Comparison OF Shear Properties for High Density Polyethylene (HDPE) and Poly vinyl Cloride (PVC) Polymers

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ABSTRACT

The properties that make plastic of direct interest to designers and engineers are its good strength to weight ratio, low manufacturing installation costs, and high durability. The strength of polymers is known to be sensitive to temperature and this generally limits their use under service temperatures. The present work addresses the effect of temperatures ranging from 0 to 70℃ on the shear properties of high-density polyethylene (HDPE) and polyvinyl chloride (PVC) materials. The results show that Yield stress increase with temperature by (15.4%) for HDPE and the temperature has no effect on yield stresses of PVC.

The modulus of elasticity varied in each temperature for both materials selected and the maximum shear strength, however, showed a slight increase in this temperature range by (1.4%) for HDPE but slightly decrease by (2%) for PVC. Shear rupture and elongation reduced by (0.02%) with increasing temperature by (1 °C) for both materials .Ductile fracture is observed to be the controlling failure mechanism at all temperatures of interest for both material and no data were recorded at 70℃ due to distortion of all specimens in this temperature selected.

Keywords: HDPE, PVC, shear properties, Temperature effect, mechanical properties.

مقارنة خواص القص لكل من بولى اثلين ذو الكثافة العالية وبولى فينول كلورايد

الخلاصة

ان الخواص التى تجعل البوليمرات مثيرة لاهتمام كل من المهندسين والمصممين هى متانته الجيده بالنسبة لوزنه كلفة تصنيعه وتجهيزه المنخفضه وتحمله العالى.

ان تاثير درجة الحراره على متانة البوليمرات يحد من استخدامها فى درجات معينه ولهذا تناول البحث تأ ثير درجة الحراره من صفر الى 70 مْ على خواص القص لكل من بولى اثلين ذو الكثافة العالية وبولى فينول كلورايد وان نتائج الدراسه توضح بآ ن ارتفاع درجات الحراره يزيد قيمة اجهاد الخضوع بنسبة 15.4 % بالنسبه للاول ولا يؤثر على الثاني .

اما معامل المرونه فانه يختلف مع اختلاف درجات الحراره لكلا المادتين كما لوحظ زيادة اجهاد القص بنسبة ضئيله بين الدرجات المختاره فى البولى اثلين ذو الكثافه العاليه ويصل الى 1.4% ويقل بنسبة 2% فى البولى فينول كلورايد.

وبالنسبه لكسر القص والاستطاله فانها تزداد بنسبة 0.02% لكل درجه حراريه واحده لكلا المادتين وكان نوع الكسر مطوليا لكافة الحالات ولم تسجل اى قرائه عند درجة70 مْ بسبب تهشم العينات عند هذة الدرجه ولكلا المادتين.

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INTRODUCTION

Requirement for almost all engineering structural materials is that they are both strong and tough (damage or tolerant) yet toughness is mutually exclusive. This is not always widely appreciated, as in common vernacular these terms are often taken to mean the something. Whereas strength is invariably a stress representing a materials resistance to non-recoverable (for example plastic) deformation [1].

Plastic or polymer materials are very elastic and malleable, they can be molded pressed or cast into different shapes. They are mostly made from petroleum and natural gas and one type of plastic is thermoplastics and they are classified as amorphous or semi- crystalline, two of these are PVC (polyvinyl chloride) which is amorphous and cheap, is the third most widely used heavy and strong, and HDPE (high density polyethylene) which is semi- crystalline and most widely used plastic, hard and more abrasion and heat resistance, both are commodity polymers [2].

Like most materials polymers is affected by temperature change. However polymers response to temperature change is significant and unique when compared to other traditional materials, because of their macromolecular nature, the covalent bonded and long chain structure which makes theme macromolecular [3]. The number averaged molecular weights deformations the mechanicals strength, and high molecular weights are beneficial for properties like a strain to break, impact resistance, wear etc. Thus natural limits are met, since too high shear and elongation viscosities that make polymers in processable [4, 5].

Hence, many types of research have discussed the shear strength of polymer and relation between temperature and mechanical properties. Hsuan,. and Koerner[6] show that polymeric materials in particular, will somewhat soften and increase in flexibility under high temperatures and will conversely somewhat harden and decrease in flexibility under cold temperatures. H.A. Alawaji [7] pointed out that, deformation modulus of High-Density Polyethylene (HDPE) and Fiberglass (GRP) pipes are decreased linearly with increasing temperature from 20 to70 °C.

Khan [8] has reported numerous experimental results in shear and uniaxial extension on different polymers, so low-density polyethylene shows more strain hardening than any other materials tested.

The strength of polymers is known to be sensitive to temperature and this generally limits their use under service temperatures lower than the glass transition temperature. The effect of temperature ranging from10 to 70 °C on the tensile properties of HDPE and PVC addressed by N. merah, F Saghir [9] and in general, a similar effect was observed on yield stresses modules of elasticity and yield strain for both materials.

Tanay Karademir [10] investigate temperature effects on interface shear behavior between smooth polyvinyl chloride (PVC) and smooth/textured high-density polyethylene (HDPE) .A unique temperature controlled chamber (TCC) was designed and developed to be utilized to simulate the field conditions at elevated temperatures and evaluate shear displacement failure mechanisms at these higher temperatures.

Marciano Laredo [11] investigates the effect of temperature on the performance of epoxy and unsaturated polyester polymer mortars (PM). PM is a composite material in which polymeric materials are used to bond the aggregates. Specimens were prepared for flexural and compressive tests, respectively, at different temperatures.

Measurements of the temperature-dependent elastic modulus and the compressive and flexural strength were conducted using a thermostatic chamber attached to a universal test machine for a range of temperatures varying from room temperature to 90 °C. The result shows that the flexural and compressive strength decreases as temperature increases, especially after matrix HDT. Epoxy polymer mortars are more sensitive to temperature variation than unsaturated polyester.

The present paper addresses the temperature effect on the mechanical properties of polymer material.

The effect of temperature is investigated by performing Shear tests at, 0, 18, 24, 30, 50 and 70 °C .This range encompasses the temperatures at which some type of polymer may be used in the different areas of the world.

Variations of the mechanical properties such as yield shear stress, modulus of elasticity, ultimate shear stresses, ultimate elongation and shear rupture with temperature are studied. The effect of temperature on the mechanical properties of HDPE is compared with PVC, and PVC (bonded with the chemical compound which is similar to the laminate composite material) (PVCC).

Experimental Procedure

To determine the influence of temperature on the mechanical strength of the HDPE, PVC, and PVCC, shear tests were performed at different temperature levels.

The specimens for shear tests were prepared commercially from high-density polyethylene (HDPE) 25mm width and 150mm length strip according to D6392 ASTM [12], and from polyvinyl chloride (PVC) according to D 882ASTM [13] as shown in Fig (1).

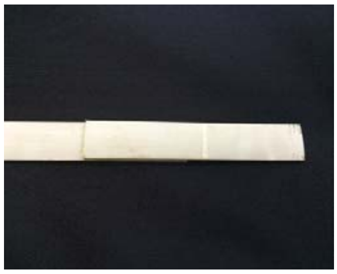


Figure (1) : A-HDPE B-PVC C-PVCC

We used threaded screw to prepare A and B specimens and binder compound with chemical composition plastic cement and UT-R as shown in Fig.2 to form C specimen.

Plastic cement **UT-R (liquid)**

Figure.(2): show binder compound used to produce C specimen.

After that heating for 24 hours at 0, 18, 24, 30, 50, 70 °C in an electric oven type Electrical furnace 1000e as shown in fig.3 and two to three tests were performed at each of the Temperatures above with a strain rate of 50mm/min.

Figure.(3) Electrical furnace 1000e.

Shear test instrument fig.4 was used and all results obtained from these tests such as yield and maximum tensile strengths, fracture strength or shear rupture, modulus of elasticity, elongation at yield and maximum elongation at break are presented in figures 6 -11 except for 70 °C because the specimens were distortion due to (degradation of the chains) as shown in Fig (5).

Figure.(4)Shear test instrument.

Figure.(5 Specimens after heating for 70 °C.

Results and Discussion:

The shear properties for polymers are dependent on temperature as shown in fig.6 to fig.11.

In general temperature has a significant effect on the mechanical properties of polymers such as modulus, tensile strength, and hardness .Polymers soften and eventually flow as they are heated. Therefore, it is important to know the limiting temperatures at which polymer components can still be loaded with moderate deformations as temperature increases in a polymeric material, a gradual expansion of the material occurs, resulting in more free volume as well as weakening of the bonding forces which form the polymer structure and constitute the network of polymer chains holding the material together. For example, a reduction in van der Waals forces occurs between molecules resulting in less internal strength with increasing temperature which is reflected in a reduced maximum tensile strength. This is accompanied by an increase in the strain that the polymer can sustain without breaking [14].

The variation of temperature is shown to have an even higher effect on the yield strength of HDPE fig.6 due to semi crystallites which reduced shear yielding while has no effect or at least very little on PVC and PVCC. It means that yield strength for HDPE is somewhat higher than PVC and temperature sensitive while of PVC is not more over .This result is opposite to the result of **Anne [2]** for comparison purposes. As expected, both PVC and PVCC have higher strength than HDPE at all temperatures fig.7. The temperature sensitivity of the strengths of PVC and PVCC materials is more than that of HDPE; The tensile strength values obtain at lower temperature were less higher than those obtained at higher temperature due to thermo-physical properties and molecular bonding strength of polymeric filaments at varied temperature conditions, HDPE(semi-crystalline thermoplastic) have lower interface shear resistance than all. These results are much coincidence with that obtained in Tanay researches about elevated temperature effect on interface shear behavior [10].

Most of HDPE post –peak strength loss .for this reason large strength loss at fracture fig.8 is that the asperities of the textured HDPE geomembrance tore or pulled the fibers of the geotextile and the geomembrane texturing was smoothed or polished on the other hand the faille PVC geomembrance tore or pulled out only a small quantity of fibers from the geomembrance which allowed the geomembrance to stay relatively intact and maintain the interface strength.

The modulus of elasticity expresses the polymer stiffness, and also lies in a broad range [15].

The variation of modulus of elasticity E as a function of absolute temperature was shown in Fig. 9. It can be observed that in the present temperature the range of E was valid at different temperature; therefore, it is evident that the filament modulus is inversely proportional to temperature. The maximum stiffness for all tests conducted in this study was obtained at the lowest temperature.

At higher temperatures, the filaments underwent larger deformation before proceeding to the occurrence of yielding or transition deformation from elastic to plastic elongation.

Shear strength characteristics pointed out a decrease of elongation value at yield point in HDPE compared with PVC and PVCC fig.10 because they have flexible and elastic nature compared with PVC and PVCC.

In HDPE rising the temperature fig. 11, the elongation increases and the body coverts from rigid and brittle (at low temperature) to soft and ductile .The HDPE has a nearly isochoric plastic deformation. Due to ductile behavior, the test was aborted before fracture occurred in the specimen compared with PVC which is rigid and strong modulus and tensile strength are high while elongation is medium exceeding.

Tensile strength characteristics pointed out a decrease of mechanical properties value in HDPE and PVC compared with PVCC (composite polymer) this may be because it was protected by resin and therefore no change occurred ,a also increase in the interfacial adhesion between the composite content which improve the stability and decreases chain sliding [5]. much similar to what was observed with **Blanco [16]**. The composite material behavior under different temperatures is an important parameter to be considered because it can, in many cases, determine the upper bound on the temperatures at which a material has suitable properties [11].

So the effect of temperature on shear and tensile strength can vary greatly for the polymers depending on bounding and sample configuration as a consequence of diversity of chain and molecular structure found within the broad range of polymer.

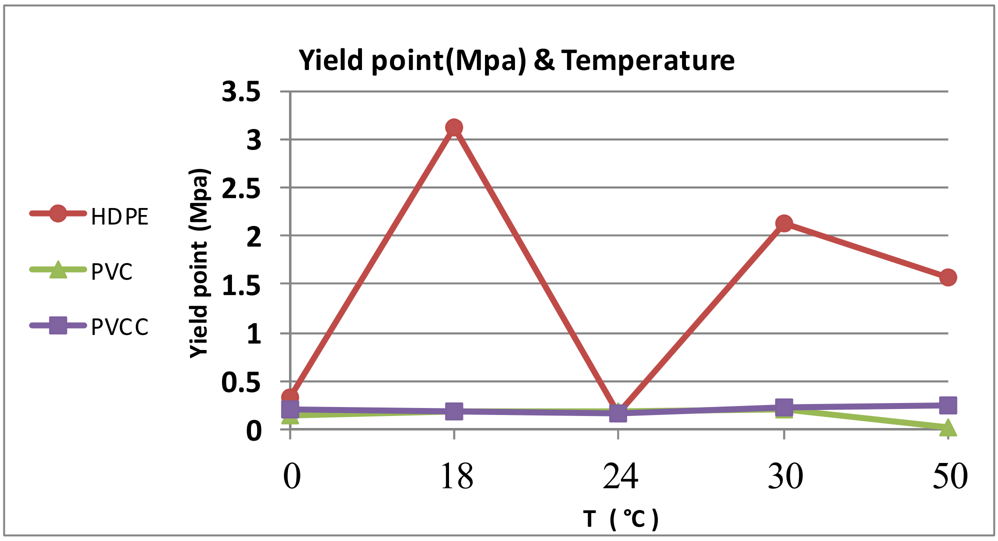


Figure.(6) Relationship between temperature and yield point for HDPE, PVC and PVCC.

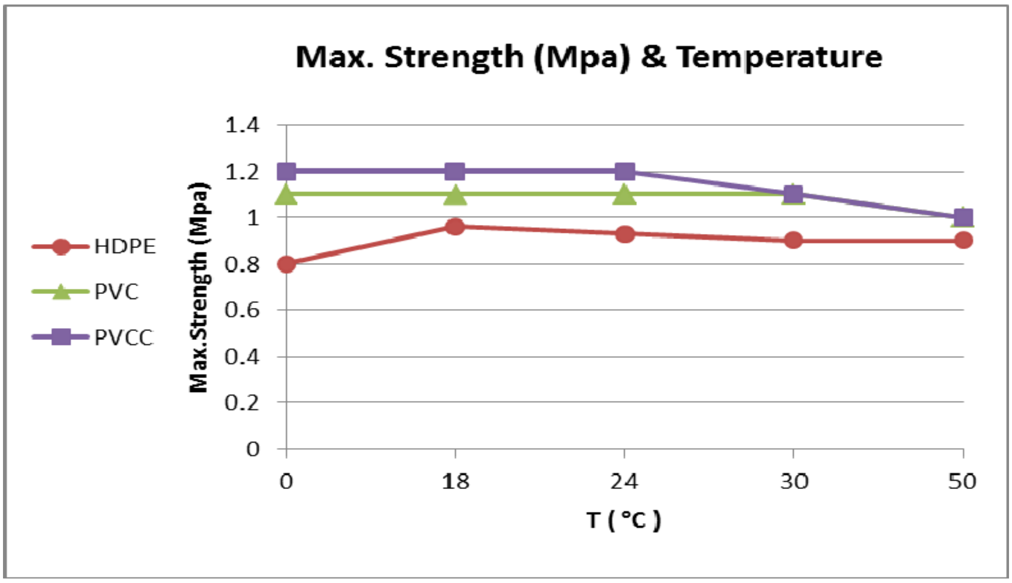


Figure.(7) Relationship between temperature and maximum strength for HDPE , PVC and PVCC.

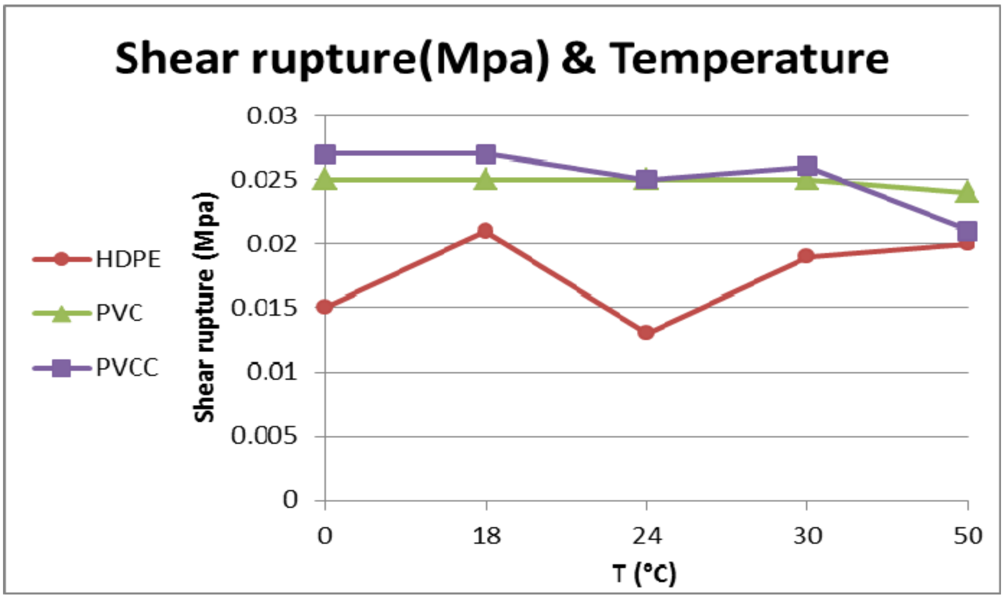


Figure.(8) Relationship between temperature and shear rupture for HDPE, PVC and PVCC.

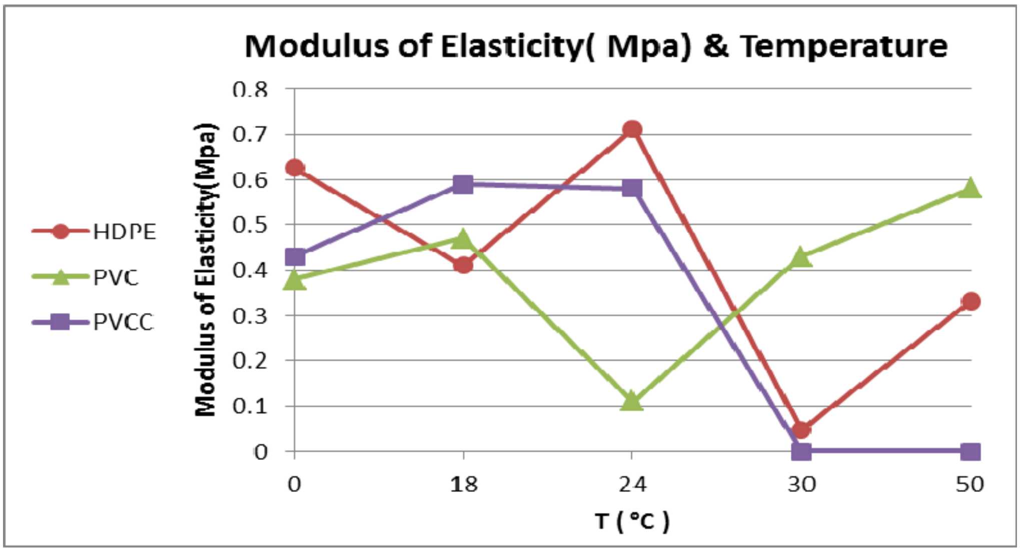
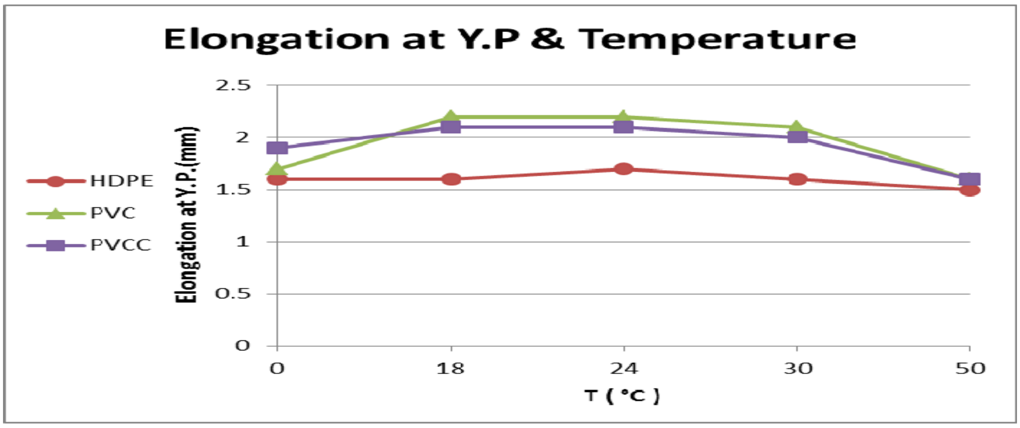
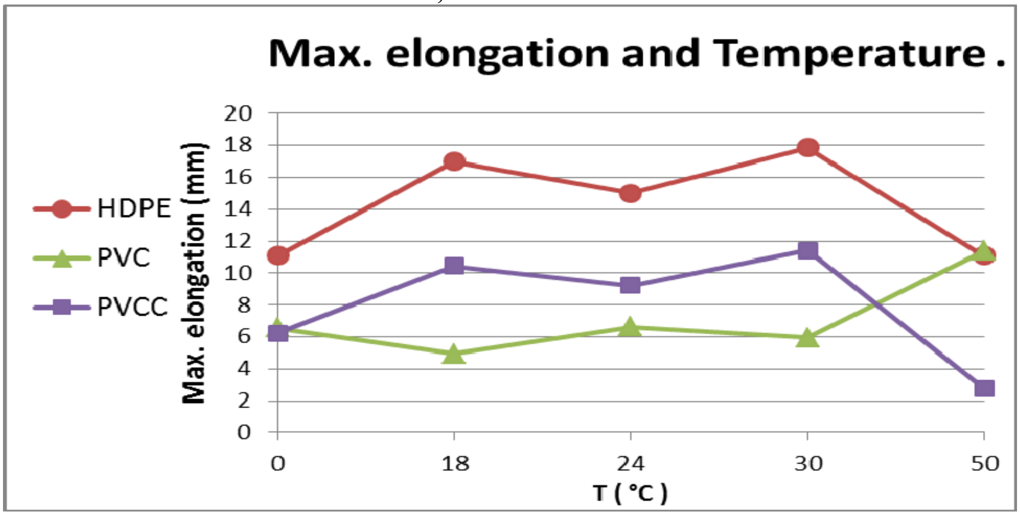


Figure.(9) Relationship between temperature and Elasticity for HDPE, PVC and PVCC.



Figure(10) Relationship between temperature and Elongation at yield point for HDPE, PVC and PVCC.



Figure(11) Relationship between temperature and maximum elongation for HDPE, PVC and PVCC.

CONCLUSIONS

1-The temperature sensitivity of the yield strength of HDPE material is more than that of PVC and PVCC and decreases with increasing temperature.

2-Increasing temperature has no effect on yield strength of PVC and PVCC but an increase in HDPE about 15.4% .

3- Effect of temperature on shear strength can vary greatly for the polymer depending on type of polymers and sample configuration.

4-Shear strength characteristics pointed out a decrease by (1.76%) of elongation values in HDPE compared with PVC and PVCC.

5-Increasing temperature to 70 °C causes distortion of the samples and no data can record for all polymers selected.

6-However the significance of temperature effect on polymers behavior has been studied, still needs further investigation.

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