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Effect of the Crosslinking Between the Asphalt and Polyethylene on the Viscoelastic Properties of Polyethylene Melt Extruding Through Capillary

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Abstract

The viscoelastic properties of polyethylene were studied with different percent of asphalt (1%,3%,5%,7% and 10%) and 1% of organic peroxide as crosslinking agent. The data shows that the 1% of asphalt loading in the polymer decrease the shear stress and viscosity of the matrix polymer in all the test temperature (170,190,210 and 230^{o}C) .The best percent of asphalt that gives controlled crosslinking between the polymer chains was 1% asphalt loading, while higher asphalt percent will increase the chain entanglements .

الخلاصة

صفات اللزوجة – صلادة للبولي أثيلين قد درست بإضافة نسب مختلفة من الأسفلت (١%، ٣%، ٥%، ٧% و ١٠%) و بإضافة ١% بيروكسيد عضوي كمادة مشابكه. أظهرت النتائج أن البوليمر الحاوي على ١% من الأسفلت يقلل جهد القص و اللزوجة في كل درجات الحرارة (٢١٠، ١٩٠، ١٧٠ و ٢٣٠ درجة مئوية). أفضل نسب من الأسفلت التي أدت إلى التشابك بين سلاسل البوليمر هي نسبة ١%، بينما النسب الأعلى زادت من نسبة المعقد بين سلاسل البوليمر.

Introduction

Many fabrication process for polymeric objects include melt extrusion in which the molten polymer is conveyed by a ram or a screw and the melt is then forced through a shaping die in continuous processing or into a mold for the manufacture of discrete molded parts[(1)]. Most commercial polymers have high molecular weight ,their chain was highly entangled for that the flow properties of these polymer differ from the low molecular weight polymer. Viscosity is an important characterizing the flow of polymer fluids[(2)].The factors affecting the viscosity were shear stress, shear rate, temperature, pressure and molecular chain structure.Crosslinking between the polymer chain and with other materials contain functional groups[(3-6)] will effect the molecular chain structure and effect the chain entanglements. In this work we study the effect of asphalt percent (0,1,3,5,7,and 10%) and 1% organic peroxide on the shear stress and viscosity of low density polyethylene 463 at different shear arte and different temperatures .

Experimental

Materials

asphalt supplied from Basrah refinery with the following specifications.

PROPERTY	VALUE
Specific gravity at 15.6 °C	1.04
Flash point °C min.	240
Penetration at 25 °C (100 gm, 5 sec, 0.1 mm)	40-50
Softening point °C	49-58
Ductility at 25 °C min. (cm)	100
Solubility in CCl_4 % w min.	99
Loss on heating % w max (5h, 163 °C)	0.5

min.: minimum, max. : Maximum

Low density polyethylene was supplied by SCPI (state company of petrochemical Industry), Basrah – Iraq with (MI=0.38 g/10min. and density=0.924 g / cm^3).2-ethyl terbutyl-hexanoate peroxide (C_{67}) was supplied by Pergon g.m.b.h company with peroxide content (98%**)**.

Instrument

1- Capillary rheometer (Instron Model 3211).the capillary die (D=1.257 mm, L/D=80)and the piston speeds (V) were 0.02,0.06,2.00,6.00 and 20.00 cm/min. .The relationship between shear rate (γ_w) and V expressed as follows:

$$\gamma_w = \frac{2}{15} V_{XH} \frac{D_b^2}{D_c^3}$$

where D_b and D_c is the diameter of the cylinder and capillary diameter.

The wall shear stress was calculated using the following equations:[(7)]

Wall shear stress (τ_w) = $\dfrac{\Delta P}{4L} \times D_b$

Where ΔP = pressure applied along the capillary ,D_b= diameter of the cylinder and L = length of the capillary .
The apparent viscosity (η_a) was calculated from the equation :

$$\eta_a = \frac{\tau_w}{\gamma_w}$$

Results and discussion

Plot of apparent shear stress versus shear rate(flow curve) of the composite PE/asphalt (different loading percent) with 1% peroxide as crosslinking agent was shown in Fig.1.It is seen that the shear stress increased with an increase of shear rate. At low value of shear rate (velocity) (2.74,9.15 and 27.4 1/S) the pure polyethylene with 1% peroxide have the lower values of shear stress ,this can be attributed to the low speed of test which gives the chain suffient time to arrange with the direction of flow. With increasing the value of shear rate the pure polyethylene shear stress was higher than the other asphalt loading and the lower value of shear stress was for 1% asphalt loading .We expected that the crosslinking between the asphalt functional groups and polyethylene chain at 1% asphalt loading gives the better control .

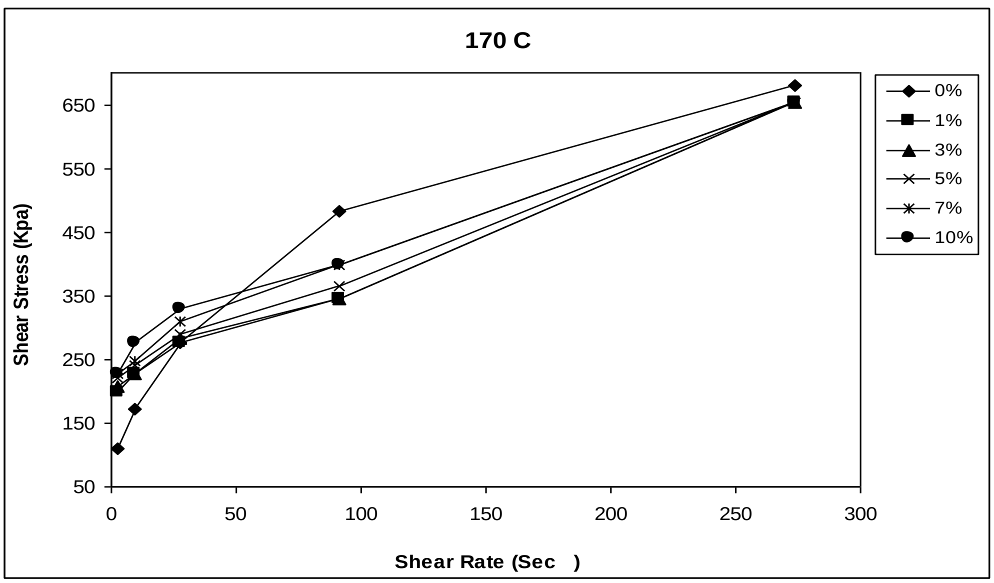

Fig.1. Relationship between apparent shear stress and shear rate for PE/asphalt and 1% peroxide at 170 ^{o}C.

arrangement of the chain and exhibited the highest flow curve. At higher temperature of test(190,210 and 230 ^{o}C), Fig.2,3 and 4 the percent of crosslinking increase between the polyethylene chains with the asphalt functional groups, which causes highly chain entanglements and the flow of polymer was restricted and the shear stress increase with the 1% asphalt loading remain with less shear stress value compared with the other percent of asphalt loading

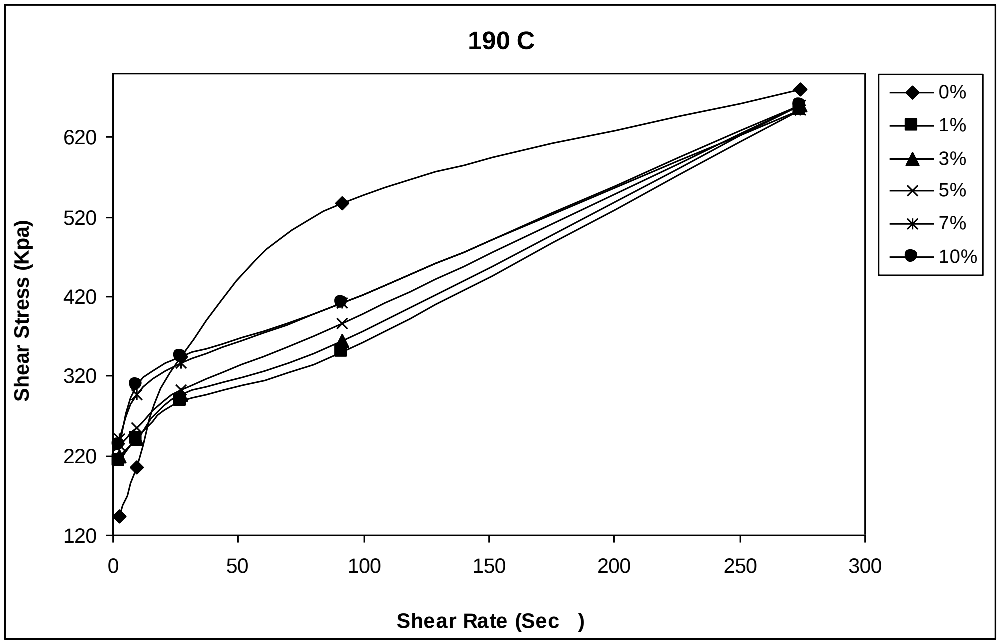

Fig.٢. Relationship between apparent shear stress and shear rate for PE/asphalt and 1% peroxide at 190 ^oC

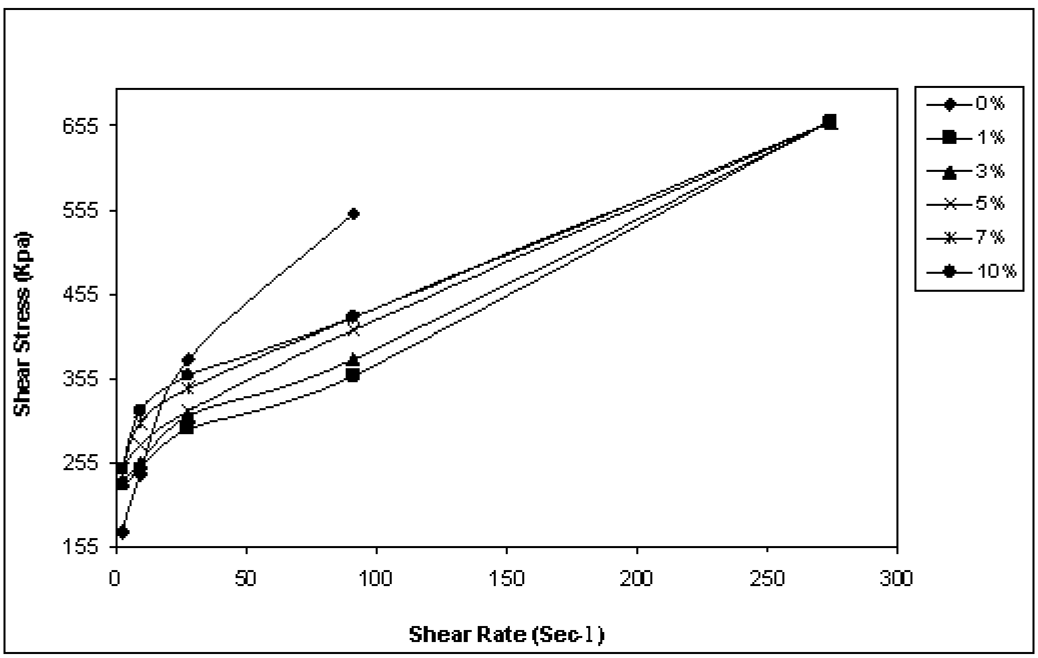

Fig.٣. Relationship between apparent shear stress and shear rate for PE/asphalt and 1% peroxide at 210 ^oC

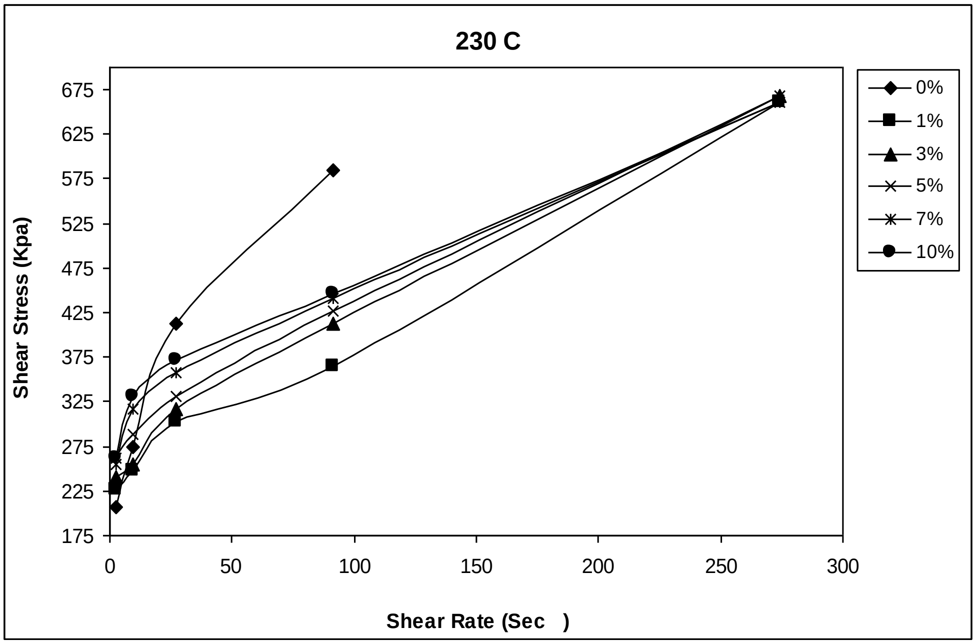

Fig.4. Relationship between apparent shear stress and shear rate for PE/asphalt and 1% peroxide at 230 ^{o}C

the relationship between the apparent shear viscosity and shear rate of the composite from PE/asphalt (different loading percent) with 1% peroxide as crosslinking agent was shown in table 1. We observed a decreasing in the value of shear viscosity with an increasing in shear rate. Therefore, for all the polyethylene melt exhibited shear thinning behavior that is the polymer was pseudopalstic[8]. at a given apparent shear rate, the apparent shear viscosity increased with increasing the temperature. The pure polyethylene with 1% peroxide show lower value of apparent shear viscosity at lower value of shear rate depending on the temperature, while the 1% percent of asphalt loading and 1% peroxide have the lower value of apparent shear viscosity. We contribute this behaviors to the appropriate crosslinking that reduce the resistance of the polyethylene to flow.

Table 1: Shows the relationship between apparent shear viscosity and shear rate

VISCOSITY (KPA/S)												
		0%				1%				3%		
$Sh.Ra(S^{-1})$	Temperature (^{O}C)											
	170	190	210	230	170	190	210	230	170	190	210	230
2.74	40.17	52.72	62.77	75.32	72.81	77.83	82.86	82.86	75.32	80.35	85.37	87.88
9.15	18.79	22.55	26.31	30.07	24.81	26.31	27.06	27.06	24.81	26.31	27.82	27.82
27.4	10.04	12.55	13.81	15.06	10.04	10.54	10.79	11.04	10.29	10.79	11.29	11.55
91.5	5.26	5.86	6.01	6.39	3.75	3.83	3.90	3.98	3.75	3.98	4.13	4.51
274	2.48	2.48			2.38	2.38	2.41	2.41	2.38	2.41	2.41	2.43
		5%				7%				10%		
2.74	80.35	85.37	90.39	95.41	82.86	87.88	90.39	92.90	82.86	85.37	90.39	95.41
9.15	26.31	27.82	30.07	31.58	27.06	32.33	33.08	34.58	30.07	33.83	34.58	36.09
27.4	10.54	11.04	11.55	12.05	11.29	12.30	12.55	13.05	12.05	12.55	13.05	13.55
91.5	3.98	4.21	4.51	4.66	4.36	4.51	4.66	4.81	4.36	4.51	4.66	4.88
274	2.38	2.41	2.41	2.43	2.38	2.385	2.41	2.41	2.38	2.41	2.41	2.41

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