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Effect of Temperature, Cross-head Speed and Duration of loads on the Mechanical Properties of PVC Polymeric Material.

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ABSTRACT

An experimental investigation and determination of the mechanical properties is carried out to show the reliability of a PVC in engineering application. For this purpose, the experimental work is divided into two groups, the first group includes a determination of the mechanical properties, such as yield stress, modulus of elasticity and maximum elongation of the initial PVC at normal conditions. The second group includes a study of the factors affecting these properties such as the effect of temperature, cross head speed and load duration by creep.

KEY WORDS

Polymer, PVC, Mechanical properties, Creep, Strain rate

INTRODUCTION

It has been known for a long time [1-13] that the mechanical properties of polymers are function of stress, temperature, and time. The design of objects composed wholly or partly of polymers requires a knowledge, therefore, of the functional dependence of the mechanical properties upon load history [4]. The small strain behaviour of amorphous polymers is described by the new-classical theory of linear visco-elasticity [2]. The tensile behaviour of polymeric material is clearly of great importance for many applied problems, particularly at high deformation in the region of yield and fracture. The present work deals with an

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EXPERIMENTAL WORK

The tensile tests were carried out on specimens shown in Fig. 1 at the normal conditions (25 °C and atmospheric pressure and at cross head speed of $V = 0.1\ mm/s$). Figure 2 shows one of tensile test results taken from the universal-testing machine model ME403. This curve represents the load-elongation relationship, from which the tensile properties of PVC are determined and given in Table 1. These properties represent the mean values of at least three tests

Table 1 Mechanical properties of PVC.

Tensile yield stress, σ_{Yt} (MPa)	52.50
Tension modulus, E_t (GPa)	1.000
Maximum elongation ΔL_f (mm)	12.80
Poisson's Ratio, ν	0.429

Tensile tests were carried out at different cross head speeds and temperatures to study their effect on the material properties. The investigated values of the speed were in the range 0.01 to 3.00 mm/s and that of the temperature were in the range of 25 to 90 °C.

RESULTS AND DISCUSSION

Effect of Cross Head Speed and Temperature

Figure 3 shows the effect of test temperature on the shape of the load elongation curve. at a cross head speed of 0.1 mm/s. Fig. 4 shows the effect of cross head speed on the shape of the load-elongation diagram. At a test temperature of 25 °C the values of tensile properties such as yield stress, modulus of elasticity and maximum elongation were determined with the variation of both of the test temperature and the loading speed as shown in Fig. 5.

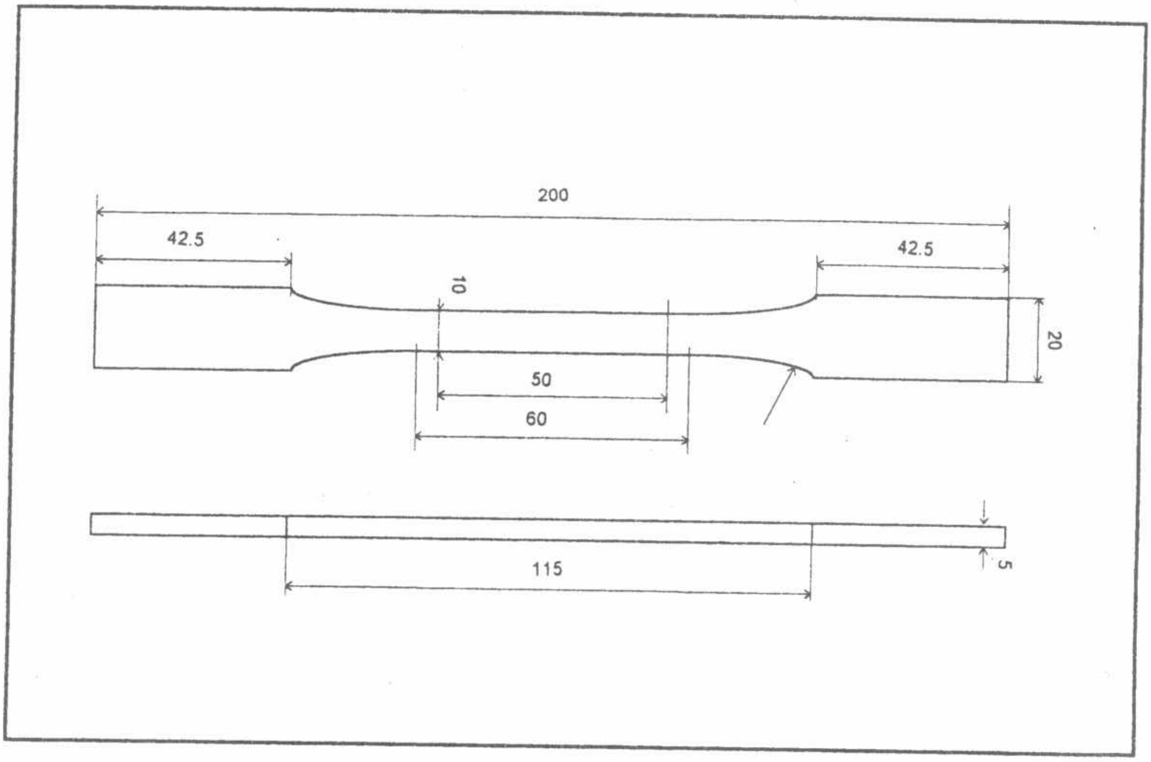


Fig. 1. Tensile Test Specimen

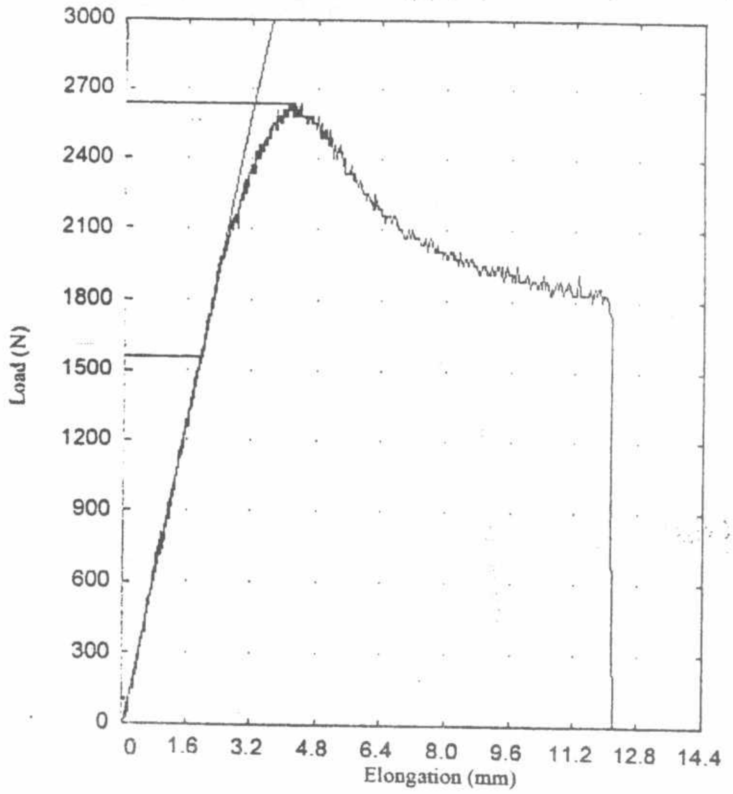


Fig. 2. The test record (load-elongation diagram) of the tensile test

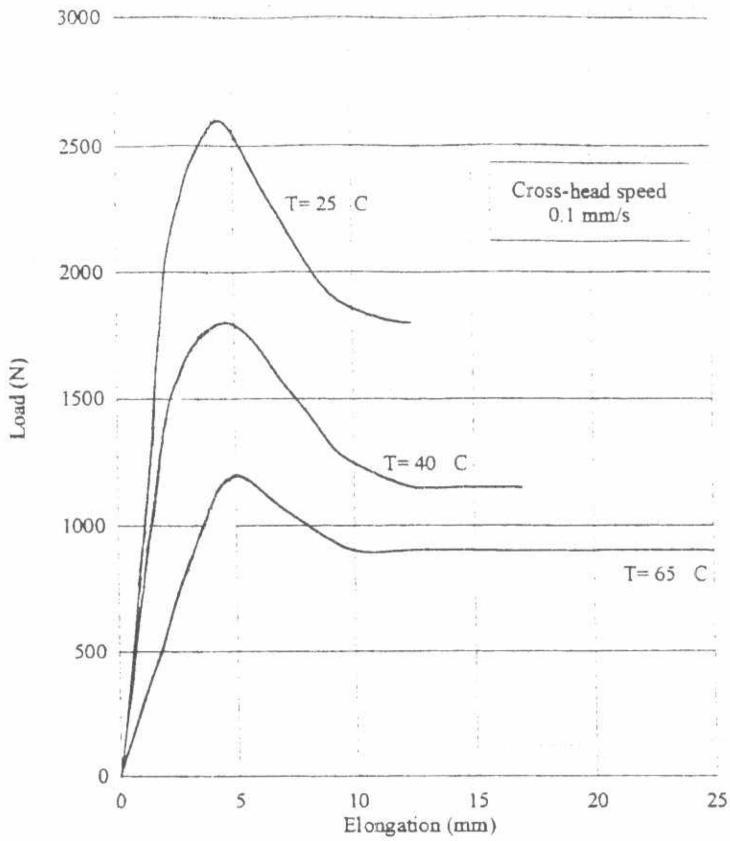


Fig. 3. Load-elongation curves at different temperatures and cross-head speed of 0.1 mm/s.

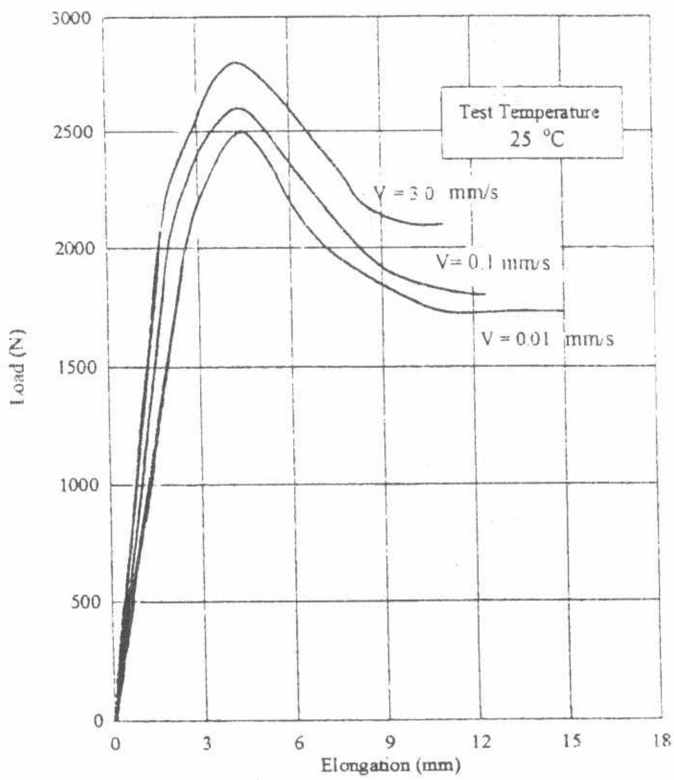
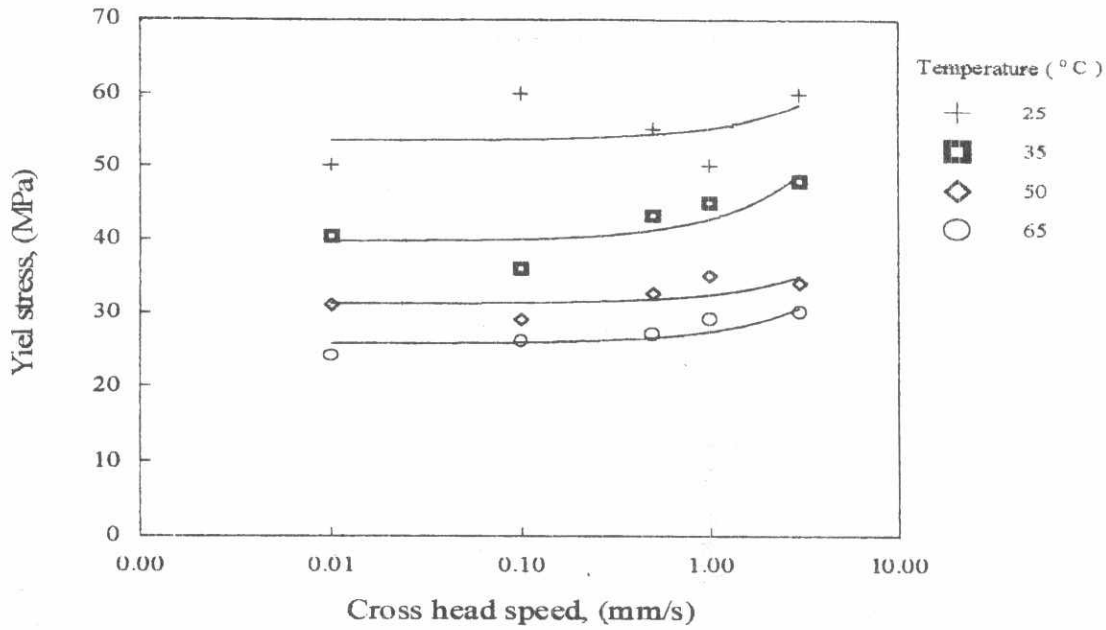


Fig. 4. Load-elongation curves at different cross-head speed and a temperature of 25 °C

Figure 5 illustrates the effect of the variation of both temperature and cross head speed on yield stress, modulus of elasticity and fracture elongation. As can be seen from Fig. 5a, the yield stress decreases as the test temperature increases, for example, the increase of the temperature from 25 °C to 65 °C at a cross head speed of 0.1 mm/s the yield stress decreases by 50%. On the other hand, yield stress increases with the increase of cross-head speed. The yield stress increases by a ratio of 36% when the speed increases from 0.01 to 3.00 mm/s at a temperature of 25 °C. The effect of temperature and cross-head speed on the mechanical properties is similar to that observed by Ref. [12] for many other polymeric materials.

The effect of temperature and speed on the modulus of elasticity is shown in Fig. 5b. The trend of variation of modulus of elasticity with both temperature and cross head speed is almost the same trend observed for the yield stress. For engineering materials, (steel, Aluminum,. .), temperature and cross-head speed up to a certain value does not affect the elastic modulus. For polymeric material, the elastic modulus is expected to be affected even by slight change in temperature and cross head speed since the micro-structure of polymeric material is very sensitive for temperature and strain rate as presented by Ref [12]. For PVC the modulus of elasticity increases by 33% the when cross head speed increases from 0.01 to 3.00 mm/s at testing temperature of 50 °C. While modulus of elasticity decrease by 37% with increase of temperature from 25 to 65 °C at cross head speed of 0.1 mm/s.

Figure 5c shows the variation of fracture elongation with both temperature and cross-head speed. As it was expected, increasing of testing temperature soften the material and increases the fracture elongation. On the other hand, the increase of cross-head speed decreases the fracture elongation.



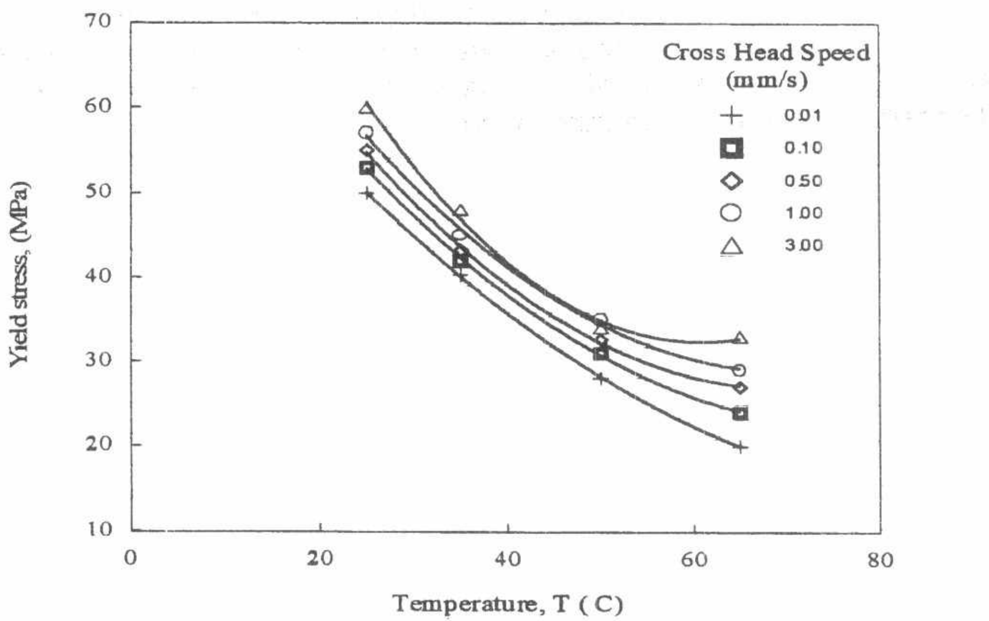
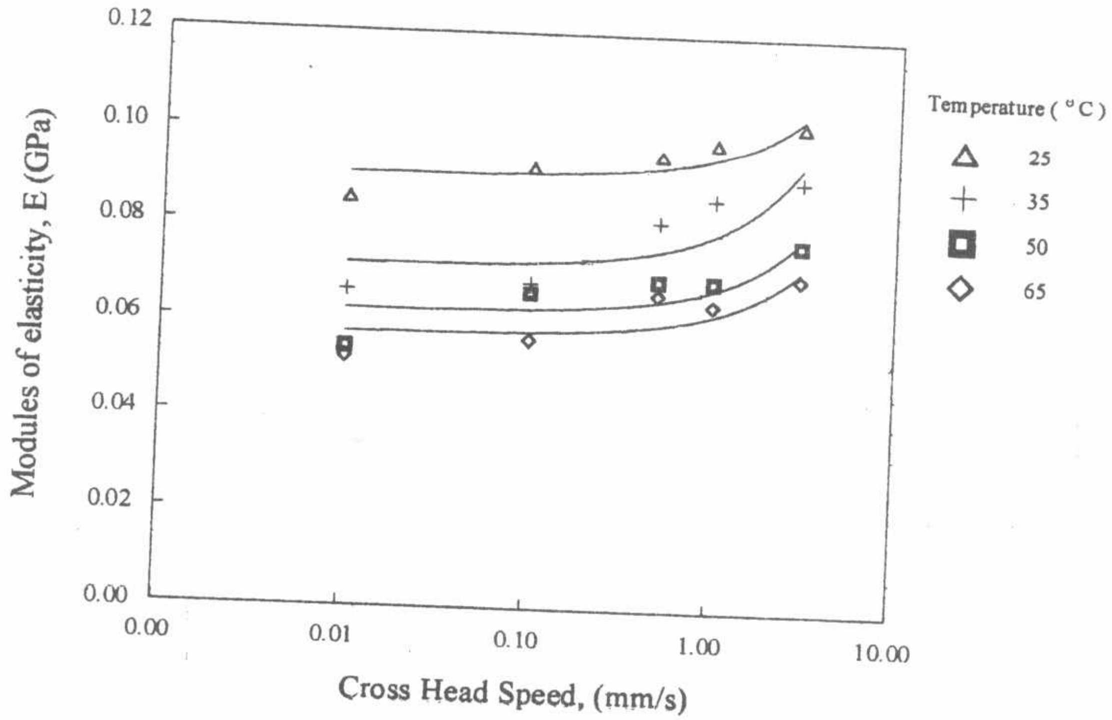


Fig. 5a. Variation of yield stress versus temperature and cross head speed.



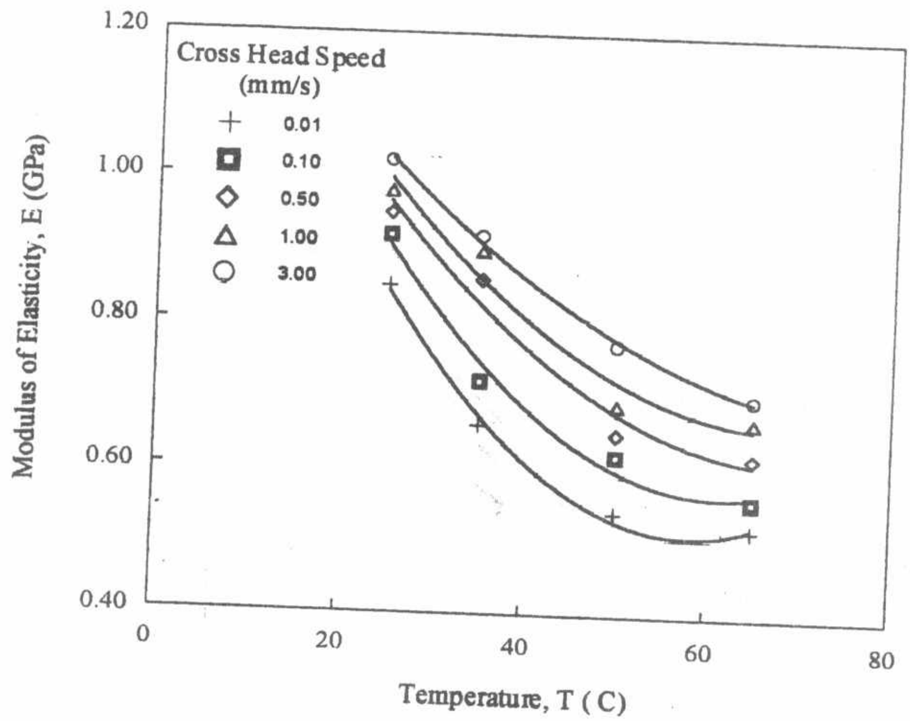
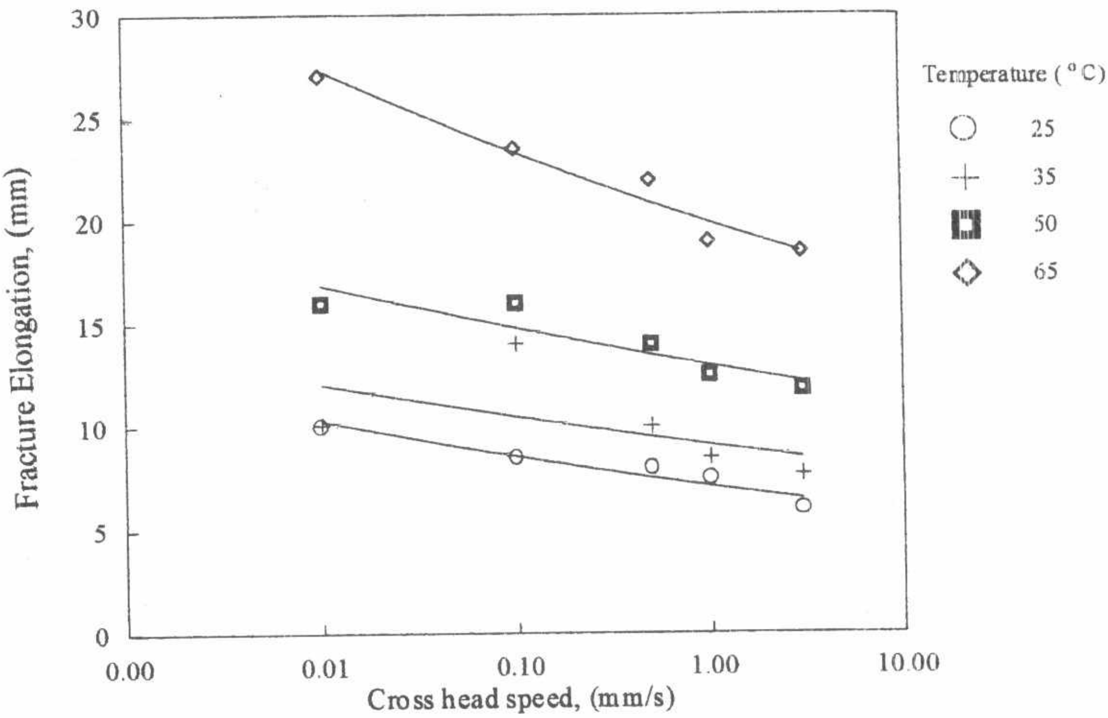


Fig. 5b. Variation of the Modulus of elasticity versus temperature and cross head speed.



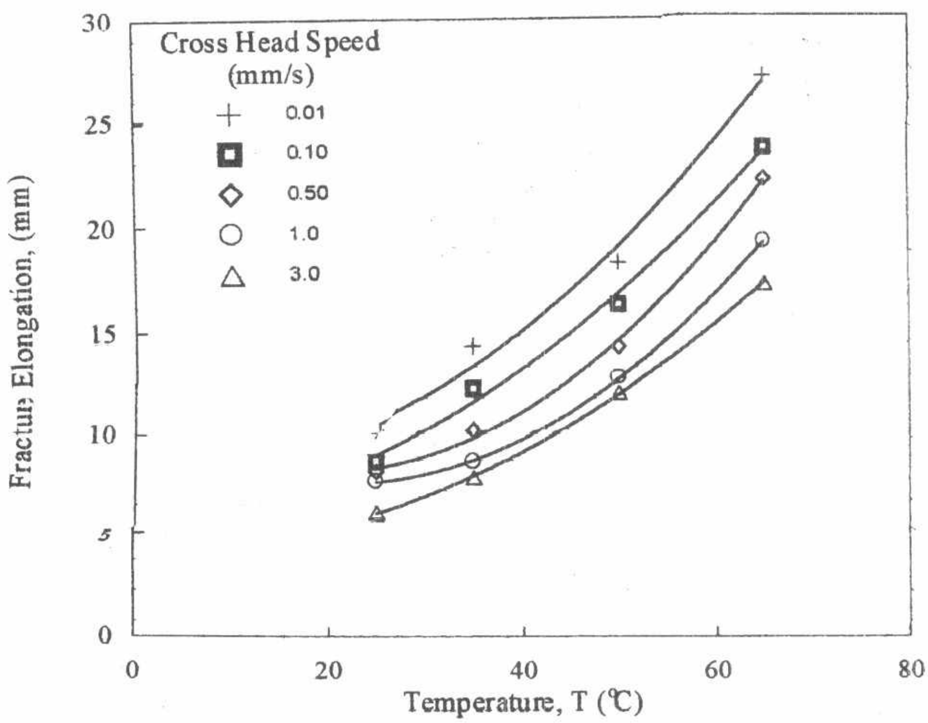


Fig. 5c. Variation of the fracture elongation versus temperature and cross head speed.

Effect of Duration of Loads

PVC as a polymeric material when subjected to a load may creep. The creep test was carried out on the creep test rig shown in Fig. 6 on tensile specimens of 5×5 mm cross section. The specimen was subjected to a constant load and the strain was calculated from the measured elongation with time.

Figure 7 shows strain variation versus time for different applied constant loads. It can be seen from the figure that the material shows the same trend for all applied stresses. Strain is kept constant for certain time and then it increases suddenly showing the onset of three phases of creep. The time needed to start yielding depends on the applied stress. Also, the amount of strain occurred at fracture depends on the applied stress.

Figure 8 shows the variation of the applied stress required having a certain value of strain 10% and 15% with time. The same trend is obtained for all strain values but with slight difference in the applied stress. As it is expected, higher value of applied stress is required to have a higher value of strain at the same period of time.

To determine the creep modulus, the isochronance curve must be constructed. This could be made by extracting the stress-strain curve at constant time from creep curves shown in Fig. 9. Stress-strain curves have been plotted at 1, 10, 100, and 1000 minute as shown in Fig. 10. Creep modulus is determined from this figure as the slope of initial tangent of the curve. This modulus depends on the time at which the stress-strain curve is extracted. The variation of this modulus with time is shown in Fig. 10. It is clear that the creep modulus decreases with the time due to the creep effect as it was found previously by Ref. [13]. Fig. (11) Shows the variation of the fracture strain with applied stress.

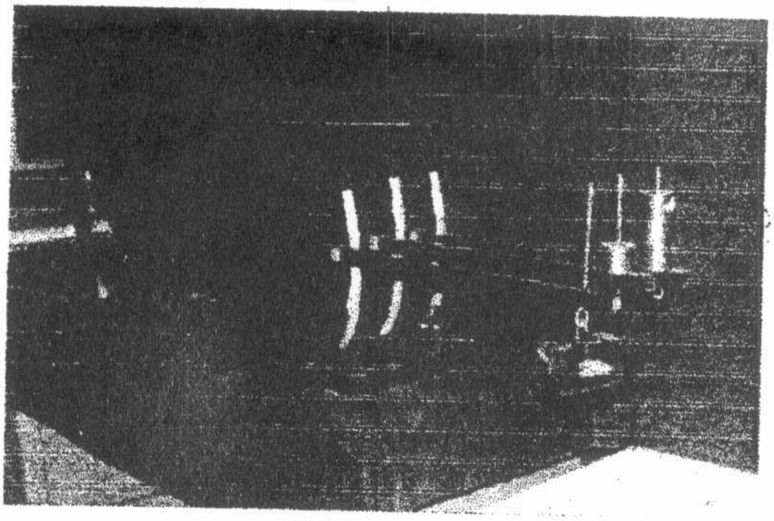


Fig. 6. Creep Test Apparatus

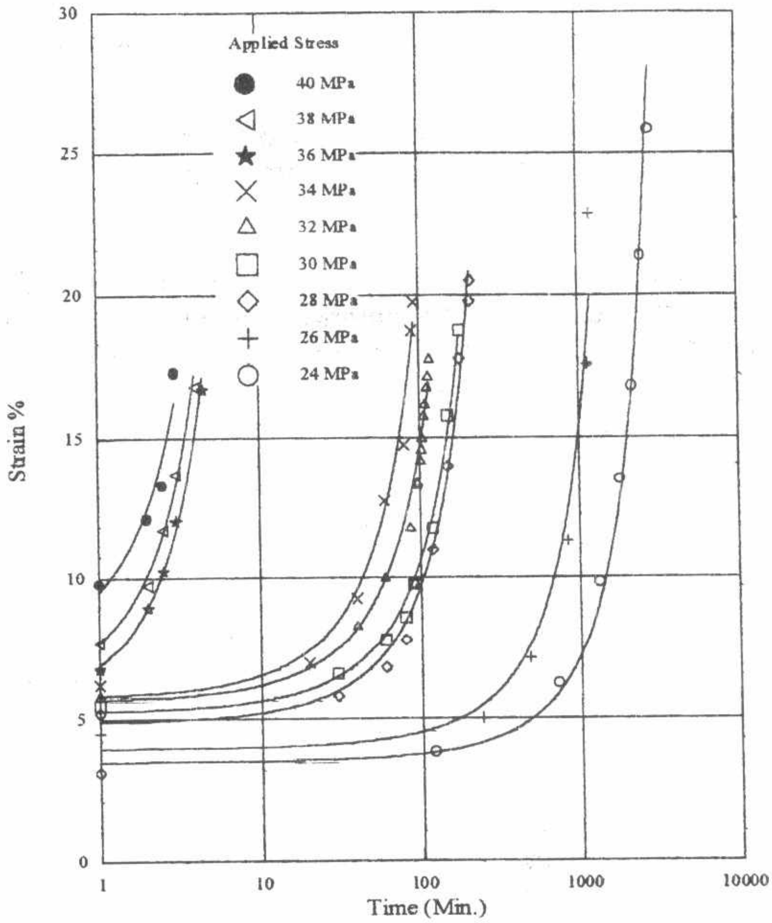


Fig. 7. Creep curves of a PVC specimens subjected to different stress levels

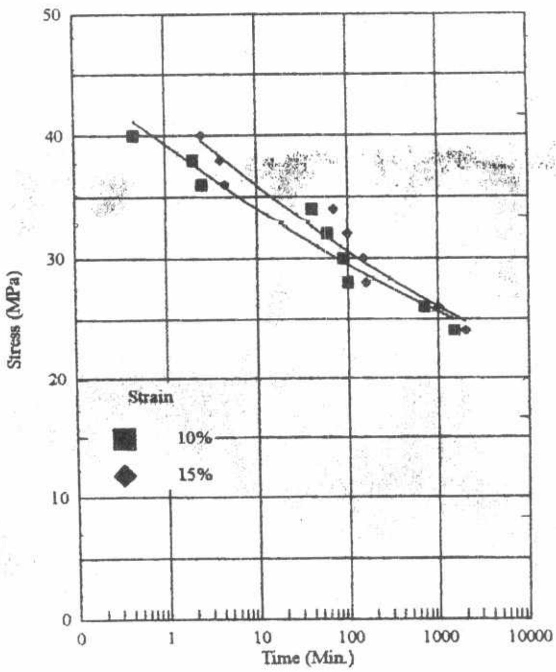


Fig. 8. Stress-Time curves for PVC at 30 °C At two different strain values.

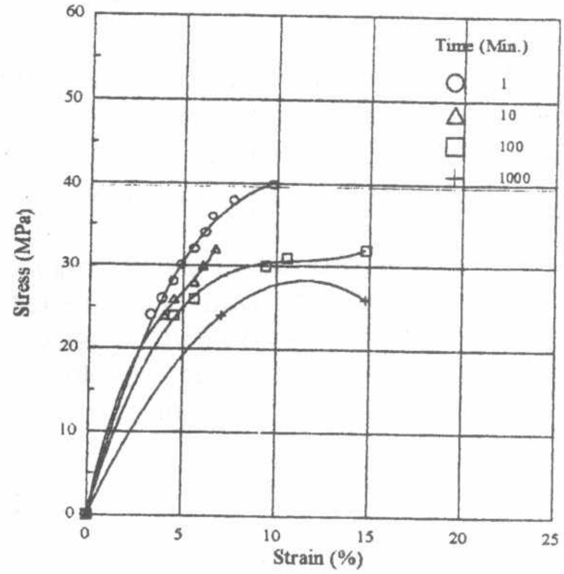


Fig. .9. Isochronance stress-strain curves for PVC at 30 °C at various times.

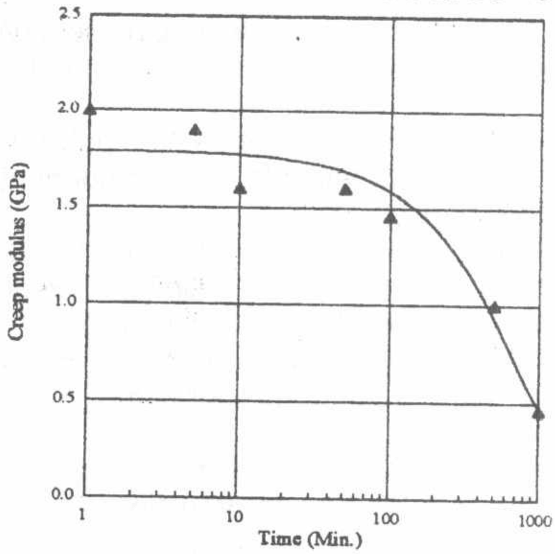


Fig. 10. Variation of the creep modulus with time

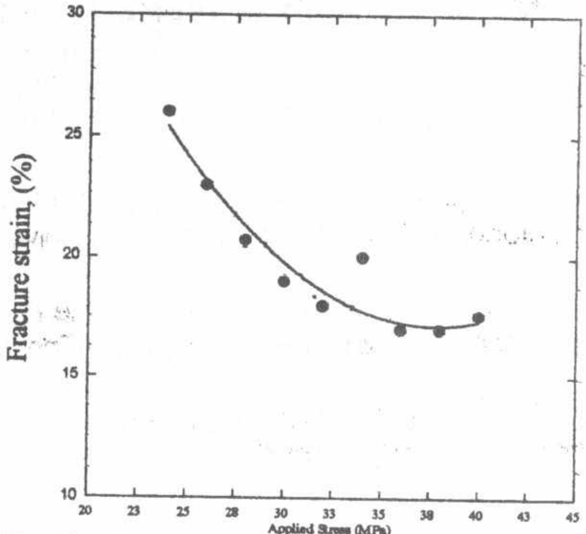


Fig. 11. Variation of the fracture strain with time at different stress levels

CONCLUSION

The mechanical properties of the PVC are greatly affected by the test temperature, the strain rate and the load duration. Increasing the test temperature, as expected, softens the polymeric material, decreases its yield stress and increases its ductility. At temperatures above the glass-transition temperature The PVC is rubber like and its ductility increases considerably. The cross head speed has a remarkable effect on the tensile properties as increasing the speed shows an increase in the yield stress and in the modulus of elasticity with a decrease in its maximum elongation at fracture. The tested PVC is sensible to the duration of the load as can be seen from the creep test results showing a considerable deformation under constant loads specially at high loads.

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