CHAPTER IV
RESULTS AND DISCUSSION

4.1 Thermal Analysis

Thermogravimetric analysis was carried out on both ESCOR® terpolymers and EAA copolymers to determine how sensitive the materials to degradation during processing. Differential scanning calorimetry was used to determine the melting temperature, and crystallization temperature of the blends, and the optimum condition that would be used for blending the two polymers.

4.1.1 Thermogravimetric Analysis

Thermogravimetric analysis (TGA) of ESCOR® terpolymers and EAA copolymers were shown in Figure 3. In general, weight loss will be observed when volatile products from degradation of the samples occurred. From the experiment, the initial weight loss of the materials began at 320-350° C and reached a constant weight plateau after losing about 98.84 - 99.02% of its initial weight. The degradation temperature of Generally state that all of the two polymers used in this experiment was 450°C.

4.1.2 Differential Scanning Calorimetry

The thermograms from differential scanning calorimetry (DSC) of two polymers were shown in table 4. All the values recorded from DSC were consistent with values reported from Exxon. Results from DSC suggested that that optimum temperature that would be used for blending the two polymers was 130°C. No fractional crystallinity results could be obtained from the DSC thermograms. This is because it was not possible to draw a baseline using the thermograms obtained
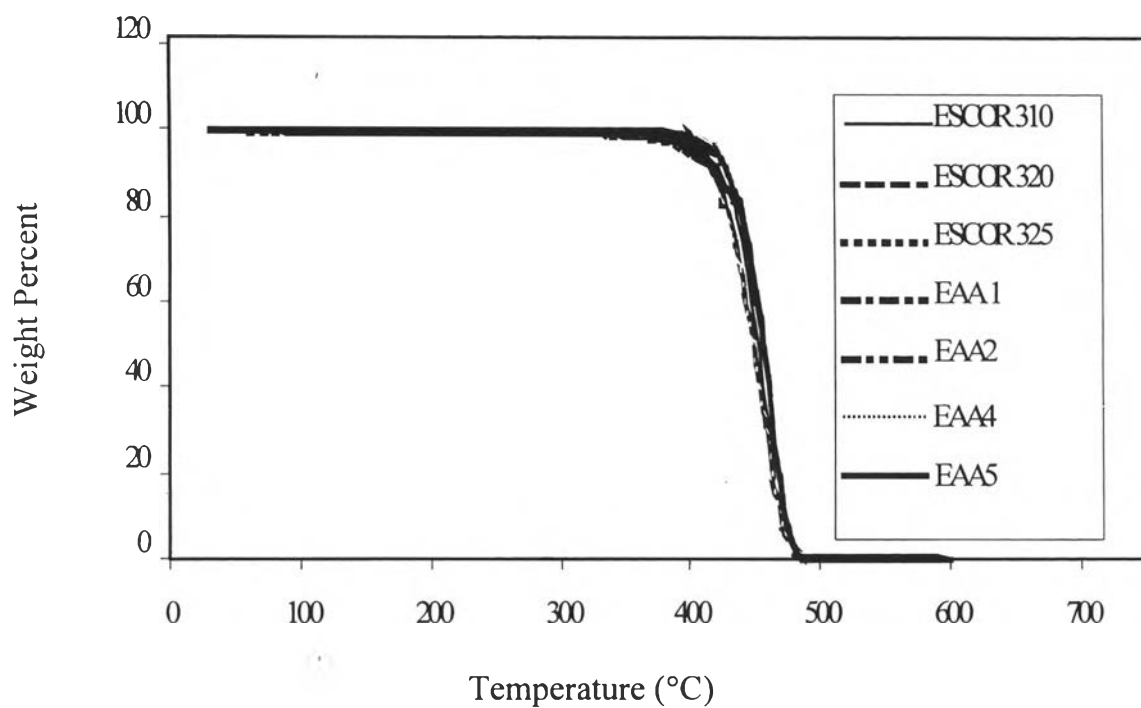
Figure 3 TGA thermograms of ESCOR® terpolymers and EAA copolymers.

Table 4 Melting temperature (T_m, °C) and crystallization temperature (T_c, °C) of the materials.

Materials	T_m (°C)	T_c (°C)
ESCOR® 310	93.5/94*	71.2/74*
ESCOR®320	77/76*	-
ESCOR® 325	73.7/73*	56/49*
EAA 1	104.1	85.2
EAA 2	102.4	81.8
EAA 4	100.2	80.3
EAA 5	98.1	73.4

*Exxon value

4.2 Mechanical Properties

Mechanical properties of the blends are shown in figure 4-7.
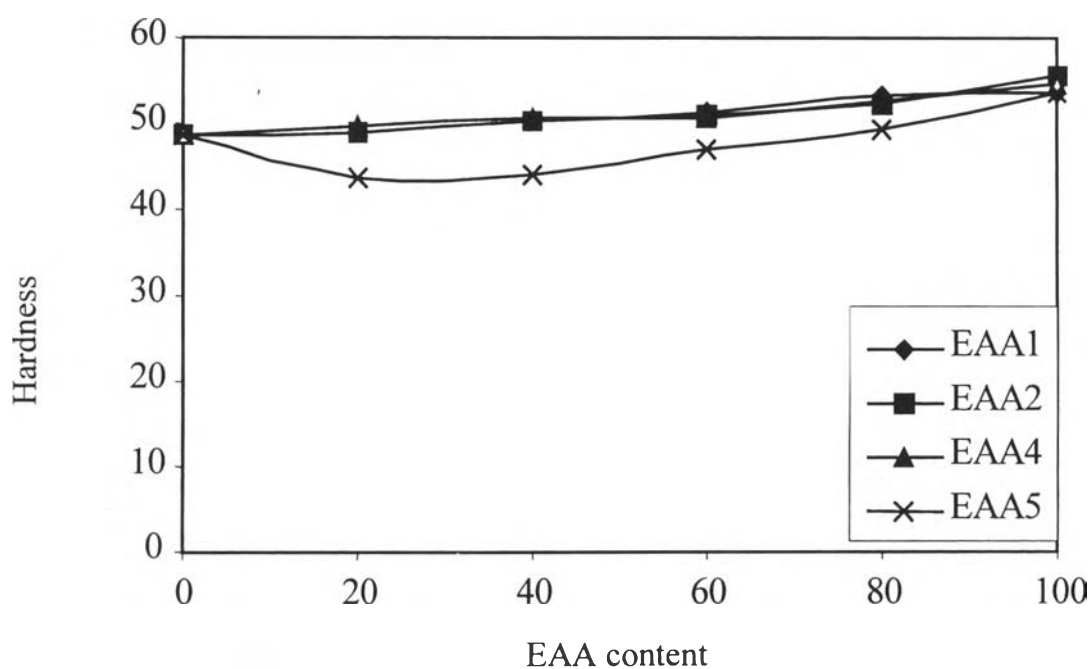
4.2.1 Hardness

Figure 4a Shore D hardness of blends of ESCOR™ 310/EAAs.

Figure 4 (a-c) show result from the hardness test of the blends measured on the shore-D scale. From the results, figure 4(a), 4(b), and 4(c) indicate that hardness gradually increase as EAA content increases from 0 wt % to 100 wt %.
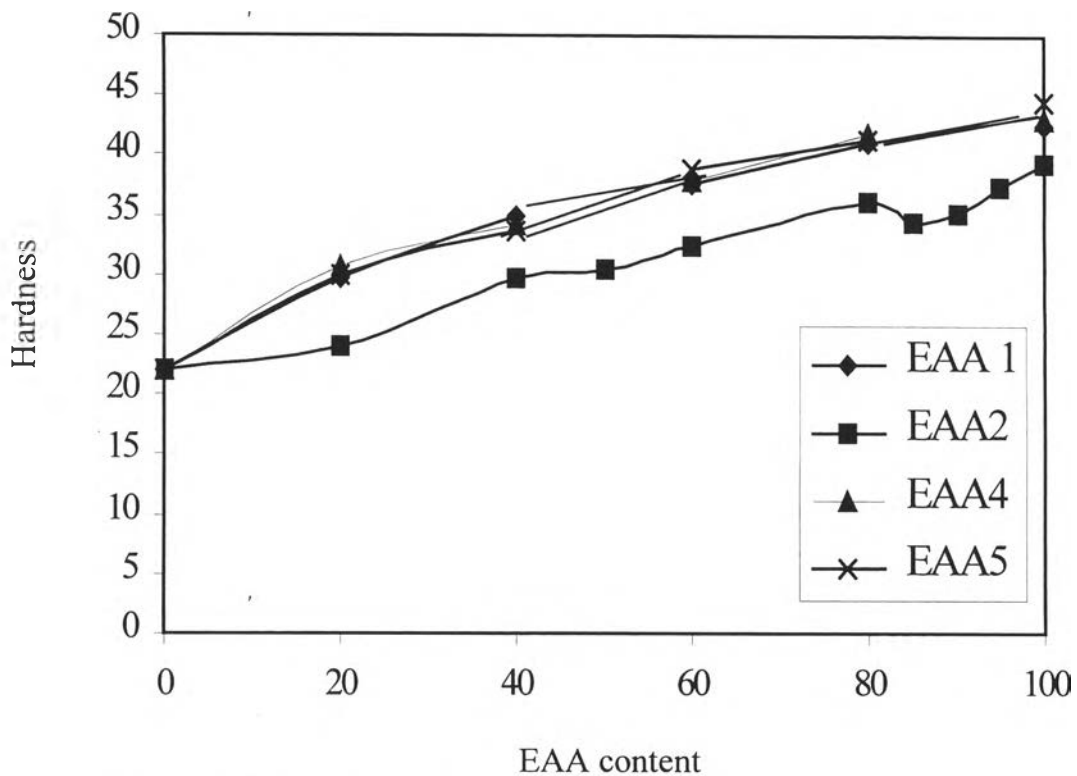
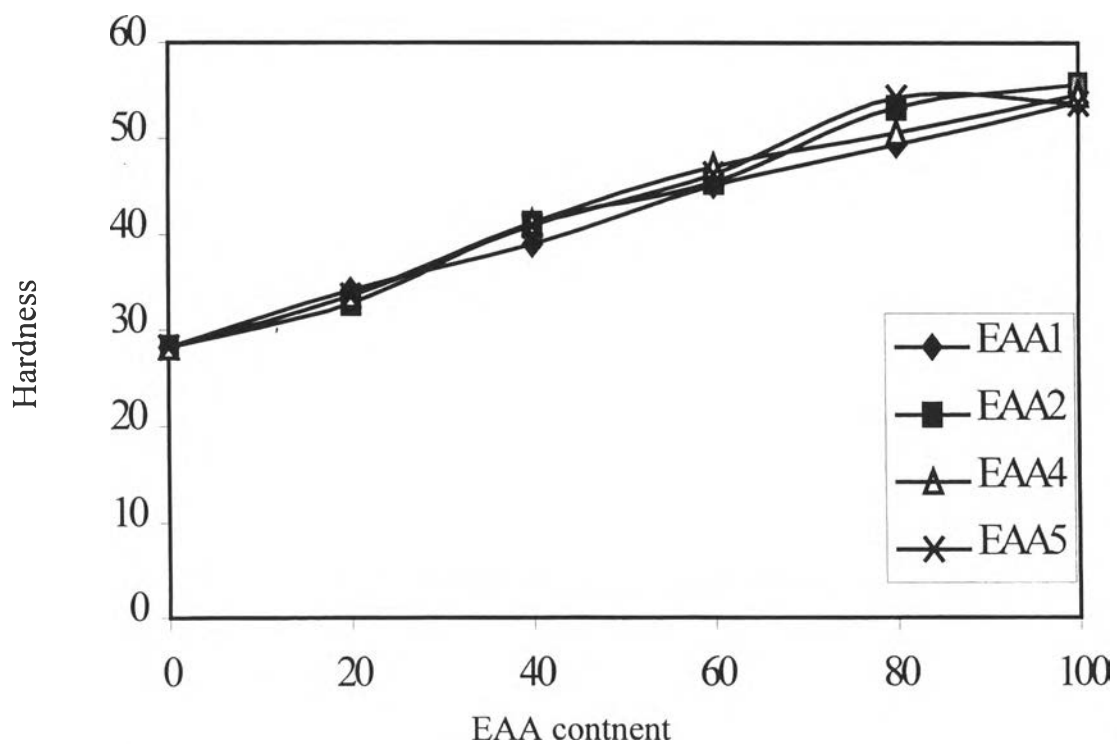**Figure 4b** Shore D hardness of ESCOR® 320/EAAs.

Figure 4c Shore D hardness of blends of ESCOR® 325/EAAs.

Most blends showed a linear relationship between hardness and blend composition. A linear relationship suggests that the fractional crystallinity scales with blend composition. Since both blends can be crystalline, one can really make no underlying conclusions regarding morphology and blend composition. Some blends showed the synergistic behavior, for example the blends of ESCOR®320/EAAs (at 80 and 95 wt % EAA content), ESCOR®325/EAA2 (at 80 wt % EAA content), and ESCOR® 325/EAA5 (at 80 wt % EAA content). This synergistic behavior is probably a result of higher crystallinity in these samples and also might be explained by the greater interaction, such as hydrogen bonding and/or dipole-dipole interaction, between the blend constituents forming these blends (Mohanty *et al.*, 1995 and Jo *et al.*, 1990).

4.2.2 Tensile Properties

4.2.2.1 Maximum Stress

The maximum stress reported was a value of maximum stress at 400% strain. This is because the entire specimens failed to break during the tensile property measurement.

It is evident from figure 5 (a-c) that the maximum strength increases (in a positive trend) as the EAA ratio in the blend increases, starting from 0 to 100 wt % of EAA. The stress values for the blends are intermediate to those of the pure components, but there is a synergism in some of the pair studied (such as ESCOR®325/EAA5 at 80 wt% EAA5 content). This could be explained by the greater interaction between the blend constituents forming these blends as suggested earlier (Mohanty *et al.*, 1995). Samples that have stresses below a linear relationship between the two stresses on the axes are probably blends that are not miscible (Deanin *et al.*, 1989)
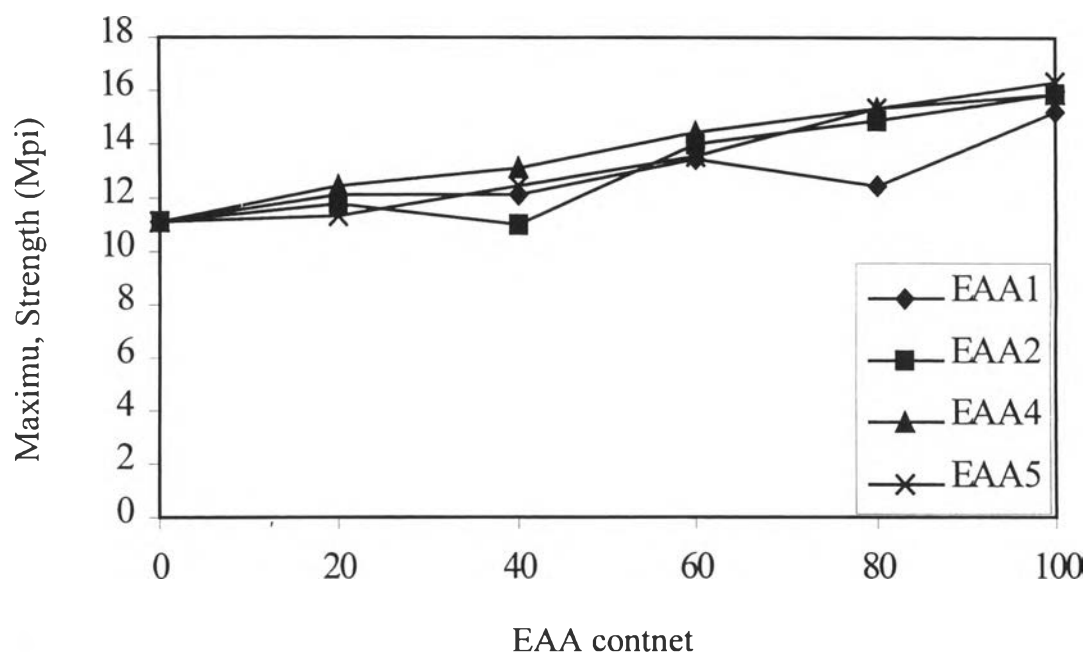
Figure 5a Maximum strength of blends of ESCOR® 310/EAAs.

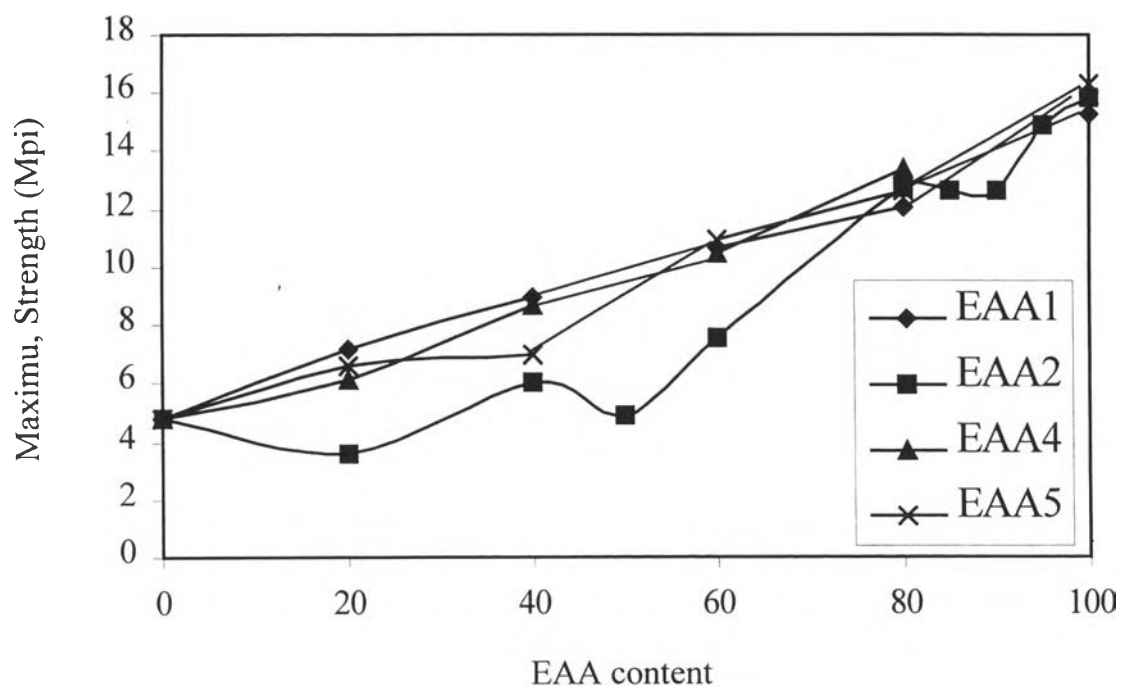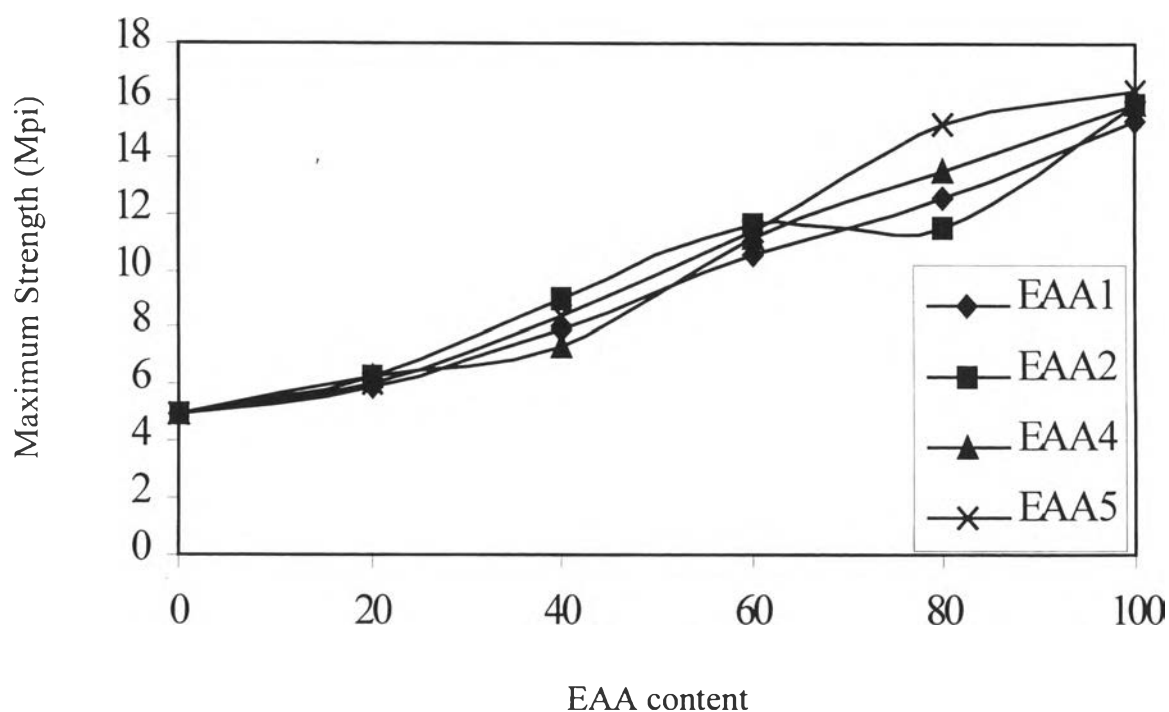**Figure 5b** Maximum strength of blends of ESCOR® 320/EAAs.

Figure 5c Maximum strength of blends of ESCOR° 325/EAAs.

Theoretically, blends containing higher proportion of EAA would show higher tensile strength as EAA would dominate the strength of the matrix due to increase in the presence of the ionic bond (Mohanty *et al.*, 1995).

2.2.3 Young's Modulus

Figure 6 (a-c) show Young's modulus of the blends. Young's modulus of the blends increases slightly with increasing EAA content. The modulus is primarily a function of two parameters in this material, the amount of orientation and the fractional crystallinity. Since nominally the same procedure was used in terms of processing, differences in orientation should be a result only of differences in viscosity, with higher viscosity materials showing higher orientations. Miscibility, especially in the melt may also be a factor as well. Some blends showed the synergistic property (such as ESCOR®320/EAA2 at 90 and 95 wt% EAA2 content),

which might be due to the molecular mobility (decreasing in crystallinity) between blend segments (Painter et al., 1997).

EAA1 and EAA4 seem to behave better that the other two materials with all three ESCOR polymers, suggesting that the viscosities of these two materials are more closely matched with the ESCOR terpolymers, and/or the miscibility is better.
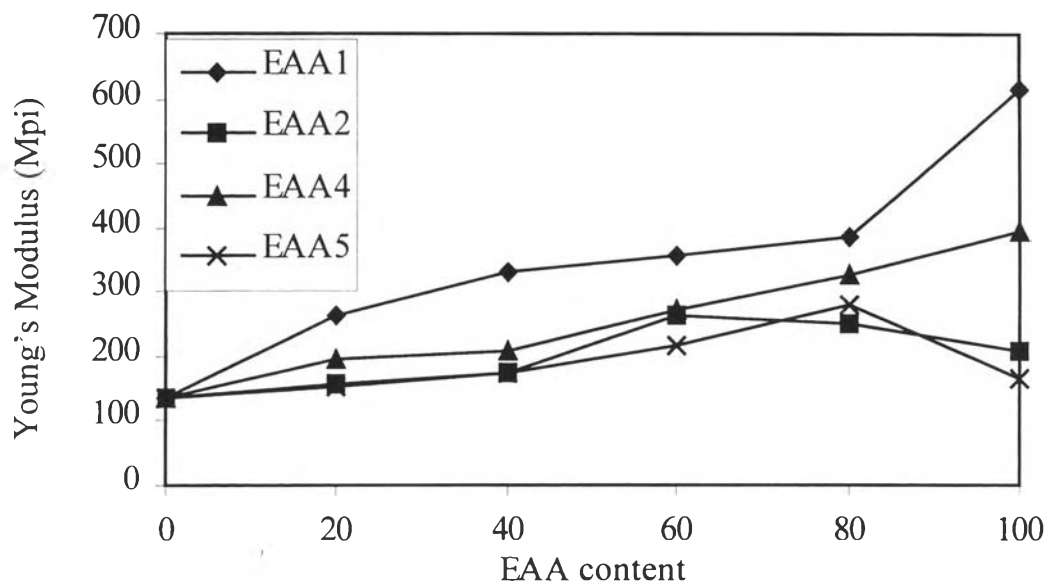

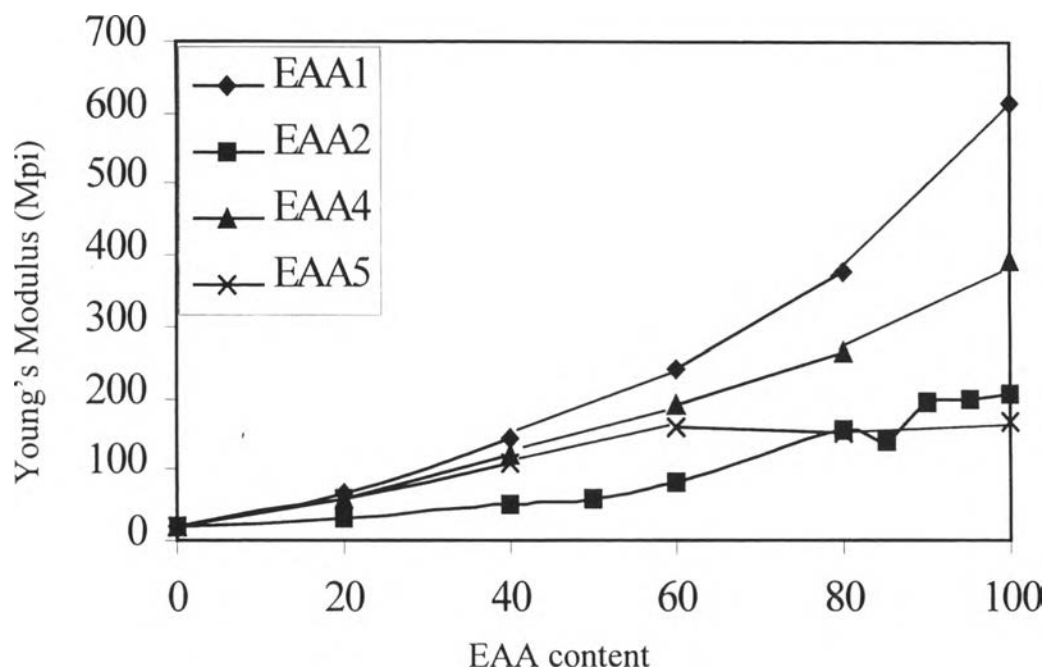**Figure 6a** Young's modulus of blends of ESCOR®310/EAAs.
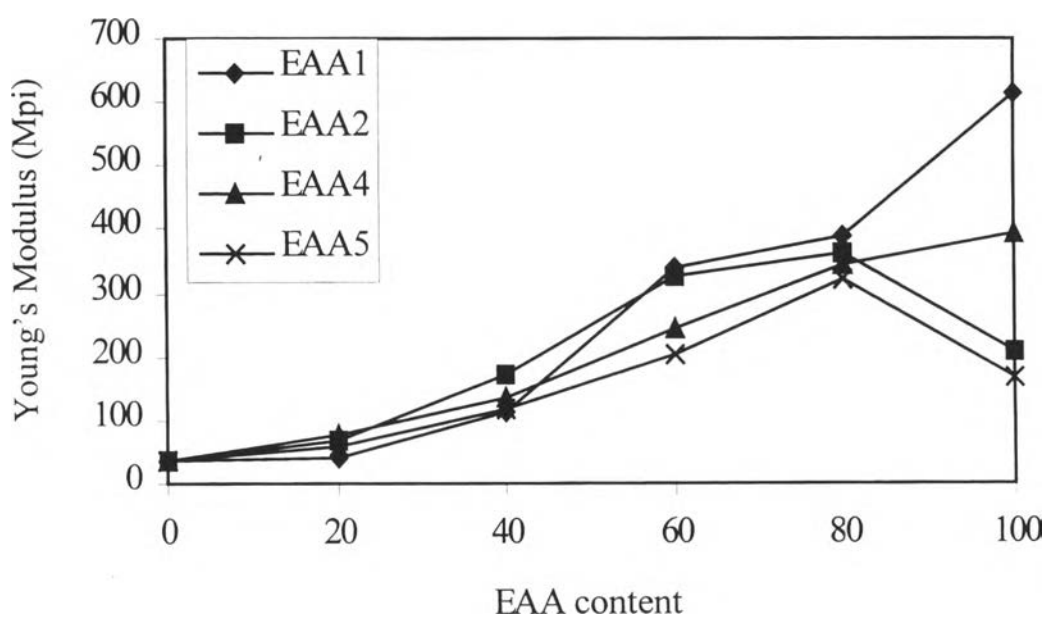
Figure 6b Young's modulus of blends of ESCOR®320/EAAs.

Figure 6c Young's modulus of blends of ESCOR®325/EAAs.

4.2.2.4 Gloss

The effect of EAA content on gloss is shown in figure 7 (a-f). As expected, EAA resulted in reducing crystallinity and therefore film clarity and gloss are higher (Mergenhagen, 1993).

For most of the blends, the gloss drops upon blending. Typically, high gloss materials are more highly valued, so this behavior is not desired. A one-phase non-crystalline material would presumably have the highest gloss, so the fact that the gloss drops in most blends probably indicates phase separation. Transparency of blends; a quick but not totally reliable method for measuring miscibility of blends (Fox *et al.*, 1980). and results from both the tensile strength and the modulus indicating phase separation occurred in theses blends. However there are a few samples where the gloss is actually higher than either pure component such as ESCOR®310/EAA5 at 80wt % EAA5 suggesting miscibility of these blends.
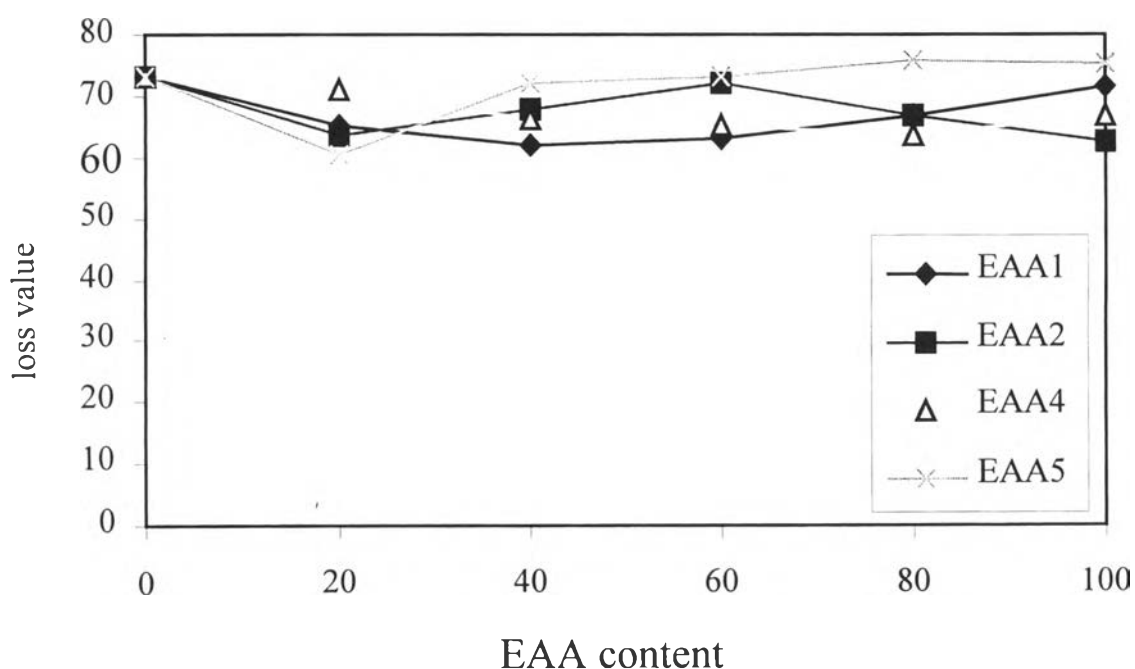

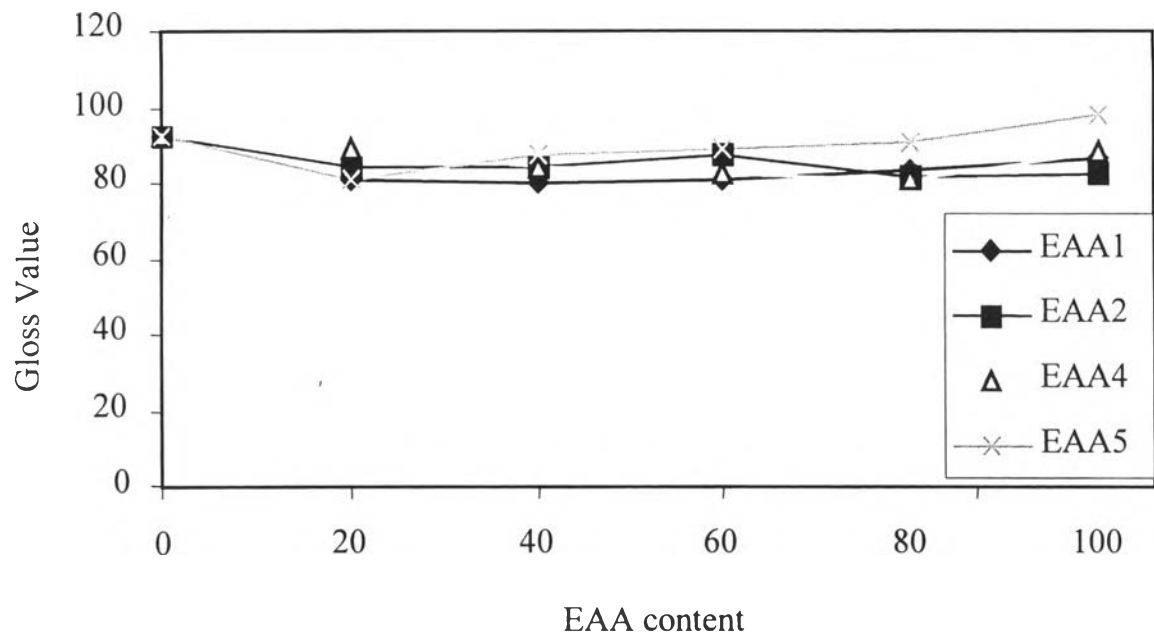**Figure 7a** Gloss of blends at 20° of ESCOR®310/EAAs blends.

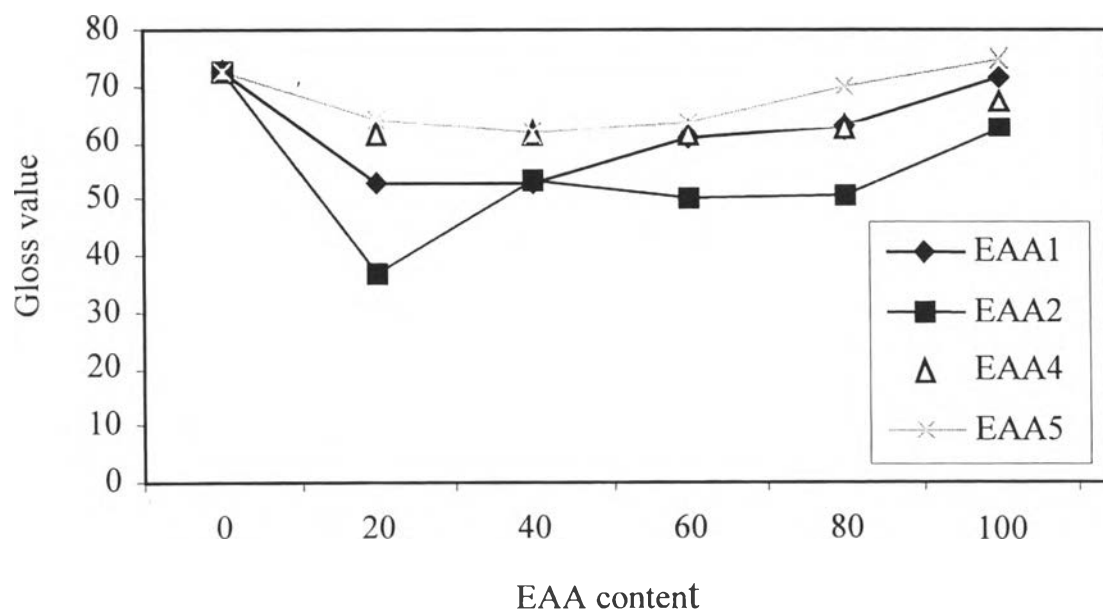**Figure 7b** Gloss of blends at 60° of ESCOR®310/EAAs blends.

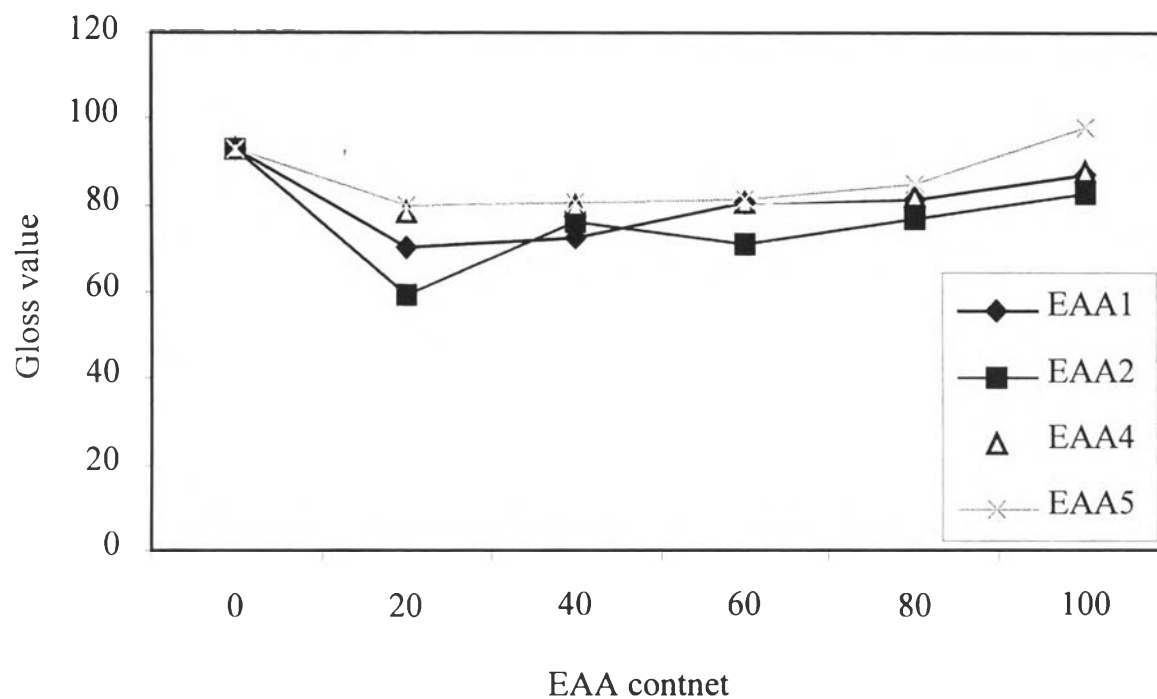**Figure 7c** Gloss of blends at 20° of ESCOR®320/EAAs blends.

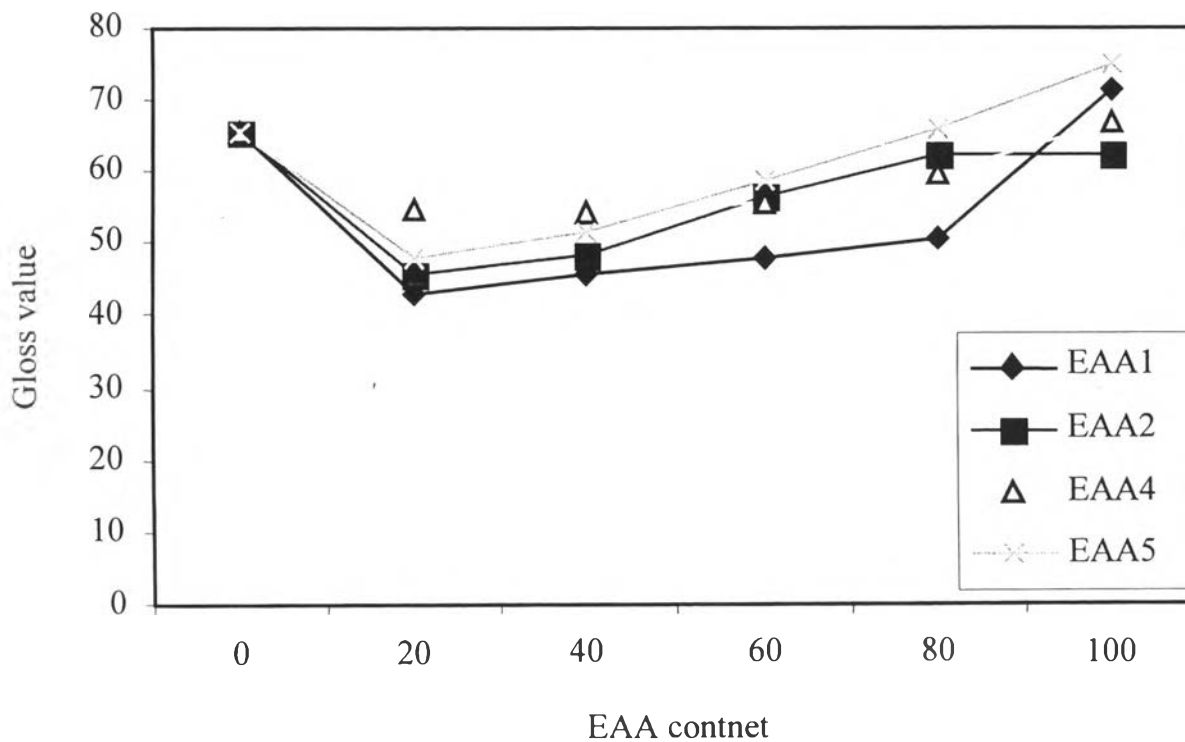**Figure 7d** Gloss of blends at 60° of ESCOR®320/EAAs blends.

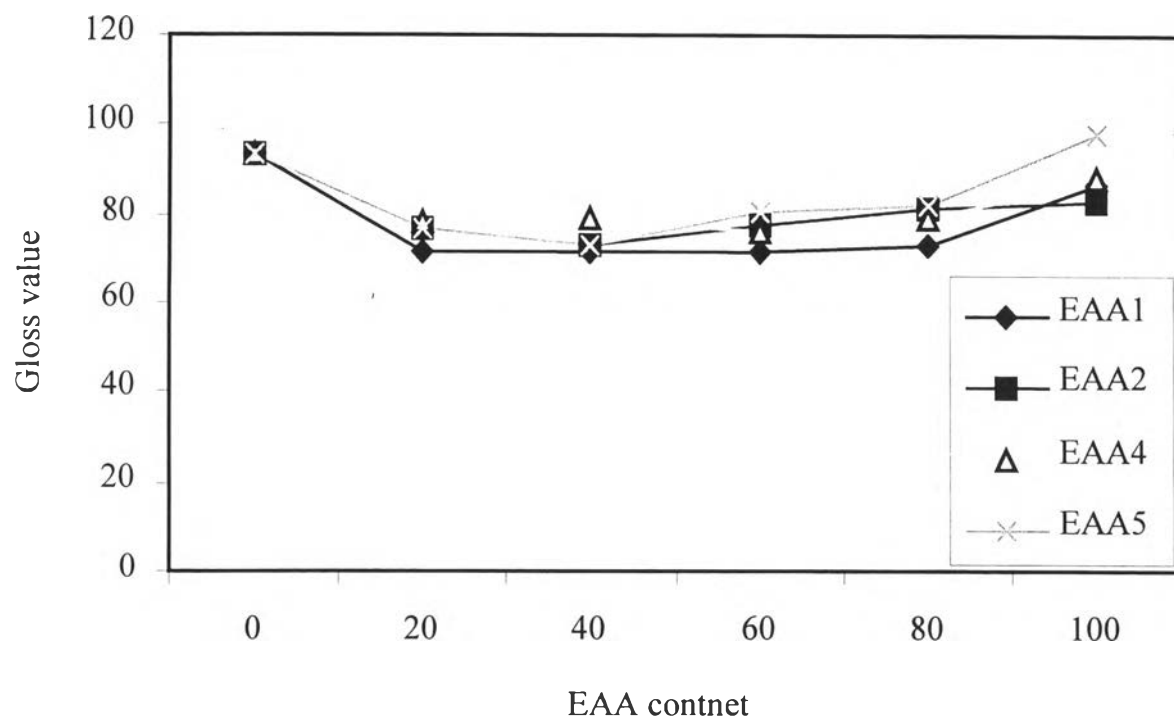**Figure 7e** Gloss of blends at 20° of ESCOR®325/EAAs blends.

Figure 7f Gloss of blends at 60° of ESCOR°325/EAAs blends.

4.3 Rheological Properties

Detail studies of ESCOR/EAA blends were carried out and ESCOR®
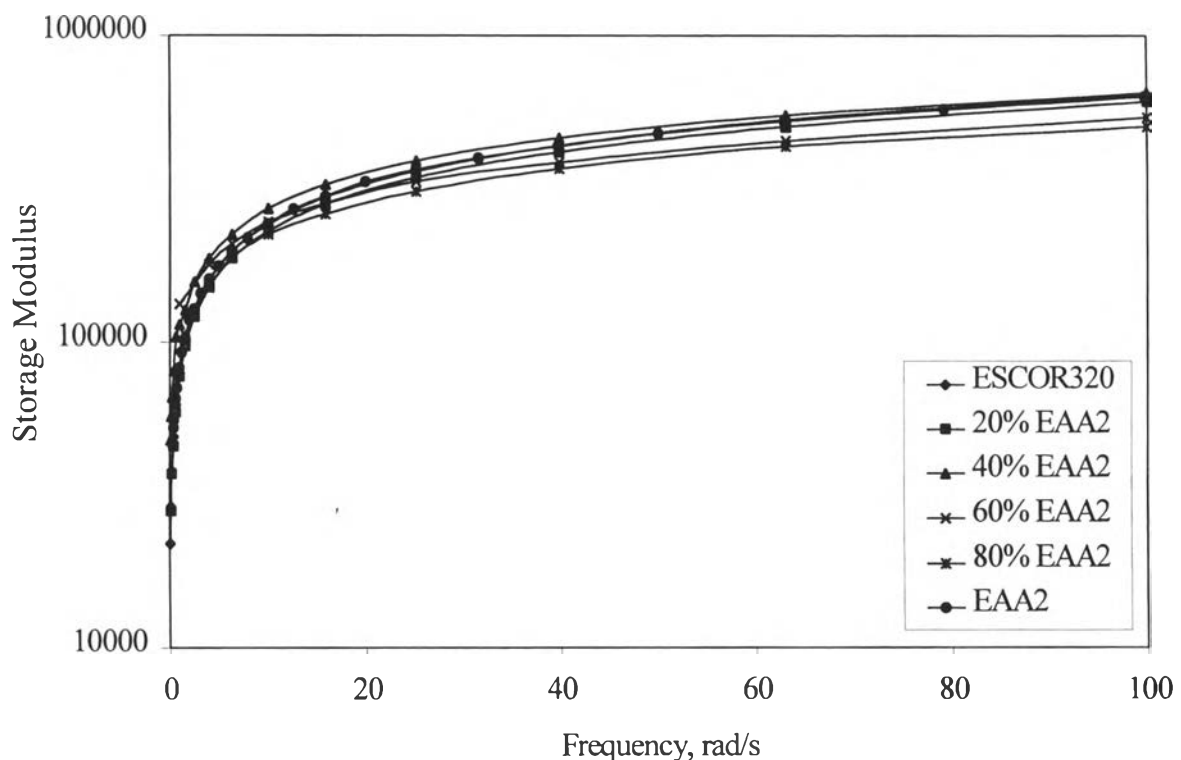320/EAA2 was chosen for this study.

Figure 8   Storage modulus, G', of ESCOR®320 terpolymer and EAA2
copolymer blends.

From tan δ (damping properties) = loss modulus (G")/ storage modulus
(G'). The good damping properties should have high storage modulus
(Aklonis *et al.,* 1983). From figure 8 and 9, suggesting that the most suitable
to use as a damping material should be the blend of ESCOR®320 terpolymer
and EAA2 copolymer blends at 60 wt % EAA2, which is accompanied with
having good mechanical properties such as hardness, gloss, and tensile
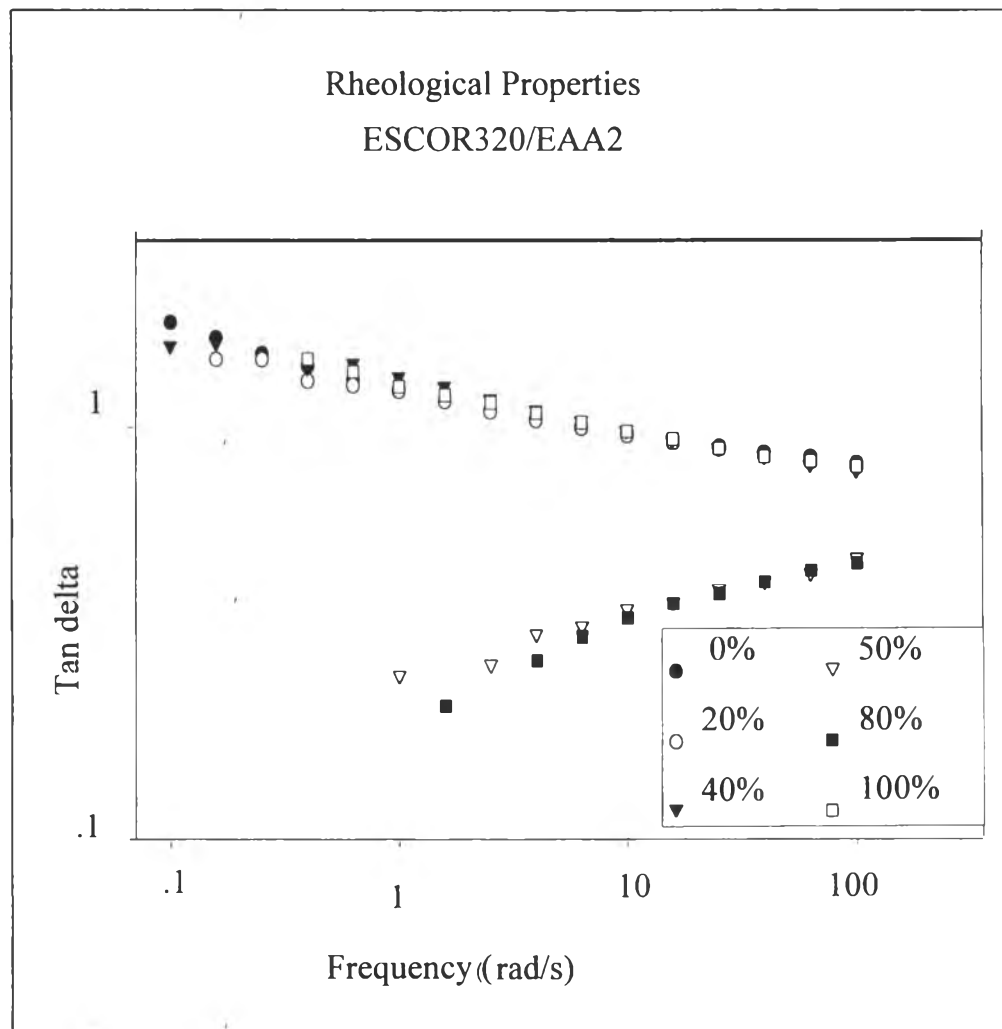properties as mention earlier.

Figure 9   Rheological property, tan δ, of ESCOR320® terpolymer and EAA2 copolymer blends.

4.4 Dynamic Mechanical Properties

Figure 10-13 show dynamic mechanical properties of the ESCOR®
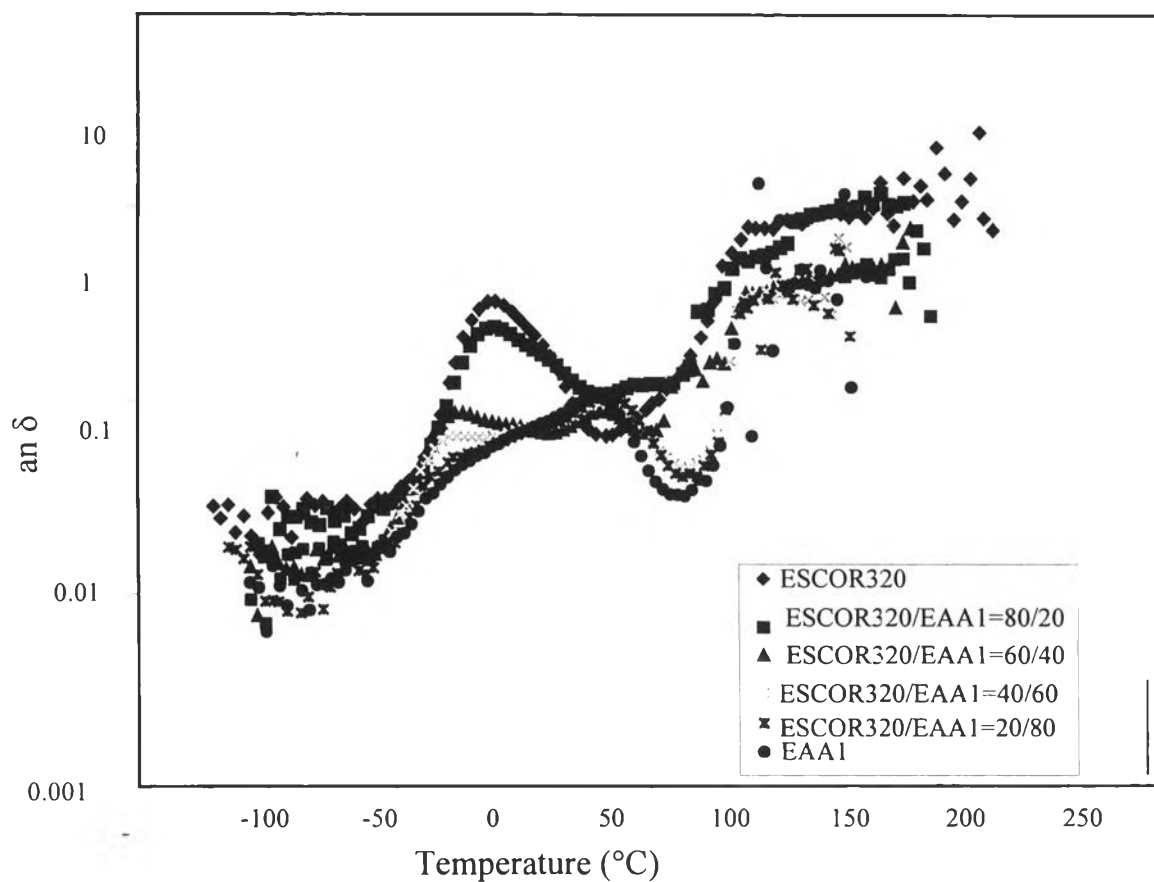terpolymers and EAA copolymers blends.

Figure 10 Dynamic mechanical property, tan δ, ESCOR®320/EAA1 blends.

The dynamic properties of the blends that exhibit single glass transition
temperature (T_g) values are the miscible one phase blends, confirming the law
of miscibility (Mohanty *et al.,* 1996).

From figure 10, indicating that the blend of ESCOR®320/EAA1 at 0,
80, and 100 wt % EAA1 have only single transition temperature (T_g) at about
−10, 40, and 50°C respectively. So, these blends should be miscible one phase

blend (Murayama, 1982) and correspond to the results from mechanical properties studied.
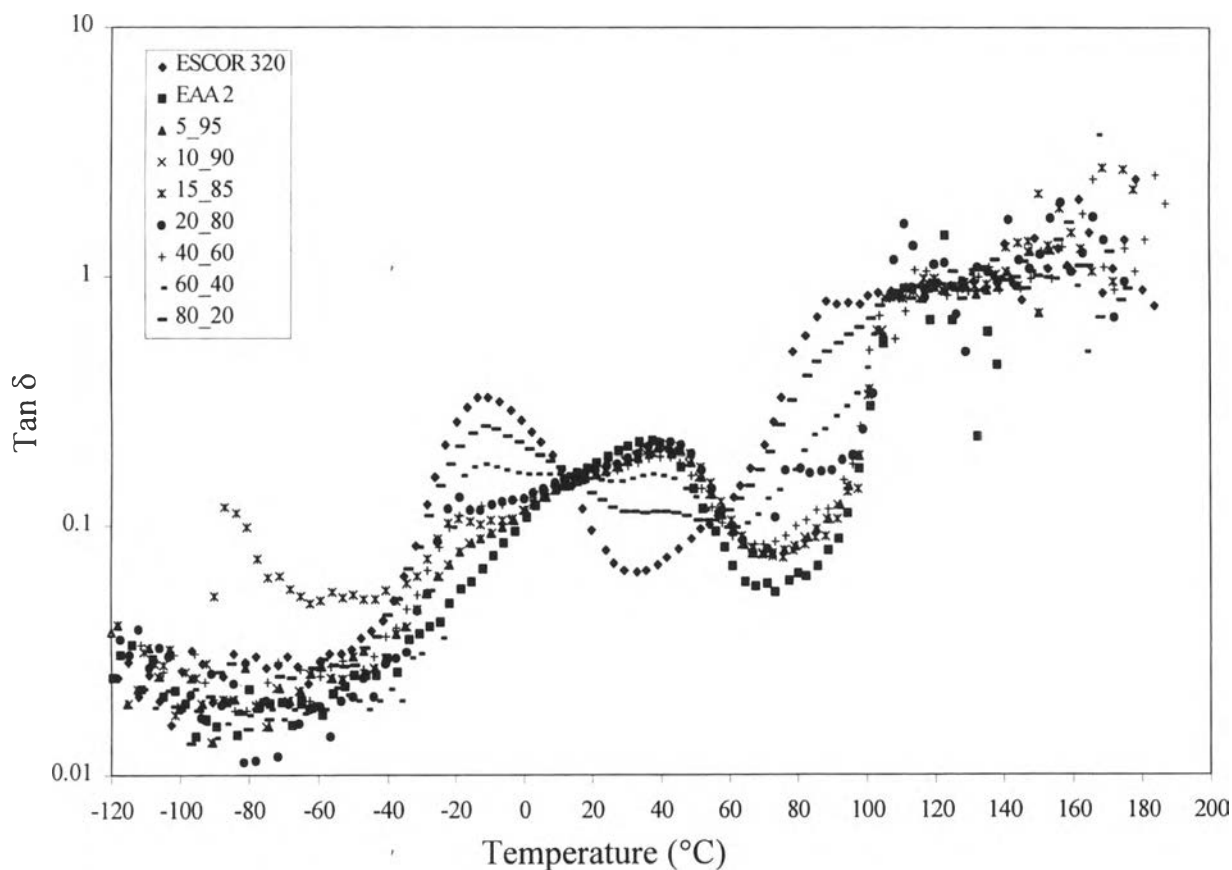

Figure 11 Dynamic mechanical property, tan δ, ESCOR®320/EAA2 blends.

From figure 11, the blend of ESCOR®320/EAA2 shows single transition peaks at 0, 90, 95, and 100 wt % EAA2 at −10, 40, and 50°C respectively. So, the miscible one phase blend should be obtained at these compositions (Murayama, 1982), corresponding to mechanical properties studied results.
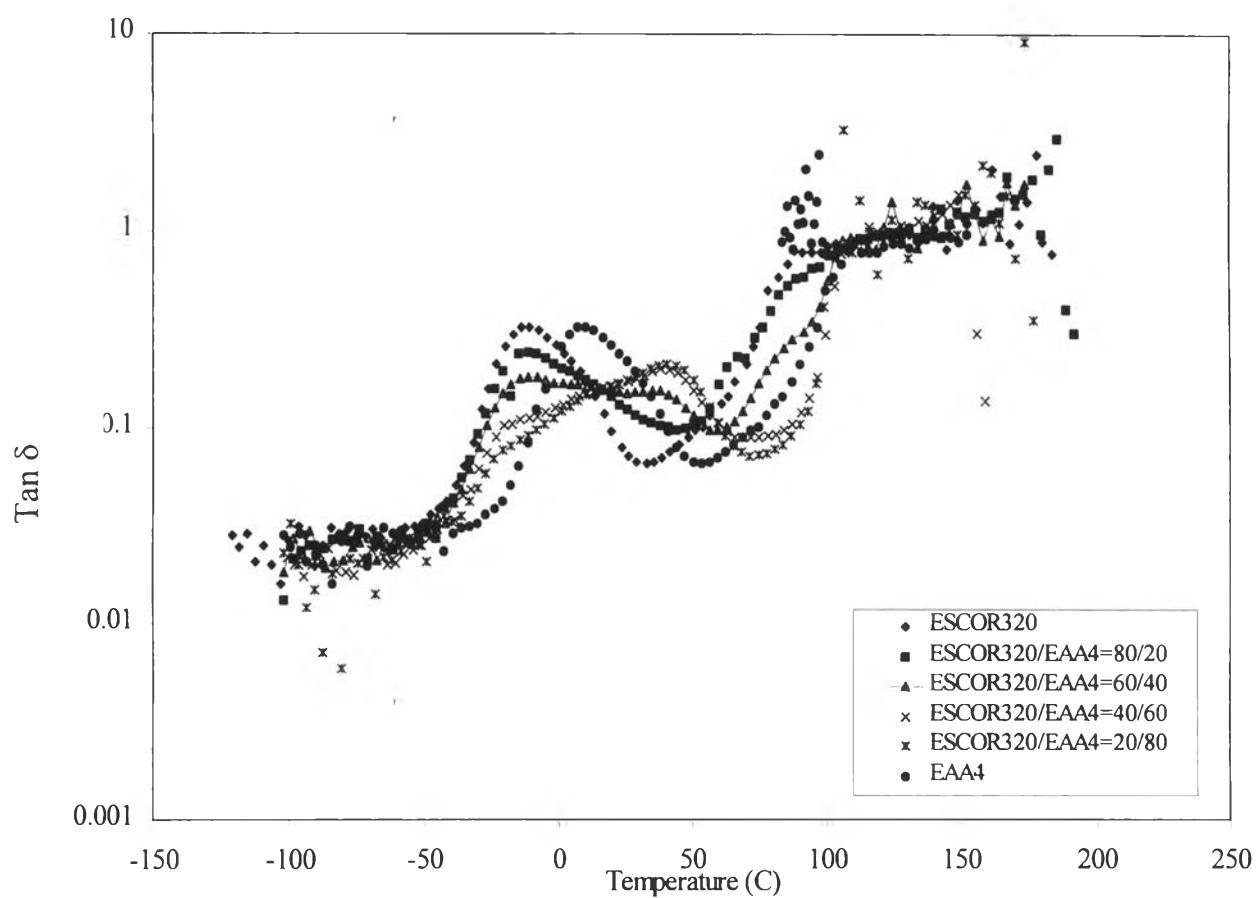
Figure 12 Dynamic mechanical property, tan δ, ESCOR®320/EAA4 blends.

From figure 12, suggesting that the blend of ESCOR®320/EAA4 show single transition peaks at 0, 20, and 100 wt % EAA4 at about −10, -10, and 10°C respectively. So, ESCOR®320/EAA4 blend at these compositions should be the miscible one phase blends (Mohanty *et al.,* 1996).
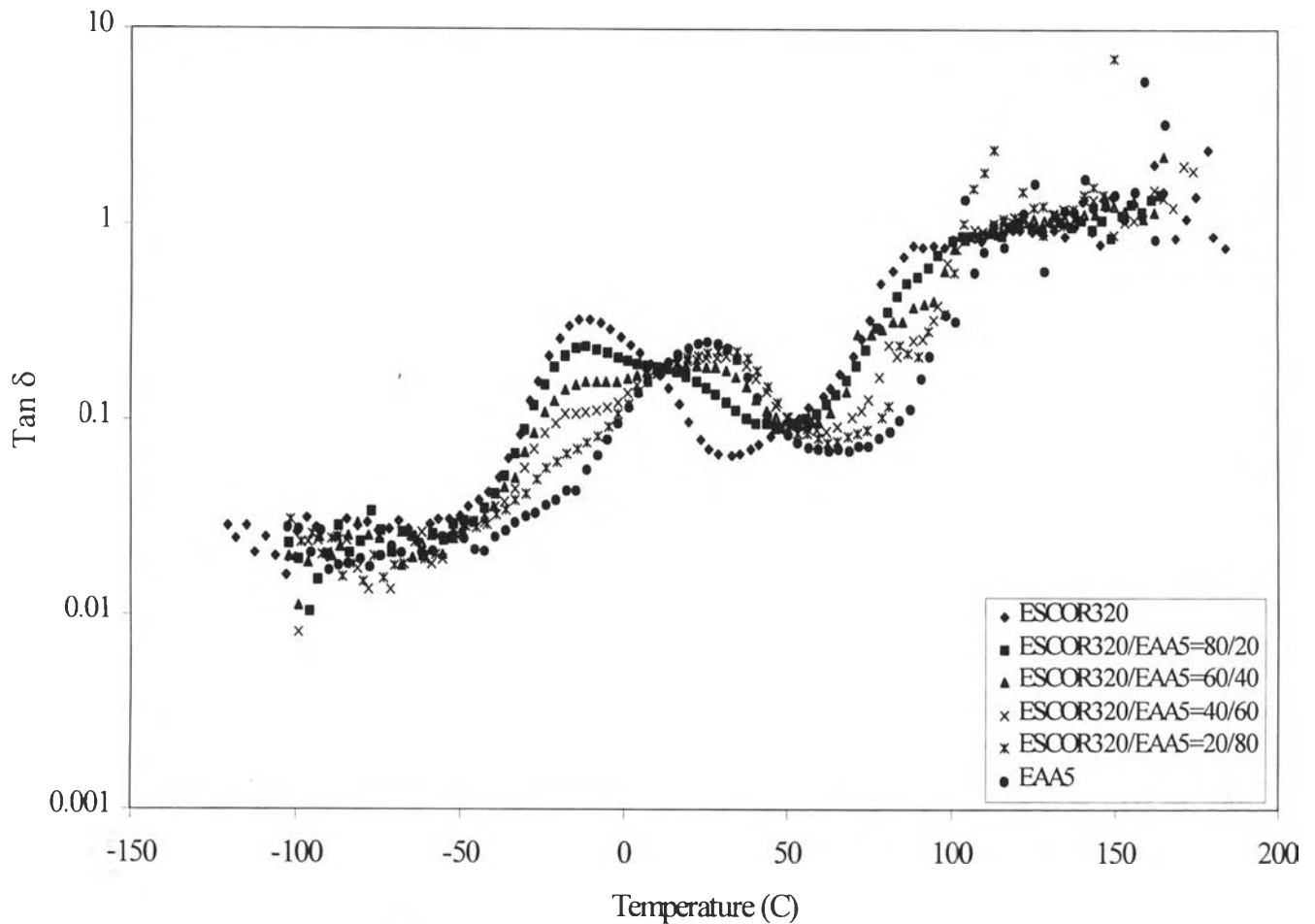
Figure 13 Dynamic mechanical property, tan δ, ESCOR®320/EAA4 blends.

From figure 13, the miscible one phase blends of ESCOR®320/EAA5 should be at 0, 80, and 100 wt % EAA5 due to single transition peaks were observed at −10, -10, and 40°C respectively (Mohanty *et al.*, 1996).

So, from all results, the more EAA content, the better mechanical properties such as hardness, gloss, and tensile properties due to greater interaction between the blend component (Mohanty *et al.*, 1996) and also the better miscibility (Jo *et al.*, 1990).