Creep Behaviour Of Polypropylene Material

[1]Shubham Rimod Padhal
[1]Mechanical Engineering
[1]S.B.Jain Institute Of Technology, Management And Research

***Abstract* - This research paper covers experiment and simulation study on creep behavior of polypropylene under different temperature and loading conditions. Experimental evaluation of creep is carried out on electro-mechanical creep testing machine equipped with the data acquisition system. It is observed that creep rate of polypropylene increases with increase in temperature and loading conditions. I section of PP with defined geometry simulated on ANSYS 16.2. Experimental observations and simulation results shows the creep deformation of PP. This method can be used to determine the effect of uni-axial loading on creep deformation of polypropylene material.**

***keywords* - Experimentation, Simulation, Polypropylene, ANSYS 16.2, Uni-axial loading.**

INTRODUCTION

Creep can be defined as the slow & progressive (increasingly continuing) deformation of a material with time under a constant stress. It is both a time & temperature dependent phenomenon. Creep is probably the most widely studied long-term property. It results from the viscoelastic flow of the polymer with time. In other words, creep is a time-dependent process where a material under an applied stress exhibits a dimensional change at high temperature. High temperature progressive deformation of a material at constant stress is called creep. The process is also temperature-dependent (i.e. increases with temperature). Normally, Creep occurs when vacancies in the material migrate toward grain boundaries that are oriented normal to the direction of the applied stress.

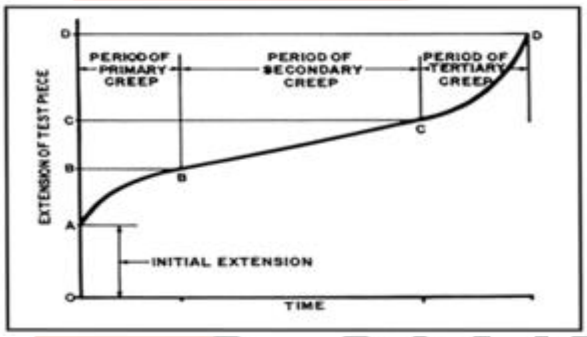

Fig 1: Stages of Creep

Creep is generally divided into three stages:-

1. Primary creep
2. Secondary creep and
3. Tertiary creep

An initial creep rate that is at least partly of elastic origin from point "0" to point "A" in Figure1.
This is followed by a region in which the elongation or deformation rate decreases with time, the so-called transient or primary creep, from region "A" to "B" of Figure 1. The portion from point "0"to point "B" occurs fairly quickly.
The next portion of the creep curve is the area of engineering interest, where the creep rate is almost constant. The portion from "B" to "C" is nearly linear and predictable. Depending on the load or stress, the time can be very long; two years in a test and several decades in service.
The fourth portion of the creep curve, beyond the constant-creep-rate or linear region, shows a rapidly increasing creep rate which culminates in failure. Even under constant-load test conditions, the effective stress may actually increase due to the damage that forms within the microstructure.

The material of specimen selected for the creep test is polypropylene (PP). Polypropylene is widely used in various applications due to its good chemical resistance. Some common uses of polypropylene includes; food packaging, automobile battery cases, disposable syringes. Investigation of creep behavior on polypropylene at different temperature and load is of practical use for improving the safety and reliability in packaging, automotive and medical applications. In this paper the tensile creep testing machine is used to study the creep behavior of PP at varying temperature and loading conditions. In this work we studied the tensile creep behavior of PP to understand the long term stability of its size and load capacity, to predict its service lifetime.

EXPERIMENTAL

A. Experimental system

The experimental system is divided into four parts. These parts include:

1. Specimen is held with the help of grippers inside the furnace.

2. Load is applied with the help of turnbuckle, spring and wire arrangement.
3. Temperature inside the furnace is controlled with the help of temperature controlling system. The specimen should be assembled and kept for 10 minutes inside the furnace in order to uniform the temperature.
4. Data Acquisition System (DAS) is used to record creep rate of (PP) specimen.

B. Experimental Method

The material of specimen selected for the tests was polypropylene. Polypropylene is mainly used in food packaging, automobile battery cases and disposable syringes. The dimensions of the specimen were shown in figure 2, with the thickness of 1.3mm. These experiments were mainly performed at a temperature range of 70 ^{0}C and 75 ^{0}C at a static load condition of 30kg.loads are mainly applied by steel wire and turnbuckle arrangement.

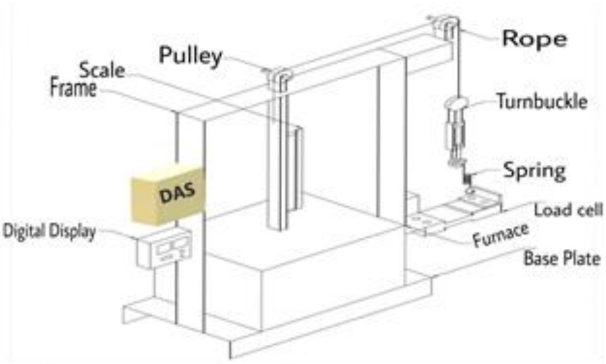

Fig 1: Schematic of the Test Setup

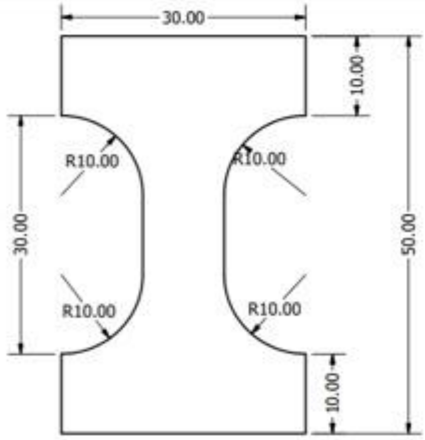

Fig. 2: Dimensions of Sample (unit: mm, thickness: 1.3mm)

Data acquisition system is mainly used to record the deformation in specimen. Variation in creep deformation was saved in SD card to further calculate the creep strain.

C. Experimental Result

In this experiment at 70 ^{0}C, 30kg load is applied to the specimen. The stress acted across the cross-section of sample is 22.638 Mpa and creep failure time was only about 1464.6 sec. At 75 ^{0}C, 30 kg load is applied to the specimen respectively, and stress induced in the specimen is about 22.638 Mpa and creep failure time is 349.2 sec. The creep fracture time and strain are shown in table 1. The creep curves at different temperatures and loading conditions are described in figure 3-4, respectively.

Table 1

Temperature, loading conditions and results for creep tests of polypropylene

Temperature (^{0}C)	Strain (%)	Deflection (mm)	Fracture time (sec)
70 ^{0}C	6	1.93	1440
	24	7.34	
	31	9.22	
	35	10.53	
	38	11.42	
	167	50.22	
75 ^{0}C	7	2.13	> 81
	32	9.61	

33	10.02
34	10.14
36	10.89
38	11.14

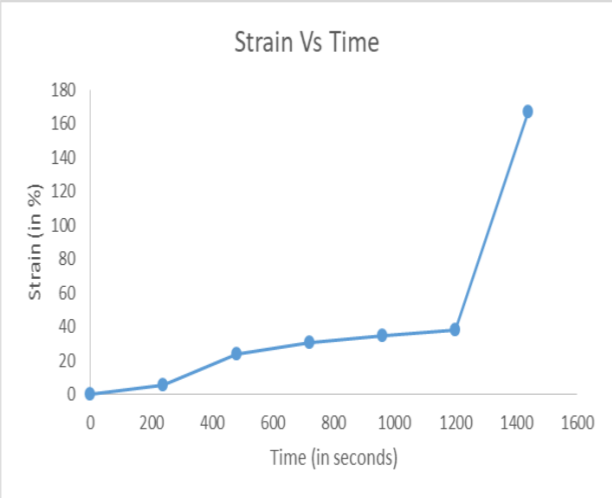

Fig 3: Creep Strain vs. Time at 70 ^{0}C

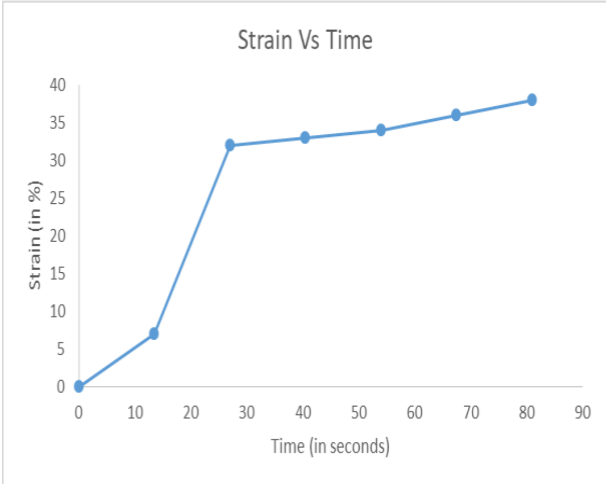

Fig 4: Creep Strain vs. Time at 75 ^{0}C

According to table 1, higher temperature decreases the tensile strength of polypropylene and accelerates creep failure of polypropylene. Figures 3-4 shows that the creep rate increases with respect to increase in temperature.

FEA SIMULATION

In this experiment finite element analysis is used to study the creep behavior of polypropylene at different temperatures and loading condition. Specimen model is meshed in 1696 elements and 649 nodes. FEA model as shown in figure 5. In this simulation uniaxial load of 30 kg is applied on the FEA model at temperature of 70 ^{0}C and 75 ^{0}C.

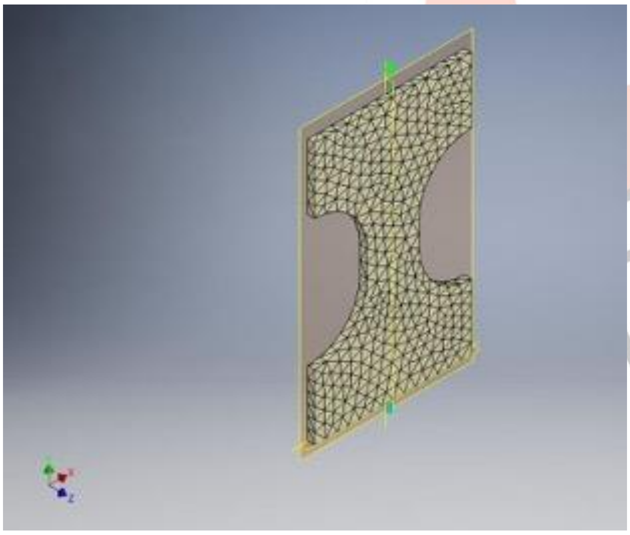

Fig 5: FEA model

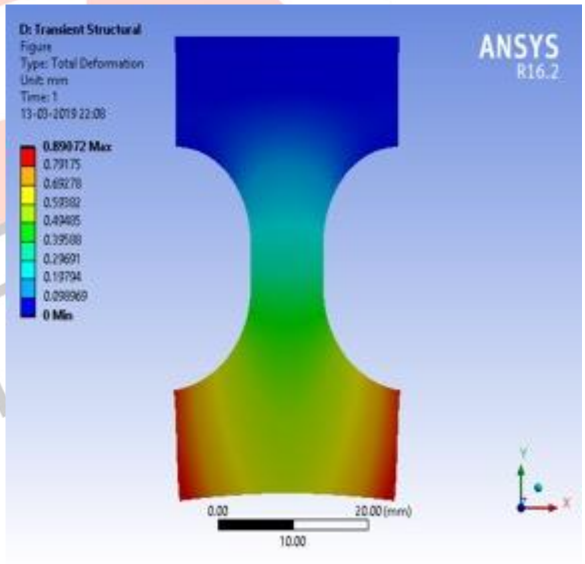

Fig 6: Total Deformation at 70 ^{0}C

For the analysis of the PP model **ANSYS WORKBENCH -16.2** is used which is a general purpose finite element computer program for engineering analysis and includes preprocessing, solution, post-processing. ANSYS used in a wide range of discipline for solutions to mechanical, thermal and electronic problems. Analysis is carried out by keeping the load constant and varying the temperature. By using this method total deformation and equivalent elastic strain at 70 ^{0}C and 75 ^{0}C is determined at 30 kg (294.3 N).

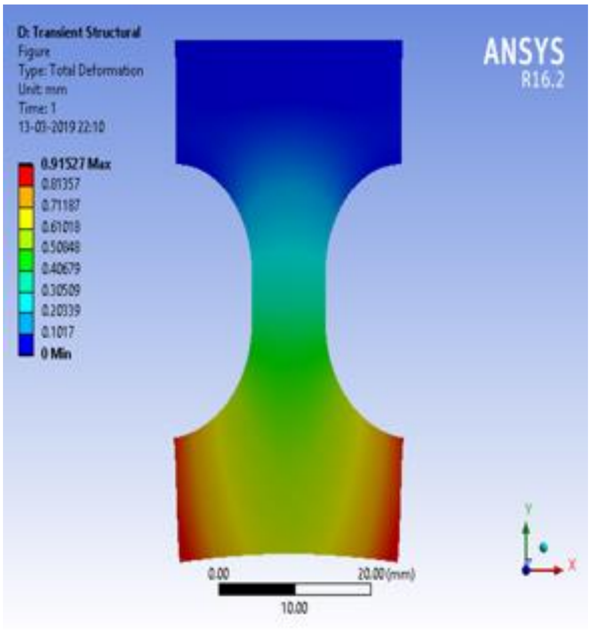

Fig 7: Total Deformation at 75 ^{0}C

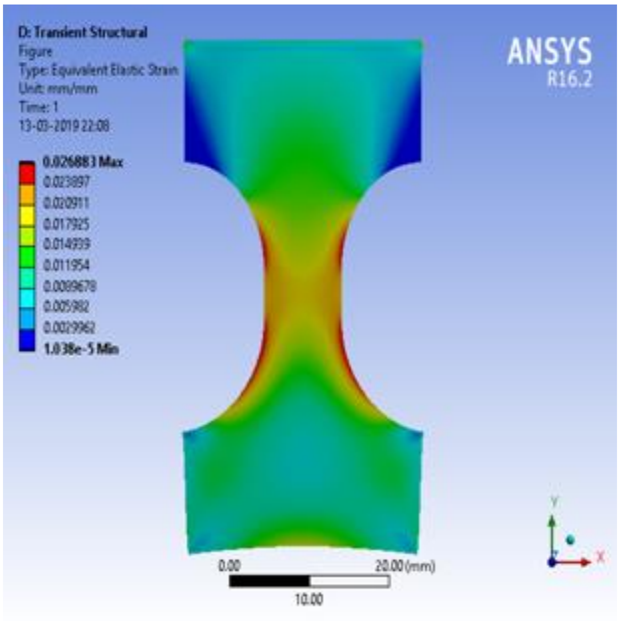

Fig 8: Elastic Strain at 70 ^{0}C

From figure 6 & 7 maximum total deformations at 70 ^{0}C is 0.89072 mm and at 75 ^{0}C deformation is 0.91527 mm. Finite element analysis shows that there is 2.45% more deformation at 75 ^{0}C than deformation at 70 ^{0}C. From this result we found that at higher temperature the maximum total deformation are increases even keeping the load constant.

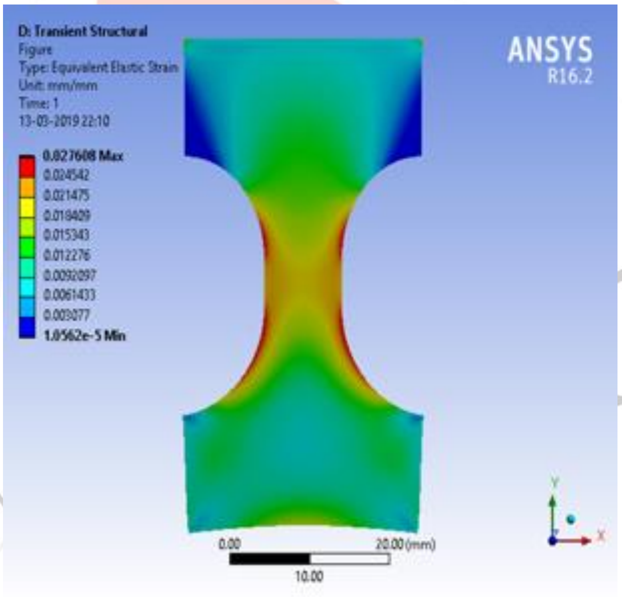

Fig 9: Elastic Strain at 75 ^{0}C

From Figure 8 & 9 equivalent elastic strain at 70 ^{0}C is 0.026883 mm and at 75 ^{0}C deformation is 0.027608 mm. It is found that at 75 ^{0}C equivalent elastic strain is 0.072 % more than elastic strain at 70 ^{0}C. Finite element analysis results prove that at higher temperature the equivalent elastic strain is increases.

CONCLUSION

1. The creep rate is increases with increase in temperature. Also several parameters like equivalent elastic strain and total deformation shows the same behavior to increase with rise in temperature.
2. The strain vs. time curve of polypropylene specimen obtained from experimental results shows same behavior.
3. It is observed that higher temperature decreases the tensile strength of polypropylene and accelerate the creep rate.
4. Finite element analysis (FEA) results prove that the FEA model introduced in this paper can successfully simulate by using ANSYS WORKBENCH – 16.2.

REFERENCES

[1] K. Bledzki and J. Gassan, Progress in Polymer Science, 24, 221-74 (1999).
[2] J. George, M. S. Sreekala, S. Thomas, Polym. Eng. Sci. 41, 1471 (2001).
[3] T.W. Strganac and H.J. Golden, Int. J. Solid Structures, 33(30), 4561- 70 (1996).
[4] P. Stefano, Polymer, 47, 5610 (2006).

[5] J.F. Li, R. Yang, J. Yu, and Y. Liu, Polym. Degrad. Stab., 93, 84 (2008).
[6] P.E. Tomlins and B.E. Read, and G.D. Dean, Polymer, 39, 355 (1998).
[7] B. E. Read, G.D. Dean, and P. E. Tomlins, Polymer, 29, 2159 (1988).
[8] J. Lai and A. Bakker, Polymer, 36, 93 (1995).
[9] R. Chen and D.R. Tyler, Macromolecules, 37, 5430 (2004).
[10] 1. Luo, W.; Wang, C.; Zhaoa, R.; Tang, X.; Tomita, Y. Creep behavior of poly (methyl methacrylate) with growing damage. Mater. Sci. Eng. A 2008, 483–484, 580–582.
[11] Luoa, W.; Liu, W. Incubation time to crazing in stressed poly (methyl methacrylate). Polym. Test. 2007, 26, 413–418.
[12] Crissman, J.M.; McKenna, G.B. Relating creep and creep rupture in PMMA using a reduced variable approach. J. Polym. Sci. Pt. B: Polym. Phys. 1987, 25, 1667–1677.