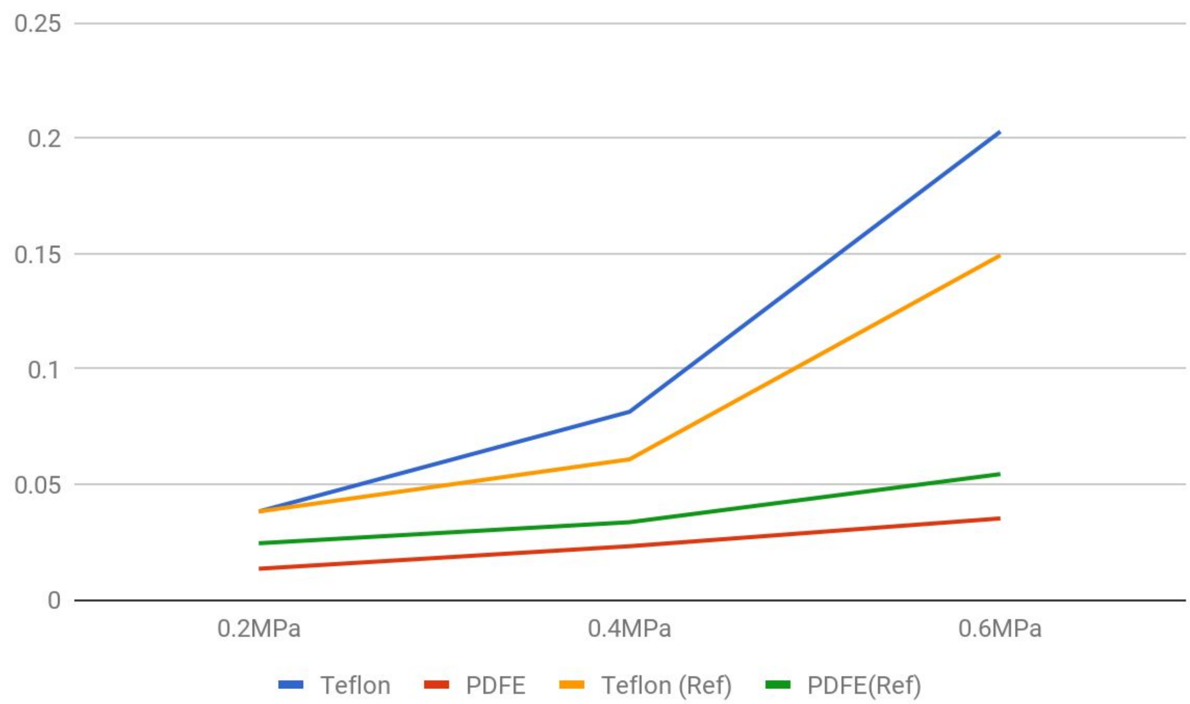
Graph 2.0 Graph shows the extension of the PDFE sample over time in room temperature



Graph 3.0 Graph shows the extension of the teflon sample over time after storing in ice water



Graph 3.0 Graph shows the extension of the PDFE sample over time after storing in ice water



Graph 4.0 Graph showing stress and strain for different materials and temperature.

3.3 Discussions

Based on the graph from the above, it can be seen that as the load applied at the end of the beam increases, the elongation for the sample increases. This is because the load applied is directly proportional to the stress that acts on the samples. The stress equation which is ($\sigma = \frac{force}{area}$) , help us to determine that stress increases when force applied onto a similar cross sectional area sample of object increases. Therefore, when a greater force is applied onto the samples, dislocation of atoms occurs due to large amount of stress and thus making the samples to elongate more. This phenomena is called dislocation creep where it takes place when the movement of dislocation perform through a crystal lattice. Therefore, in order for the dislocation creep to take place, high stresses and relatively low temperature is needed to fulfill the conditions.

Technically, when the load applied is fixed, the elongation and the creep rate for the sample decreases when the temperature decreases. This can be explained by the Arrhenius equation that can be defined as the constant relation between the steady rate mechanism and the diffusion rate of atom. As diffusion rate increases, the creep rate as well as the elongation of the sample increases (Clyne, 2018).

Arrhenius equation:

$$D = D_0 \exp(-Q / RT)$$

where D = diffusion coefficient (m^2/s)

D_o = pre-exponential (m^2/s)

Q_d = activation energy (J/mol)

R = gas constant (8.314 J/mol-K)

T = absolute temperature (K)

According to the equation from the above, it is shown that the diffusion rate is having a constant ratio to the temperature. When diffusion rate decreases, temperature as well as the creep rate decreases. However, based on graph 2 and graph 4 which is polyethylene in room temperature and ice water, the results shown is opposite to the theory of Arrhenius equation. Therefore, this will be justified in error analysis.

From the graphs shown on the above, it can be clearly seen that the polyethylene which is also known as PDFE has a smaller creep rate and elongation compared to PTFE (teflon). Polyethylene is formed from a long CH chain figure 6 and it is nonpolar. Due to their symmetrical molecular structure, they are also easier to crystallize and hence polyethylene can be considered as partially crystalline. Besides, when a molecule has higher crystallinity, the density of the molecules tend to increase as well as the stability, and therefore we can justify that the creep rate and the elongation for using PDFE sample is smaller.

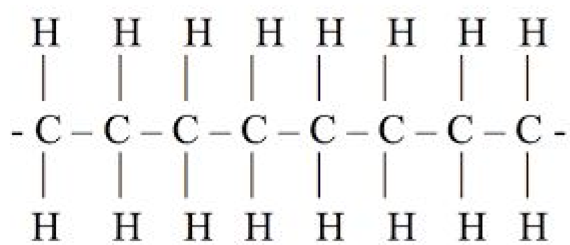


Figure 6. molecular structure of polyethylene (PDFE).

The PTFE molecules is large enough for the electron to move around easily, hence the dispersion forces will increase and this is known as Van Der Waals forces of dispersion. This kind of force will be created when temporary fluctuating dipoles set up as electrons move around freely in the molecules. Therefore, we can conclude that the dispersion force is dependant to the size of the molecule. The larger the size of the molecule, the greater the forces of dispersion. However, there is an issue that interrupt the bonding of C-F bond which is fluorine. Fluorine itself is so electronegative that make the electron in the C-F bond held closely and packed together. Therefore it inhibits the motions of the electron from moving as fast as we expected.

Other than forces of dispersion, Van Der Waals also contain dipole-dipole interactions. However in the each Teflon (PTFE) molecules, they contain negatively charged fluorine atom which gave a repulsion force between the bonds. The forces of dispersion is weak and the dipole-dipole reaction that causes repulsion determine that the Van Der Waals in the molecule of teflon is weak. Last but not least, this can be prove that why polyethylene (PDFE) has higher creep resistance compared to Teflon (PTFE) .

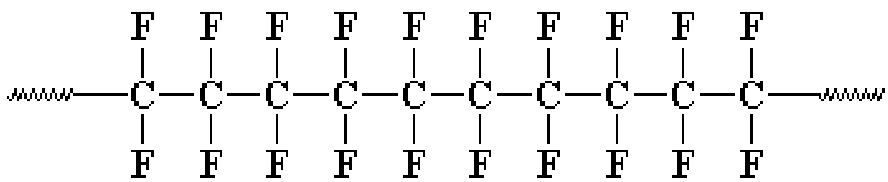


Figure 7. Molecular structure for Teflon (PTFE).

4.0 Error Analysis

Based on the discussion from the above, lower temperature will give lower creep rate and smaller elongation. However the readings taken for the polyethylene (PDFE) in ice water has a higher elongation compared to PDFE in room temperature. In this situation, we can conclude that error has been made during the experiment. The samples for the PDFE that is taken out from the ice-filled container to be used for conducting the experiment will absorbs heat from the surrounding once they are taken out. Therefore the readings that were recorded down will be imprecise and the values will be higher compare to the theoretical values. We can improve this error by placing the samples for both teflon and polyethylene into a conditioning box and screwed it onto the Gunt Creep Testing Machine that helps to keep the samples always at a lower temperature.

Figure 8. The conditioning box.

Besides, the graph from the above that we have plotted from the above contains only for initial and secondary creep stage. The reason of this error is because only 3 minutes time frame is provided to complete each experiment for both samples that are using different load applied and temperature. The time frame is too short for the tertiary creep stage to occur because it only starts to enter the third phase after some time.

From the intermolecular bonds, where Teflon is non polar due to the C-F bonds, and PDFE should have a stronger polar bond. As PDFE should be stronger, and have less elongation, the data from room temperature experiment supports this claim. However, for the creep specimens of low temperature which are exposed to ice water, it seems that Teflon instead has longer elongation in all cases. This could be explained as the specimens were submerged in ice water, and may have absorbed water in the process, leading to changes in the molecular structure and forces. This may have led to the difference in material strength between room temperature and cold temperature.

5.0 Conclusion

Based on the finding obtain from the experiment, we can draw the conclusion that Teflon (PTFE) will elongate more compared to polyethylene (PDFE) both in high and low temperature when a high stress in applied to the sample. This is due to the molecular structure of the samples. The molecular structure of Teflon consist of carbon and fluorine has a weaker Van der Waals force due to its electronegativity whereas the molecular structure of polyethylene consist of carbon and hydrogen provides a much more stable structure and high resistance to creep. Referring to the graphs above, it's clear that when the time of a constant weight is applied increase, the extension of both Teflon and polyethylene increase at room temperature. Other than that, the extension of Teflon and polyethylene also increase when a constant weight is applied over the same amount of time when both samples are at lower temperature. For example, at room temperature, when 4 N of force is applied for 60 seconds, the Teflon extended for 1.68mm while the polyethylene extended for 0.475mm. The highest extensions for Teflon and polyethylene at room temperature are 5.07mm and 0.88mm respectively. In low temperature, when 4 N of force is applied for 60 seconds on both samples, the extensions of Teflon is 1.087mm while polyethene is 0.74mm. The highest extensions for Teflon and polyethylene at lower temperature is 3.66mm and 1.36mm respectively.

A few improvement can be done to improve the results obtain from the experiment. For example, the experiment should be repeated for at least 3 times and obtain the average of the results for better accuracy. Other than that, the samples should be cooled to low temperature by putting it into a fridge rather than into cold water as the samples may absorb water and affect the results obtained. The creep test should also be conducted for longer than 3 minutes as suggested to get a better and detailed understanding of creep resistance of the materials.

In terms of real life applications, by understanding the creep of a material we are able to determine which material would be most suitable to do the job and advantages of one material's use over another.For example, the first creep testing machine were created in order to test the materials for aircrafts at high altitudes,temperatures and pressure.

6.0 References

American Society for Testing Materials (ASTM), 2011 "Standard Test Methods for Conducting Creep, Creep-Rupture, and Stress Rupture Tests of Metallic Materials", West Conshohocken, PA: ASTM International.

Clyne. B, 2018 "Effects of Stress and Temperature", University of Cambridge, accessed 22 April 2018, https://www.doitpoms.ac.uk/tlplib/creep/stress.php

Courtney. T. H, 2005 "Mechanical Behaviour of Materials" Second Edition, Long Grove, Illinois: Waveland Press.

Evans. R. W, Wilshire. B, 1993 "Introduction to Creep", Ann Arbor, MI: University of Michigan

Mather. G, 2018 "Creep and creep testing", accessed 21 April 2018, https://www.twi-global.com/technical-knowledge/job-knowledge/creep-and-creep-testing-081/

Pursuit Engineering, 2017 "Creep Testing" Accessed 21 April 2018, https://pursuitengineering.blogspot.my/2017/01/creep-test_2.html

The ARC, 2017 “Creep Deformation in materials”, accessed 21 April 2018, https://web.iit.edu/sites/web/files/departments/academic-affairs/academic-resource-center/pdfs/MaterialsCreep.pdf