

CHAPTER 5

Results and Discussions

Many researchers have been involved in the study of polymer blends with liquid crystal and they have observed that liquid crystal can reduce the viscosity of the blend. Almost all researchers have focused on liquid crystal polymer, but only a few works were done with low molar mass liquid crystal.

From the literature survey in Chapter 2, the polymer blends, which contained liquid crystal polymers were improved in their processability with the viscosity reduction in melting state while the mechanical properties such as tensile strengths were improved like the composite materials. However, the amount of LCP in the blend has to be larger than 5% by weight. The researches of low molar mass liquid crystal blend on the processability, mechanical properties and thermal properties are rarely found.

In this research, the blends of low molar mass liquid crystals with several types of commercial polymers, such as polycarbonate (PC), polyamide 6 (PA6), polyoxymethylene (POM) and the commodity polymers, such as polyethylene (PE), polypropylene (PP) will be explored. The rheological, thermal and mechanical properties of these polymers and their blends with low molar mass liquid crystal are investigated. Moreover, the preliminary studies about ternary blends of SAN/PMMA and low molar mass liquid crystal are also examined.

Polymer processing is more and more important in the future. At present, several materials around us consist of plastics, the new engineering polymers, which will have more applications in replacing the other usual materials, such as woods or metals. The processing of this material is very difficult and consumes very high energy, so the viscosity reduction of these materials in the processing make it easier and directly preserves the energy consumption. The processability can be improved, while the other important properties, such as thermal and mechanical properties are not affected from these changes.

Four types of low molar mass liquid crystal, CBC33, CBC53, HP5N, and BCH5 were chosen by their morphology transition in this research. The pairs between selected base polymers and these low molar mass liquid crystals, that have the anisotropic melt temperature matched to the process temperature of the base polymers, were selected as the representatives of other blends

5.1 Effects of low molar mass liquid crystal on the properties of the chosen base polymers.

There are eight systems of blends between low molar mass liquid crystals and several base polymers:

System 1 : Polycarbonate (PC) and CBC33

System 2 : PC and CBC53

System 3 : Nylon 6 and CBC53

System 4 : Polyoxymethylene (POM) and HP5N

System 5 : Polypropylene (PP) and HP5N

System 6 : High Density Polyethylene (HDPE) and BCH5

System 7 : Styrene Acrylonitrile copolymer (SAN) and BCH5

System 8 : Poly(methyl methacrylate), (PMMA) and BCH5.

The investigated properties are rheological properties as viscosity , thermal properties as glass transition temperature (T_g) and crystalline melting temperature (T_m) and mechanical properties as tensile strength.

5.1.1 Rheological properties

Shear viscosity of the base polymers and their blends were determined by a Haake RS 75 rheometric measurements with the parallel plate sensors.

5.1.1.1 Effects of CBC33 on PC

The rheometric measurements of PC and its blends with CBC33 at 0.25, 0.5 and 1.0 percent by weight of CBC33 are carried out with shear rate sweep mode at 290°C , the range of study shear rate is $0 - 500 \text{ s}^{-1}$ within 10 minutes of measuring time. The shear rate versus shear viscosity of these blends at above percent composition of CBC33 is shown in Figure 5-1 and the percent composition of CBC33 versus shear viscosity of these blends at various ranges of shear rate is presented in Figure 5-2.

The rheological properties of PC and its blends are in the range of the pseudoplastic behavior. From Figure 5-2, when applied more shear rate, the shear viscosity will be lower. The influences of CBC33 on the shear viscosity of PC in Figure 5-1 show the significant drop continuously when adding it in PC. The more concentration of CBC33 in the PC, the less viscosity of blend. At the measuring

temperature, the structure of CBC33 is in the anisotropic phase with nematic structure. The orientation of mesogenic group in the disperse phase tends to lubricate the melt polymer [Imrie, 1995]. This would be expected that the flow properties of PC were significantly improved by adding CBC33.

5.1.1.2 Effects of CBC53 on PC

The rheometric measurements of PC and its blends with CBC53 at 0.25, 0.5 and 1.0 percent by weight of CBC53 are carried out with shear rate sweep mode at 290°C, the range of study shear rate is 0 – 500 s⁻¹ within 10 minutes of measuring time. The shear rate versus shear viscosity of these blends at above percent composition of CBC53 is shown in Figure 5-3 and the percent composition of CBC53 versus shear viscosity of these blends at various ranges of shear rate is presented in Figure 5-4.

The rheological properties of PC and its blends are also in the range of the pseudoplastic behavior. From Figure 5-4, when applied more shear rate, the shear viscosity will be lower. The influences of CBC53 on the shear viscosity of PC in Figure 5-3 show that the viscosity drop significantly and continuously when adding CBC53 in PC. At 1% by weight of CBC53, the shear viscosity of PC is decreased about 84%. This would be expected that the flow properties of PC were also improved by adding CBC53. The same results of CBC33 and CBC53 may be come from the deformation and orientation of liquid crystals in flow direction. [Fles, 1995].

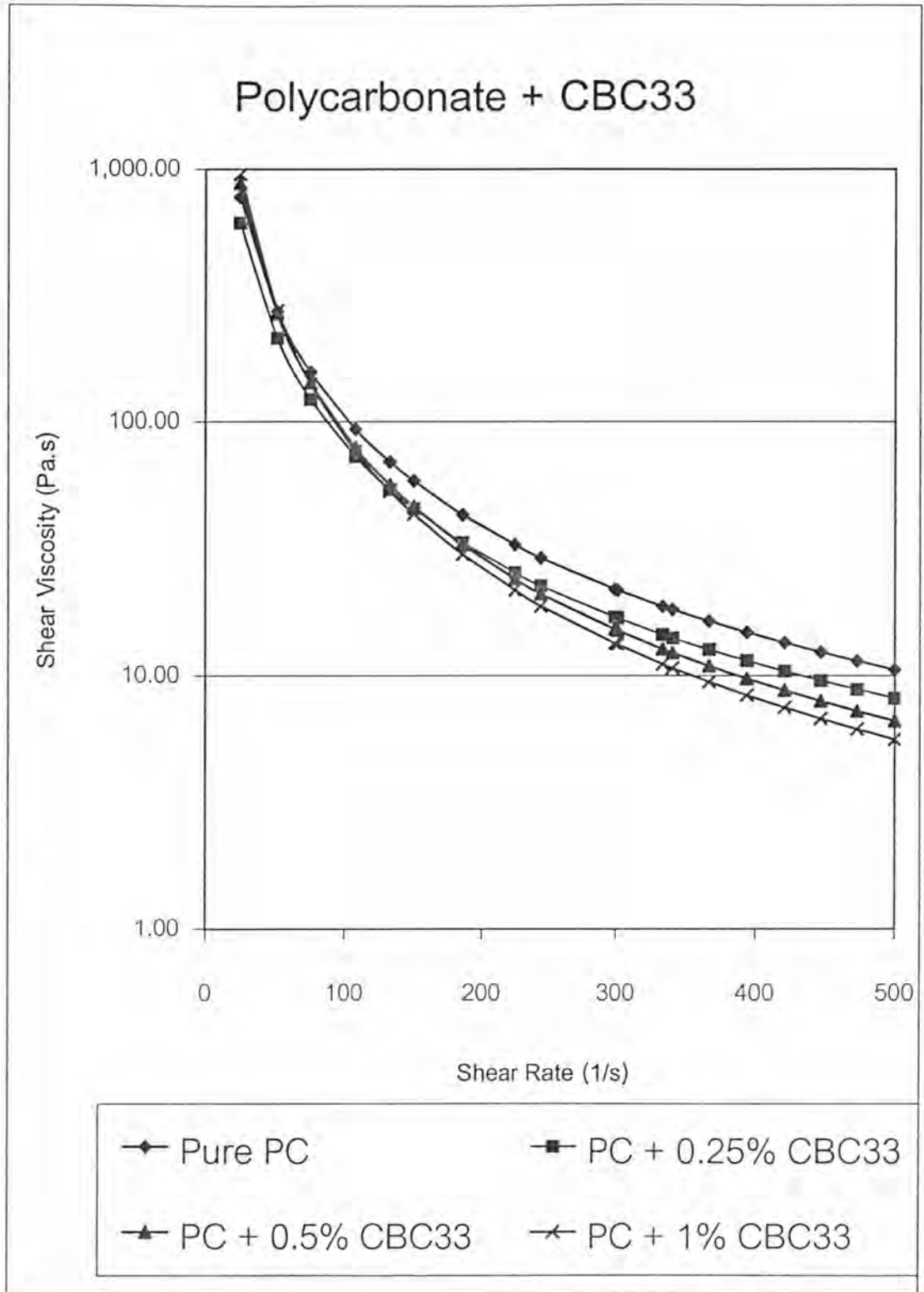


Figure 5-1 Shear Viscosity of PC versus shear rate at various composition of CBC33

Shear viscosity of PC versus percentage of CBC33 at various of shear rate

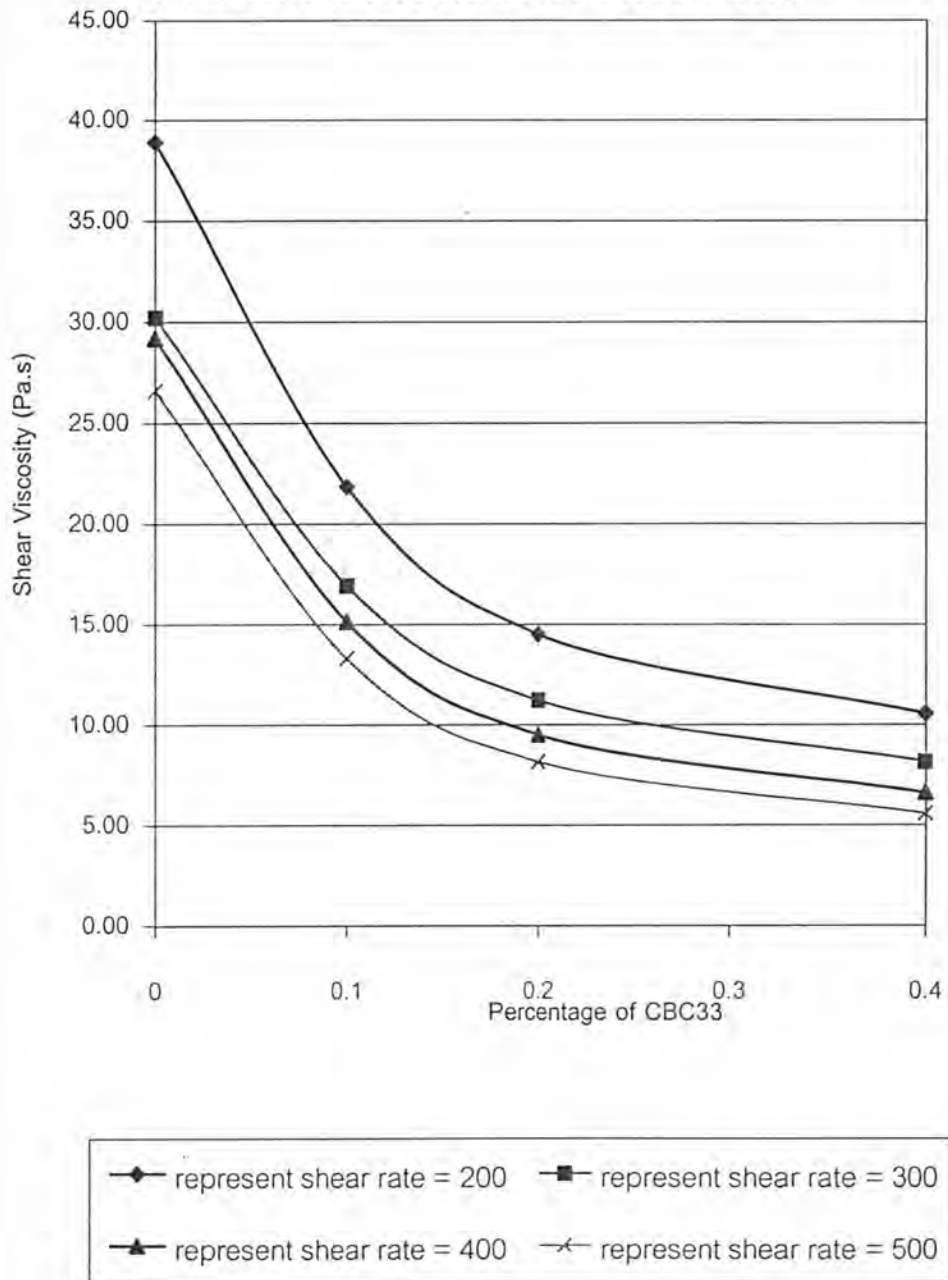


Figure 5-2 Shear Viscosity of PC versus % composition of CBC33 at various range of shear rate

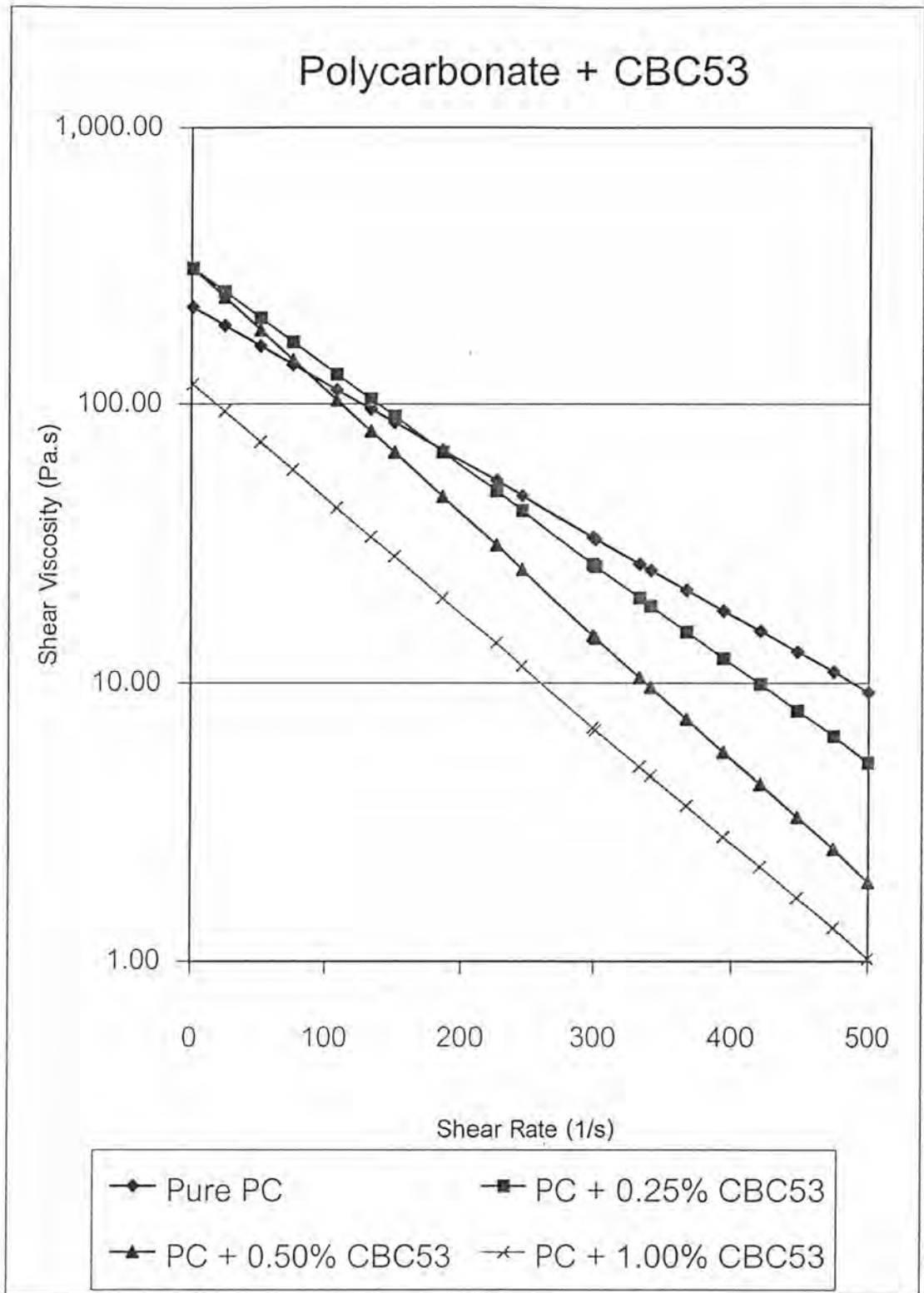


Figure 5-3 Shear Viscosity of PC versus shear rate at various composition of CBC53

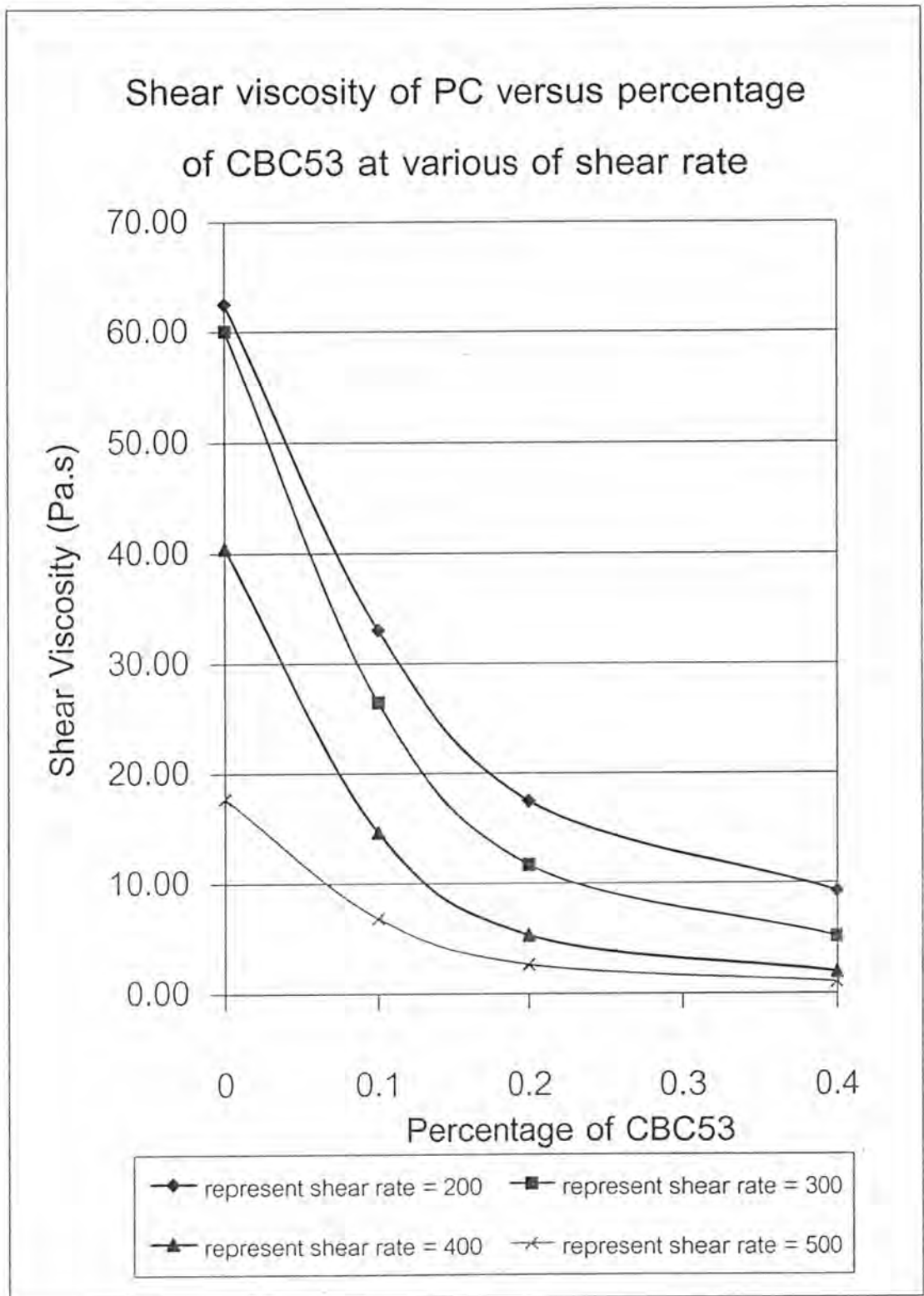


Figure 5-4 Shear Viscosity of PC versus % composition of CBC53 at various range of shear rate

5.1.1.3 Effects of CBC53 on PA6

The rheometric measurements of PA6 and its blends with CBC53 at 0.1, 0.2 and 0.4 percent by weight of CBC53 are carried out with shear rate sweep mode at 225°C at the range of study shear rate is 0 – 500 s⁻¹ within 10 minutes of measuring time. The shear rate versus shear viscosity of these blends at various percent composition of CBC53 as above is shown in Figure 5-5 and the percent composition of CBC53 versus shear viscosity of these blends at various ranges of shear rate is presented in Figure 5-6.

The rheological properties of PA6 and its blends are also shown the pseudoplastic behavior. From Figure 5-6, when applied more shear rate, the shear viscosity will be lower. The influences of CBC53 on the shear viscosity of PA6 in Figure 5-5 show that the viscosity drop significantly and continuously when adding CBC53 in PA6. The more content of CBC53 in the PA6, the less viscosity of blend. Only adding 0.4 % by weight of CBC53 in the blends, the shear viscosity of PA6 decrease about 42 %. At the measured temperature, the structure of CBC53 is in the anisotropic phase with smectic structure. The orientation of mesogenic group in the disperse phase tends to lubricate the melt polymer [Imrie, 1995]. This would be expected that the flow properties of PA6 were also improved by adding CBC53.

5.1.1.4 Effects of HP5N on POM

The rheometric measurements of POM and its blends with HP5N at 0.1, 0.2 and 0.4 percent by weight are carried out with shear rate sweep mode at 200°C, the range of study shear rate is 0 – 500 s⁻¹ within 10 minutes of measuring time. The shear rate versus shear viscosity of these blends at percent composition of HP5N above

is shown in Figure 5-7 and the percent composition of HP5N versus shear viscosity of these blends at various ranges of shear rate is presented in Figure 5-8.

The rheological properties of POM and its blends are also shown the pseudoplastic behavior. From Figure 5-8, when applied more shear rate, the shear viscosity will be lower. The influences of HP5N on the shear viscosity of POM in Figure 5-7 show that the viscosity drop significantly and continuously when adding HP5N in POM. At only 0.4% by weight of HP5N, the shear viscosity of the POM blend is decreased about 70%. This would be expected that the flow properties of POM were also significantly improved by adding HP5N.

5.1.1.5 Effects of HP5N on PP

The rheometric measurements of PP and its blends with HP5N at 0.1, 0.2 and 0.4 percent by weight are carried out with shear rate sweep mode at 200°C, the range of study shear rate is 0 – 500 s⁻¹ within 10 minutes of measuring time. The shear rate versus shear viscosity of these blends at above percent composition of HP5N is shown in Figure 5-9 and the percent composition of HP5N versus shear viscosity of these blends at various ranges of shear rate is presented in Figure 5-10.

The rheological properties of PP and its blends are also shown the pseudoplastic behavior. From Figure 5-10, when applied more shear rate, the shear viscosity will be lower. The influences of HP5N on the shear viscosity of PP in Figure 5-9 show the significant and continuous decrease in the blend viscosity, when adding HP5N in PP, but within the less effects than the POM blend. At 0.4% by weight of HP5N, the shear viscosity of PP is decreased about 47%. However, this would be expected that the flow properties of PP were also improved by adding HP5N.

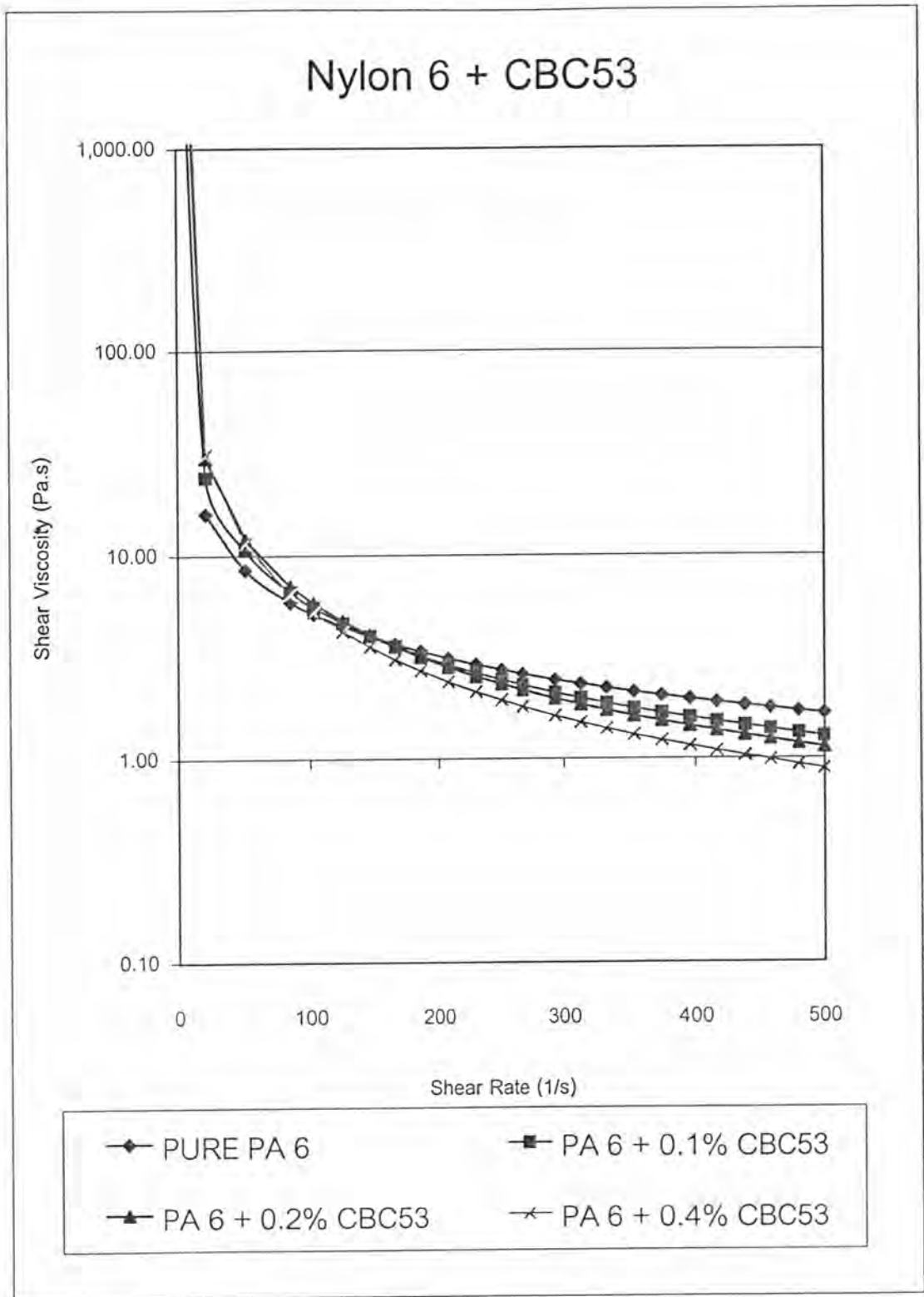


Figure 5-5 Shear Viscosity of PA6 versus shear rate at various composition of CBC53

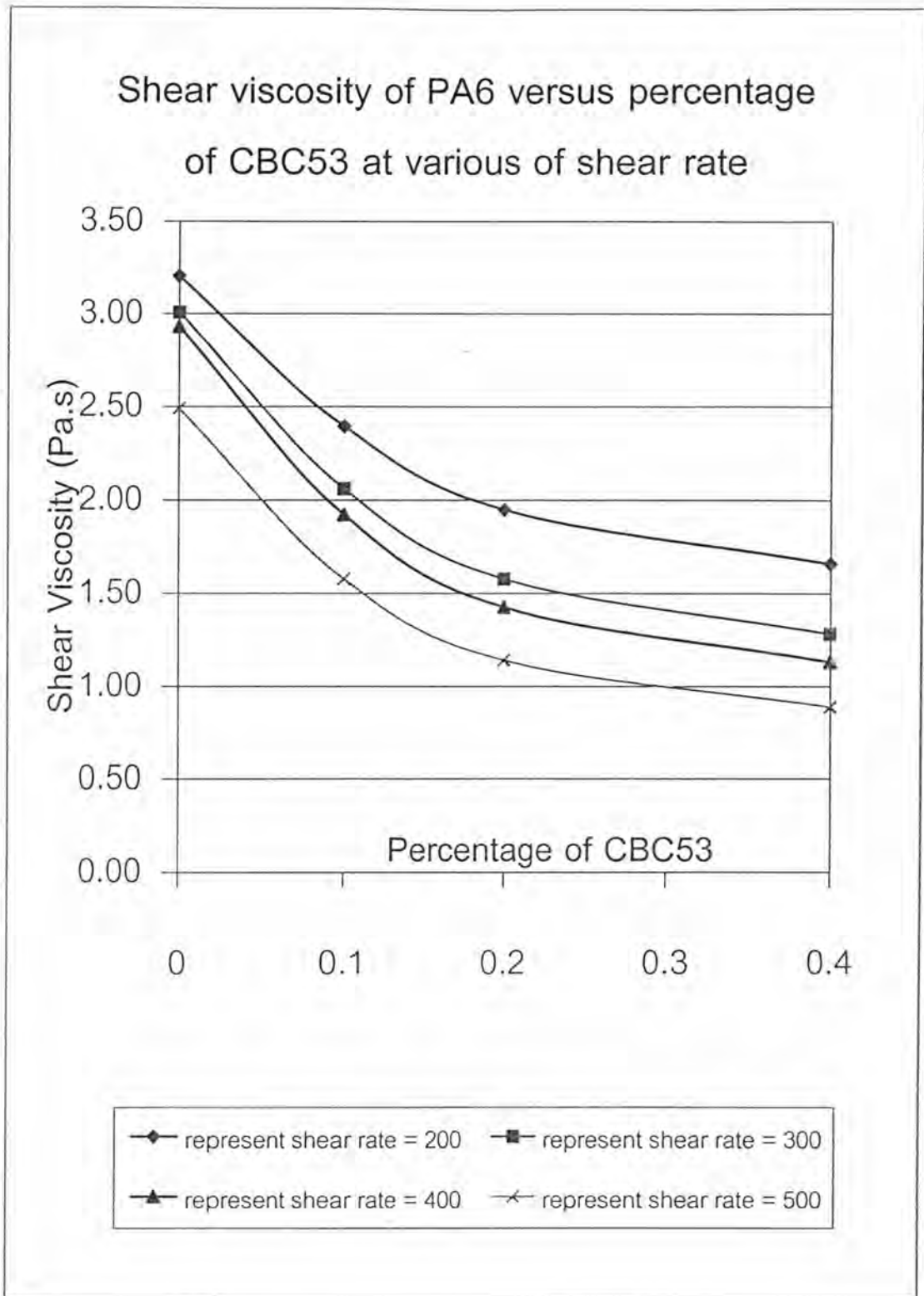


Figure 5-6 Shear Viscosity of PA6 versus % composition of CBC53 at various range of shear rate

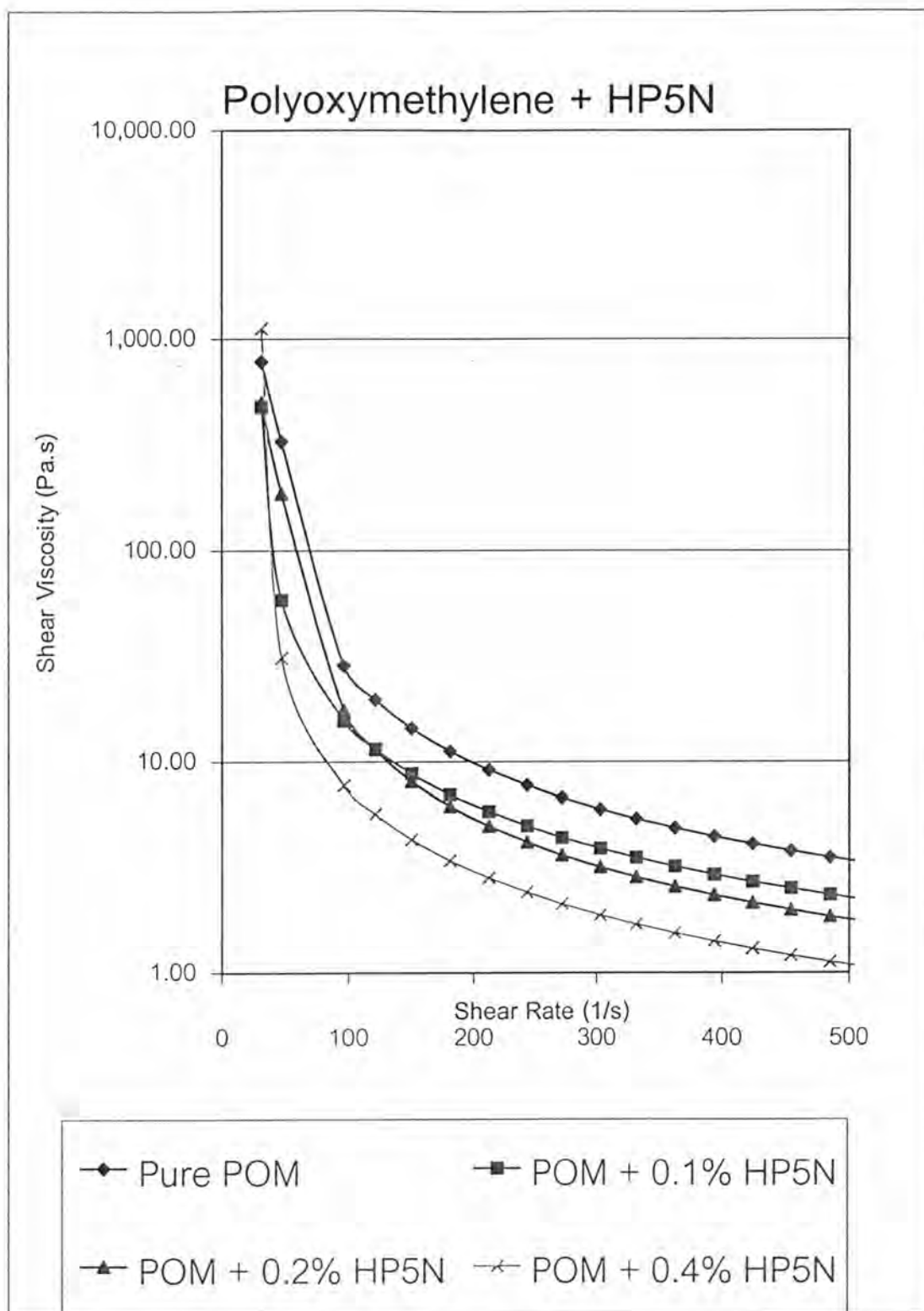


Figure 5-7 Shear Viscosity of POM versus shear rate at various composition of HP5N

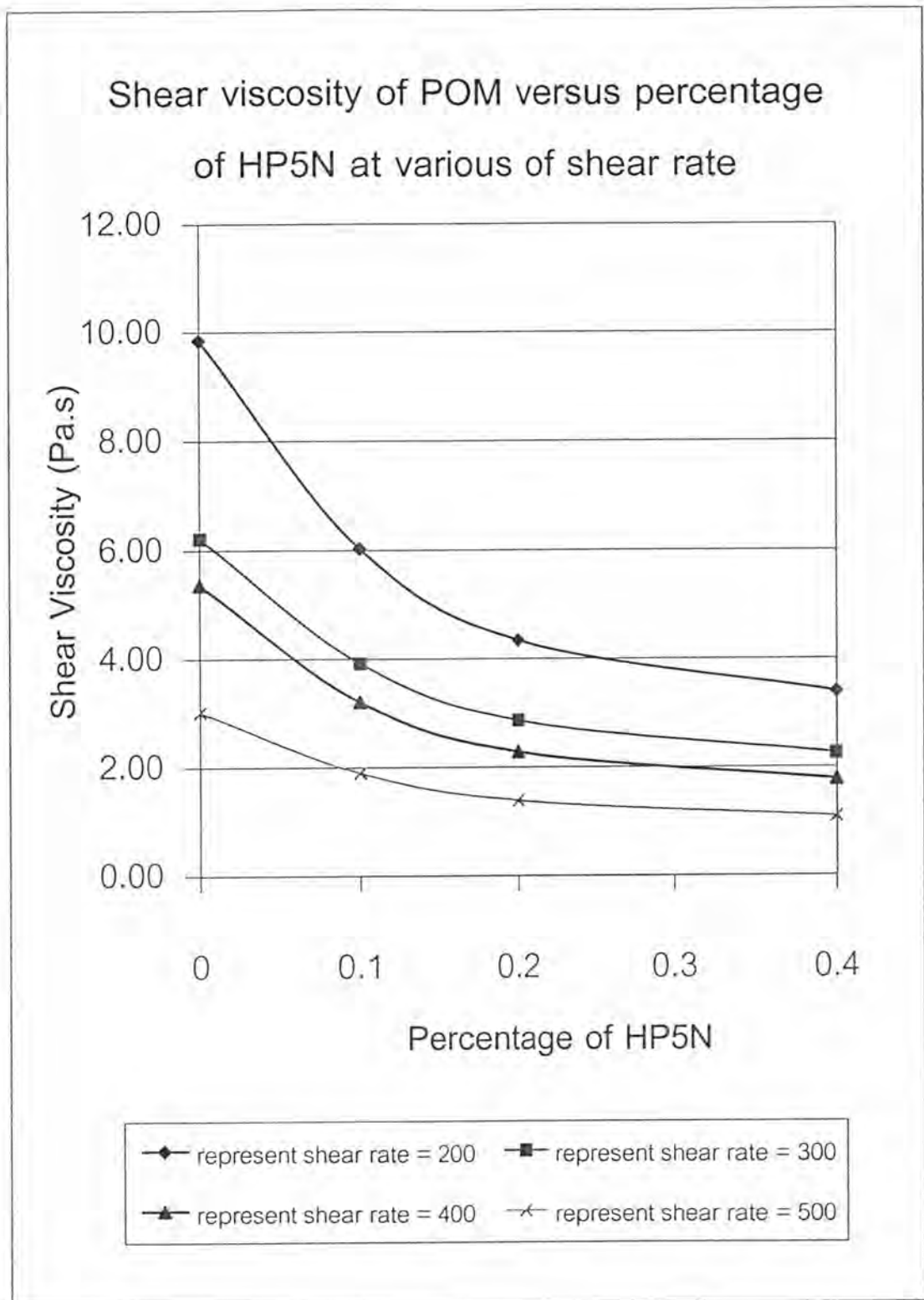


Figure 5-8 Shear Viscosity of POM versus % composition of HP5N at various range of shear rate

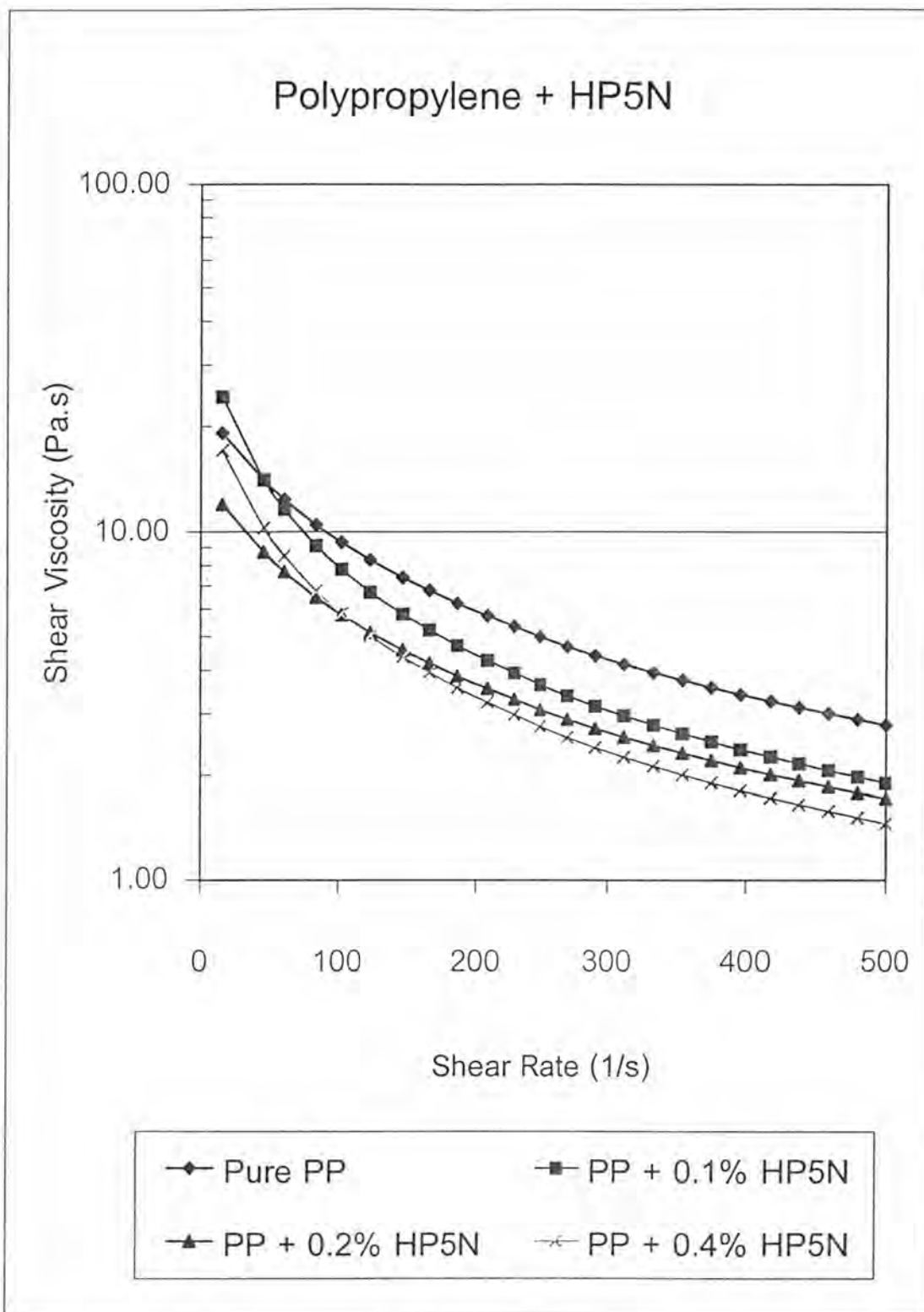


Figure 5-9 Shear Viscosity of PP versus shear rate at various composition of HP5N

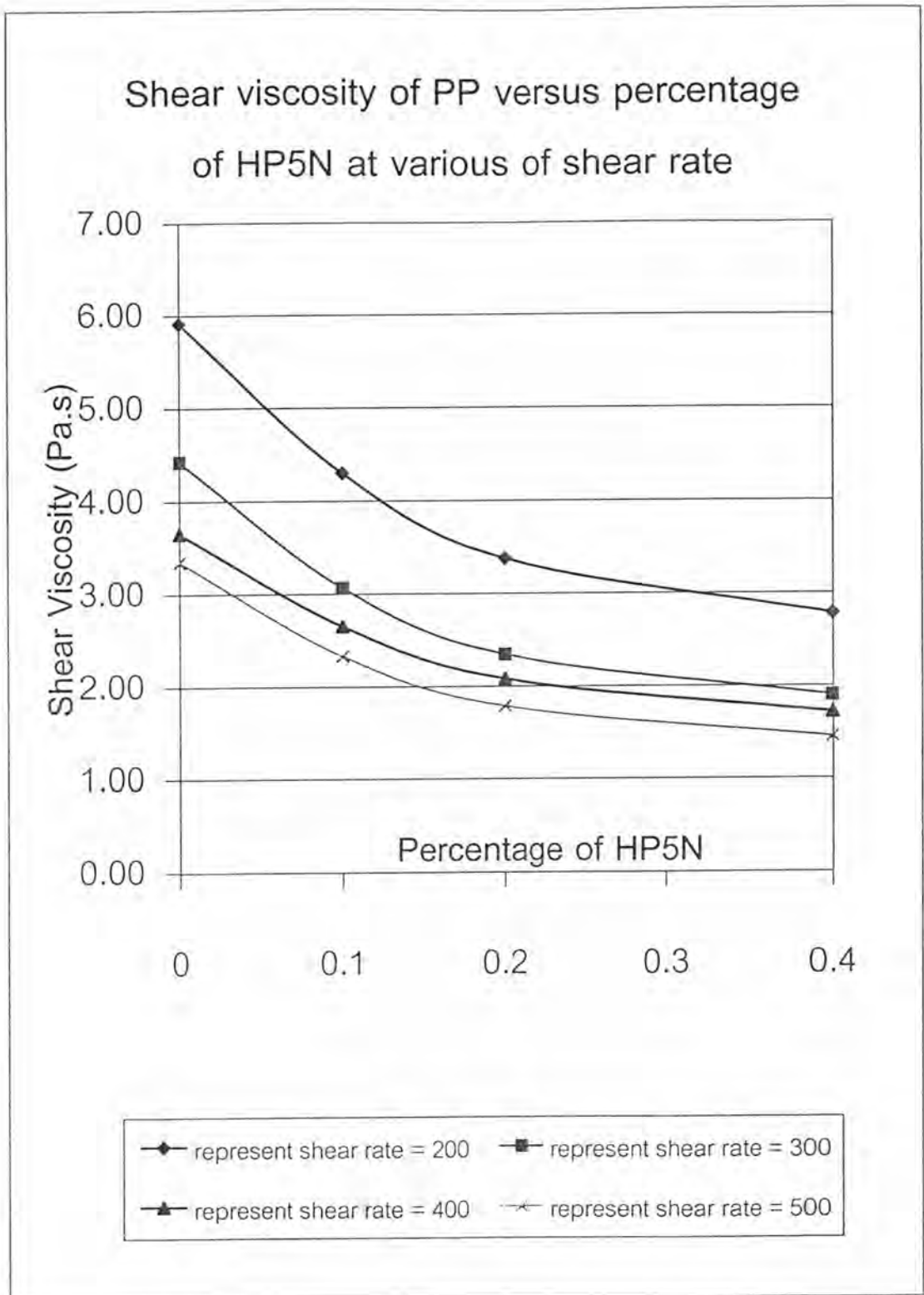


Figure 5-10 Shear Viscosity of PP versus % composition of HP5N at various range of shear rate

5.1.1.6 Effects of BCH5 on properties of HDPE

The rheometric measurements of HDPE and its blends with BCH5 at 0.1, 0.2 and 0.4 percent by weight are carried out with shear rate sweep mode at 200°C at the range of study shear rate is 0 – 500 s⁻¹ within 10 minutes of measuring time. The shear rate versus shear viscosity of these blends at above percent composition of BCH5 is shown in Figure 5-11 and the percent composition of BCH5 versus shear viscosity of these blends at various ranges of shear rate is presented in Figure 5-12.

The rheological properties of HDPE and its blends are also shown the pseudoplastic behavior. From Figure 5-12, when applied more shear rate, the shear viscosity will be lower. The influences of BCH5 on the shear viscosity of PE in Figure 5-11 show the viscosity decreases continuously when adding BCH5 in PE. At 0.4% by weight of BCH5, the shear viscosity of PE is decreased around 22%. This would be expected that the flow properties of PE were also improved by adding BCH5.

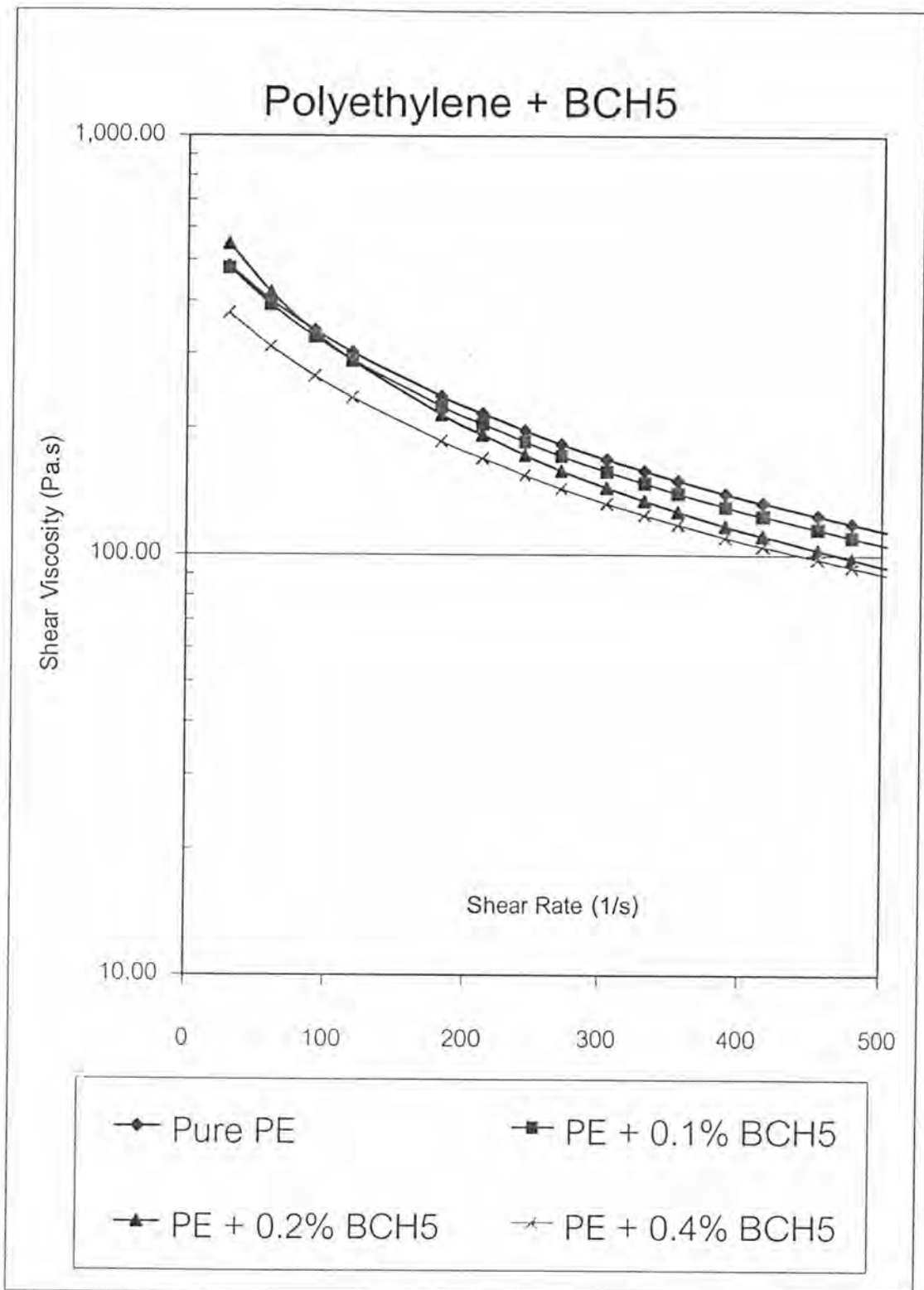


Figure 5-11 Shear Viscosity of HDPE versus shear rate at various composition of BCH5

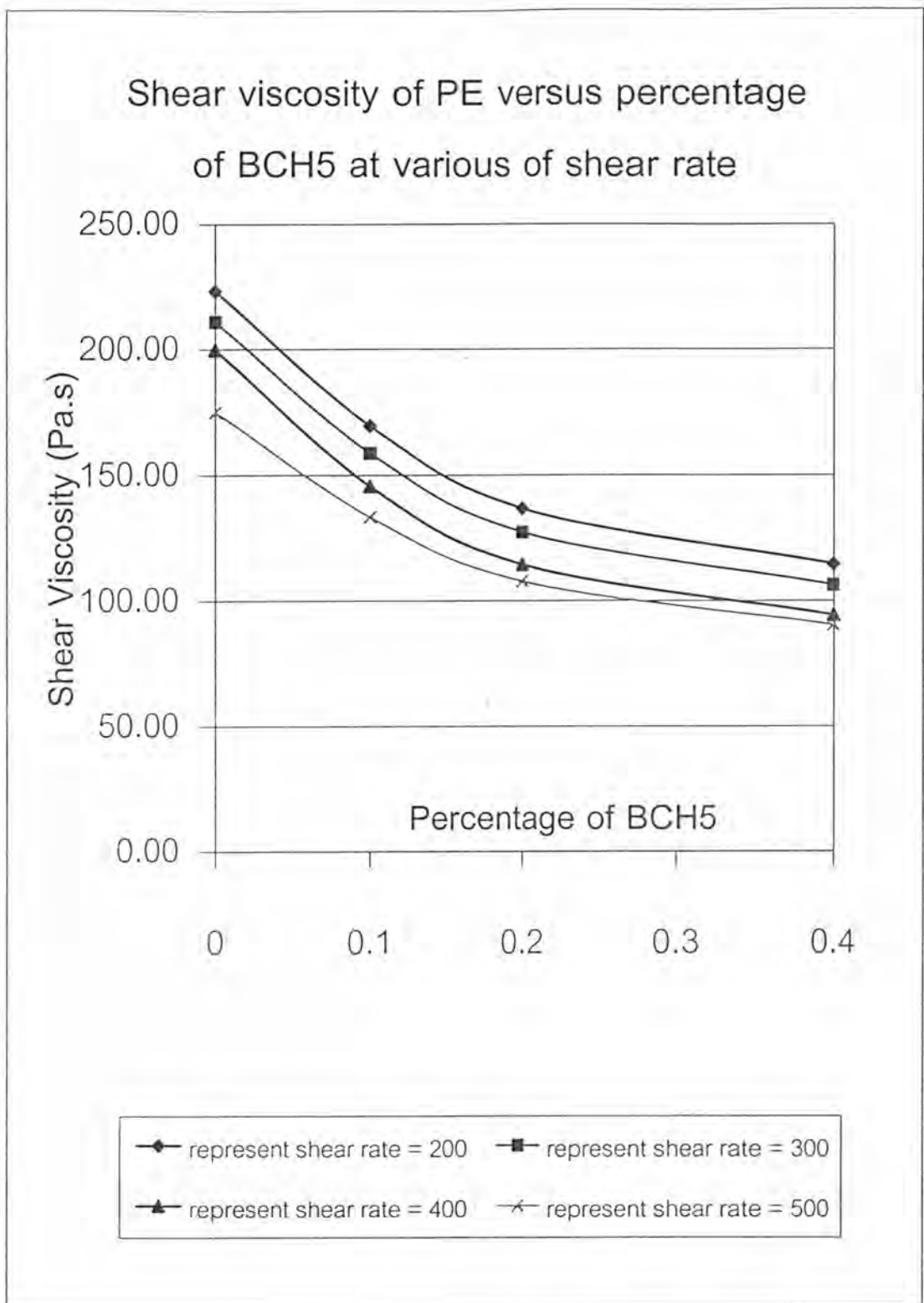


Figure 5-12 Shear Viscosity of HDPE versus %composition of BCH5 at various range of shear rate

5.1.1.7 Effects of BCH5 on properties of SAN

The rheometric measurements of SAN and its blends with BCH5 at 0.1, 0.2 and 0.4 percent by weight are carried out with frequency sweep mode at 200°C. The preliminary experiment was carried out to determine the linearity stress from stress-strain curve in order to select this shear stress that presented linear viscoelastic region to apply in the frequency sweep experiments. The examples of preliminary experiment curves is shown in appendix B.

The oscillating frequency was start from 10^2 to 10^3 Hz.

The frequency versus complex viscosity of these blends at various percent composition of BCH5 as above is shown in Figure 5-13 and the percent composition of BCH5 versus steady state viscosity of these blends are shown in Figure 5-14.

The rheological properties of SAN and its blends are also shown the pseudoplastic behavior. From Figure 5-14, when applied more shear rate or frequency, the viscosity will be lower. The influences of BCH5 on the steady state viscosity of SAN in Figure 5-13 show the significant and continuous decrease in viscosity, when adding BCH5 in SAN. At 0.4% by weight of BCH5, the steady state viscosity of SAN is decreased around 60%. This would be expected that the flow properties of SAN were also improved by adding BCH5.

The steady-state viscosity from this experiments is base on Cox-Merz Rule. The rule can explain that the complex viscosity is equal to the steady-state viscosity or zero-shear viscosity over a small range of shear rate or frequency.

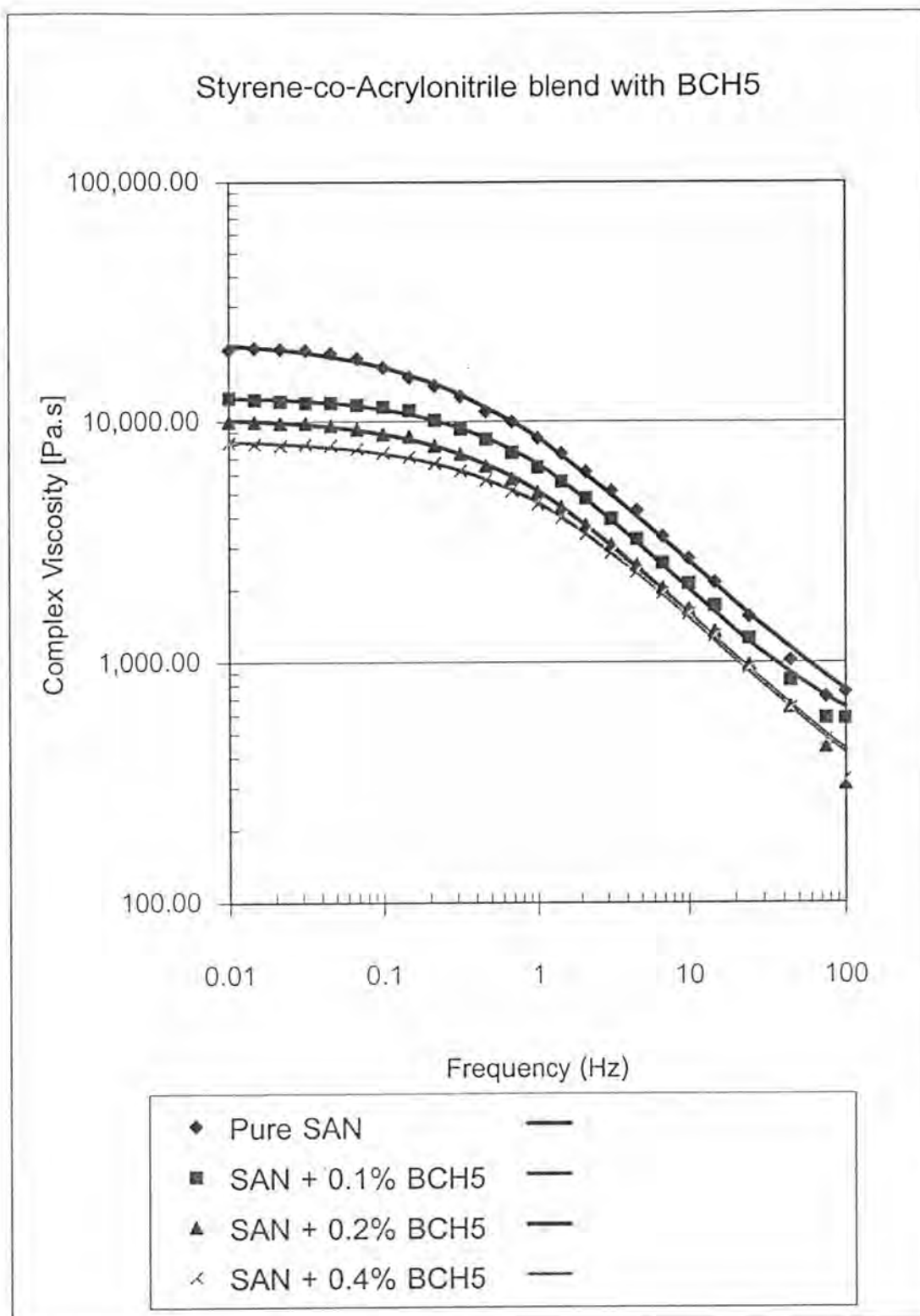


Figure 5-13 Complex Viscosity of SAN versus frequency at various composition of BCH5

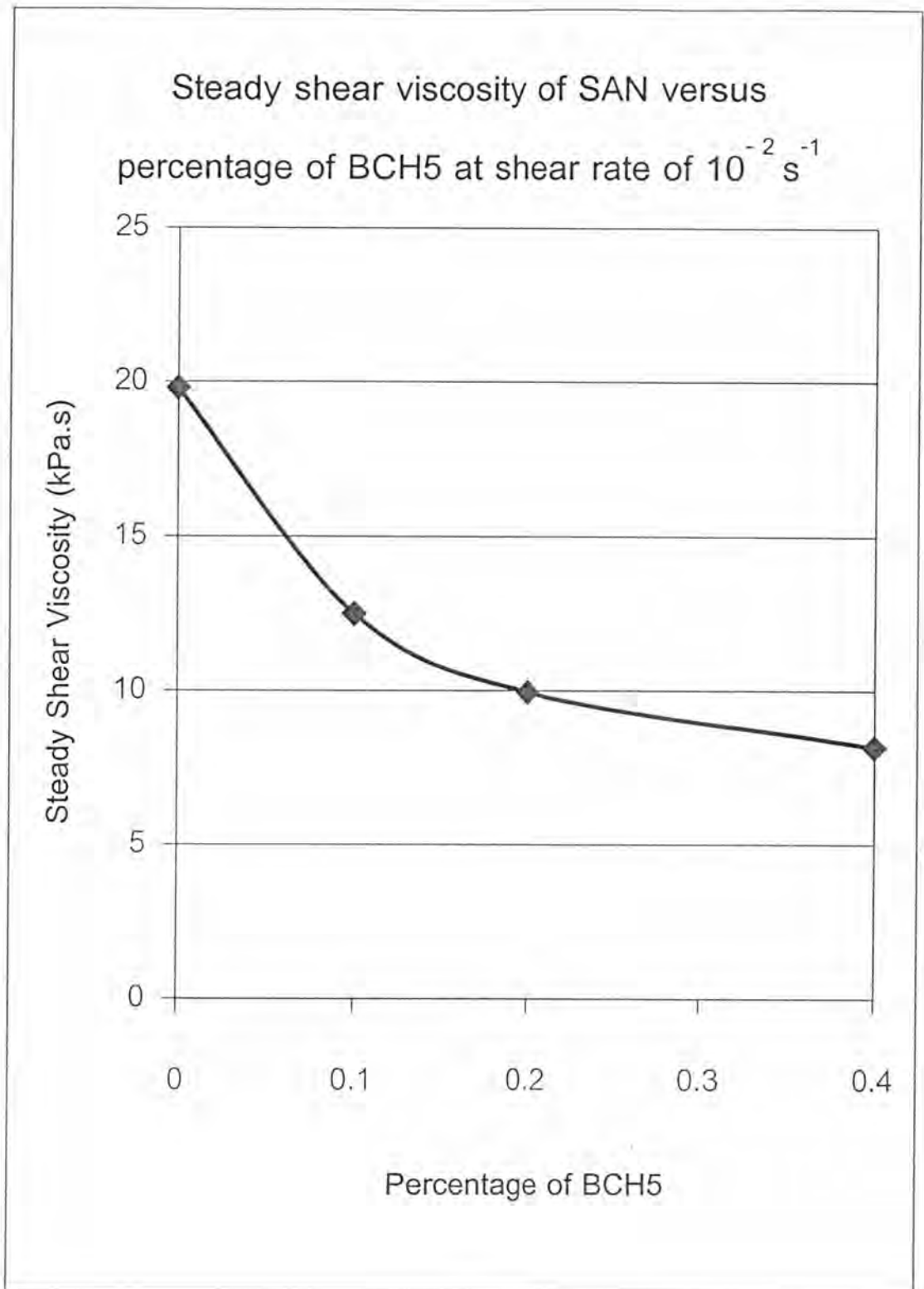


Figure 5-14 Steady Shear Viscosity of SAN versus % composition of BCH5

5.1.1.8 Effects of BCH5 on properties of PMMA

The rheometric measurements of PMMA and its blends with BCH5 at 0.1, 0.2 and 0.4 percent by weight are carried out with frequency sweep mode at 200°C. The preliminary experiment was also carried out to determine the linearity stress from stress-strain curve in order to select this shear stress that presented linear viscoelastic region to apply in the frequency sweep experiments like the SAN.

The oscillating frequency was started from 10^2 to 10^{-2} Hz.

The frequency versus complex viscosity of these blends at various percent composition of BCH5 as above is shown in Figure 5-15 and the percent composition of BCH5 versus zero-shear viscosity of these blends Figure 5-16.

The rheological properties of PMMA and its blends are also shown the pseudoplastic behavior. From Figure 5-16, when applied more shear rate or frequency, the viscosity will decrease. The influences of BCH5 on the steady state viscosity of PMMA in Figure 5-15 show the significant and continuous decrease in viscosity, when adding BCH5 in PMMA. At 0.4% by weight of BCH5, the zero-shear viscosity of SAN is decreased around 57%. These effects of BCH5 in the properties of PMMA are similar to SAN. This would be expected that the flow properties of PMMA were also improved by adding BCH5 as it happened to SAN.

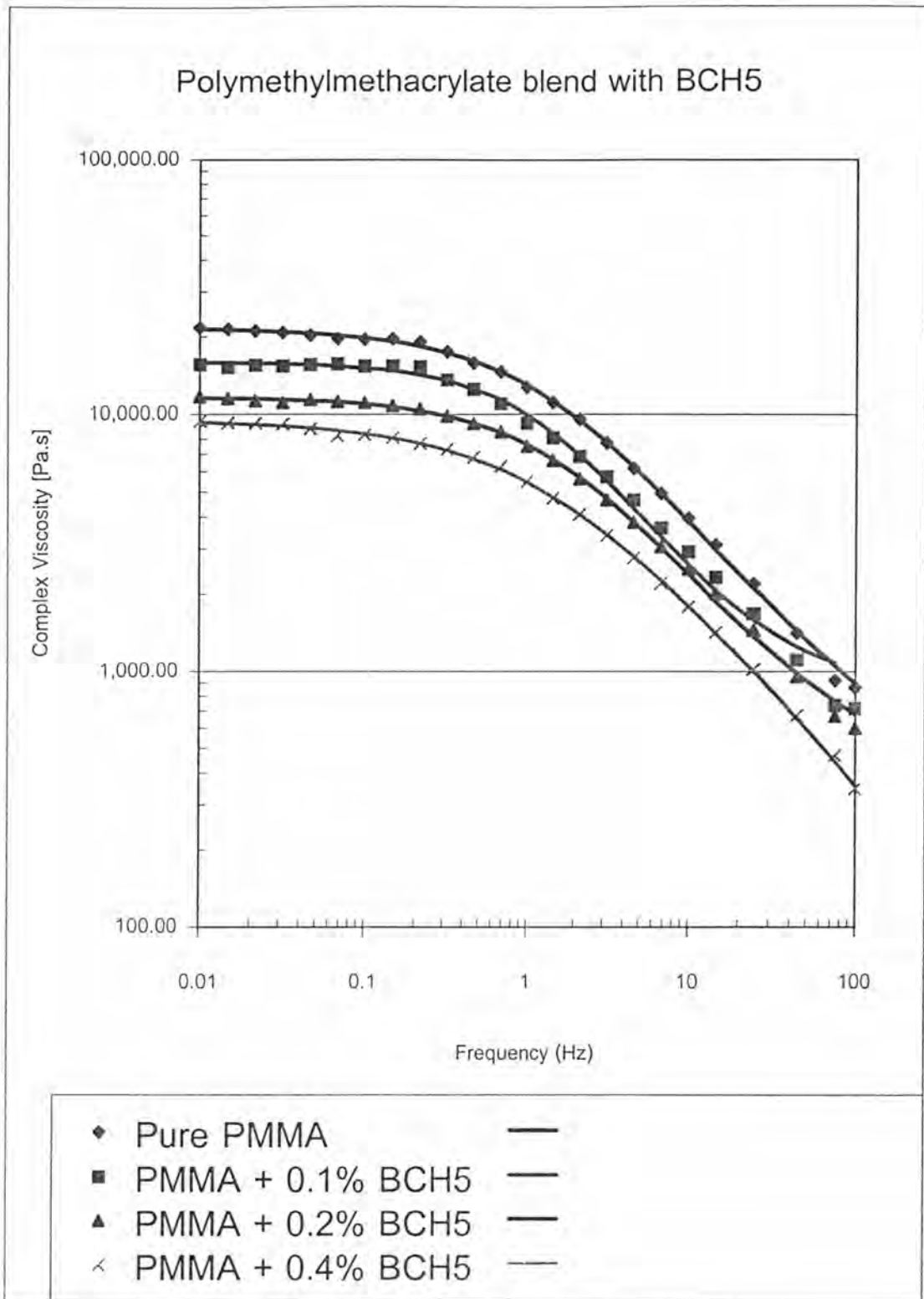


Figure 5-15 Complex Viscosity of PMMA versus frequency at various composition of BCH5

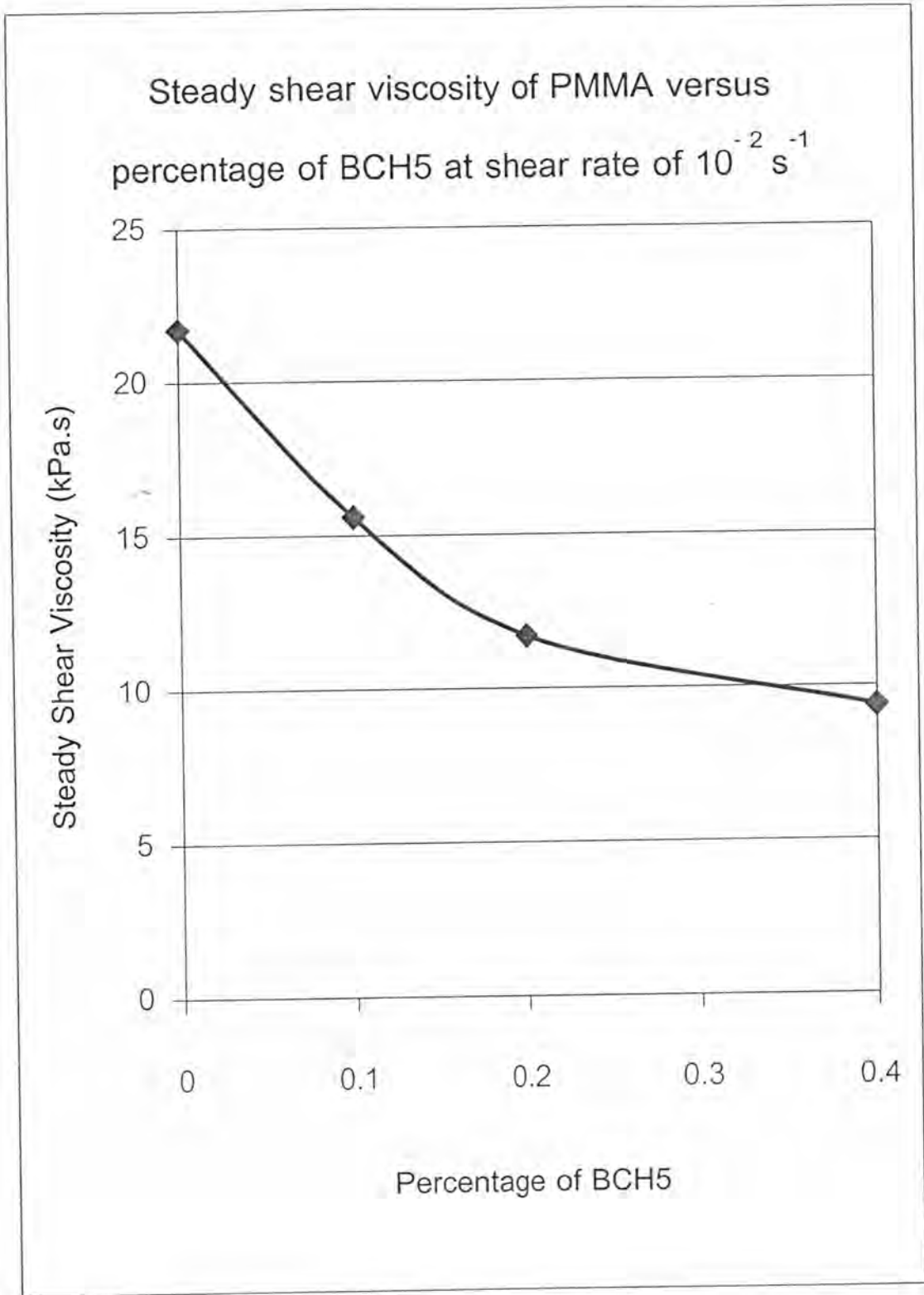


Figure 5-16 Steady Shear Viscosity of PMMA versus %composition of BCH5

5.1.2 Thermal properties

The glass transition temperature (T_g) of those blends is determined by the differential scanning calorimeter (DSC). T_g is a characteristic of the amorphous part of polymers. At T_g , a dramatic change occurs in the local movement of molecular level of polymer chain from glassy state to rubbery state, which change almost of the physical and mechanical properties of polymer [Brandup, et. al., 1989].

Table 5-1 is shown the T_g of PP and its blends with HP5N, SAN and its blends with BCH5, and PMMA and its blends with BCH5 respectively. From this Table, T_g of base polymers are very closely to their blends with liquid crystals, that the difference between T_g of PP and its blends is around 3°C and less than 1°C in case of T_g of SAN and PMMA and their blends (see the raw data in appendix C). This difference is not significant. The crystalline melting point of PP, HDPE and their blends with liquid crystal, which present in Table 5-2 is not significantly different, similar to the T_g . These phenomena may be the result of the very small amount of low molar mass liquid crystal in the matrix phase of the base polymer are not enough to plasticize the blends to such an extent that the significant reducing in T_g and T_m of the blends can be observed.

Table 5-1 Glass transition temperature of PP, SAN and PMMA and their blends with liquid crystals

Sample	Glass transition temperature (°C)
Pure PP	0.9
PP + 0.4% HP5N	4.7
Pure SAN	104.9
SAN + 0.4% BCH5	104.4
Pure PMMA	96.0
PMMA + 0.4% BCH5	95.5

Table 5-2 The crystalline melting temperature of PP, HDPE and their blends with liquid crystals

Sample	Crystalline melting temperature (°C)
Pure PP	162.1
PP + 0.4% HP5N	161.9
Pure PE	131.2
PP + 0.4% BCH5	133.1

5.1.3 Mechanical properties

Many researches tried to explain the effects of liquid crystalline polymers (LCP) on the properties of the base polymer that LCP can act as the reinforcing fillers to improve the mechanical properties of the base polymers as the composite materials. The studies about the effects of low molar mass liquid crystal on properties of the base polymers are very hard to find and almost all the researches are subject to focus on the phase behaviors of the low molar mass liquid crystal blends.

In this studies, the tensile strengths of base polymers and their blends are determined to investigate the effects of low molar mass liquid crystal on the mechanical properties of those base polymers.

Figure 5-17 to Figure 5-22 show the tensile strengths of the base polymers and their blends with low molar mass liquid crystals in the base polymer of PC, POM, PP, PE, SAN and PMMA. From all Figures, they show that the tensile strengths of base polymers and their blends with low molar mass liquid crystals are not significantly change (the difference of tensile strengths between base polymers and their blends with liquid crystal are less than 4 percent for every experiments, see the raw data in appendix D). In general, the addition of small filler can reduce the tensile strength of the blends [Kulichikhin, et. al., 1997]. These cause may be come from the trace of liquid crystal in the matrix phase of polymer that are not enough to affect the mechanical properties of the blends.

Tensile strength of PC and their blends with CBC53

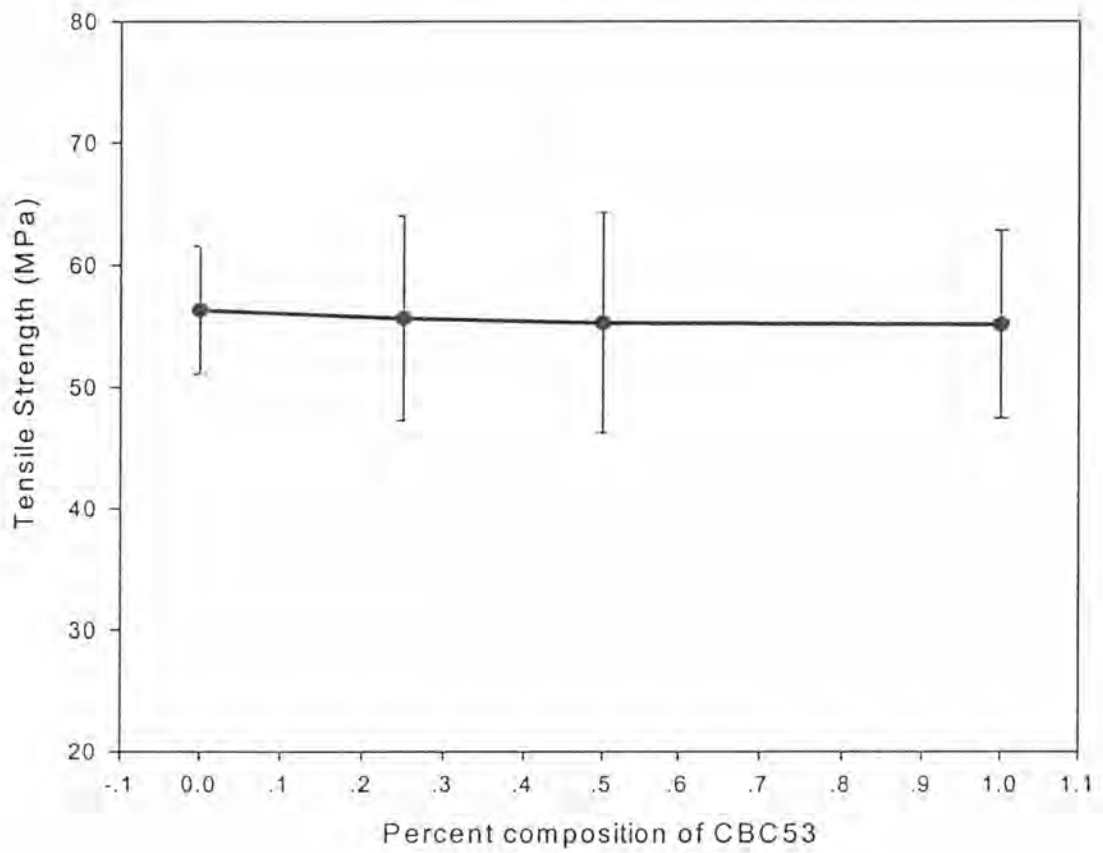


Figure 5-17 Tensile strength of PC and their blends with CBC53

Tensile strength of POM and their blends with HP5N

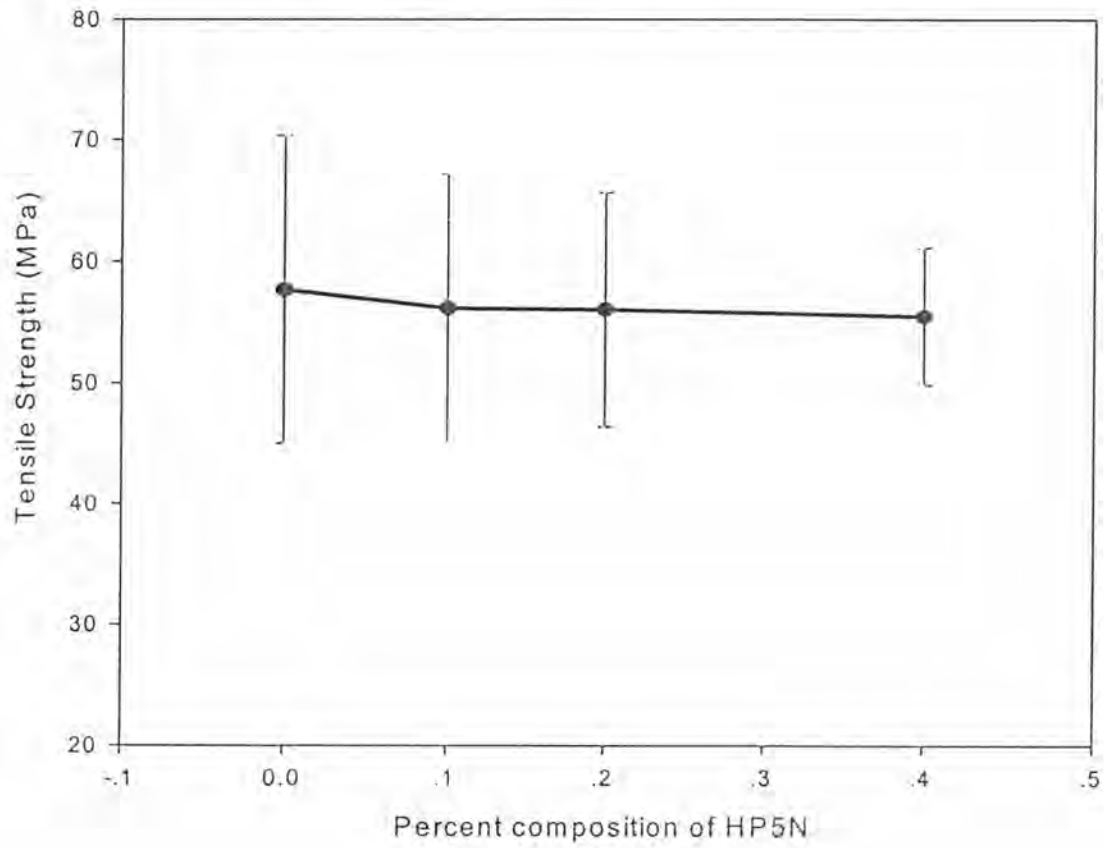


Figure 5-18 Tensile strength of POM and their blends with HP5N

Tensile strength of PP and their blends with HP5N

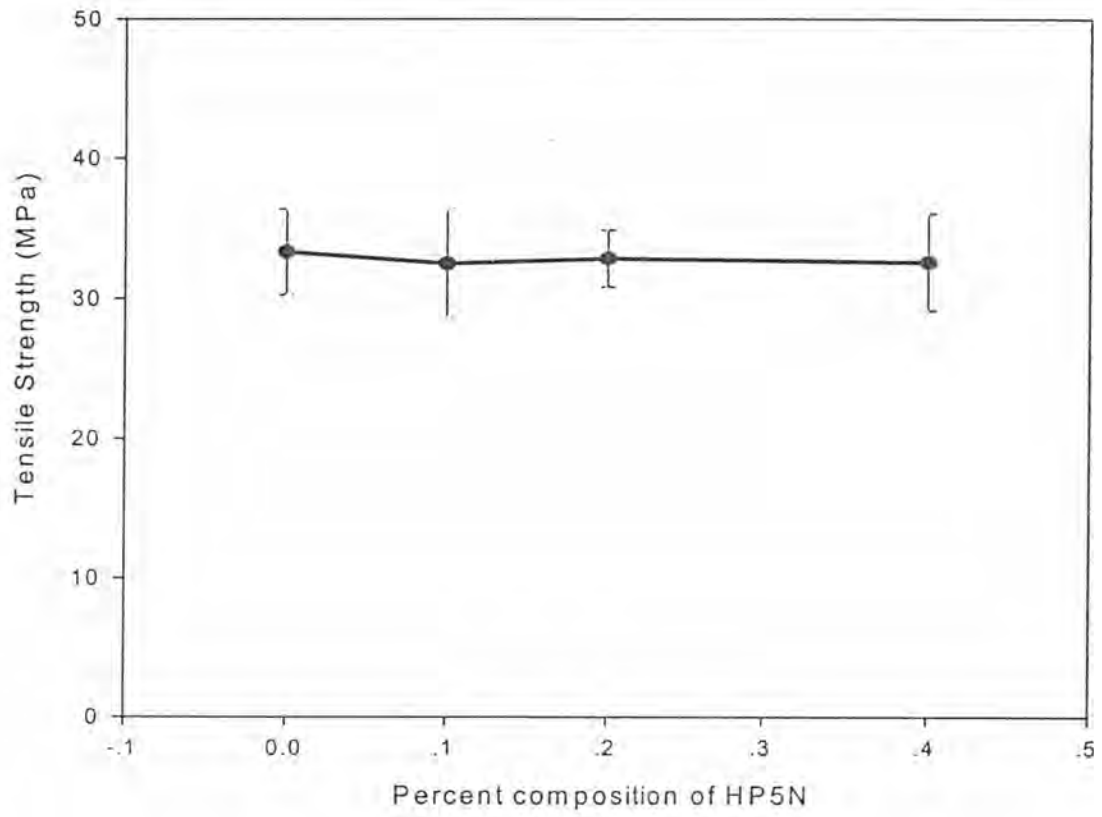


Figure 5-19 Tensile strength of PP and their blends with HP5N

Tensile strength of PE and their blends with BCH5

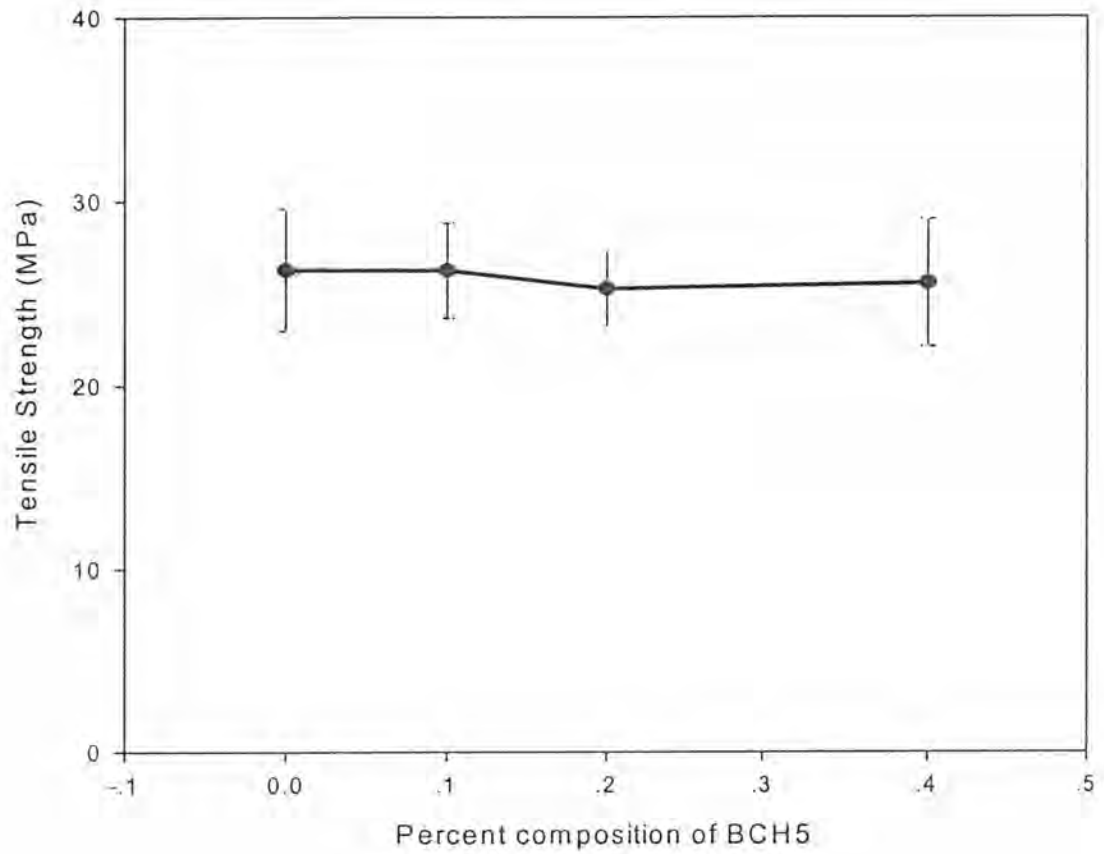


Figure 5-20 Tensile strength of HDPE and their blends with BCH5

Tensile strength of SAN and their blends with BCH5

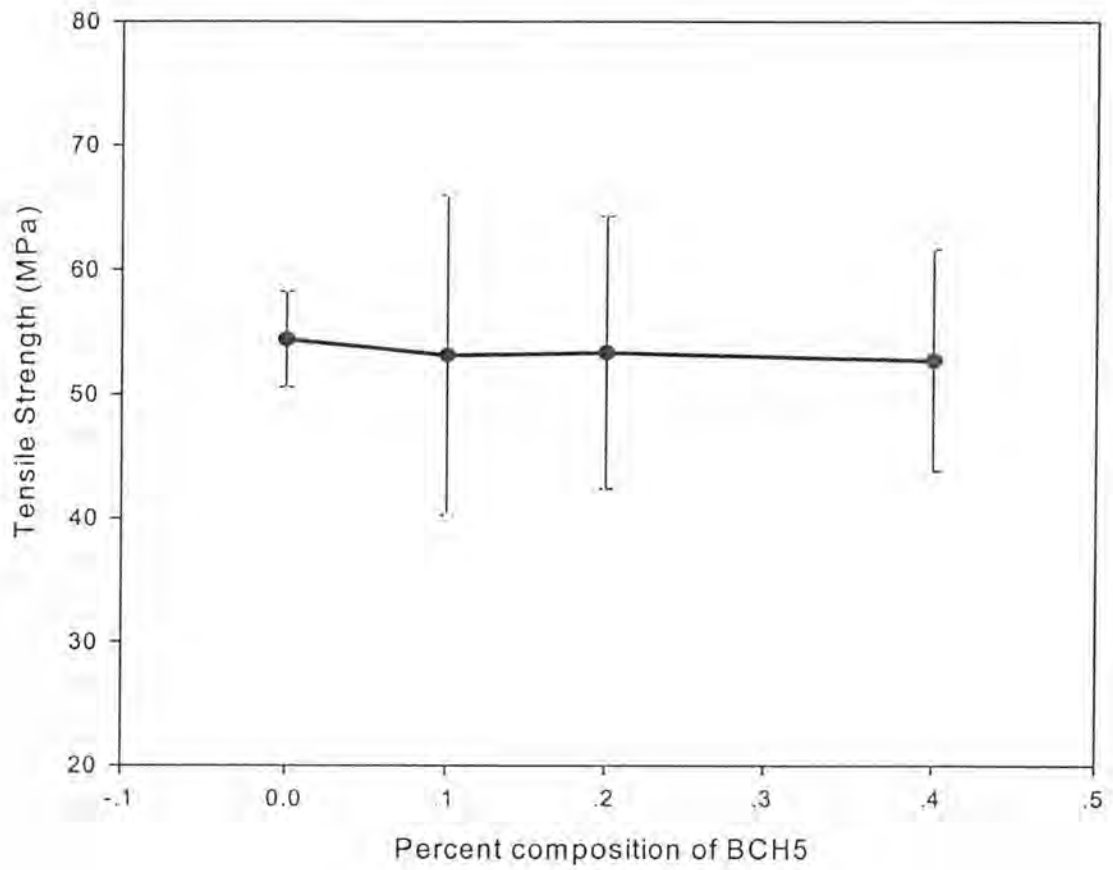


Figure 5-21 Tensile strength of SAN and their blends with BCH5

Tensile strength of PMMA and their blends with BCH5

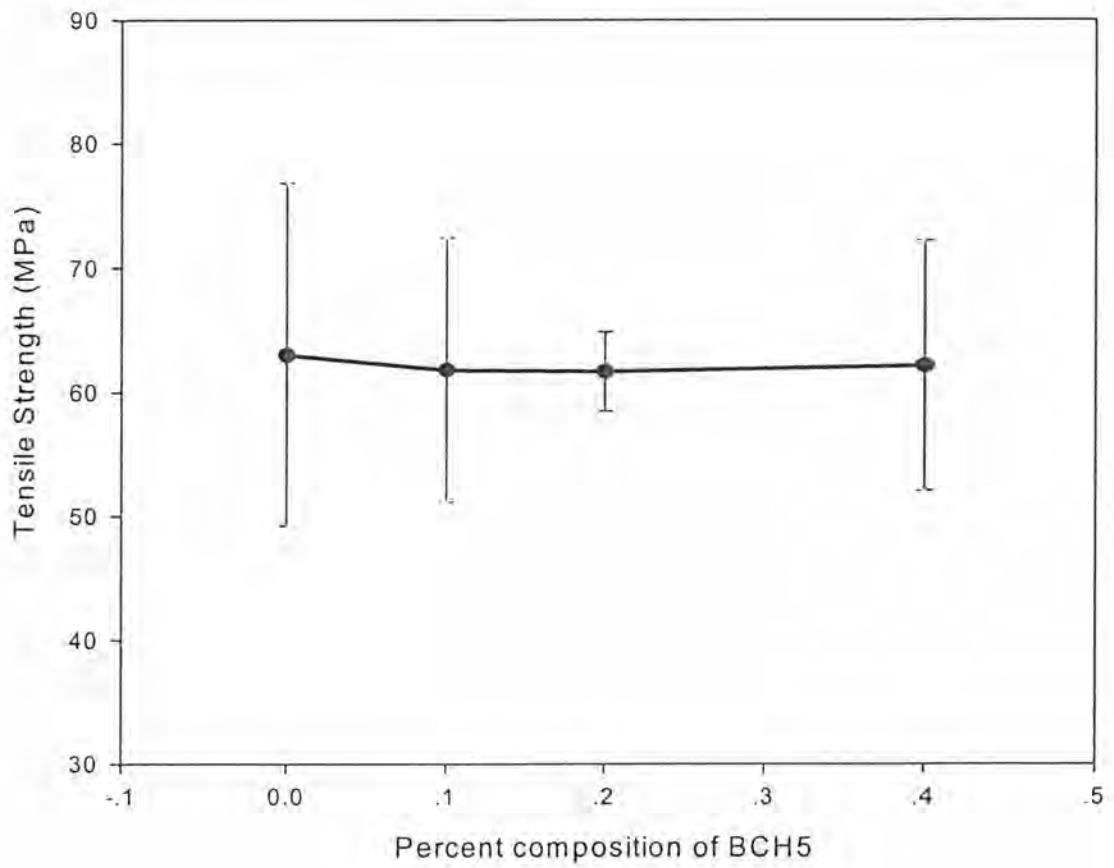


Figure 5-22 Tensile strength of PMMA and their blends with BCH5

The results of this work may lead to the development for the better processable properties of engineering polymer by adding the low molar mass liquid crystals. In the melting state, the liquid crystal can reduce the viscosity of the melt base polymer. If the viscosity is reduced, the operating temperature can be lower down. In other words, the production rate of the processing process can be increased at the same heat consumption. Moreover, the complicated shape of products can be made and finally the mould temperature may be reduced. The tensile strength and the glass transition temperature of the blends are not significantly different from pure base polymers.

5.2 Effect of low molar mass liquid crystal on properties of polymer alloys.

The preliminary studies of ternary blends of liquid crystal and polymer alloy are investigated in this research. From literature, only few papers that published the behavior of complex blends of liquid crystal polymer and polymer alloys. Xie, et. al. [2000] investigated the ternary blends of poly (butylene terephthalate, PBT), polyamide 6,6 (PA6,6) and a liquid crystalline copolyester base on p- aminobenzoic acid (ABA) and poly(ethylene terephthalate, PET), and found the lubricating effects of LCP on the polymer alloys. However, the study of low molar mass liquid crystals on properties of polymer alloys was very rarely found.

Polymer alloys comprising SAN and PMMA at various compositions, 80/20, 60/40, 40/60 and 20/80 percent by weight of SAN/PMMA will be explored. Low molar mass liquid crystal, BCH5 would be applied to the blends like the ternary components blends. The rheological behaviors of binary polymer alloys and their ternary additives would be investigated.

5.2.1 Effects of low molar mass liquid crystals on thermal properties of polymer alloys

Table 5-3 presents the T_g of the binary phase polymer alloys SAN/PMMA at composition 80/20, 60/40, 40/60 and 20/80 weight percent and their ternary blends with 0.4% BCH5. From these Figures, the T_g of binary phase polymer alloys are very close to the T_g of their blends when added the ternary phase liquid crystals. The difference in T_g between each composition is less than 3 °C. These cases may happen because the too small quantity of liquid crystal in the matrix phases of polymers. The amounts of LC are not significant enough to plasticize the binary blend to reduce the T_g.

Figure 5-23 represents the glass transition temperature of pure SAN, pure PMMA and their binary blends at various percent compositions, including the ternary system with 0.4% BCH5 at the same composition of SAN. The results show that the T_g of SAN is higher than PMMA and the binary blends of each composition arranged in series between that of pure component. The ternary blends with liquid crystal are in the same trend, but slightly lower.

Table 5-3 Glass transition temperature of the binary blends of SAN/PMMA and their ternary blends with 0.4% BCH5.

Sample	Glass transition temperature (°C)	
	0% BCH5	0.4% BCH5
SAN80/PMMA20	102.1	102.8
SAN60/PMMA40	101.9	100.6
SAN40/PMMA60	99.9	99.8
SAN20/PMMA80	99.1	96.8

Table D-4 Tensile strength of PE and its blends with BCH5

Sample	Tensile Strength (MPa)
Pure PE	26.28
PE + 0.1% BCH5	26.23
PE + 0.2% BCH5	25.39
PE + 0.4% BCH5	25.74

Table D-5 Tensile strength of SAN and its blends with BCH5

Sample	Tensile Strength (MPa)
Pure SAN	54.39
SAN + 0.1% BCH5	53.12
SAN + 0.2% BCH5	53.34
SAN + 0.4% BCH5	52.73

Table D-6 Tensile strength of PMMA and its blends with BCH5

Sample	Tensile Strength (MPa)
Pure PMMA	63.01
PMMA + 0.1% BCH5	61.79
PMMA + 0.2% BCH5	61.68
PMMA + 0.4% BCH5	62.14

Vita

Mister Suraphan Powanusorn was born in Bangkok, Thailand in April 30, 1975. He received the Bachelor Degree of Engineering in Chemical Engineering from the Department of Chemical Engineering, Srinakharinwirot University in 1996. He entered the Master of Engineering in Chemical Engineering Program at Chulalongkorn University in 1998.

Glass Transition of SAN/PMMA/0.4%BCH5 blends Versus Percent Composition of SAN

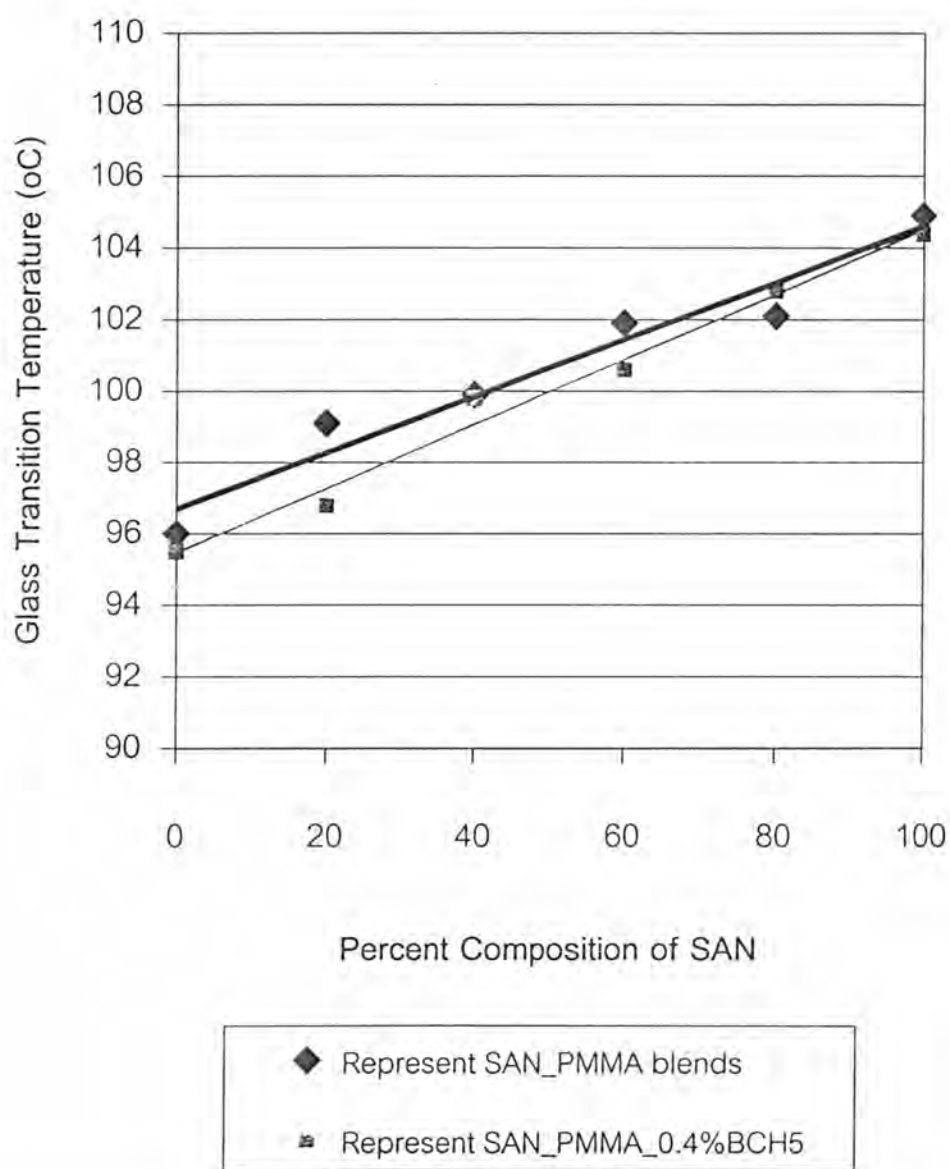


Figure 5-23 The glass transition temperature polymer alloys versus percent composition of SAN

5.2.2 Effects of low molar mass liquid crystal on the rheological properties of polymer alloys

The rheometric measurements of polymer alloys SAN/PMMA at various composition (80/20, 60/40, 40/60 and 20/80 percent by weight of SAN/PMMA) and their ternary blends with BCH5 at 0.1, 0.2 and 0.4 percent by weight of BCH5 are carried out with both shear sweep and frequency sweep mode at 200°C.

For the shear sweep mode, the range of experimental shear rate is 0 – 500 s⁻¹ within 10 minutes of measuring time.

For the frequency sweep, the preliminary experiment was carried out to determine the linearity stress from stress-strain curve and select this shear stress presented in linear viscoelastic region for application in the frequency sweep experiments. The oscillating frequency was started from 10² to 10⁻³ hz.

Figure 5-24 presents the zero shear viscosity of pure SAN, PMMA and their binary blends at the shear rate of 10⁻² Hz. versus percentage of SAN. The phase diagram of these SAN-PMMA has already been investigated by S. Sompradeekul [1998] and the results showed the lower critical solution temperature (LCST), which has the critical point around 10 – 20 % by weight of SAN. The phase separation region is close to 200°C, which is the experimental temperature of this research. So the phase separation might exist near the 20% weight of SAN and would disturb the rheology of the ternary blends at around 20% weight of SAN due to the lack of adhesion at interfacial layer [Li, et. al., 1995].

Zero shear viscosity of SAN-PMMA and their binary blends versus percentage of the blends at frequency of 10^{-2} hz

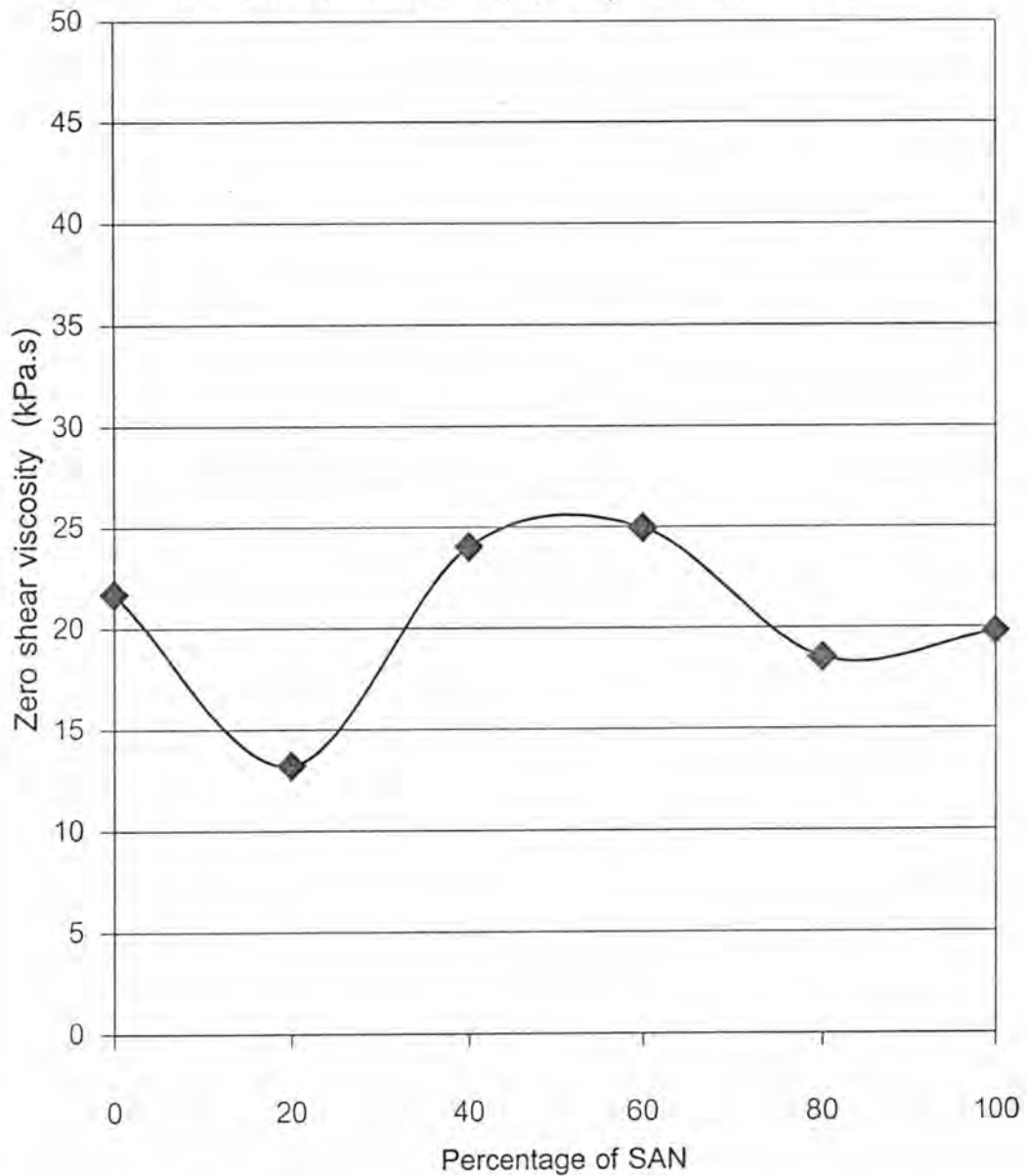


Figure 5-24 Zero shear viscosity of SAN, PMMA and their blends at various compositions of SAN

The frequency versus complex viscosity of the ternary blends at various percent composition of BCH5 as above (by the frequency sweep experiments) is shown in Figure 5-25 to Figure 5-28, and the shear rate versus shear viscosity of the ternary blends is shown in Figure 5-29 to Figure 5-32.

The Figure 5-25 and Figure 5-29 represented the rheological properties of the blends of 80/20 SAN/PMMA and the blends of 80/20 SAN/PMMA with BCH5. The rheological properties of the blends of 80/20 SAN/PMMA and their ternary blends from both graphs show the pseudoplastic behavior, that when applied more shear rate or frequency, the shear viscosity should be lower down. The influences of BCH5 on the shear viscosities of the ternary blends in the each Figure show the continuous viscosity reduction when adding BCH5 in the polymer alloys. However, the rate of decreasing of viscosity in the ternary blend is not as significantly different as that of the pure polymers in Part 5.1.1.

Figure 5-26 and Figure 5-30, represented the rheological properties of the blends of 60/40 SAN/PMMA, Figure 5-27 and Figure 5-31 represented that properties of the blends of 40/60 SAN/PMMA, and the ternary blends with BCH5. The results of these blends are the same as the composition of the blends of 80/20 SAN/PMMA, represented in the Figure 5-25 and Figure 5-29. They show that the pseudoplastic behavior of polymer melt and the adding of liquid crystal improve the flow ability of the blends.

Figure 5-28 and Figure 5-32 showed the opposite results from other Figures. At that composition, the polymer alloys comprising SAN_20 and PMMA_80 percent by weight. The binary phase of SAN/PMMA at this composition possesses the lowest shear viscosity compare with other binary compositions. The influences of BCH5 on the shear viscosity of these ternary blends show the significant increase continuously when adding more BCH5. The more content of BCH5 in the ternary blends, the more viscosity of the ternary blends. This phenomenon may come from the fine dispersion of small molecular liquid crystal that reduces the interfacial energy between the phases [Kozlowski and La Mantia, 1997] as explained in the top on this section and induce the good adhesion at the interface [Seo, 1997]

To investigate this partially miscible polymer alloys, it may be necessary to neglect the composition of the blends of 20/80 SAN/PMMA which may have the effects from the phase separation limit. Figure 5-33 presents the steady state viscosity of the binary polymer alloys and their ternary blends with liquid crystal BCH5 versus the weight percent of SAN. The Figure shows that the viscosity of the binary blends of pure SAN, Pure PMMA and BCH5 are reduced more than their ternary blends. The zero-shear viscosity of SAN and 0.4% BCH5 reduces around 59%, comparing with zero shear viscosity of pure SAN, the zero-shear viscosity of PMMA and 0.4% BCH5 reduces around 57%, comparing with zero shear viscosity of pure PMMA, while the zero shear viscosity of the blends of 80/20, 60/40 and 40/60 percent by weight of SAN/PMMA with 0.4% BCH5 reduce only 20-30 %. The blends of SAN/PMMA are partially miscible blends and the addition of BCH5 can improve the flow ability and may affect the interfacial between two components. The effect of BCH5 by viscosity reduction may less than that of pure component. In other words, the synergistic viscosity behavior of the binary blend SAN/PMMA can be observed when adding the liquid crystal BCH5.

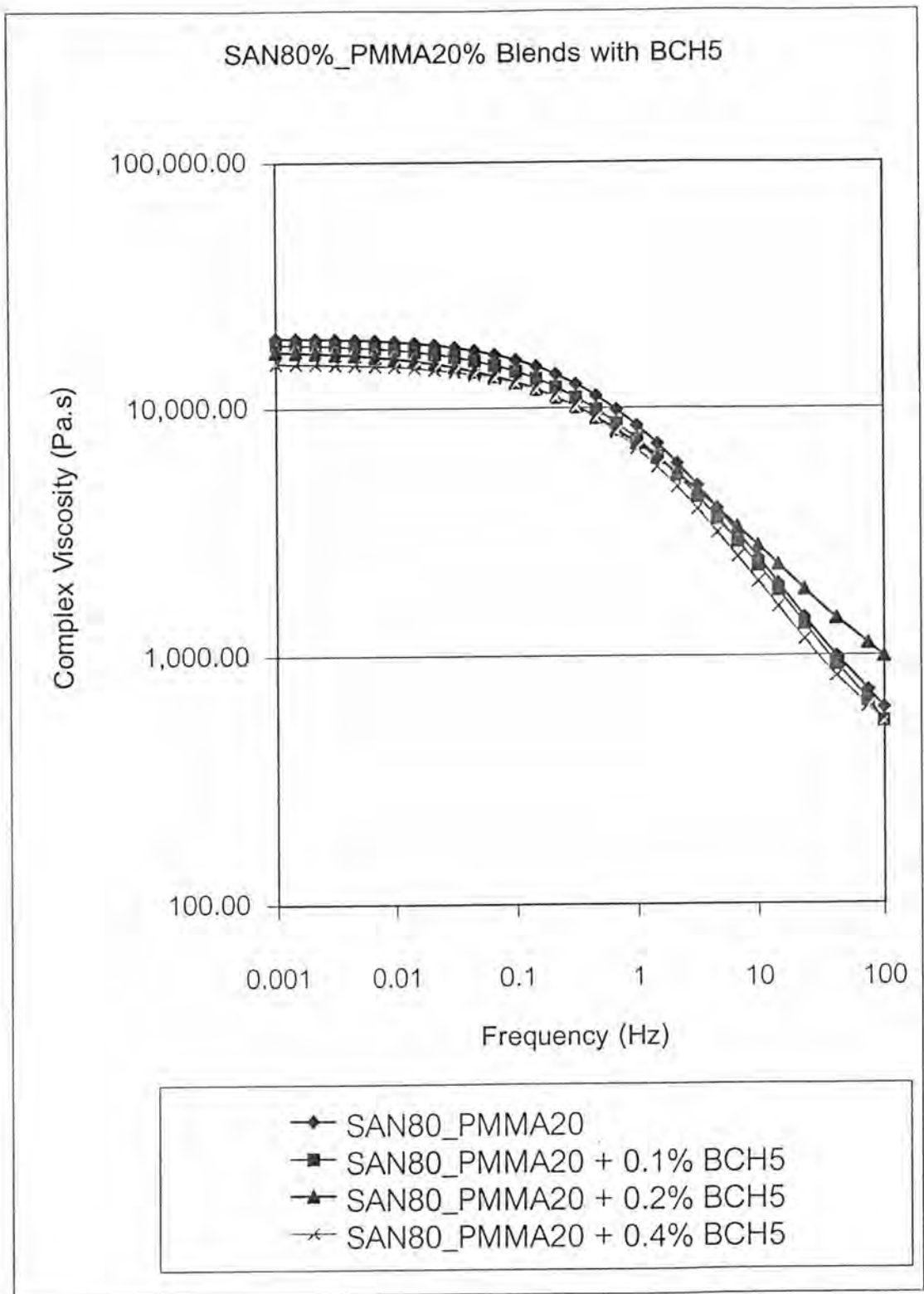


Figure 5-25 Complex Viscosity of the blends of 80/20 SAN/PMMA versus frequency at various composition of BCH5

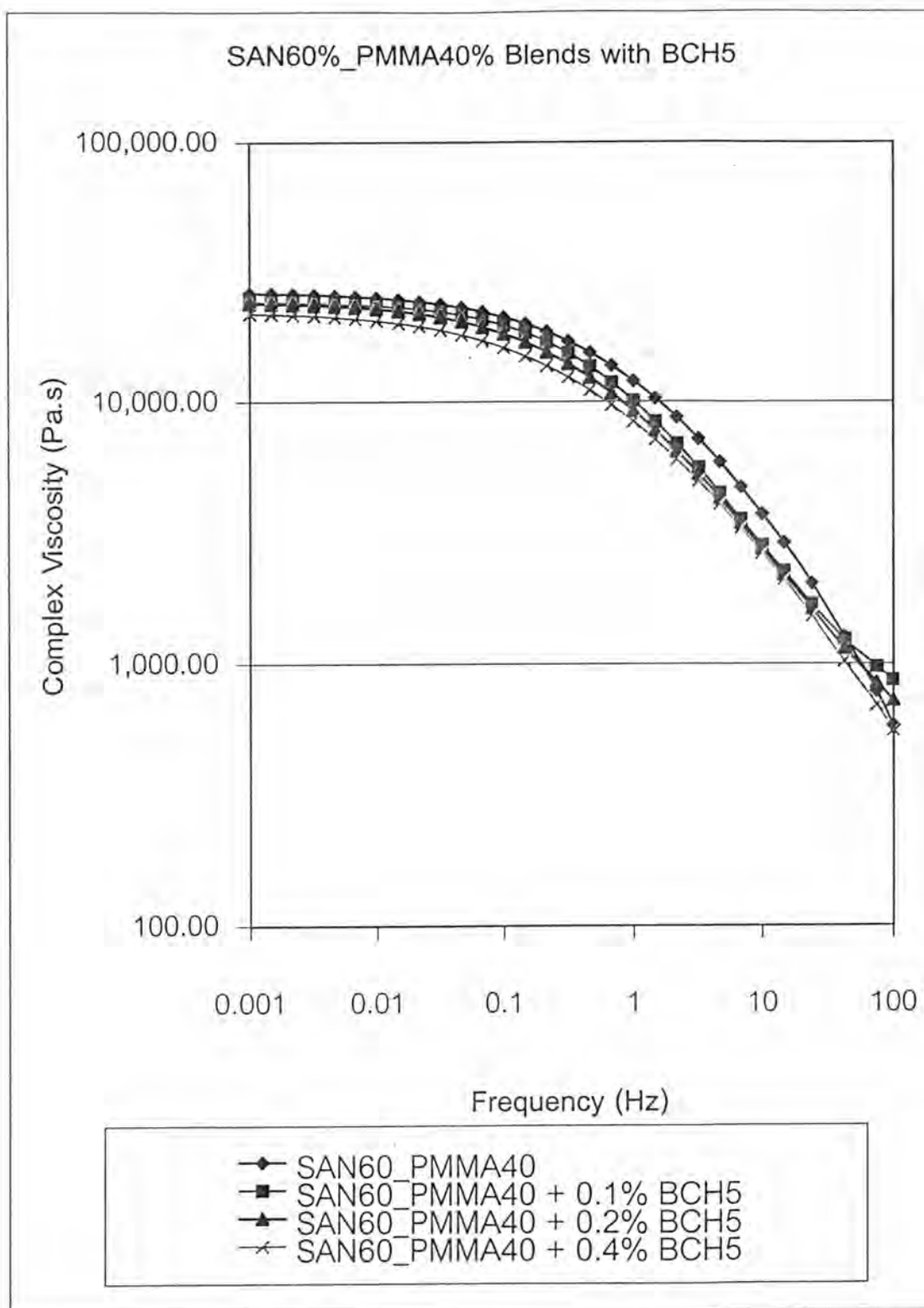


Figure 5-26 Complex Viscosity of the blends of 60/40 SAN/PMMA versus frequency at various composition of BCH5

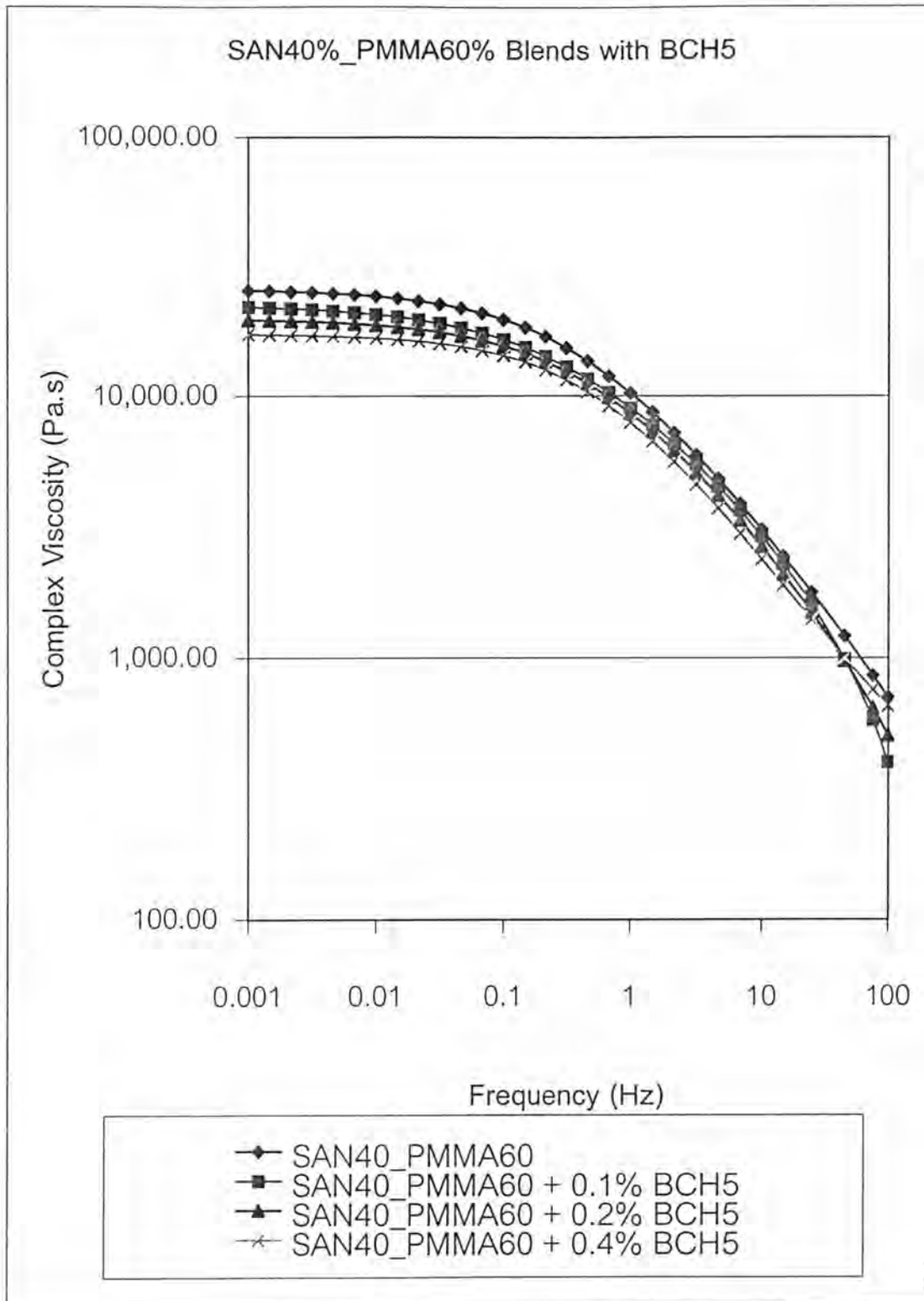


Figure 5-27 Complex Viscosity of the blends of 40/60 SAN/PMMA versus frequency at various composition of BCH5

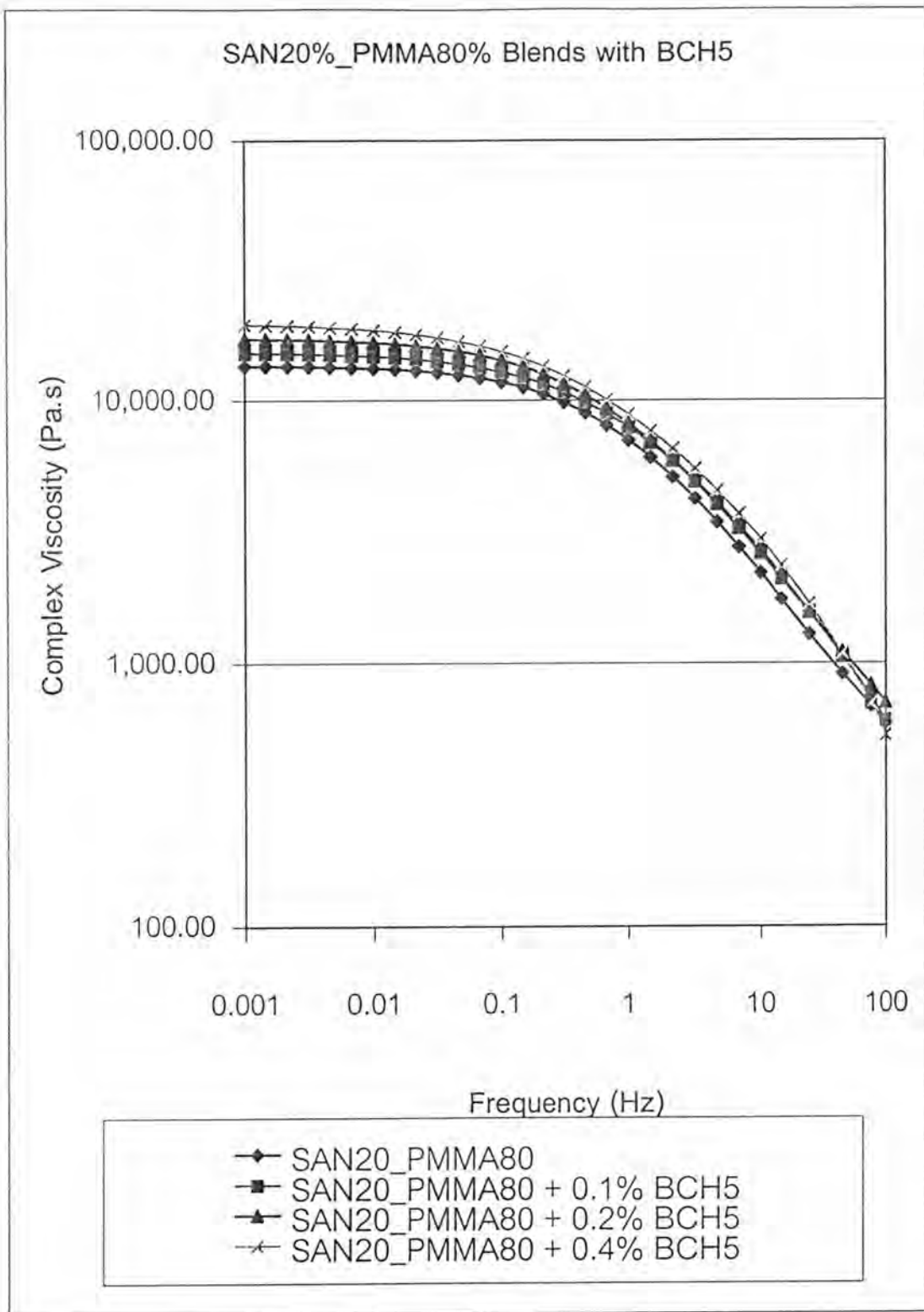


Figure 5-28 Complex Viscosity of the blends of 20/80 SAN/PMMA versus frequency at various composition of BCH5

Shear Viscosity of SAN80/PMMA20+BCH5

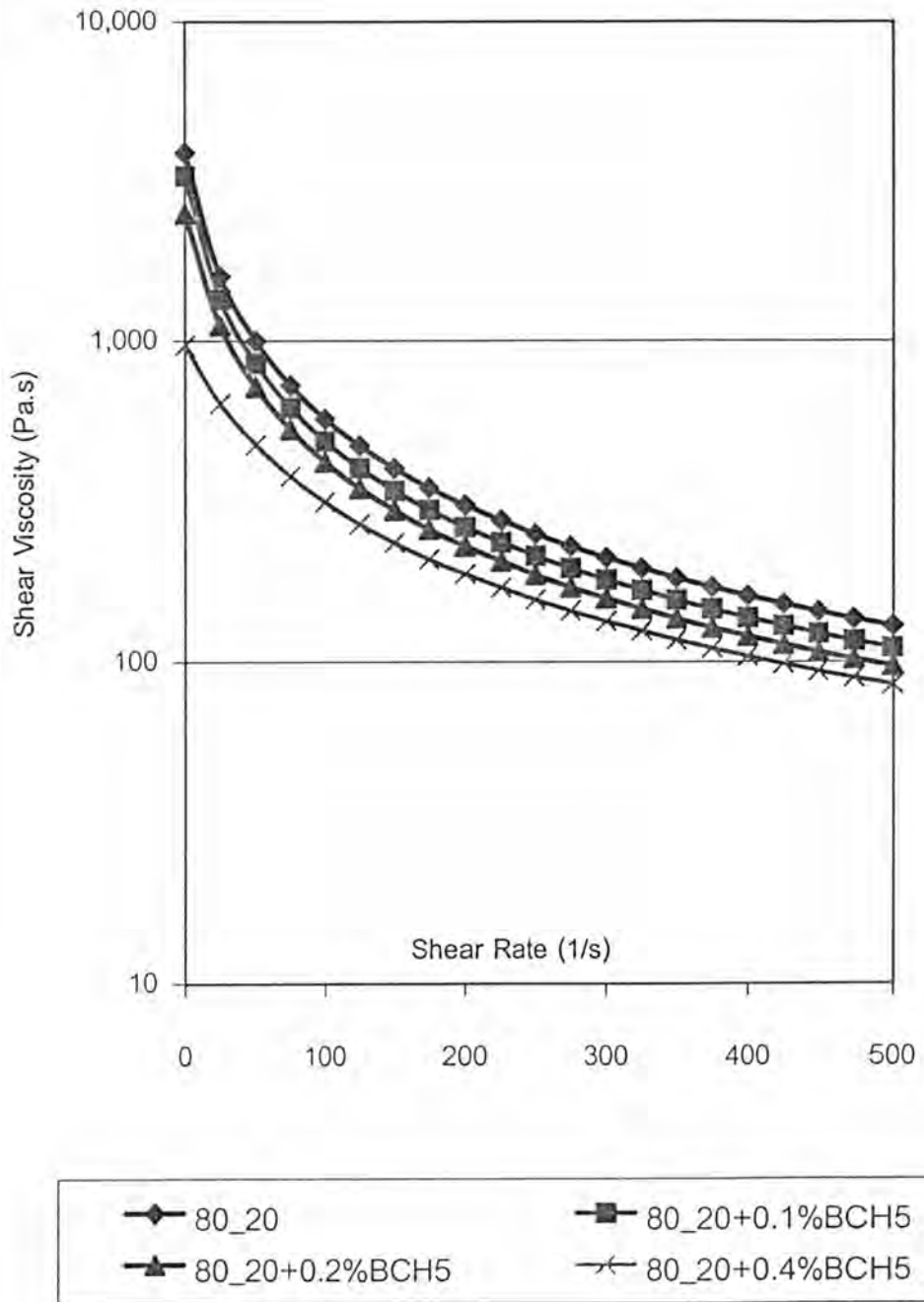


Figure 5-29 Shear Viscosity of the blends of 80/20 SAN/PMMA versus shear rate at various composition of BCH5

Shear Viscosity of SAN60/PMMA40+BCH5

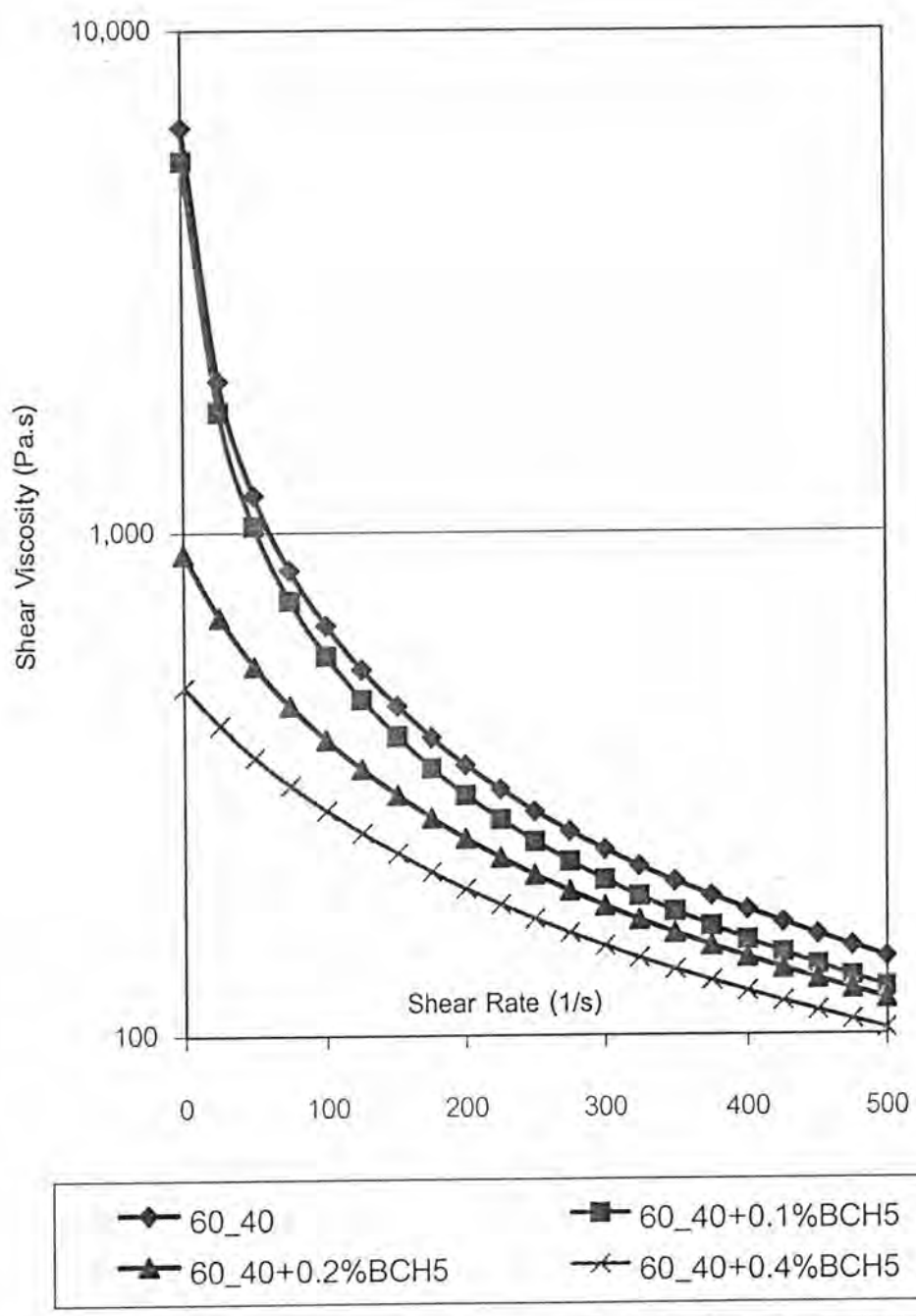


Figure 5-30 Shear Viscosity of the blends of 60/40 SAN/PMMA versus shear rate at various composition of BCH5

Shear Viscosity of SAN40/PMMA60+BCH5

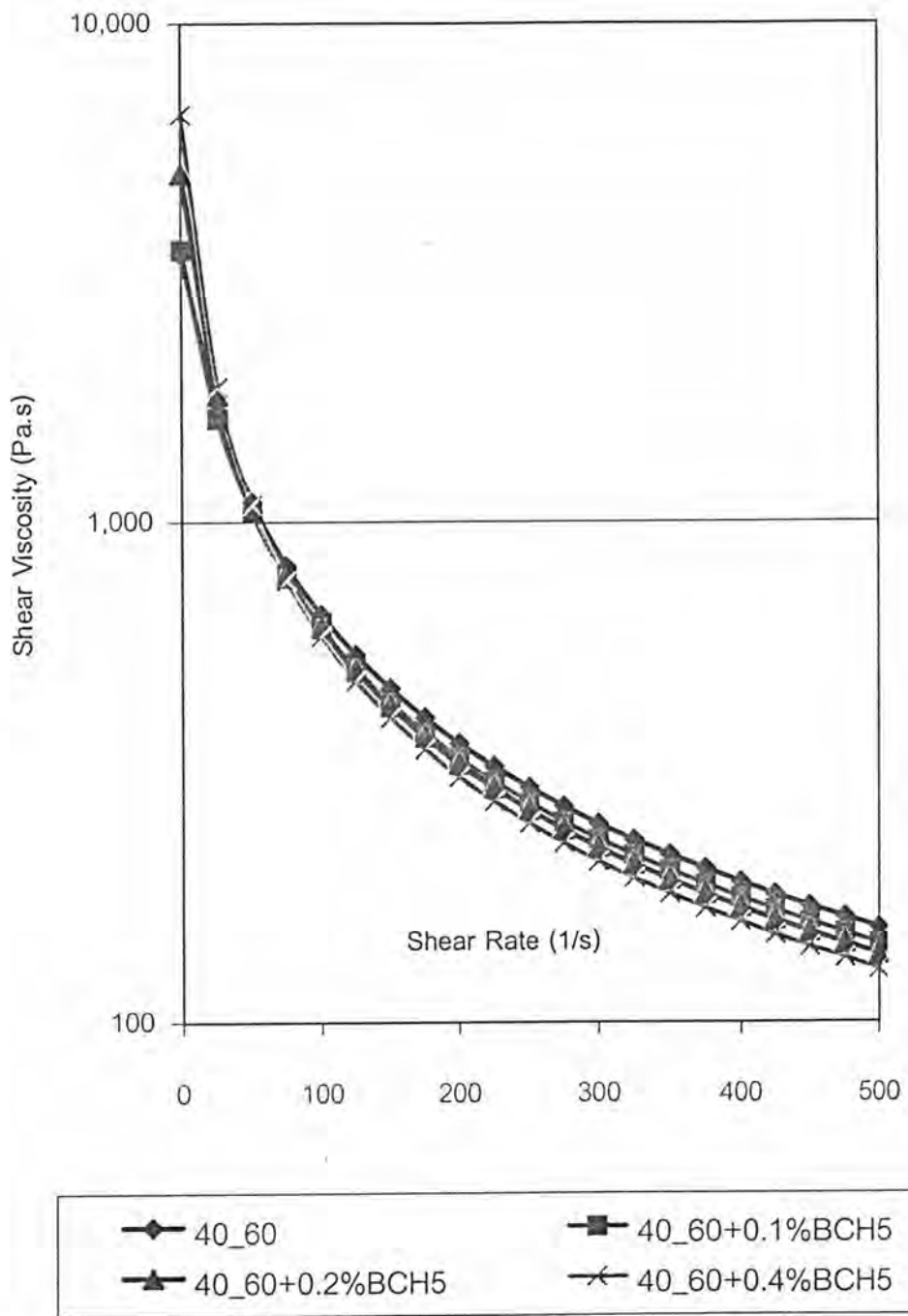


Figure 5-31 Shear Viscosity of the blends of 40/60 SAN/PMMA versus shear rate at various composition of BCH5

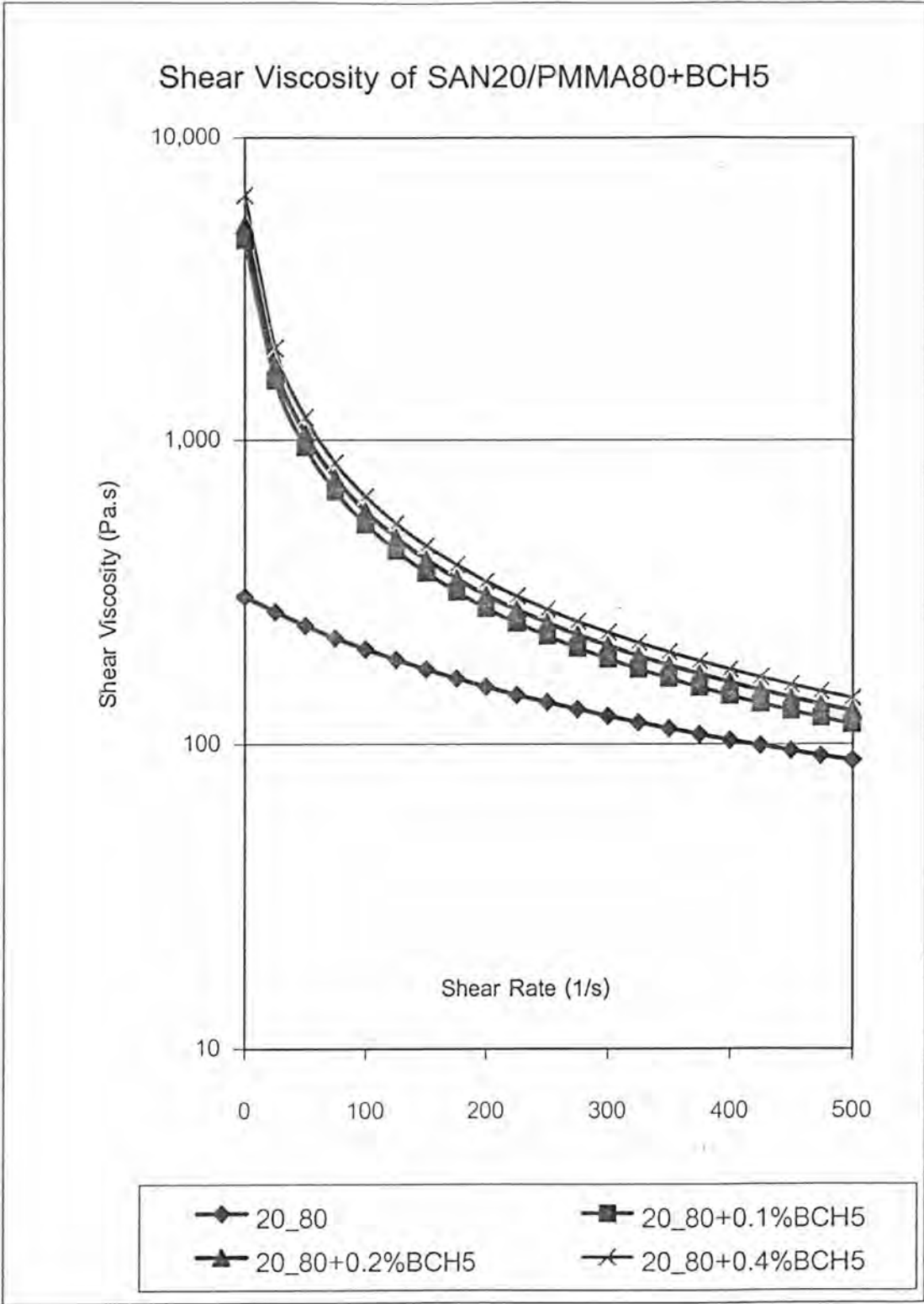


Figure 5-32 Shear Viscosity of the blends of 20/80 SAN/PMMA versus shear rate at various composition of BCH5

Zero-Shear Viscosity of SAN, PMMA and their blends versus percent composition of blends at frequency of 10^{-2} hz

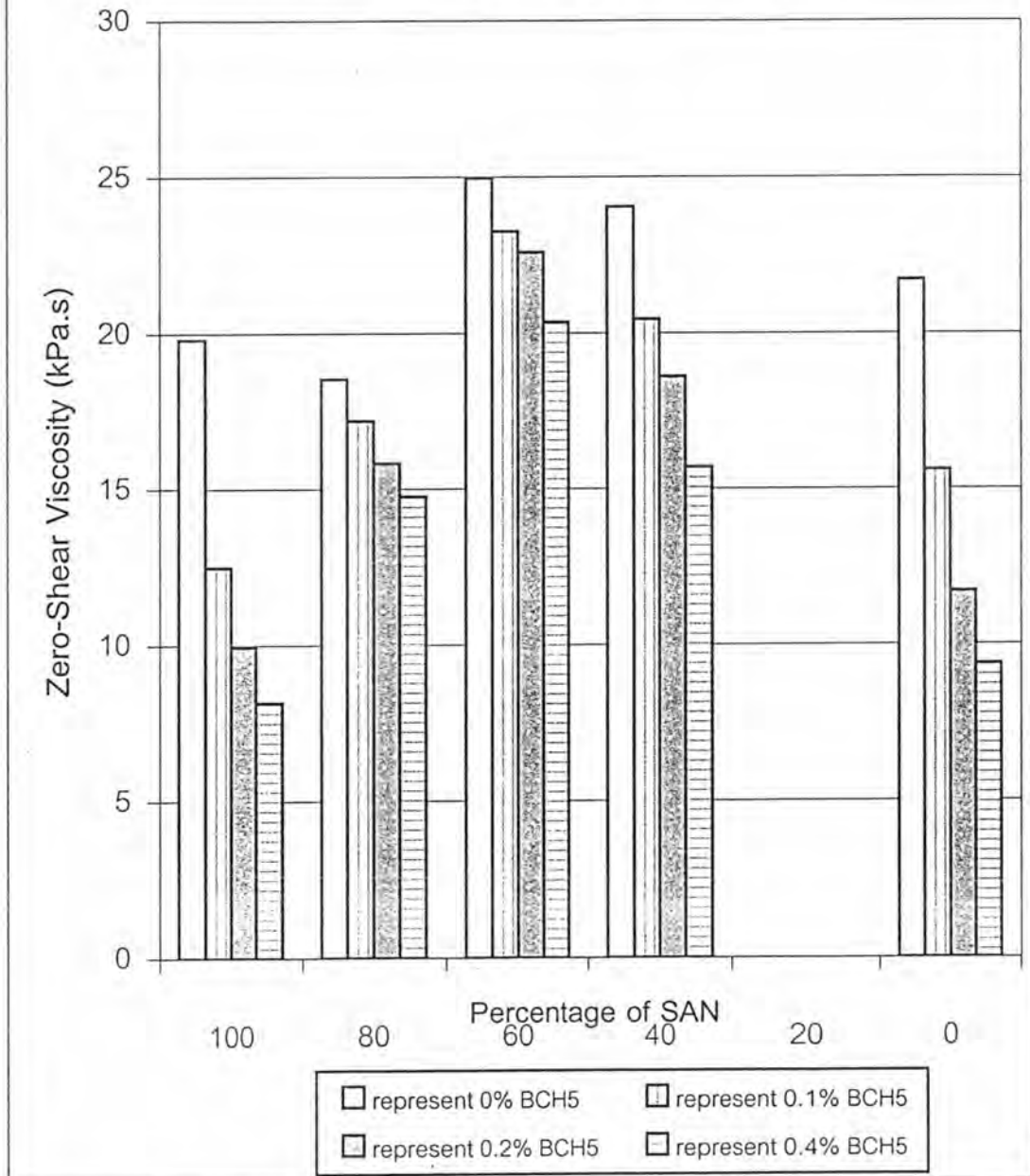


Figure 5-33 The zero shear viscosity of each blends with various percent of BCH5 versus percentage of SAN