แม่สีเข้มข้นสำหรับพอลิเมอร์โอลิฟินิกและสไตรินิก

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UNIVERSAL MASTERBATCH FOR OLEFINIC AND STYRENIC POLYMERS

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งานวิจัยฉบับนี้ได้ศึกษาถึง การใช้พอลิเอทิลีนความหนาแน่นสูงเป็นเรซินพาหะในแม่สีเข้มข้น สำหรับนำไปผสมกับพอลิเมอร์โอลิฟินิกและสไตรินิก ซึ่งพอลิเมอร์โอลิฟินิกประกอบด้วย โพลิโพรพิลีน พอลิเอทิลีนความหนาแน่นสูง และพอลิเอทิลีนความหนาแน่นต่ำ ส่วนพอลิเมอร์สไตรินิกประกอบด้วย โพลิสไตรีนและอะไครโลไนไตรบิวตะไดอีนสไตรีน แม่สีเข้มข้นประกอบด้วยพอลิเอทิลีนความหนาแน่นสูง 40 ถึง 60 เปอร์เซ็นต์ ไททาเนียมไดออกไซด์ 38 ถึง 58 เปอร์เซ็นต์ และซิงค์สเตียเรต 2 เปอร์เซ็นต์ โดยน้ำหนัก เมื่อผสมแม่สีเข้มข้นนี้ 5 เปอร์เซ็นต์ ลงไปในพอลิเมอร์โอลิฟินิกและสไตรินิกจะมีคุณสมบัติเชิงกลใกล้เคียงกับกรณีที่ไม่ผสมแม่สีเข้มข้น ขณะที่เมื่อใช้พอลิเอทิลีนความหนาแน่นต่ำ เป็นเรซินพาหะ ในแม่สีเข้มข้น เมื่อผสมแม่สีเข้มข้นนี้ 5 เปอร์เซ็นต์ ลงไปในพอลิเมอร์โอลิฟินิกและสไตรินิก พบว่าคุณสมบัติเชิงกลจะแตกต่างจากกรณีที่ไม่ผสมแม่สีเข้มข้น ผลการศึกษาแสดงว่าพอลิเอทิลีนความหนาแน่นสูงเป็นเรซินพาหะในแม่สีเข้มข้นที่ดีกว่าพอลิเอทิลีนความหนาแน่นต่ำ

ผลจากการทดสอบความเข้ากันได้ ด้วยกล้องจุลทรรศน์อิเลคตรอนแบบส่องกราด พบว่าเมื่อนำแม่สีเข้มข้นที่ใช้พอลิเอทิลีนความหนาแน่นสูงเป็นเรซินพาหะ ไปผสมกับพอลิเมอร์โอลิฟินิกและสไตรินิก สามารถผสมเข้ากันได้ดีกับพอลิเมอร์ดังกล่าว

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SARAPEE THONGSRI : UNIVERSAL MASTERBATCH
FOR OLEFINIC AND STYRENIC POLYMERS
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This research describes an investigation of the use of HDPE as a carrier resin in universal masterbatch for blending with olefinic and styrenic polymers. Olefinic polymers are comprisng of PP, HDPE and LDPE while styrenic polymers are HIPS and ABS. The composition of universal masterbatch is consisting of 40 to 60 % HDPE, 38 to 58 % TiO_2, and 2 % by weight Zn-st. When 5 percent of this universal masterbatch was blended with pure olefinic and styrenic polymers, the mechanical properties of olefinic and styrenic polymer blends were similar to those of pure olefinic and styrenic polymers. When LDPE was used as a carrier resin in universal masterbatch, the 5 % blending with olefinic and styrenic polymers gave inferior mechanical properties to those of pure olefinic and styrenic polymers. The results of this study show that HDPE is a better color carrier resin than LDPE.

The compatibility test using Scanning Electron Microscopy showed that polymer blends using universal masterbatch, which has HDPE as a carrier resin and olefinic and styrenic polymers were rather homogeneous.

Department…Petrochemistry and Polymer Science ……… Student’s signature………………
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ABBREVIATIONS

ABS : Acrylonitrile Butadiene Styrene Copolymer
DSC : Differential Scanning Calorimetry
EVA : Ethylene Vinyl Acetate Copolymer
HDPE : High Density Polyethylene
HDT : Heat Distortion Temperature
HIPS : High impact polystyrene
kgf/cm^2 : Kilogram force per cubic centimetre
LDPE : Low Density Polyethylene
MFR : Melt Flow Rate
mm : millimetre
^{O}C : Celcius degree
PC : Polycarbonate
PMMA : Poly(methyl methacrylate)
PP : Polypropylene
PVC : Poly(vinyl chloride)
SAN : Styrene-acrylonitrile
SEM : Scanning Electron Microscope
TGA : Thermal Gravimetry Analysis
TiO_2 : Titanium dioxide
wt% : percent by weight
Zn-st : Zinc stearate

CHAPTER I

INTRODUCTION

1.1 Background

The coloring of moulded plastic products can be achieved by adding a small percentage of color masterbatch into the main bulk of base polymer during processing. Indeed, this practice has been accepted widely in the industry. Since the primary objective of this practice is to color the products. The amount of the color masterbatch added being normally less than 5 percent by weight, emphasis has only been placed on how well the products are colored. [1]

The past three decades have been seen a major growth in the use of olefinic and styrenic polymers as materials for construction, insulation, packaging and transportation applications. This period has also seen desired level of color masterbatch mix with base polymers and how to use the color masterbatch with olefinic and styrenic polymers. Typically, in the color masterbatch market, Low Density Polyethylene (LDPE) has been used as a carrier resin. The color masterbatch composition comprises 40 to 60 % by weight of TiO_2 pigment, 0.2 to 0.5 % by weight of processing aid, and about 40 to 60 % by weight of carrier resin.

Universal masterbatch as the name suggests implies using a single carrier resin to make a color concentrate which can be used to color all polymers. [2]

Olefinic polymers, in this research, consist of polyethylene and polypropylene, which have good mechanical properties such as good solvent resistance, mouldability and good toughness. Because of their properties and their moderate cost, olefinic and styrenic polymers have been chosen for using in a wide range of applications. They are used for toy, bottle, film, etc.

Styrenic polymers, in this research, consist of polystyrene and acrylonitrile butadiene styrene, which is widely used for television, telephone, toy and computer. Styrenic polymers have good mechanical properties such as good toughness, impact strength and mouldability.

In the prior art, certain Ethylene Vinyl Acetate copolymer (EVA) was recommended as a carrier resin of universal masterbatch for thermoplastic polymers. Eventhough EVA has good compatibility with other polymers and dyes due to the polar vinyl acetate monomer, but it suffers from the thermal decomposition at temperatures above 230 ^{o}C giving acidic volatiles. Therefore, masterbatch compositions using EVA as a carrier resin are generally not suitable to use in thermoplastic polymers, which will be exposed to temperatures greater than 230 ^{o}C during processing. The Styrene Butadiene Styrene (SBS) block copolymer is another type of resin use in masterbatch composition to improve the mechanical properties of carrier resin. Generally, when SBS is utilized in a masterbatch composition with high levels of fillers, the viscosity of the masterbatch becomes unacceptably high, so that SBS as a carrier resin is stable at higher temperatures. [3]

Universal color concentrate (Universal masterbatch) has many conflicting requirements for coloring of different polymers. Nevertheless the use of acrylic polymer, which has narrow molecular weight dispersity as a carrier resin in universal masterbatch is acceptable for PS, ABS, PC, PMMA, SAN and PVC blending. The determination of acrylic polymer with other polymers such as PE and PP are not recommended.

In this research HDPE will be used as a carrier resin in universal masterbatch for olefinic and styrenic polymers. The universal masterbatches will compose of carrier resin and additives, which envisage have certain advantages over the existing commercial universal masterbatch, namely: lower cost, maintaining or improving mechanical properties and wide range of applications.

1.2 Objectives

1. To investigate the use of HDPE 6105 JU as a carrier resin for olefinic and styrenic polymers.
2. To compare the effects of using different carrier resin, between HDPE 6105 JU and LDPE ST 1018, in universal masterbatch on olefinic and styrenic polymers.

1.3 Scope of the Investigation

The carrier resins used in this study are HDPE 6105 JU and LDPE ST 1018. The mechanical properties of the blending will be measured according to the following procedures.

1. Preparations of universal masterbatches by hot melt in extruder machine. The composition of universal masterbatches will contain carrier resin, titanium dioxide and processing aid with the amount of carrier resins are varied from 40, 50, and 60% by weight.
2. Preparing the specimens of olefinic and styrenic polymers after blending with universal masterbatches by the following procedure:
    - Blending of olefinic and styrenic polymers with universal masterbatches in the extruder machine.
    - The pellets are moulded by injection method in order to provide specimens for testing.

3. The compatibility of olefinic and styrenic polymers blended with universal masterbatches is determined by Scanning Electron Microscopy.

4. The mechanical properties of olefinic and styrenic polymers blended with universal masterbatches such as izod impact strength, tensile strength, heat distortion temperature and melt flow rate will be investigated.

CHAPTER II

LITERATURE SURVEY

2.1 Theoretical background

2.1.1 Thermoplastic masterbatches

Thermoplastic masterbatches are a complex blending of the base thermoplastic polymer, a pigment and range of additive materials, normally use in production of agricultural film, packaging film, and injection moulding. A range of additive materials to be added in the masterbatch will improve the physical properties of the polymers. These properties include anti-blocking, slip properties of polyethylene film, anti-fibrillation, antistatic, stability against uv light and oxidation.

Thermal analysis is a very useful tool for the characterization of the physical properties of both masterbatches and finished product. The Differential Scanning Calorimetry (DSC) is used to identify the melt profiles of masterbatches and to determine oxidative stability. Thermogravimetric Analysis (TGA) is very useful for the determination of the composition of masterbatches, for comparison of a material with competitive products. [4]

Color masterbatch is generally a carrier resin containing one or more additives. The most common additive is a pigment, which imparts color to the base polymer. The color masterbatch is generally added to, and mixed with a base polymer to add a desired level of pigment. The amount of color masterbatch mixed with a base polymer varies depending on the pigmentation desired in the base polymer. Typically, 0.5 to 30 % by weight of color masterbatch is added to the base polymer.

Typical additives and pigments are carbon black, titanium dioxide, calcium carbonate, talc, and organic pigments. Other additives, such as ultraviolet stabilizers, antioxidants, slip stabilizers, lubricants, optical brighteners, antifog and antistatic agents may be incorporated into the universal masterbatch composite. In addition to imparting desirable properties to the universal masterbatch and the thermoplastic polymer that will incorporate the universal masterbatch, carbon black has been used as a black pigment. Similarly, titanium dioxide has been used as a white pigment in universal masterbatch compositions. To some degree, thermoplastic polymers suffer a decrease in mechanical performance when pigments are added. While not wishing to be so limited, the decreasing in performance to non-uniform dispersions of the pigment. While some attempts have been made in altering the viscosity of the thermoplastic polymers to achieve improved dispersion, a masterbatch which achieves uniform pigment dispersion at elevated loading which is compatible over a broad range of thermoplastic polymers, and maintains or improves the mechanical properties of the thermoplastic would be considerable improvement in the art.

Polyethylene based masterbatches are the most widely available, although masterbatch compounds are available in most types of resin, e.g. polypropylene, polystyrene, polyvinyl chloride etc. [5]

2.1.2 Properties of High Density Polyethylene (HDPE)

HDPE is a thermoplastic polyolefin manufactured by the polymerization of ethylene. Although HDPE has been available since 1956, this plastic has not reached a mature status. Product and market development continues to open new markets and applications for this versatile material.

HDPE is a highly crystalline, nonpolar thermoplastic. The appearance of natural HDPE is milky white with some degree of translucence in thin sections. Polyethylene has excellent chemical resistance to most household and industrial chemicals. Chemical attack does happen with certain classes of chemicals such as aggressive oxidizing agents, aromatic hydrocarbons, and halogenated hydrocarbons. The polymer does not absorb moisture and provides good water vapor barrier, which makes it useful in packaging applications. HDPE has good electrical properties, especially dielectric strength, making it well suited for wire and cable applications. Medium to high molecular weight grades offer superb impact resistance at ambient conditions and even at temperatures as low as –40 ^{O}F.

The specific properties of each HDPE grade are a combination of four primary variables: density, molecular weight, molecular weight distribution, and additives. Different catalysts are also used to customize polymers for special performance characteristics. These variables are combined to produce grades that offer an optimum balance of properties for different applications. HDPE has density above 0.940 g/cc. Homopolymers have the highest density, greatest stiffness, best barrier properties, and high melting point. Higher density generally improves mechanical strength properties such as tensile strength, stiffness, and hardness.

2.1.3 Properties of Low Density Polyethylene (LDPE)

Low Density Polyethylene (LDPE) is a thermoplastic obtained through the high-pressure free radical polymerization of ethylene. LDPE is the oldest member of the polyethylene family of resin.

In LDPE, Melt Flow Rate (MFR) affects the flow properties of the resin and properties involving large deformations of the finished product. Decreasing the MFR (increasing the molecular weight) increases most strength properties while, at same time, decreased the ease of flow and the ability to draw the resin down to thin gages during fabrication process.

The degree of crystallinity in LDPE is a function of the amount of short chain branching present in the resin. In LDPE, crystallinity normally falls in the range of 30 to 40 %.

Increasing crystallinity in LDPE results in an increase in stiffness, chemical resistance, barrier properties, tensile strength, and heat resistance; and a decrease in impact strength, tear strength, and stress-crack resistance.

LDPE grades are available to satisfy requirements of most thermoplastics processing techniques, including blown film extrusion, cast film extrusion, extrusion coating, wire and cable coating, injection moulding, and blow moulding. [6]

2.1.4 Dispersion of titanium dioxide pigments in universal color concentrate

Titanium dioxide pigments are used throughout the plastics industry to provide opacity, whiteness and weatherability in polymer articles. The light scattering performance of titanium dioxide pigments is dependent upon the state of dispersion. For maximum light scattering efficiency the pigment should be uniformly dispersed and exist as discrete single crystals. However, economic considerations dictate the acceptable levels of dispersion are achieved in the shortest possible times. Elimination of large agglomerates is particularly important, as these cause screen pack blocking, tearing of the film or surface blemishes in the finished article.

Good dispersion of the pigment in masterbatch is essential for the production of homogeneously pigmented films. The degree of dispersion is depend on the type and concentration of titanium dioxide used, the wetting power of the polymer and the compression and shear forces generated during the incorporation process.

In comparison with other pigments, titanium dioxide is easy to disperse in plastics. This is largely due to modification of the crystal surface with inorganic coatings such as hydrous alumina or hydrous silica. [5]

2.1.5 Theory and basic principles of improving polymer blend

Dispersion is a two-phase system in which one phase (the dispersed phase) is homogeneously distributed as small particles within a second phase called the continuous phase. This yields complete encapsulation of an ingredient or additive as the dispersed phase. When the dispersed phase is formulated at a high concentration (15 to 95 % active) the product is often called a masterbatch.

During the production of dispersion, three stages are encountered. First, incorporation of the large agglomerates occurs as they are encapsulated by the polymer phase. Second, the agglomerates are distributed randomly throughout the system. And finally, the actual dispersion process beings with the agglomerates being reduced into smaller ones.

Equipment used to manufacture color masterbatch includes the two-roll rubber mill, internal mixers and compounding extruders.

The primary particle shape can influence the system rheology and, therefore, the dispersion process. Products with low melting points can be difficult to pre-disperse at high concentrations due to the melt influence on the system rheology and processing shear. Similarly, the continuous polymer phase should be of sufficient viscosity at processing temperatures to insure adequate shear input to attain good dispersion of the additive.

The resulting color masterbatch viscosity should be similar to the viscosity of the compound into which it is being incorporated to insure good mixing. The continuous phase of the color masterbatch must also be compatible with the final compound.

Color masterbatch may be supplied in slab form, cut into cubes or extrude into pellets. The cube / pellet form is preferred for automatic weighing operations. Extruded pellet forms may also be strained to eliminate contaminants and undispersed particles. [7]

2.2 Literature review

Wong [1] described that the coloring of moulded plastic products can be achieved easily by adding a small percentage of color masterbatch into the main bulk of plastic resin during processing. The amount of the color masterbatch added is normally 4 to 5 % by weight. ABS and SAN were chosen to be the moulding polymer in an injection machine. Both of visual observation and tensile test indicated that the best condition was achieved at 4% of color masterbatch and color masterbatch with higher melt flow rate gave more homogeneous color than that of lower melt flow rate.

Webling [8] developed color masterbatches for aliphatic polyketones. When the color masterbatches are used the notched impact strength actually increases from 18 to 23 mJ/mm (white coloration) and even with intensive black coloration it does not drop below its normal value.

Petinoit and Rasquin [3] prepared white masterbatches using 60 % by weight of TiO_2 pigment, 0.6 % by weight of processing aid (Zn-st), 0.5 % by weight of antioxidant, 6 % by weight of viscosity modifier and 32.9 % by weight of SBS as a carrier resin. The thermoplastic polymer such as POM, PC, PBT, PMMA and PA were used. The mechanical properties were tested on the base thermoplastic polymers and also on the thermoplastic polymers containing 5 % by weight of white masterbatch, and the results gave similar, or improved mechanical properties in comparison with those of the thermoplastic polymers.

Ogbobe [9] described various methods for assessing the degree of dispersion of additive in LDPE masterbatches and polyolefin blending with LDPE masterbatches. Initial examination of additive dispersion in masterbatches was considered necessary to insure that any inferior dispersions in the blending were not caused by poor dispersion in the masterbatch. X-ray microradiography and light microscopy have shown that the dispersion of the pigments in the LDPE masterbatches used in this study, particularly those containing iron oxide, barium sulfate, calcium sulfide and zinc sulfide are invariably bad. The inferior additive dispersion observed in some polyolefin blending with LDPE masterbatches may have been partly due to the poor dispersion in the masterbatch.

SEM showed that the LDPE masterbatch stayed as a separated phase in each of the polyolefin blending with LDPE masterbatches. The LDPE therefore stayed as streaks in the polyolefin blending with LDPE masterbatches, causing a greater part of the additive to remain in the streaks.

Yu, Menashi and Kaul [10] investigated the performance of the carbon black filled masterbatch as a function of carbon black loading, morphology, and polymer / carbon black interaction in order to provide the guidelines for formulating masterbatches. Use of a carrier resin with lower melt viscosity than the letdown resin can reduce this relative viscosity and improve the physical properties of the letdown. The melt viscosity model for carbon black in ABS and SAN was derived.

Brenner [11] investigated the composition and the usage of masterbatches which is defined as highly filled concentrates of additives which are diluted to give a desired level of functional performance.This process is widely used with a range of filler and carrier types to give masterbatches formulation for typically a 2%-5% addition level during primary moulding operations.

Benkreira [12] described that a good masterbatch will had a lower melting point than its target host polymer and will be rather less viscous than target host polymer at the process temperature and shear rate. The data clearly indicated that in terms of these two indicators viscosity ratio is the major factor, though melting point plays an important role. Modifying the high viscous, but cheap and easily handled can be developed with the low viscous carrier. In order to reach the target of low melting point and low viscosity of masterbatches between 10 and 200 Pa.s at the processing shear rate and temperature would appear to be a promising target area for optimizing further.

Yoshiko [13] provided an ethylenic masterbatch that has no difficulty to handle such as fusion or stickiness. The result shows high thermal stability and excellent compatibility to other resin components to be a matrix. This masterbatch comprises 40-95 % by weight of an ethylene elastomer that is prepared by copolymerization of ethylene and an olefin of 3-20 carbon number. It has a density of 0.856 – 0.88 g/cm^3 an MFR of 0.1-100 g/10 mins and 5-60 % by weight of a crystalline polyolefin.

Michiro [14] described the coating resin composition for pigment dispersion comprising of a resin for pigment dispersion and a dispersant, wherein a copolymer of a monomer mixture comprising 65-100 % by weight of styrene monomer and 0-35 % by weight of alkyl (1-8 C) (meth) acrylate is used as the dispersant.

Akira [15] described the composition having excellent moldability, mechanical and thermal properties, that useful in the fields of blow-molding, vacuum forming, extrusion molding, expansion molding by including a polymer of an alkyl (meth) acrylate and a thermoplastic resin. The objective thermoplastic resin composition is produced by including preferably 0.01 –50 % by weight of a polymer composed of an alkyl (meth) acrylate having a 2-30 C alkyl group.

Peng, Tsung, Shiun and Hui [16] prepared black masterbatch for polyester polymer consisting of:

(a) 25-99.7 % of polyester polymer by weight
(b) 0.1-20 % of dispersive second polyester by weigh and/or 0.1-15 % EVA by weight
(c) 0.1-40 % of carbon black by weight; whereby the black masterbatch can be easily manufactured by a simple process without polluting the environment.

Seiichiro and Eisuke [17] prepared a highly concentrated masterbatch of fine inorganic particles, which is not detrimental to the desirable properties inherent in a polyolefin film. It has good dispersibility, and is useful for a film having good properties including appearance.

Kazuhiko, Masaharu, Rikuo and Shingo [18] produced the titled pellets containing uniformly and finely dispersed colorant by kneading a thermoplastic polymer with a colorant by a kneader at the first stage, and pelletizing the mixture using a twin-screw kneader extruder at the second stage.The objective masterbatch coloring polymer pellet is produced by carrying out the first stage kneading of a thermoplastic polymer such as polyethylene terephthalate and a colorant such as carbon black at a weight ratio of 90/10 or 45/55 using a kneader or a bunbury mixer and carrying out the second stage kneading and pelletization of the mixture using a twin-screw kneader extruder. The second-stage kneading is carried out preferably by diluting the mixture with a thermoplastic polymer.

As far as we know, there is no work on universal masterbatch using HDPE as a carrier resin.

CHAPTER III

EXPERIMENTAL

3.1 Materials

1. Polyethylene (PE)
    - High-Density Polyethylene (HDPE 6105 JU)
        : Thai Polyethylene Co., Ltd.
    - Low-Density Polyethylene (LDPE ST 1018)
        : Thai Petrochemical Industrial Co., Ltd.
2. Acrylonitrile Butadiene Styrene copolymer (ABS LUSTRAN 250)
    : Bayer Polymer Co., Ltd.
3. Polypropylene (PP 2300 K)
    : Thai Petrochemical Industrial Co., Ltd.
4. High Impact Polystyrene (HIPS 825-10)
    : Eternal Co., Ltd.
5. Titanium dioxide pigment (TiO_2)
    : Ishihara Co., Ltd.
6. Zinc stearate (Zn-st)
    : Taiwan Nichiyu Chemical Co., Ltd.

3.2 Apparatus

1. Scanning Electron Microscope (SEM) ; Model JSM 6400
2. Izod impact testing machine ; Toyo seiki seisaku , ltd.
3. Compression machine ; Shinto metal industries ltd.
4. Extruder machine ; Saitama
5. Tensometer ; Monsanto
6. Heat distortion temperature ; Toyo seiki seisaku , ltd.
7. Melt flow meter ; Technol seven
8. Injection moulding machine ; Sanjo seiki co., ltd.
9. Differential Scanning Calorimeter ; NETZSCH DSC 200

3.3 Preparation of universal masterbatches compositions.

In this research, the ingredients of universal masterbatches have been designed using the formula of color masterbatches available in the market. White color universal masterbatches were prepared by varying the ratio of HDPE 6105 JU (LDPE ST 1018) as a carrier resin from 40 % to 60 % by weight, titanium dioxide as pigment from 38 % to 58 % by weight, and fixed the quantity of Zinc stearate at 2 % by weight.

The universal masterbatches are designated as M/H 4058, M/H 5048, M/H 6038, M/L 4058, M/L 5048 and M/L 6038. The HDPE 6105 JU was used as a carrier resin in M/H 4058, M/H 5048 and M/H 6038. While LDPE ST 1018 was used as a carrier resin in M/L 4058, M/L 5048 and M/L 6038. The compositions of universal masterbatches are listed in Table 3.1 to 3.2. The universal masterbatches were blended and extruded at ambient temperature using the following procedure:

a) Universal masterbatches were prepared by blending appropriate amount of the compositions by hands as shown in table 3.1.

Table 3.1 **The preparation of universal masterbatches.**

Universal masterbatch	HDPE 6105 JU (kg)	LDPE ST 1018 (kg)	TiO_2 (kg)	Zn-st (kg)
M/H 4058	0.8	-	1.16	0.04
M/H 5048	1.0	-	0.96	0.04
M/H 6038	1.2	-	0.76	0.04
M/L 4058	-	0.8	1.16	0.04
M/L 5048	-	1.0	0.96	0.04
M/L 6038	-	1.2	0.76	0.04

b) After blending, each blend was extruded by a single screw extruder machine at a zone temperature profiles 210 ^{O}C – 220 ^{O}C and screw speed 150 rpm. The blend was extruded and quenched in water and palletized.

c) In order to compare the performance characteristics imparted by the universal masterbatch, compositions with a desired base thermoplastic polymer (ABS, HIPS, HDPE, LDPE and PP) were prepared. Performance tests were conducted on the base thermoplastic polymer, and also on thermoplastic polymer compositions containing 5 and 15 percent by weight of M/H 4058, M/H 5048, M/H 6038, M/L 4058, M/L 5048, and M/L 6038. The performance tests conducted on each composition are compatibility, tensile strength, izod impact, melt flow rate and heat distortion temperature.

Table 3.2 **The composition of universal masterbatches.**

Composition	Carrier resin / TiO_2 / Zn-st level (by weight)					
	M/H 4058	M/H 5048	M/H 6038	M/L 4058	M/L 5048	M/L 6038
HDPE 6105 JU	40%	50%	60%	-	-	-
LDPE ST 1018	-	-	-	40%	50%	60%
TiO_2	58%	48%	38%	58%	48%	38%
Zn-st	2%	2%	2%	2%	2%	2%

Table 3.3 **The ratio of carrier resin, TiO_2 and Zn-st after blending with universal masterbatches at 5 and 15 percent.**

Universal masterbatch		Composition		
Formula	(%)	Carrier resin (%)	TiO_2 (%)	Zn-st
M/H 4058	5	2.0	2.9	0.1
M/H 4058	15	6.0	8.7	0.1
M/H 5048	5	2.5	2.4	0.1
M/H 5048	15	7.5	7.2	0.1
M/H 6038	5	3.0	1.9	0.1
M/H 6038	15	9.0	5.7	0.1
M/L 4058	5	2.0	2.9	0.1
M/L 4058	15	6.0	8.7	0.1
M/L 5048	5	2.5	2.4	0.1
M/L 5048	15	7.5	7.2	0.1
M/L 6038	5	3.0	1.9	0.1
M/L 6038	15	9.0	5.7	0.1

3.4 Preparation for the blending of olefinic and styrenic polymers with universal masterbatches at 5 and 15 percent.

Olefinic polymer, including HDPE 6105 JU, LDPE ST 1018, PP 2300 K and styrenic polymer, including ABS LUSTRAN 250, and HIPS 825-10 were blended with universal masterbatches at 5 and 15 percent as shown in table 3.3. The blends were extruded using an extruder machine at a zone temperature profile 210 ^{O}C – 220 ^{O}C, temperatures at die 210 ^{O}C for HDPE 6105 JU, LDPE ST 1018, PP 2300 K, and 220 ^{O}C for ABS LUSTRAN 250, HIPS 825-10 and screw speed of extruder machine is 150 rpm.

Table 3.4 **Synergistics blending of olefinic and styrenic polymers with universal masterbatches at 5 and 15 percent.**

Composition	Synergist Universal masterbatch level (by weight)	
	at 5%	at 15%
HDPE 6105 JU : M/H 4058	95 : 5	85 : 15
LDPE ST 1018 : M/H 4058	95 : 5	85 : 15
PP 2300 K : M/H 4058	95 : 5	85 : 15
ABS LUSTRAN 250 : M/H 4058	95 : 5	85 : 15
HIPS 825-10 : M/H 4058	95 : 5	85 : 15
HDPE 6105 JU : M/H 5048	95 : 5	85 : 15
LDPE ST 1018 : M/H 5048	95 : 5	85 : 15
PP 2300 K : M/H 5048	95 : 5	85 : 15
ABS LUSTRAN 250 : M/H 5048	95 : 5	85 : 15
HIPS 825-10 : M/H 5048	95 : 5	85 : 15

Table 3.4 (continued)

Composition	Synergist Universal masterbatch level (by weight)	
	at 5%	at 15%
HDPE 6105 JU : M/H 6038	95 : 5	85 : 15
LDPE ST 1018 : M/H 6038	95 : 5	85 : 15
PP 2300 K : M/H 6038	95 : 5	85 : 15
ABS LUSTRAN 250 : M/H 6038	95 : 5	85 : 15
HIPS 825-10 : M/H 6038	95 : 5	85 : 15
HDPE 6105 JU : M/L 4058	95 : 5	85 : 15
LDPE ST 1018 : M/L 4058	95 : 5	85 : 15
PP 2300 K : M/L 4058	95 : 5	85 : 15
ABS LUSTRAN 250 : M/L 4058	95 : 5	85 : 15
HIPS 825-10 : M/L 4058	95 : 5	85 : 15
HDPE 6105 JU : M/L 5048	95 : 5	85 : 15
LDPE ST 1018 : M/L 5048	95 : 5	85 : 15
PP 2300 K : M/L 5048	95 : 5	85 : 15
ABS LUSTRAN 250 : M/L 5048	95 : 5	85 : 15
HIPS 825-10 : M/L 5048	95 : 5	85 : 15
HDPE 6105 JU : M/L 6038	95 : 5	85 : 15
LDPE ST 1018 : M/L 6038	95 : 5	85 : 15
PP 2300 K : M/L 6038	95 : 5	85 : 15
ABS LUSTRAN 250 : M/L 6038	95 : 5	85 : 15
HIPS 825-10 : M/L 6038	95 : 5	85 : 15

3.5 Preparation of the specimen for compatibility test.

For Scanning Electron Microscopy samples were prepared by cutting a small (1 mm) rectangular specimen out of a compression machine. The thin section was examined and photographed in a JSM 6400 at 15 kV. Photomicrographs were provided at x 2500 magnification.

3.6 Test Methods

Various properties of olefinic and styrenic polymers blended with universal masterbatches at 5 and 15 percent were tested using the condition listed in Table 3.5 to 3.8.

Table 3.5 **The conditions for testing of PE compositions.**

Properties	Unit	Test method	Specimen	Condition
Tensile Strength	kgf/cm^2	ASTM D-638	ASTM type I 3.0 mm Thickness	speed : 30 mm/min
Izod Impact Strength	kgf-cm/cm^2	ASTM D-256	1/8”x1/2”x2.5”	Notched bar
Melt Flow Rate	g/10 mins	ASTM D-1238	5 g.	190 ^{O}C x 2.16 kg

Table 3.6 The conditions for testing of PP compositions.

Properties	Unit	Test method	Specimen	Condition
Tensile Strength	kgf/cm^2	ASTM D-638	ASTM type I 3.0 mm Thickness	speed : 30 mm/min
Izod Impact Strength	kgf-cm/cm^2	ASTM D-256	1/8”x1/2”x2.5”	Notched bar
Melt Flow Rate	g/10 mins	ASTM D-1238	5 g.	230 ^{O}C x 2.16 kg

Table 3.7 The conditions for testing of ABS compositions.

Properties	Unit	Test method	Specimen	Condition
Tensile Strength	kgf/cm^2	ASTM D-638	ASTM type I 3.0 mm Thickness	speed : 10 mm/min
Izod Impact Strength	kgf-cm/cm^2	ASTM D-256	1/8”x1/2”x2.5”	Notched bar
Melt Flow Rate	g/10 mins	ASTM D-1238	5 g.	220 ^{O}C x 10.0 kg
Heat Distortion Temperature	^{O}C	ASTM D-648	1/4”x1/2”x2.5”	18.6 kg/cm

Table 3.8 **The conditions for testing of HIPS compositions.**

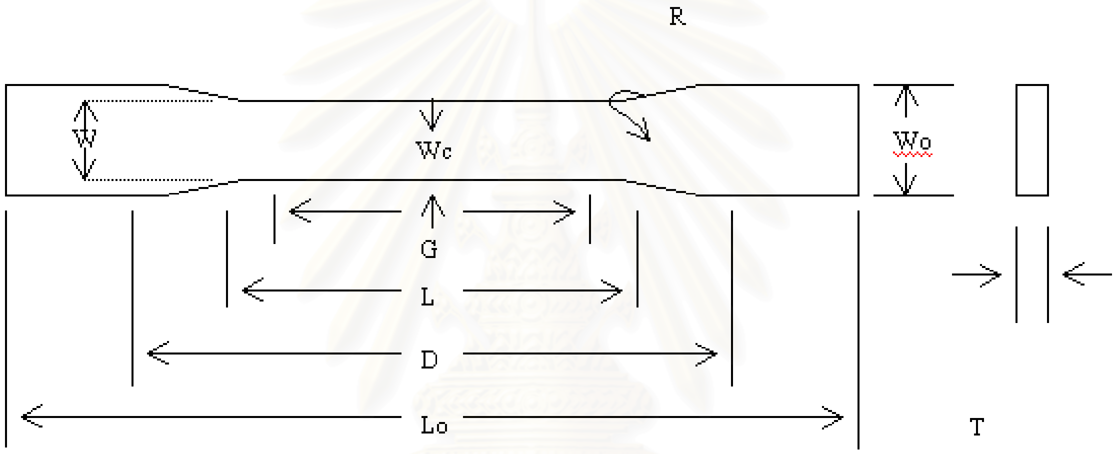
Properties	Unit	Test method	Specimen	Condition
Tensile Strength	kgf/cm^2	ASTM D-638	ASTM type I 3.0 mm Thickness	speed : 10 mm/min
Izod Impact Strength	$kgf\text{-}cm/cm^2$	ASTM D-256	1/8”x1/2”x2.5”	Notched bar
Melt Flow Rate	g/10 mins	ASTM D-1238	5 g.	200 ^{O}C x 5.0 kg
Heat Distortion Temperature	^{O}C	ASTM D-648	1/4”x1/2”x2.5”	18.6 kg/cm

3.6.1 Mechanical Properties Testing

Mechanical properties of olefinic and styrenic polymer blends were measured by following the ASTM test methods as following:

ASTM D-638: Standard test method for tensile properties.

The test specimens (Type I) dimension is shown in figure 3.1



W: 3 mm Wo: 19 mm G: 50 mm R: 76 mm

L: 57 mm Lo: 165 mm D: 115 mm

Figure 3.1 Schematic of tensile test specimen (Type I)

The tensile testing conditions were as follows:

Temperature : 23.0 °C

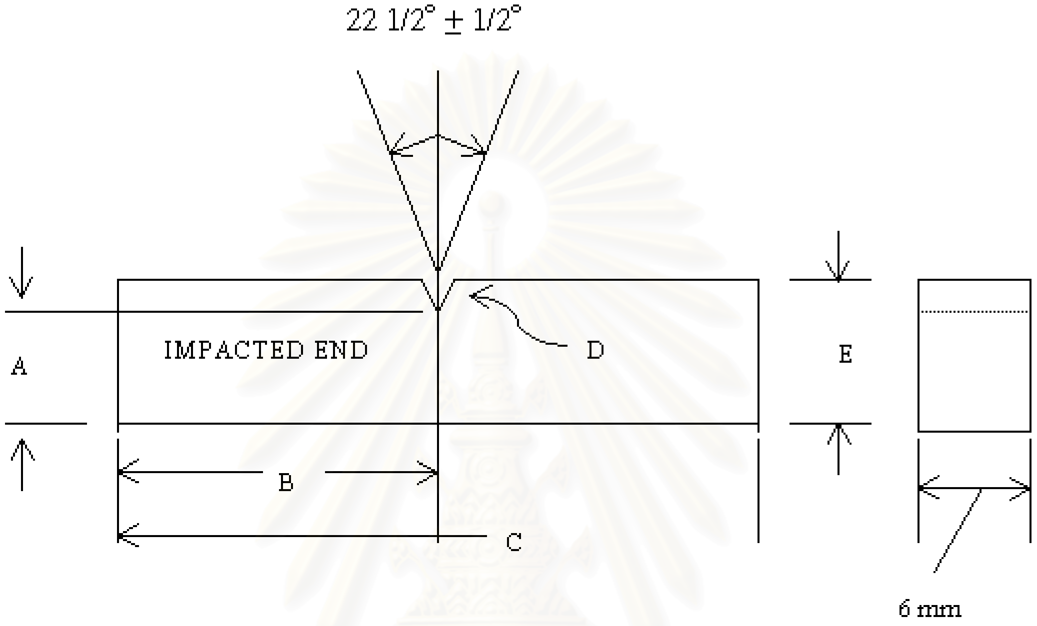
Relative humidity : 50.0 %

Distance between grips : 115 mm

Gage length : 50 mm

ASTM D-256: Standard test method for Izod impact.

The test specimens dimension for test is shown in figure 3.2



Unit: mm

A: 10.16 ± 0.05

B: 32.00 max. 31.50 min.

C: 64.00 max. 63.00 min.

D: 0.25 ± 0.05

E: 12.70 ± 0.15

Figure 3.2 Schematic of Izod impact test specimen.

The machine parameters and testing conditions of the impact test are listed below:

Temperature	:	23.0	^{O}C
Relative humidity	:	50.0	%
Depth of specimen	:	10.16	mm
Pendulum capacity	:	11.0	J

ASTM D-648: The test method for Heat distortion temperature.

At least three test specimens were used for the test. The specimen was tested under the conditions in Table 3.3. For ABS and HIPS resins the specimens were kept at 23 ± 2 °C and 50 ± 5 % relative humidity for not less than 40 hours prior to testing.

ASTM D-1238: The test method for melt flow rate.

At least three specimens were used for the test. The pellets of olefinic and styrenic polymers were extruded and dried at 90 °C for about 3 hrs.

3.7 Thermal Analysis

In this research, the samples, weighing about 5 mg, were analyzed on a NETZSCH DSC 200 instrument. The heating rate was 10 °C /min from ambient temperature to 300 °C. The results are shown in Figure B-1 to B-11 in Appendix B.

CHAPTER IV

RESULTS AND DISCUSSION

4.1 Determination of the compatibility of olefinic and styrenic polymer blends

The compatibility of M/H 4058 at 5 percent, which used HDPE 6105 JU as a carrier resin in olefinic and styrenic polymers is the most important factor on mechanical properties. The result of scanning electron microscopy is shown in Figure 4.1 to 4.11.

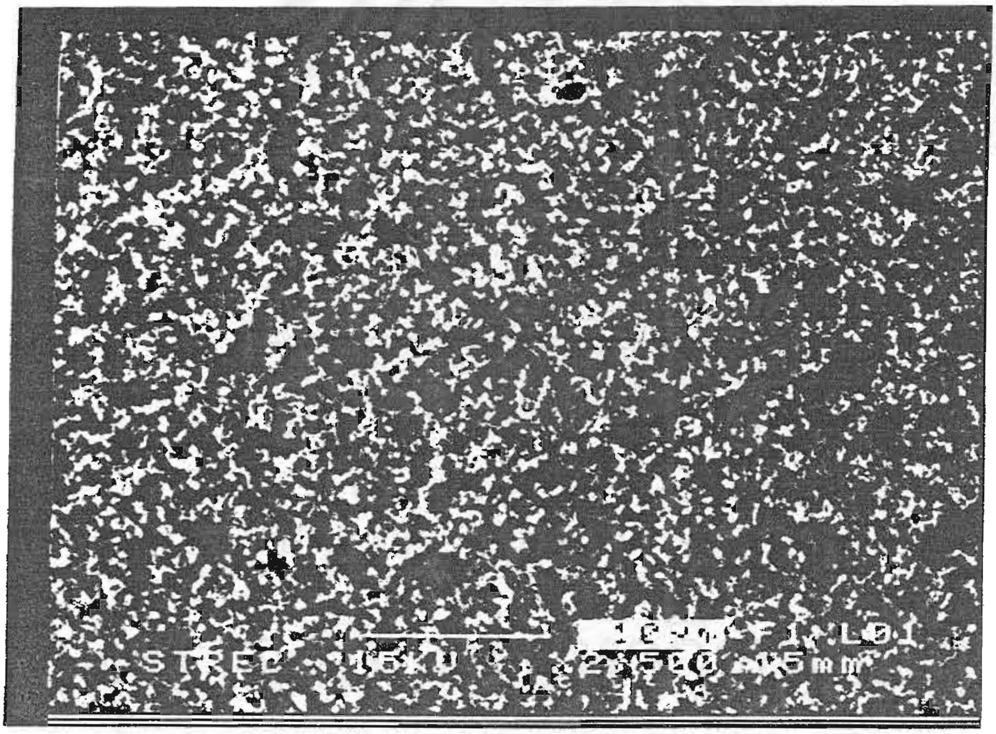


Figure 4.1 Scanning Electron Micrograph of M/H 4058.

Figure 4.2 Scanning Electron Micrograph of HDPE 6105 JU.

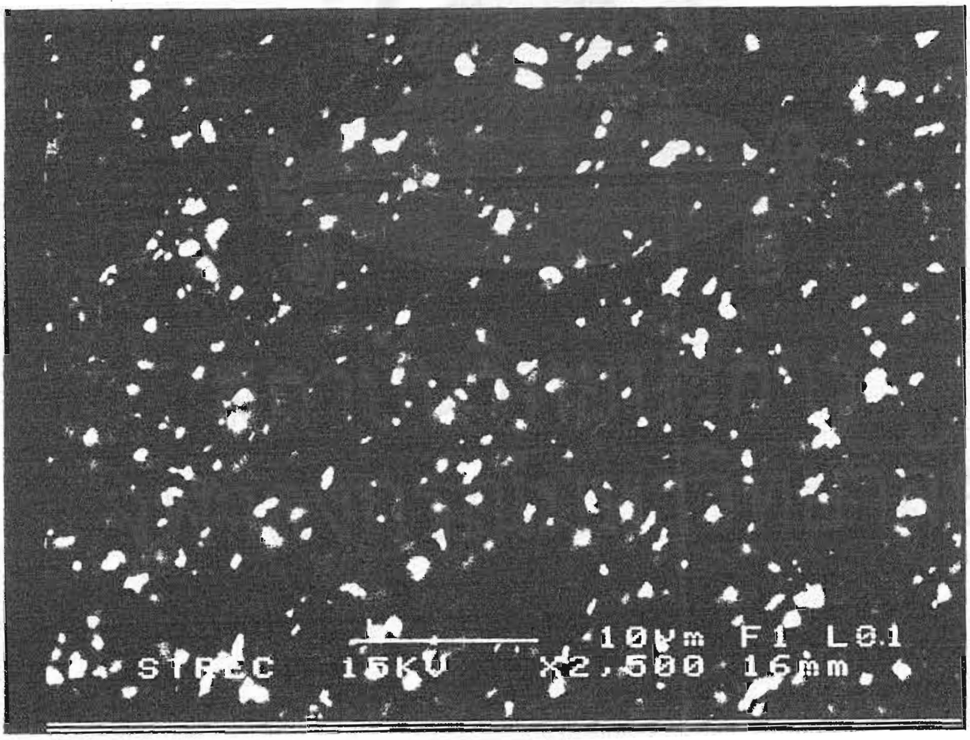


Figure 4.3 Scanning Electron Micrograph of HDPE 6105 JU blend with M/H 4058 at 5 %.

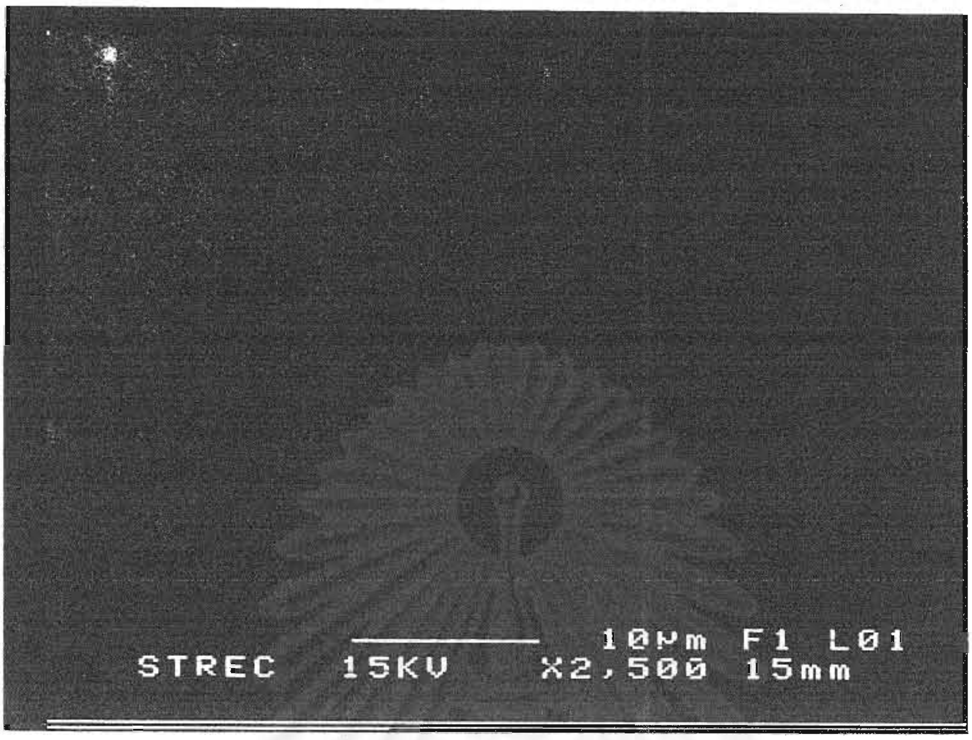


Figure 4.4 Scanning Electron Micrograph of LDPE ST 1018.

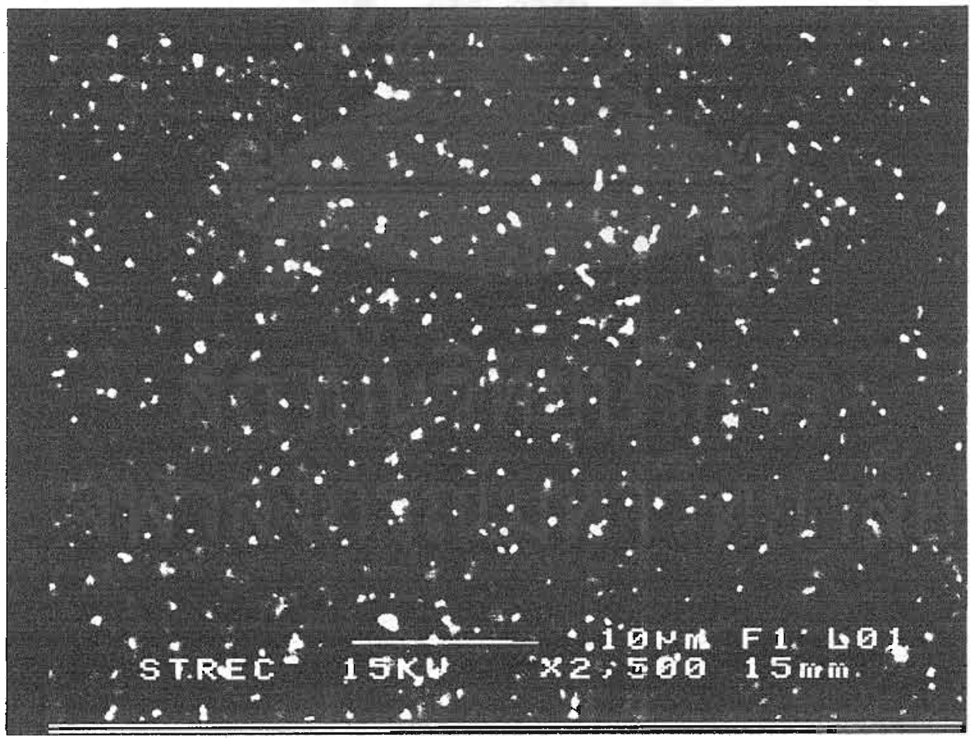


Figure 4.5 Scanning Electron Micrograph of LDPE ST 1018 blend with M/H 4058 at 5 %.

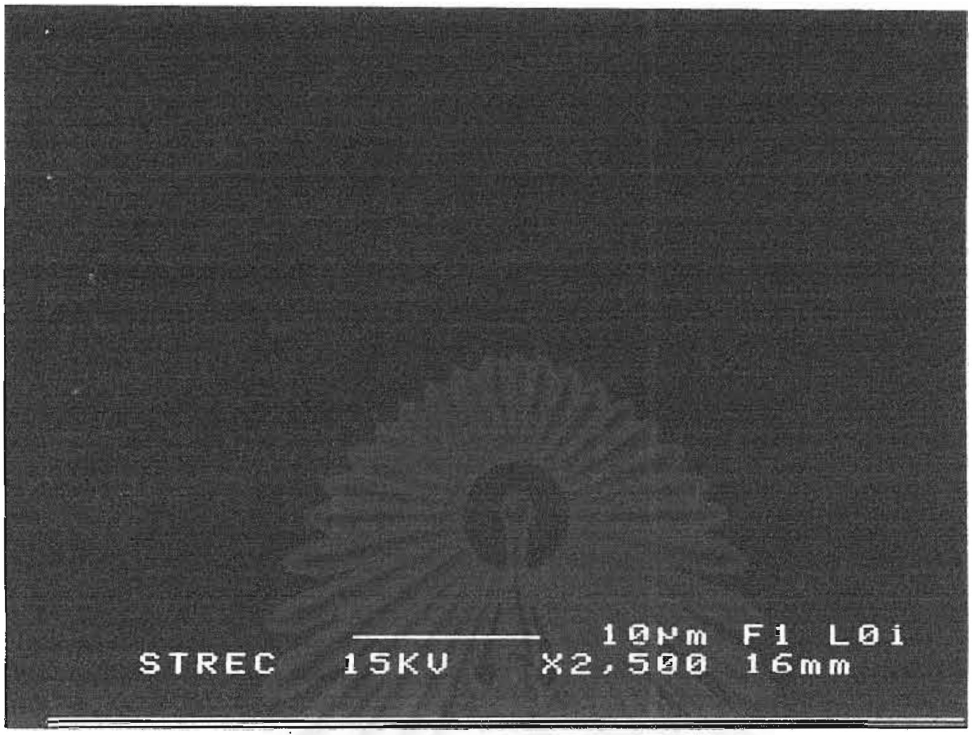


Figure 4.6 Scanning Electron Micrograph of PP 2300 K.

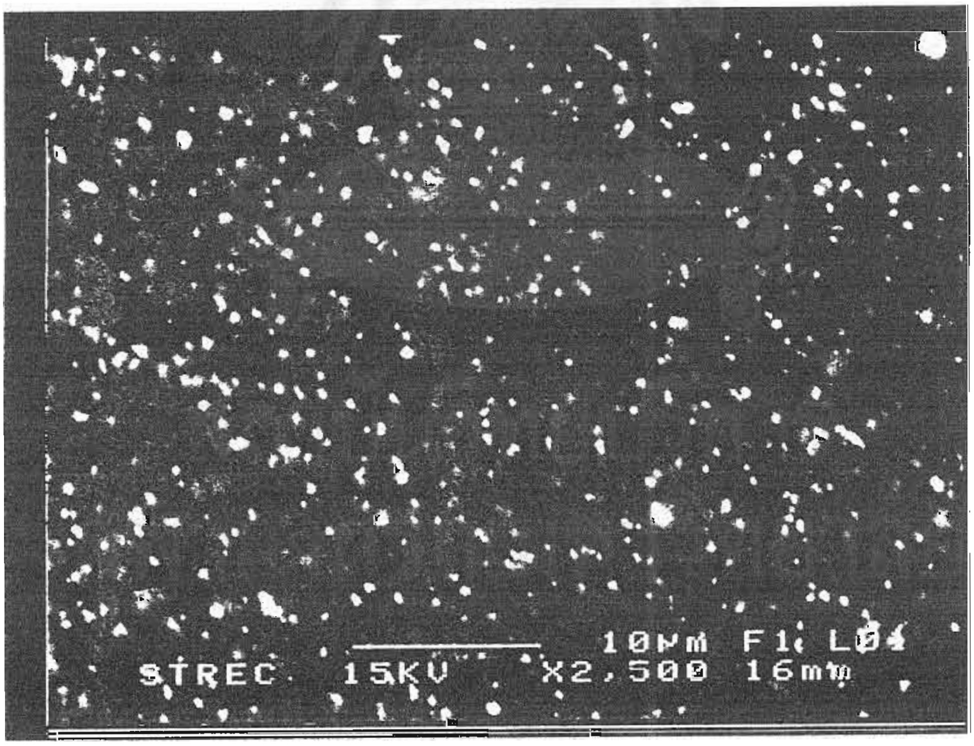


Figure 4.7 Scanning Electron Micrograph of PP 2300 K blend with M/H 4058 at 5 %.

Figure 4.8 Scanning Electron Micrograph of ABS LUSTRAN 250.

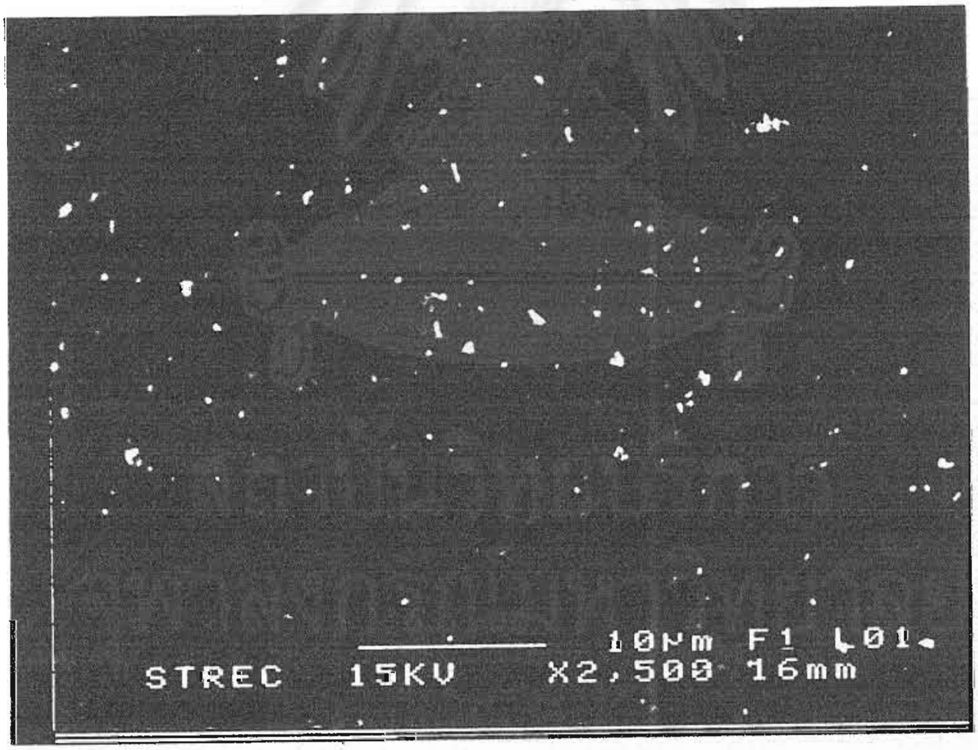


Figure 4.9 Scanning Electron Micrograph of ABS LUSTRAN 250 blend with M/H 4058 at 5 %.

Figure 4.10 Scanning Electron Micrograph of HIPS 825-10.

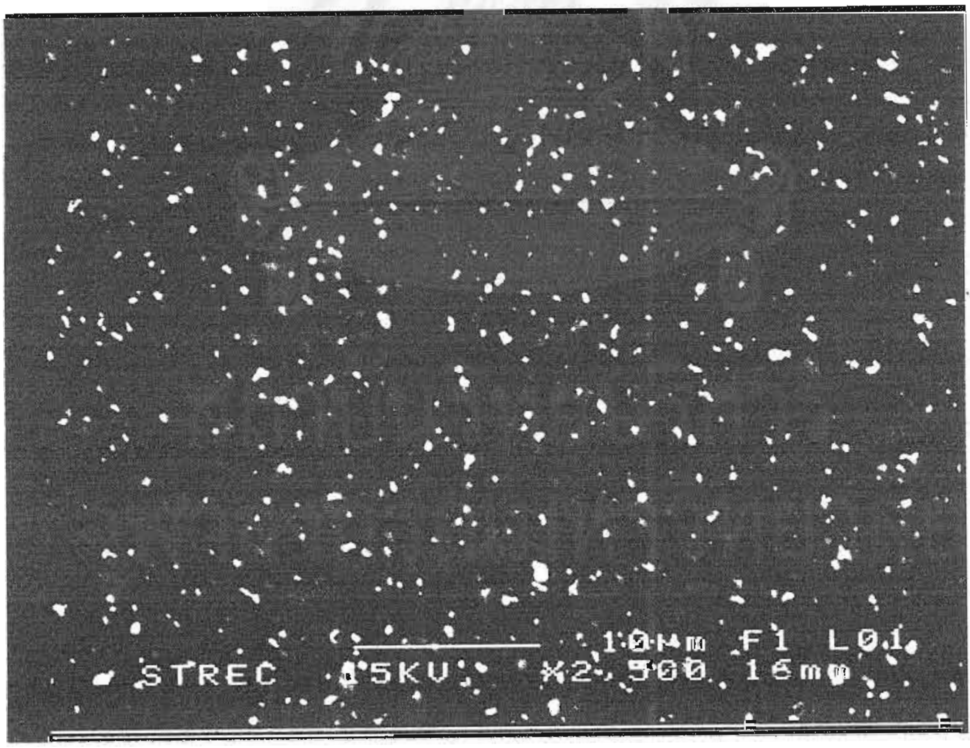


Figure 4.11 Scanning Electron Micrograph of HIPS 825-10 blend with M/H 4058 at 5 %.

For scanning electron microscopy, Figure 4.1 shows a scanning electron microgragh of M/H 4058 containing 58 percent of TiO_2 and 40 percent of HDPE 6105 JU. Our studies on TiO_2 in M/H 4058 using SEM have shown that the dispersability of TiO_2 in the M/H 4058 used in this study is very good. The TiO_2 particles were distributed through out the whole matrix.

Figure 4.2 to 4.3 show scanning electron micrograghs of pure HDPE 6105 JU and its blend with M/H 4058 at 5 percent. It can be seen that TiO_2 in M/H 4058 is well distributed in HDPE 6105 JU matrix.

Figure 4.4 to 4.11 show scanning electron micrograghs of pure LDPE ST 1018, PP 2300K, ABS LUSTRAN 250, and HIPS 825-10 and most of their blends with M/H 4058 at 5 percent. It can be seen that TiO_2 in M/H 4058 is well distributed in most of the polymer matrixes.

4.2 Mechanical properties of olefinic and styrenic polymers blend with universal masterbatches.

To select the suitable formulation of universal masterbatch and the blending ratio of universal masterbatch with olefinic and styrenic polymers, the values of melt flow rate, izod impact, heat distortion temperature and tensile strength of olefinic and styrenic polymers, and their blends with universal masterbatches at 5 and 15 % were measured and are shown in Table 4.1 to 4.5 and plotted in figure 4.12 to 4.28.

Table 4.1 The effects of adding universal masterbatches on the mechanical properties of HDPE 6105 JU.

Blending Ratio (%)		MFR	Tensile Strength	Izod Impact
Universal masterbatch : HDPE 6105 JU		(g/10 mins)	(kgf/cm^2)	(kgf-cm/cm^2)
	- : 100	5.5	263.2	4.4
M/H 4058	5 : 95	5.6	247.5	4.5
	15 : 85	5.9	239.7	4.4
M/H 5048	5 : 95	5.8	245.1	4.4
	15 : 85	5.9	245.7	4.3
M/H 6038	5 : 95	5.7	247.3	4.4
	15 : 85	5.8	249.1	4.4
M/L 4058	5 : 95	5.9	228.2	4.4
	15 : 85	6.2	231.5	4.2
M/L 5048	5 : 95	5.8	234.8	4.4
	15 : 85	6.2	223.5	4.3
M/L 6038	5 : 95	5.8	226.4	4.4
	15 : 85	6.2	231.3	4.2

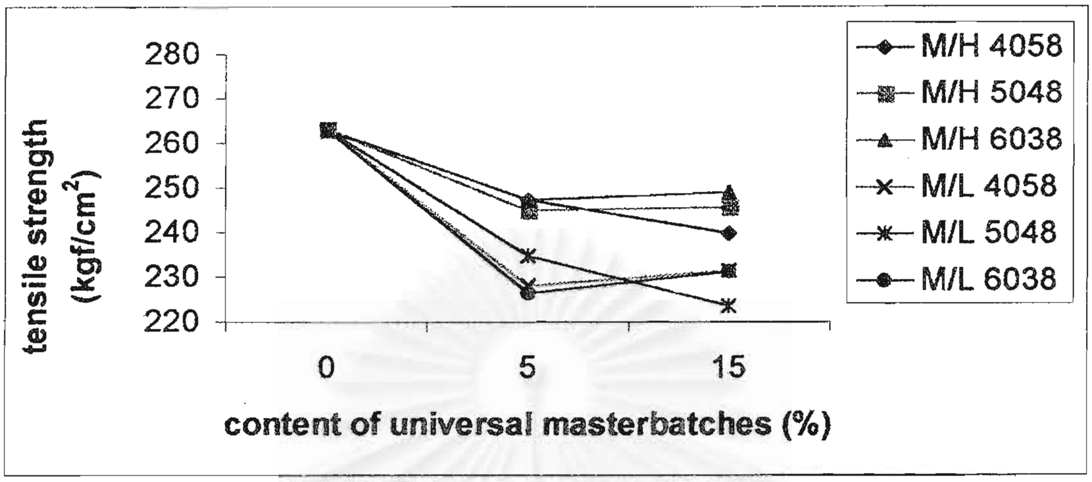


Figure 4.12 Tensile strength of HDPE 6105 JU blended with 5 and 15 percent of universal masterbatches.

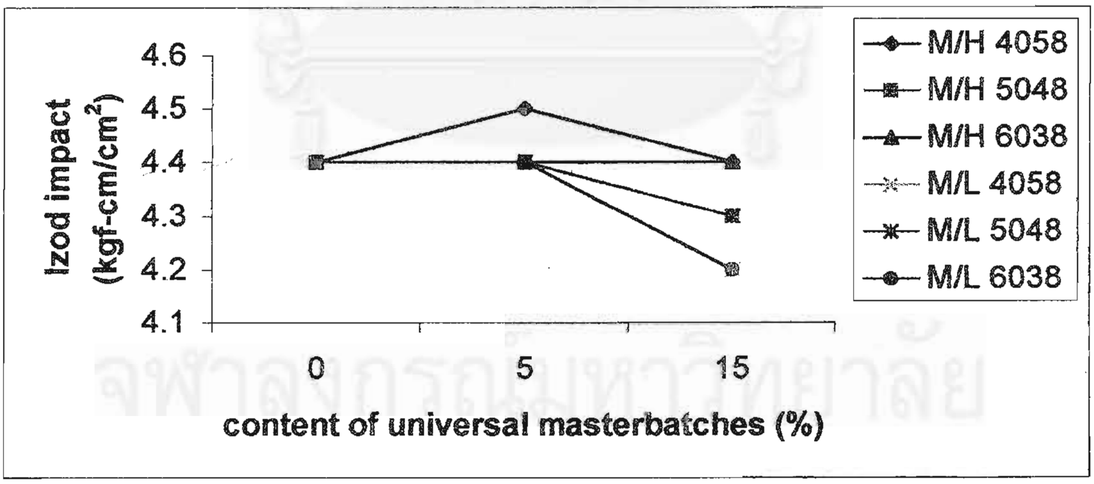


Figure 4.13 Izod impact of HDPE 6105 JU blended with 5 and 15 percent of universal masterbatches.

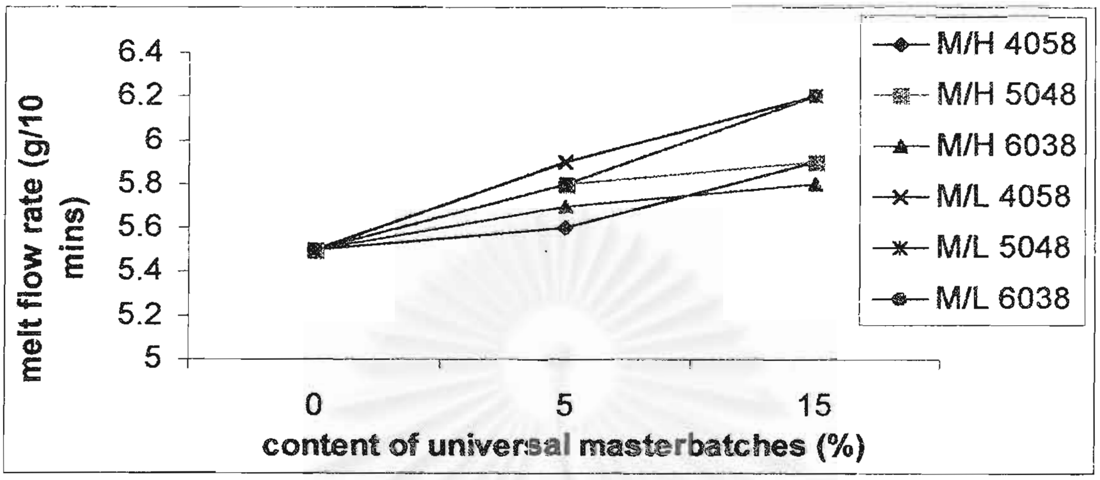


Figure 4.14 Melt flow rate of HDPE 6105 JU blended with 5 and 15 percent of universal masterbatches.

4.2. 1 Mechanical properties of HDPE 6105 JU blended with universal masterbatches.

Tensile strength of HDPE 6105 JU blended with universal masterbatches, which are M/H 4058, M/H 5048, M/H 6038, M/L 4058, M/L 5048, and M/L 6038 at 5 and 15 percent were measured. The results are shown in table 4.1 and figure 4.12. It can be seen that tensile strength of HDPE 6105 JU blended with M/H 4058, M/H 5048 and M/H 6038 is about 10 percent lower than pure HDPE 6105 JU and the tensile strength of HDPE 6105 JU blended with M/L 4058, M/L 5048, and M/L 6038 is more than 10 percent lower than pure HDPE 6105 JU. This result could be explained by the fact that thermoplastic polymers suffer a decrease in mechanical performance when pigments are added. [3]

From figure 4.14 and table 4.1, melt flow rate of HDPE 6105 JU blended with M/H 4058, M/H 5048, and M/H 6038 at 5 and 15 percent are about 5 percent higher than pure HDPE 6105 JU. The melt flow rate was increased after blending with M/L4058, M/L 5048, and M/L 6038 at 15 percent because of the contribution of LDPE, which has higher melt flow rate.

From figure 4.13 and table 4.1, izod impact of HDPE 6105 JU blended with M/H 4058, M/H 5048, M/H 6038, M/L 4058, M/L 5048, and M/L 6038 at 5 and 15 percent are similar to those of pure HDPE 6105 JU.

Therefore the suitable formulation of universal masterbatches blending with HDPE 6105 JU are M/H 4058, M/H 5048, and, M/H 6038 at 5 percent. Because carrier resin incorporating a universal masterbatches composition have substantially similar or maintain mechanical properties in comparison with those of the virgin plastics.

Table 4.2 The effects of adding universal masterbatches on the mechanical properties of LDPE ST 1018.

Blending Ratio (%)				MFR	Tensile Strength	Izod Impact
Universal masterbatch		:	LDPE ST 1018	(g/10 mins)	(kgf/cm^2)	(kgf-cm/cm^2)
	-	:	100	23.3	156.5	40.1
M/H 4058	5	:	95	23.4	167.0	37.2
	15	:	85	20.6	142.7	40.4
M/H 5048	5	:	95	22.8	167.6	37.7
	15	:	85	19.7	143.8	37.5
M/H 6038	5	:	95	22.5	164.4	37.4
	15	:	85	18.3	144.8	38.6
M/L 4058	5	:	95	25.1	156.8	31.4
	15	:	85	26.8	151.8	42.9
M/L 5048	5	:	95	25.4	152.8	39.5
	15	:	85	26.7	153.8	41.9
M/L 6038	5	:	95	25.5	156.4	36.8
	15	:	85	27.1	156.8	39.3

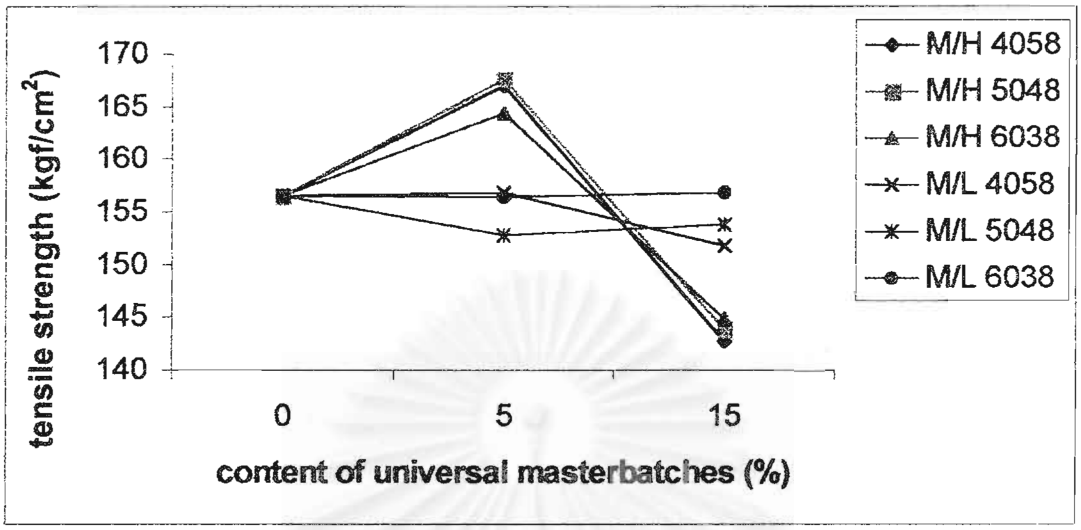


Figure 4. 15 Tensile strength of LDPE ST 1018 blended with 5 and 15 percent of universal masterbatches.

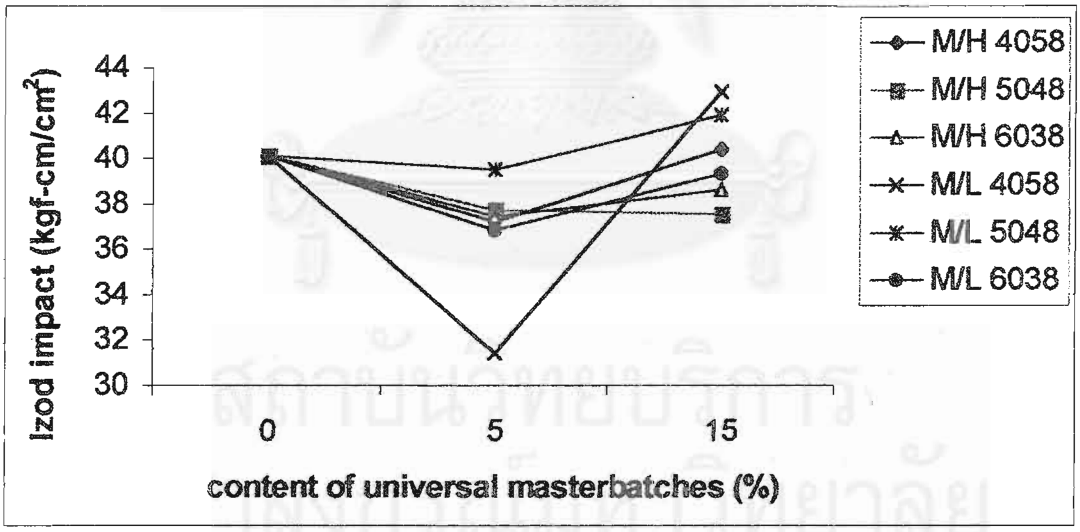


Figure 4. 16 Izod impact of LDPE ST 1018 blended with 5 and 15 percent of universal masterbatches.

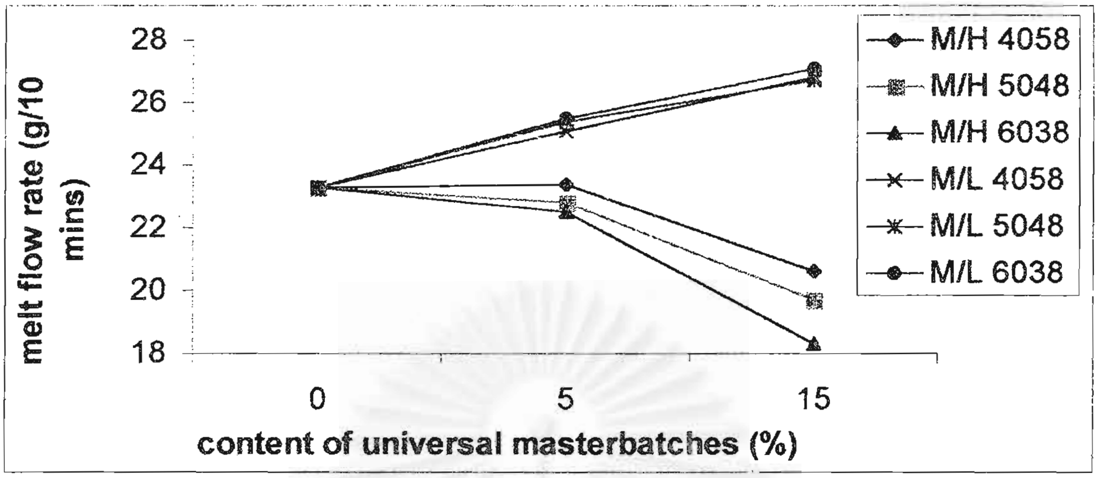


Figure 4. 17 Melt flow rate of LDPE ST 1018 blended with 5 and 15 percent of universal masterbatches.

4.2.2 Mechanical properties of LDPE ST 1018 blended with universal masterbatches.

From table 4.2 and figure 4.15, the tensile strength of LDPE ST 1018 blended with M/H 4058, M/H 5048, and M/H 6038 at 5 percent is higher than pure LDPE ST 1018. This effect came from the tensile strength of carrier resin in masterbatches. However, the blend at 15 percent gave lower tensile strength than pure LDPE ST 1018, due to a higher amount of carrier resin. The tensile strength of LDPE ST 1018 blending with M/L 4058, M/L 5048, and M/L 6038 at 5 and 15 percent is similar to pure LDPE ST 1018. Because TiO_2 was well dispersed in masterbatch, so that M/L 4058, M/L 5048 and M/L 6038 can maintain tensile strength of LDPE ST 1018 blend.

From table 4.2 and figure 4.17, melt flow rate of LDPE ST 1018 blend with M/H 4058, M/H 5048, and M/H 6038 at 5 and 15 percent are around 5 percent lower than melt flow rate of pure LDPE ST 1018. This effect came from the melt flow rate of carrier resin.

However, melt flow rate of LDPE ST 1018 blended with M/L 4058, M/L 5048, and M/L 6038 at 5 and 15 percent are higher than melt flow rate of pure LDPE ST 1018, perhaps due to the addition of titanium dioxide pigment.

Table 4.2 and figure 4.16 show the results of izod impact of LDPE ST 1018 and its blends with M/H 4058, M/H 5048, and M/H 6038 at 5 and 15 percent which are lower than pure LDPE ST 1018. However, izod impact of LDPE ST 1018 blended with M/L 4058, M/L 5048, and M/L 6038 at 5 percent is lower than pure LDPE ST 1018.

From this data, the suitable formulas of universal masterbatches blending with LDPE ST 1018 are M/H 4058, M/H 5048, and M/H 6038 at 5 percent because they can maintain mechanical properties of LDPE ST 1018 blend.

Table 4.3 The effects of adding universal masterbatches on the mechanical properties of PP 2300 K.

Blending Ratio (%)				MFR	Tensile Strength	Izod Impact
Universal masterbatch		:	PP 2300 K	(g/10 mins)	(kgf/cm^2)	(kgf-cm/cm^2)
	-	:	100	5.4	288.2	9.0
M/H 4058	5	:	95	4.9	275.5	10.5
	15	:	85	4.9	274.6	14.5
M/H 5048	5	:	95	4.7	278.0	11.2
	15	:	85	4.7	266.5	13.9
M/H 6038	5	:	95	4.8	282.9	11.3
	15	:	85	5.0	269.5	13.9
M/L 4058	5	:	95	4.9	283.6	10.0
	15	:	85	6.4	284.9	17.0
M/L 5048	5	:	95	4.7	266.7	10.7
	15	:	85	6.0	245.1	16.9
M/L 6038	5	:	95	4.9	270.3	10.6
	15	:	85	5.4	246.0	14.7

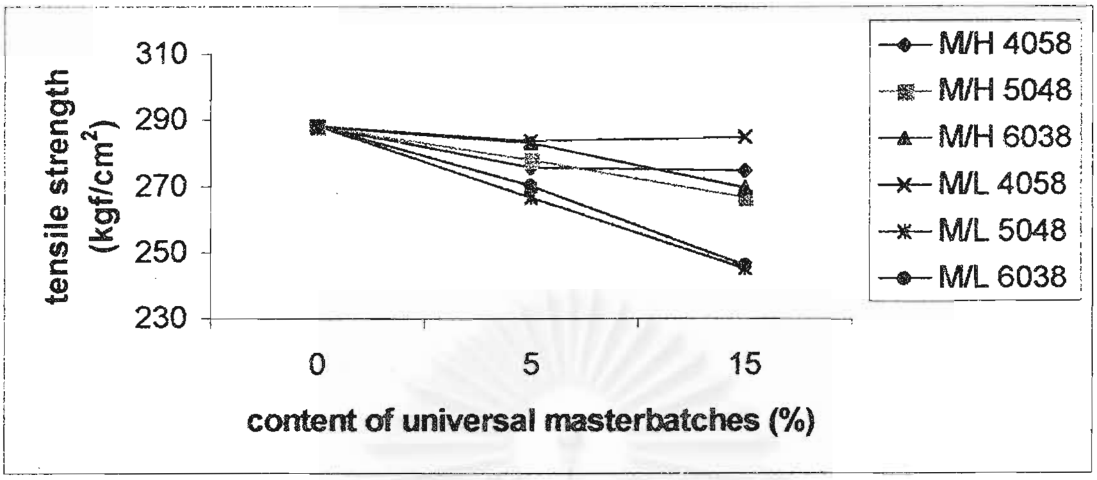


Figure 4.18 Tensile strength of PP 2300 K blended with 5 and 15 percent of universal masterbatches.

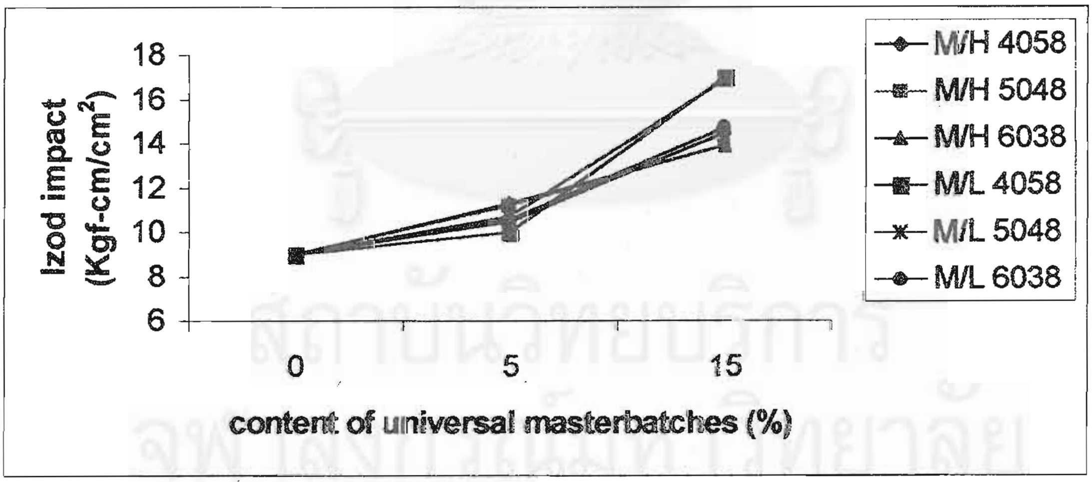


Figure 4.19 Izod impact of PP 2300 K blended with 5 and 15 percent of universal masterbatches.

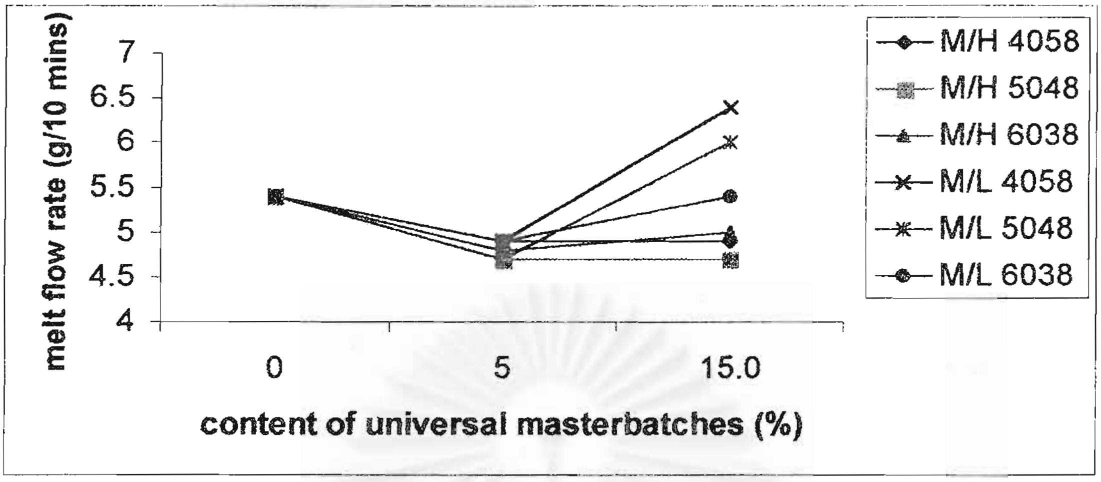


Figure 4.20 Melt flow rate of PP 2300 K blended with 5 and 15 percent of universal masterbatches.

4.2. 3 Mechanical properties of PP 2300K blended with universal masterbatches.

From table 4.3, and figure 4.18, it can be seen that the effect of universal masterbatch on tensile strength of PP 2300 K blending with M/H 4058, M/H 5048, and M/H 6038 at 5 and 15 percent are only 5 percent lower than pure PP 2300 K. Because the tensile strength of carrier resin (HDPE 6105 JU) is similar to that of PP 2300 K, and TiO_2 is well dispersed in PP 2300 K, therefore it can maintain the tensile strength of pure PP 2300 K. In case of PP 2300 K blending with 5 percent M/L 4058, M/L 5048, and M/L 6038 the tensile strength is lower than blending with M/H 4058, M/H 5048, and M/H 6038.

According to table 4.3 and figure 4.19, the izod impact of PP 2300 K blending with universal masterbatches at 5 percent are higher than pure PP 2300 K. Moreover the blend at 15 percent are higher than the blend at 5 percent. According to the data observed by Wong [2] when the color masterbatch was added, the polymer becomes tougher and more elastic. Never Theless, at 5 percent of the blend, increasing in izod impact will not affect the properties of PP 2300K.

From table 4.3 and figure 4.20, melt flow rate of PP 2300 K blended with universal masterbatches at 5 percent is lower than pure PP 2300 K. However, blending with 15 percent M/L 4058, M/L 5048 and M/L 6038 gave higher melt flow rate than pure PP 2300 K. Never Theless, at 5 percent of the blend decreasing in melt flow rate will not affect the properties of PP 2300K.

From this results, the suitable formula of universal masterbatches blending with PP 2300 K are M/H 4058, M/H 5048 and M/H 6038 at 5 percent, because they can maintained and improved the mechanical properties of PP 2300 K after blending.

<u>Table 4.4</u> The effects of adding universal masterbatches on the mechanical properties of HIPS 825-10.

Blending Ratio (%)		MFR	Tensile Strength	Izod Impact	HDT
Universal masterbatch : HIPS 825-10		(g/10 mins)	(kgf/cm^2)	(kgf-cm/cm^2)	^{o}C
	0 : 100	5.2	215.7	8.8	81.3
M/H 4058	5 : 95	5.4	213.0	8.3	82.2
	15 : 85	6.8	197.5	5.7	82.4
M/H 5048	5 : 95	5.4	208.3	7.9	82.5
	15 : 85	7.0	199.9	4.9	82.3
M/H 6038	5 : 95	5.4	210.9	7.9	82.4
	15 : 85	7.1	195.9	3.8	82.1
M/L 4058	5 : 95	5.7	202.2	8.2	82.3
	15 : 85	9.4	184.1	4.4	81.9
M/L 5048	5 : 95	6.2	201.7	7.4	82.1
	15 : 85	11.2	176.9	3.9	82.6
M/L 6038	5 : 95	6.2	207.5	7.7	82.6
	15 : 85	13.0	168.4	3.5	81.9

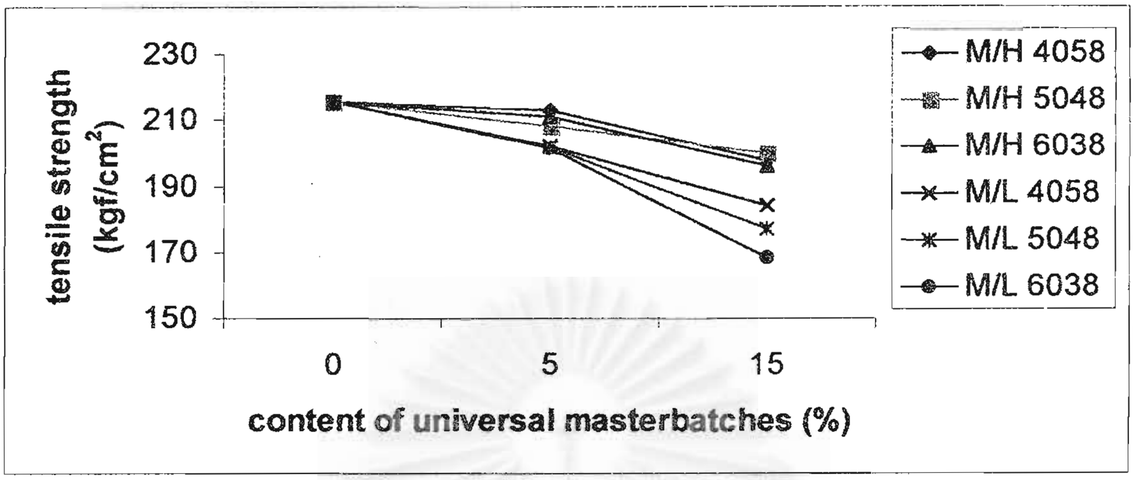


Figure 4.21 Tensile strength of HIPS 825-10 blended with 5 and 15 percent of universal masterbatches.

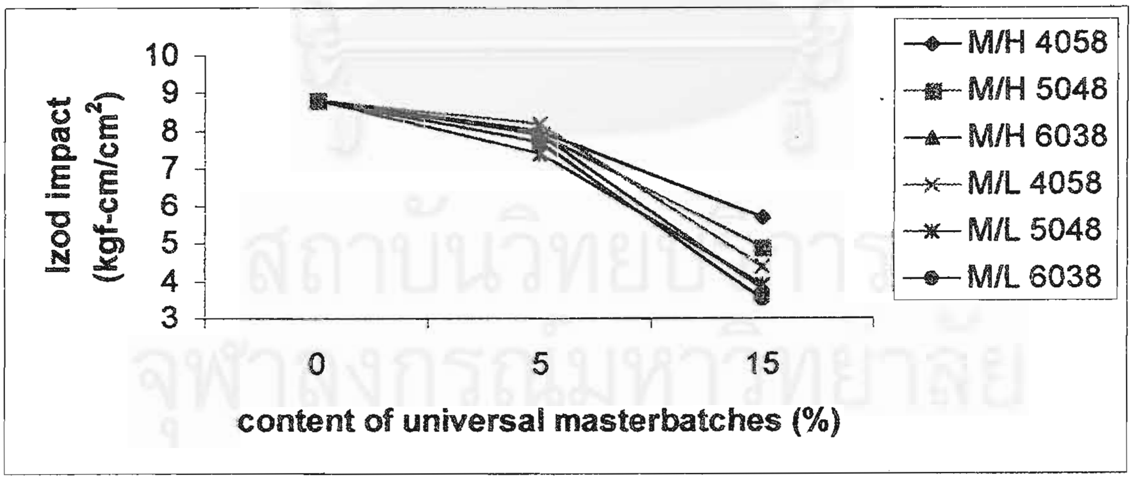


Figure 4.22 Izod impact of HIPS 825-10 blended with 5 and 15 percent of universal masterbatches.

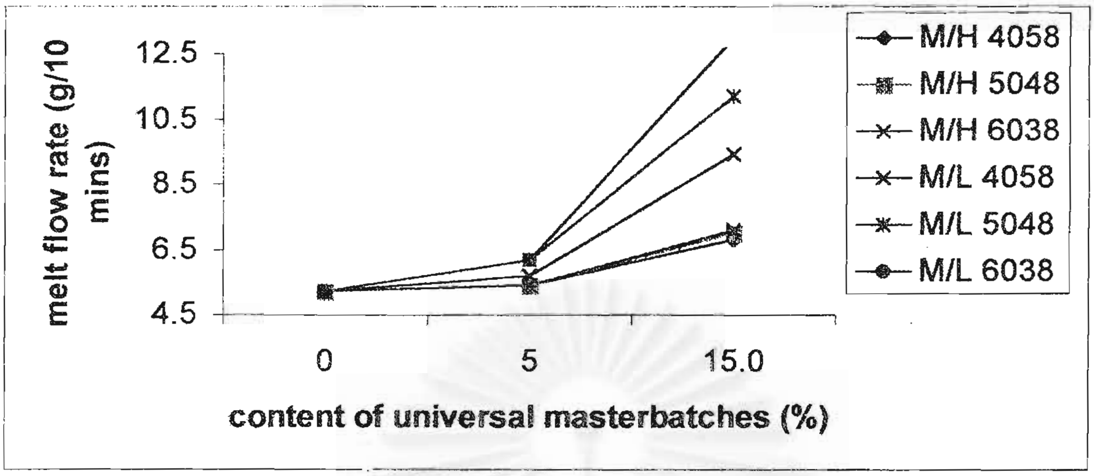


Figure 4.23 Melt flow rate of HIPS 825-10 blended with 5 and 15 percent of universal masterbatches.

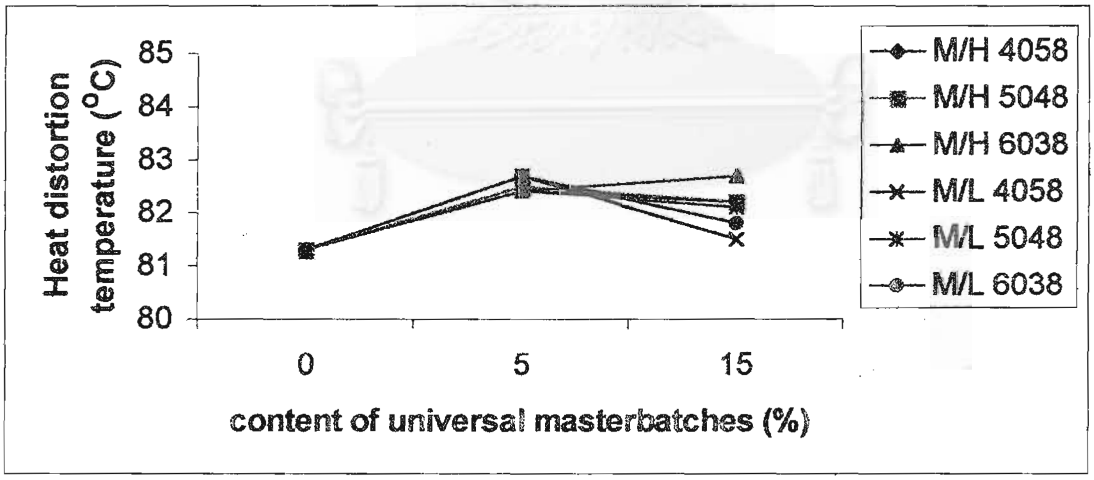


Figure 4.24 Heat distortion temperature of HIPS 825-10 blended with 5 and 15 of universal masterbatches.

4.2.4 Mechanical properties of HIPS 825-10 blended with universal masterbatches.

In general, adding titanium dioxide pigment into polystyrene will decrease its tensile strength and izod impact. From table 4.4 and figure 4.21, tensile strength of HIPS 825-10 blended with M/H 4058, M/H 5048 and M/H 6038 at 5 percent are slightly decreased when compared with pure HIPS 825-10. However blending at 15 percent gave lower tensile strength than blending at 5 percent. In the same way, the blend of HIPS 825-10 with M/L 4058, M/L 5048 and M/L 6038 at same concentration gave lower tensile strength than blending with M/H 4058, M/H 5048 and M/H 6038.

Melt flow rate of HIPS 825-10 blended with M/H 4058, M/H 5048, and M/H 6038 at 5 percent is approximately 4 percent higher than melt flow rate of pure HIPS 825-10. However, blending at 15 percent gave higher value than blending at 5 percent. In the same way, blending with M/L 4058, M/L 5048 and M/L 6038 at same concentration gave higher melt flow rate than blending with M/H 4058, M/H 5048 and M/H 6038. However, blending at 5 percent of M/H 4058, M/H 5048, and M/H 6038 will not affect the properties of HIPS 825-10.

Izod impact of HIPS 825-10 blended with M/H 4058, M/H 5048, and M/H 6038 at 5 percent are slightly decreased when compared with pure HIPS 825-10. However, blending at 15 percent gave lower value than blending at 5 percent, due to an increasing in titanium dioxide pigment. However, blending with M/H 4058, M/H 5048, and M/H 6038 at 5 percent will not affect the properties of HIPS 825-10.

From table 4.4 and figure 4.24, the HDT of HIPS 825-10 blended with M/H 4058, M/H 5048, M/H 6038, M/L 4058, M/L 5048 and M/L 6038 at 5 percent gave similar behavior to pure HIPS 825-10.

Table 4.5 The effects of adding universal masterbatches on the mechanical properties of ABS LUSTRAN 250.

Blending Ratio (%)				MFR	Tensile Strength	Izod Impact	HDT
Universal masterbatch		:	ABS LUSTRAN 250	(g/10 mins)	(kgf/cm^2)	(kgf-cm/cm^2)	^{O}C
	-	:	100	48.9	489.6	14.6	88.7
M/H 4058	5	:	95	48.4	463.9	11.4	88.4
	15	:	85	56.1	398.7	7.9	85.6
M/H5048	5	:	95	48.4	466.7	10.9	88.3
	15	:	85	63.2	394.2	7.5	86.6
M/H 6038	5	:	95	50.0	465.6	10.4	88.4
	15	:	85	68.6	377.3	7.4	86.7
M/L 4058	5	:	95	47.3	455.6	12.5	87.6
	15	:	85	68.8	380.6	11.3	85.7
M/L 5048	5	:	95	48.4	446.2	11.9	88.3
	15	:	85	76.0	344.2	10.8	84.4
M/L 6038	5	:	95	54.6	454.6	13.1	87.3
	15	:	85	88.9	322.7	12.4	84.4

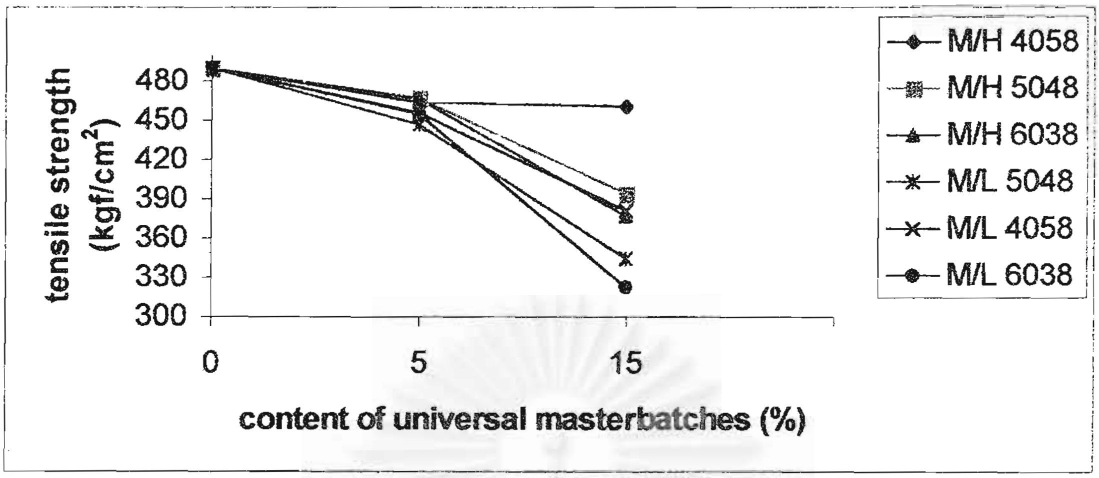


Figure 4.25 Tensile strength of ABS LUSTRAN 250 blended with 5 and 15 percent of universal masterbatches.

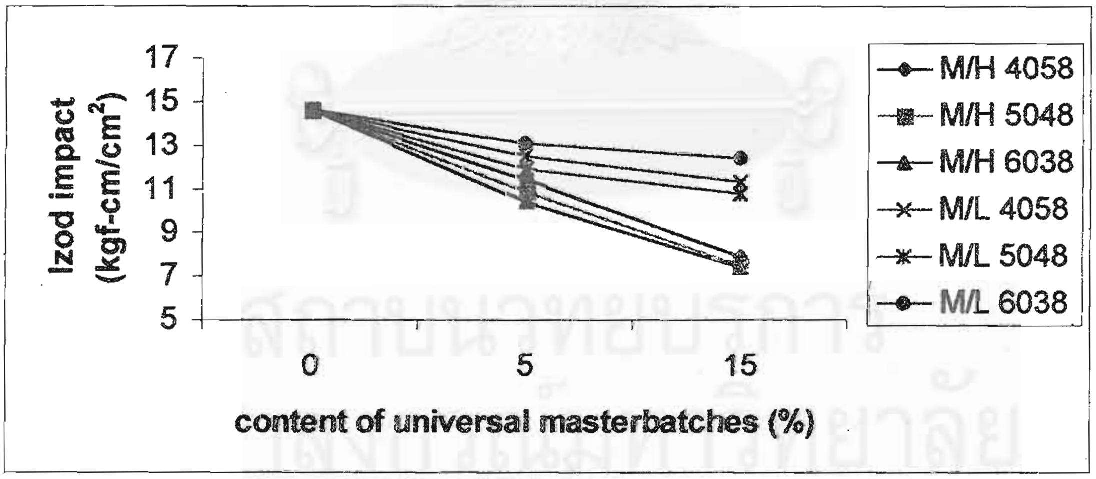


Figure 4.26 Izod impact of ABS LUSTRAN 250 blended with 5 and 15 percent of universal masterbatches.

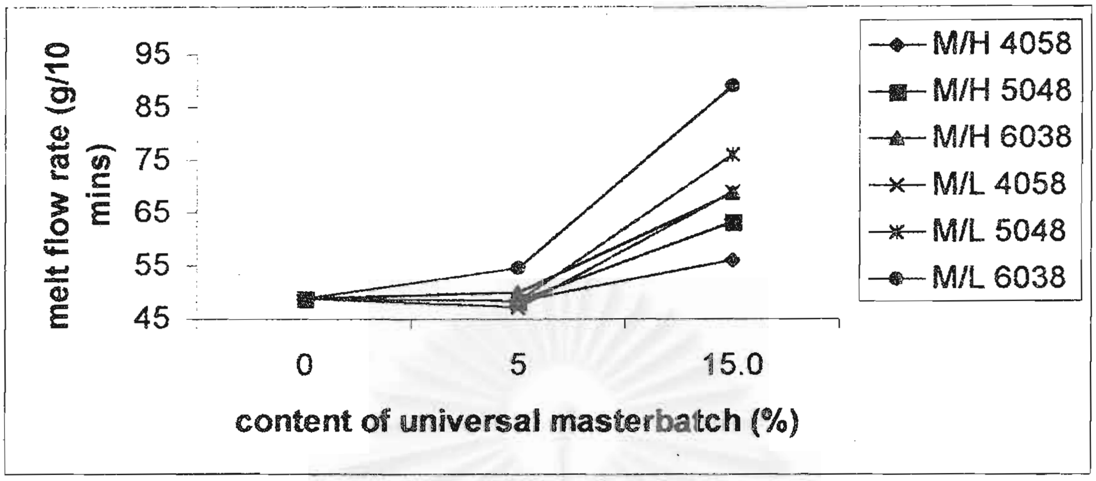


Figure 4.27 Melt flow rate of ABS LUSTRAN 250 blended with 5 and 15 percent of universal masterbatches.

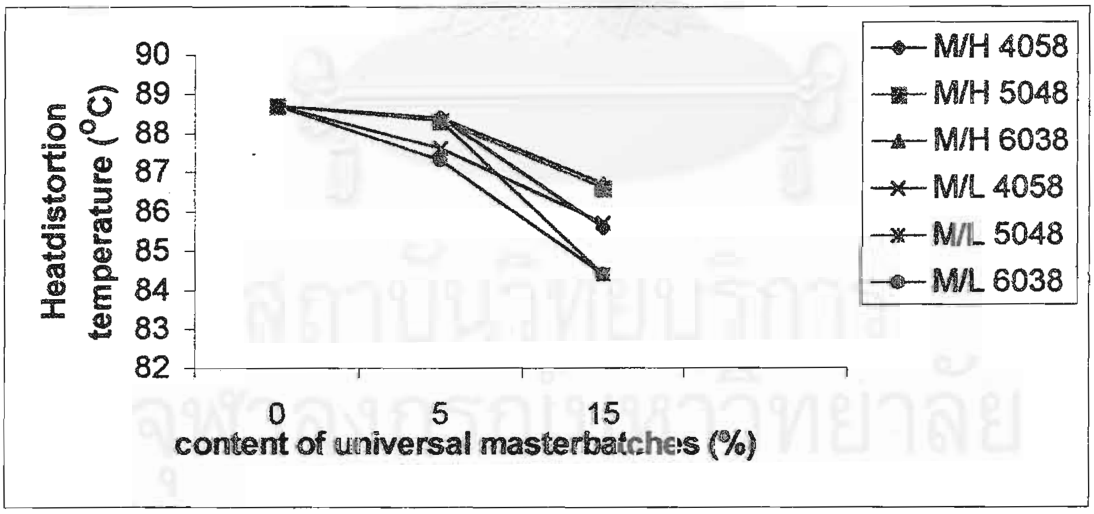


Figure 4.28 Heat distortion temperature of ABS LUSTRAN 250 blended with 5 and 15 percent of universal masterbatches.

4.2.5 Mechanical properties of ABS LUSTRAN 250 blended with universal masterbatches.

The tensile strength and izod impact of ABS LUSTRAN 250 blend prepared by melt blending was measured using a tensometer and izod impact-testing machine. The concentration of M/H 4058, M/H 5048 and M/H 6038 at 5 and 15 % in this research is comparable to the same concentration of M/L 4058, M/L 5048 and M/L 6038, which different in carrier resin. In generally, adding titanium dioxide pigment into ABS matrix will decrease tensile strength and izod impact.

From table 4.5 and figure 4.25 to 4.26, the tensile strength and izod impact of ABS LUSTRAN 250 blended with M/H 4058, M/H 5048, M/H 6038, M/L 4058, M/L 5048, and M/L 6038 at 5 and 15 percent are lower than pure ABS LUSTRAN 250. However, the tensile strength of ABS LUSTRAN 250 blend with M/H 4058, M/H 5048, and M/H 6038 are lower than ABS LUSTRAN 250 blend with M/L 4058, M/L 5048 and M/L 6038. These results could be explained by the fact that tensile strength of LDPE as a carrier resin in M/L 4058, M/L 5048 and M/L 6038 is lower than that of HDPE as a carrier resin in M/H 4058, M/H 5048, and M/H 6038.

Table 4.5 and figure 4.27 show that the blending at 5 percent of all universal masterbatches can maintain melt flow rate properties of ABS LUSTRAN 250, excepted the blending with M/L 6038 in which the melt flow rate is higher than pure ABS LUSTRAN 250. The blending at 15 percent of all universal masterbatches increases melt flow rate, due to the influence of carrier resin. The blends with M/L 4058, M/L 5048 and M/L 6038 gave higher value when comparable with M/H 4058, M/H 5048, and M/H 6038 at the same composition and concentration.

Table 4.5 and figure 4.28, show that the HDT of ABS LUSTRAN 250 blended with M/H 4058, M/H 5048, and M/H 6038 at 5 percent gave similar behavior to pure ABS LUSTRAN 250. However, blending with M/L 4058, M/L 5048, and M/L 6038 gave lower HDT than blending with M/H 4058, M/H 5048, and M/H 6038. The blend at 15 percent of M/H 4058, M/H 5048, M/H 6038, M/L 4058, M/L 5048, and M/L 6038 are all gave lower value than pure ABS LUSTRAN 250. Therefore, it can be concluded that HDT of ABS LUSTRAN 250 blended depend on the properties of carrier resin in universal masterbatch.

4.3 Thermal Analysis

Figure B-1 shows the result from the analysis of M/H 4058 at heating rate of 10 degree/min. Note the endothermic peak with a very long leading edge and peak temperature of 128.7 ^{o}C associated with the melt of the polymer component of the masterbatch recipe. At temperatures above the melt of the polymer the DSC thermogram displays a flat baseline whilst the material remains stable to oxidation.

Figure B-2 to B-3 show the results from the analysis of HDPE 6105 JU and it blends with M/H 4058 at 5 percent. The endothermic peaks of DSC have a single peak, and melting temperature at 132.1 and 131.6 ^{o}C respectively. The endothermic peak of HDPE 6105 JU blends is similar to pure HPDE 6105 JU.

Figure B-4 to B-5 show the result from the analysis of LDPE ST 1018 and it blends with M/H 4058 at 5 percent. The endothermic peak of pure LDPE ST 1018 max at 104.2 ^{o}C, while LDPE ST 1018 blend gave a sharp endothermic peak at 102.4 ^{o}C and carrier resin in M/H 4058 was oxidized at 123.3 ^{o}C. However, the compatibility of it blends still show the characteristic of carrier resin and virgin polymer.

Figure B-6 to B-7 show the result from the analysis of PP 2300 K and it blends with M/H 4058 at 5 percent. The endothermic peak of pure PP 2300 K is at 167.7 °C and the DSC profile of PP 2300 K blend shows a small peak of carrier resin at 124.2 °C and a sharp peak of PP 2300 K at 167.5 °C.

HIPS 825-10 and ABS LUSTRAN 250 are an amorphous polymer. Figure B-8 to B-11 show a glass transition temperature from the analysis of HIPS 825-10, ABS LUSTRAN 250 and they are blended with M/H 4058 at 5 percent. The endothermic peak of pure HIPS 825-10, ABS LUSTRAN 250 at 105.9°C and 98.9 respectively. The DSC profile shows a sharp peak of carrier resin in M/H 4058 of HIPS 825-10 and ABS LUSTRAN 250 blend. It can be seen that glass transition temperature peak of HIPS 825-10 blend is lower than pure HIPS 825-10.

The above results show the potential of DSC techniques as valuable tools for the characterization of polymer masterbatches and polymer blends. In these results, figure B-1 to B-11 can be concluded that the DSC curves of olefinic and styrenic polymer blends were occurred at lower temperature than pure polymer. Therefore, the polymer blends still show the characteristic of carrier resin and virgin polymer.

CHAPTER V

CONCLUSION

This research involved the universal masterbatch which imparts color to the olefinic polymer, which are comprising of PP 2300 K, HDPE 6105 JU and LDPE ST 1018 and styrenic polymer, which are comprising of ABS LUSTRAN 250 and HIPS 825-10. In this study, blending of olefinic and styrenic polymers with 5 percent universal masterbatch using HDPE as a carrier resin is better than blending olefinic and styrenic polymers with 5 percent universal masterbatch using LDPE ST 1018 as a carrier resin. The universal masterbatch with HDPE as a carrier resin can maintain mechanical properties such as tensile strength, izod impact, melt flow rate and heat distortion temperature of the polymer blends. The dispersion of TiO_2 in M/H 4058 is well distributed in most of the polymer blends.

In conclusion the mechanical properties of olefinic and styrenic polymers blended with 5 percent universal masterbatch M/H 4058, M/H 5048, and M/H 6038 do not differ significantly. These three universal masterbatches formulas can help improve and maintain tensile strength and izod impact when blending with HIPS 825-10 and ABS LUSTRAN 250. Furthermore, cost of universal masterbatch in which HDPE was used as a carrier resin is lower than that using LDPE as a carrier resin. The optimized formulas of the best universal masterbatch M/H 4058, M/H 5048, and M/H 6038 are shown below:

Composition of masterbatch	M/H 4058	M/H 5048	M/H 6038
HDPE 6105 JU	40 %	50%	60 %
TiO_2	58 %	48%	38 %
Zn-st	2 %	2%	2%

Suggestions

In this research, it was concluded that HDPE 6105 JU was suitable to be used as a carrier resin in universal masterbatch M/H to impart color for olefinic and styrenic polymers. However, the formulation of M/H 4058 can eliminate the problem that may be come from the properties of carrier resin when blending with other polymers, because of the formulation M/H 4058 have a lowest carrier resin in that composition. In some cases required high opacity, whiteness and weatherability formulation is necessary. However, TiO_2 was used as a white pigment in this study. Therefore, other pigments should be tried in order to evaluate the generality of using HDPE as carrier resin.

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APPENDICES

APPENDIX A

Table A-1 Tensile strength of ABS and ABS blends with Universal Masterbatches (M/H 4058, M/H 5048, M/H 6038, M/L 4058, M/L 5048 and M/L 6038)

Composition	Specimen	Width (mm)	Thick (mm)	Tensile strength (kgf/cm^2)
ABS NATURAL	1	12.85	2.99	482.2
	2	12.85	2.99	491.3
	3	12.83	2.99	490.4
	4	12.87	3.01	490.8
	5	12.87	3.00	493.5
	Mean	12.85	3.00	489.6
	S.D.	-	-	4.33
ABS with 5% of M/H 4058	1	12.85	2.98	461.6
	2	12.83	2.97	461.1
	3	12.82	2.98	462.9
	4	12.81	2.97	464.8
	5	12.82	2.97	469.0
	Mean	12.83	2.97	463.9
	S.D.	-	-	3.20
ABS with 15% of M/H 4058	1	12.81	2.99	399.3
	2	12.81	2.98	399.4
	3	12.82	2.99	399.4
	4	12.82	2.98	399.9
	5	12.82	2.99	399.9
	Mean	12.82	2.99	398.7
	S.D.	-	-	0.29
ABS with 5% of M/H 5048	1	12.84	2.97	464.6
	2	12.82	2.98	465.4
	3	12.81	2.97	468.0
	4	12.84	2.98	468.3
	5	12.82	2.98	467.1
	Mean	12.83	2.98	466.7
	S.D.	-	-	1.62

Table A-1 (continued)

Composition	Specimen	Width (mm)	Thick (mm)	Tensile strength (kgf/cm^2)
ABS with 15% of M/H 5048	1	12.85	2.98	394.3
	2	12.85	2.99	390.0
	3	12.86	3.05	396.6
	4	12.82	2.98	396.1
	5	12.84	2.99	393.8
	Mean	12.84	3.00	394.2
	S.D.	-	-	2.61
ABS with 5% of M/H 6038	1	12.81	2.98	461.8
	2	12.82	2.98	465.7
	3	12.85	2.98	467.6
	4	12.82	2.97	467.3
	5	12.82	2.97	465.8
	Mean	12.82	2.98	465.6
	S.D.	-	-	2.31
ABS with 15% of M/H 6038	1	12.81	2.99	377.1
	2	12.81	2.98	377.0
	3	12.86	2.99	377.0
	4	12.83	2.98	376.7
	5	12.79	2.99	378.8
	Mean	12.82	2.99	377.3
	S.D.	-	-	0.84
ABS with 5% of M/L 4058	1	12.86	2.98	456.9
	2	12.82	2.98	455.8
	3	12.81	2.98	455.0
	4	12.85	2.98	454.6
	5	12.82	2.98	455.5
	Mean	12.83	2.98	455.6
	S.D.	-	-	0.88
ABS with 15% of M/L 4058	1	12.83	2.98	380.0
	2	12.85	2.99	380.5
	3	12.85	2.98	380.9
	4	12.85	2.99	380.0
	5	12.86	2.99	381.6
	Mean	12.85	2.99	380.6
	S.D.	-	-	0.67

Table A-1 (continued)

Composition	Specimen	Width (mm)	Thick (mm)	Tensile strength (kgf/cm^2)
ABS with 5% of M/L 5048	1	12.88	2.99	444.2
	2	12.88	2.99	445.4
	3	12.89	2.99	448.2
	4	12.88	2.99	446.8
	5	12.88	2.99	446.6
	Mean	12.88	2.99	446.2
	S.D.	-	-	1.51
ABS with 15% of M/L 5048	1	12.78	2.98	346.4
	2	12.78	2.99	346.3
	3	12.77	2.99	339.3
	4	12.78	2.99	344.3
	5	12.79	2.99	344.9
	Mean	12.78	2.99	344.2
	S.D.	-	-	2.90
ABS with 5% of M/L 6038	1	12.88	2.99	453.9
	2	12.89	2.99	455.7
	3	12.88	2.99	454.6
	4	12.88	2.99	453.1
	5	12.88	2.99	455.9
	Mean	12.88	2.99	454.6
	S.D.	-	-	1.19
ABS with 15% of M/L 6038	1	12.85	2.99	327.1
	2	12.85	2.99	320.1
	3	12.84	2.99	317.1
	4	12.85	2.99	327.8
	5	12.85	2.98	321.6
	Mean	12.85	2.99	322.7
	S.D.	-	-	4.60

Table A-2 Tensile strength of PP and PP blends with Universal Masterbatches (M/H 4058, M/H 5048, M/H 6038, M/L 4058, M/L 5048 and M/L 6038)

Composition	Specimen	Width (mm)	Thick (mm)	Tensile strength (kgf/cm^2)
PP NATURAL	1	12.66	2.97	285.0
	2	12.68	2.96	285.4
	3	12.68	2.96	288.4
	4	12.66	2.96	286.9
	5	12.69	2.96	295.5
	Mean	12.67	2.96	288.2
	S.D.	-	-	4.27
PP with 5% of M/H 4058	1	12.62	2.95	275.3
	2	12.64	2.95	275.9
	3	12.66	2.98	275.2
	4	12.66	2.95	275.5
	5	12.66	2.95	275.7
	Mean	12.65	2.96	275.5
	S.D.	-	-	0.29
PP with 15% of M/H 4058	1	12.67	2.96	279.9
	2	12.67	2.97	274.4
	3	12.66	2.97	270
	4	12.65	2.97	276.3
	5	12.65	2.97	272.4
	Mean	12.66	2.97	274.6
	S.D.	-	-	3.38
PP with 5% of M/H 5048	1	12.63	2.93	279.3
	2	12.62	2.93	277.4
	3	12.64	2.94	278.3
	4	12.64	2.95	274.7
	5	12.63	2.95	280.4
	Mean	12.63	2.94	278.0
	S.D.	-	-	2.17

Table A-2 (continued)

Composition	Specimen	Width (mm)	Thick (mm)	Tensile strength (kgf/cm^2)
PP with 15% of M/H 5048	1	12.66	2.96	268.1
	2	12.67	2.97	267.2
	3	12.65	2.96	264.5
	4	12.67	2.97	267.9
	5	12.65	2.97	264.8
	Mean	12.66	2.97	266.5
	S.D.	-	-	1.72
PP with 5% of M/H 6038	1	12.66	2.95	283.5
	2	12.66	2.95	281.4
	3	12.66	3.00	283.1
	4	12.64	2.90	285.7
	5	12.65	2.96	280.6
	Mean	12.65	2.95	282.9
	S.D.	-	-	1.99
PP with 15% of M/H 6038	1	12.69	2.97	271.1
	2	12.69	2.97	267.1
	3	12.66	3.01	269.5
	4	12.67	2.97	270.6
	5	12.65	3.01	269.2
	Mean	12.67	2.99	269.5
	S.D.	-	-	1.55
PP with 5% of M/L 4058	1	12.67	2.97	280.7
	2	12.67	2.96	280.8
	3	12.68	2.96	282.7
	4	12.66	2.97	287.2
	5	12.68	2.96	286.7
	Mean	12.67	2.96	283.6
	S.D.	-	-	3.15
PP with 15% of M/L 4058	1	12.69	2.98	285.5
	2	12.66	2.97	282.0
	3	12.68	2.99	286.2
	4	12.70	2.97	283.8
	5	12.66	2.96	287.2
	Mean	12.68	2.97	284.9
	S.D.	-	-	2.06

Table A-2 (continued)

Composition	Specimen	Width (mm)	Thick (mm)	Tensile strength (kgf/cm^2)
PP with 5% of M/L 5048	1	12.65	3.00	264.7
	2	12.68	2.98	267.1
	3	12.67	2.97	263.6
	4	12.70	2.98	268.7
	5	12.70	2.98	269.4
	Mean	12.68	2.98	266.7
	S.D.	-	-	2.50
PP with 15% of M/L 5048	1	12.67	2.96	249.5
	2	12.67	2.96	241.3
	3	12.67	2.96	244.7
	4	12.65	2.96	243.3
	5	12.65	2.96	246.8
	Mean	12.66	2.96	245.1
	S.D.	-	-	3.17
PP with 5% of M/L 6038	1	12.75	2.99	269.2
	2	12.71	2.96	271.4
	3	12.59	2.98	270.9
	4	12.71	2.97	271.2
	5	12.77	2.97	269.0
	Mean	12.71	2.97	270.3
	S.D.	-	-	1.15
PP with 15% of M/L 6038	1	12.71	2.98	246.9
	2	12.72	2.97	248.1
	3	12.71	2.97	249.1
	4	12.71	2.97	244.5
	5	12.71	2.97	241.3
	Mean	12.71	2.97	246.0
	S.D.	-	-	3.13

Table A-3 Tensile strength of HDPE and HDPE blends with Universal Masterbatches (M/H 4058, M/H 5048, M/H 6038, M/L 4058, M/L 5048 and M/L 6038)

Composition	Specimen	Width (mm)	Thick (mm)	Tensile strength (kgf/cm^2)
HDPE NATURAL	1	12.65	2.95	266.3
	2	12.66	2.95	261.4
	3	12.67	2.95	259.6
	4	12.65	2.95	263.8
	5	12.65	2.95	265.0
	Mean	12.66	2.95	263.2
	S.D.	-	-	2.71
HDPE with 5% of M/H 4058	1	12.65	2.96	249.1
	2	12.67	2.96	247.1
	3	12.66	2.97	246.5
	4	12.65	2.96	249.2
	5	12.66	2.96	245.4
	Mean	12.66	2.96	247.5
	S.D.	-	-	1.66
HDPE with 15% of M/H 4058	1	12.71	2.98	239.0
	2	12.70	2.99	239.4
	3	12.71	2.98	239.8
	4	12.72	2.98	239.8
	5	12.70	2.99	240.5
	Mean	12.71	2.98	239.7
	S.D.	-	-	0.56
HDPE with 5% of M/H 5048	1	12.63	2.95	246.4
	2	12.60	2.95	244.3
	3	12.66	2.94	247.6
	4	12.63	2.94	242.3
	5	12.64	2.94	245.1
	Mean	12.63	2.94	245.1
	S.D.	-	-	2.03

Table A-3 (continued)

Composition	Specimen	Width (mm)	Thick (mm)	Tensile strength (kgf/cm^2)
HDPE with 15% of M/H 5048	1	12.71	2.97	244.5
	2	12.72	2.95	246.6
	3	12.70	2.97	247.6
	4	12.72	2.98	244.3
	5	12.69	2.96	245.3
	Mean	12.71	2.97	245.7
	S.D.	-	-	1.41
HDPE with 5% of M/H 6038	1	12.93	2.95	246.8
	2	12.68	2.95	247.4
	3	12.68	2.95	249.5
	4	12.68	2.95	245.5
	5	12.68	2.96	247.1
	Mean	12.73	2.95	247.3
	S.D.	-	-	1.45
HDPE with 15% of M/H 6038	1	12.67	2.93	251.0
	2	12.67	2.95	249.0
	3	12.66	2.95	248.7
	4	12.65	2.96	247.8
	5	12.65	2.95	249.0
	Mean	12.66	2.95	249.1
	S.D.	-	-	1.17
HDPE with 5% of M/L 4058	1	12.66	2.95	229.4
	2	12.67	2.94	227.3
	3	12.66	2.95	226.6
	4	12.67	2.95	229.9
	5	12.67	2.95	227.8
	Mean	12.67	2.95	228.2
	S.D.	-	-	1.40
HDPE with 15% of M/L 4058	1	12.64	2.94	232.4
	2	12.64	2.94	231.0
	3	12.64	2.94	233.3
	4	12.64	2.94	229.6
	5	12.67	2.94	231.0
	Mean	12.65	2.94	231.5
	S.D.	-	-	1.43

Table A-3 (continued)

Composition	Specimen	Width (mm)	Thick (mm)	Tensile strength (kgf/cm^2)
HDPE with 5% of M/L 5048	1	12.65	2.95	235.2
	2	12.65	2.95	236.2
	3	12.65	2.95	235.5
	4	12.65	2.95	233.6
	5	12.62	2.95	233.4
	Mean	12.64	2.95	234.8
	S.D.	-	-	1.23
HDPE with 15% of M/L 5048	1	12.69	2.96	225.6
	2	12.70	2.97	222.8
	3	12.71	2.96	223.5
	4	12.69	2.97	223.6
	5	12.68	2.96	222.1
	Mean	12.69	2.96	223.5
	S.D.	-	-	1.31
HDPE with 5% of M/L 6038	1	12.55	2.96	228.5
	2	12.60	2.97	227.7
	3	12.64	2.96	229.8
	4	12.62	2.96	222.0
	5	12.60	2.96	224.2
	Mean	12.60	2.96	226.4
	S.D.	-	-	3.23
HDPE with 15% of M/L 6038	1	12.72	2.98	230.8
	2	12.66	2.98	232.3
	3	12.66	2.98	230.2
	4	12.70	2.98	230.8
	5	12.69	2.97	232.6
	Mean	12.69	2.98	231.3
	S.D.	-	-	1.05

Table A-4 Tensile strength of HIPS and HIPS blends with Universal Masterbatches (M/H 4058, M/H 5048, M/H 6038, M/L 4058, M/L 5048 and M/L 6038)

Composition	Specimen	Width (mm)	Thick (mm)	Tensile strength (kgf/cm^2)
HIPS NATURAL	1	12.87	2.98	217.9
	2	12.88	2.98	211.6
	3	12.85	2.98	215.1
	4	12.81	2.97	216.5
	5	12.84	2.98	217.5
	Mean	12.85	2.98	215.7
	S.D.	-	-	2.54
HIPS with 5% of M/H 4058	1	12.88	2.98	213.3
	2	12.88	2.98	213.0
	3	12.87	2.98	213.2
	4	12.86	2.97	213.3
	5	12.88	2.97	212.3
	Mean	12.87	2.98	213.0
	S.D.	-	-	0.42
HIPS with 15% of M/H 4058	1	12.89	2.98	197.8
	2	12.89	2.98	197.6
	3	12.89	2.98	197.8
	4	12.89	2.98	197.1
	5	12.89	2.98	197.3
	Mean	12.89	2.98	197.5
	S.D.	-	-	0.31
HIPS with 5% of M/H 5048	1	12.88	2.97	208.1
	2	12.87	2.97	208.4
	3	12.88	2.98	208.6
	4	12.88	2.98	207.0
	5	12.88	2.98	209.5
	Mean	12.88	2.98	208.3
	S.D.	-	-	0.90

Table A-4 (continued)

Composition	Specimen	Width (mm)	Thick (mm)	Tensile strength (kgf/cm^2)
HIPS with 15% of M/H 5048	1	12.89	2.97	201.5
	2	12.89	2.98	201.7
	3	12.88	2.98	199.1
	4	12.88	2.98	197.4
	5	12.88	2.98	200.0
	Mean	12.88	2.98	199.9
	S.D.	-	-	1.78
HIPS with 5% of M/H 6038	1	12.88	2.97	211.6
	2	12.87	2.97	210.4
	3	12.88	2.97	211.1
	4	12.88	2.97	210.2
	5	12.88	2.97	211.2
	Mean	12.88	2.97	210.9
	S.D.	-	-	0.58
HIPS with 15% of M/H 6038	1	12.89	2.98	197.3
	2	12.89	2.98	194.0
	3	12.88	2.98	196.0
	4	12.88	2.98	196.2
	5	12.88	2.98	196.2
	Mean	12.88	2.98	195.9
	S.D.	-	-	1.20
HIPS with 5% of M/L 4058	1	12.88	2.97	203.3
	2	12.86	2.97	201.5
	3	12.88	2.97	201.1
	4	12.86	2.97	203.0
	5	12.88	2.97	202.0
	Mean	12.87	2.97	202.2
	S.D.	-	-	0.95
HIPS with 15% of M/L 4058	1	12.89	2.98	184.3
	2	12.89	2.98	182.1
	3	12.90	2.98	182.1
	4	12.89	2.98	186.7
	5	12.88	2.98	185.1
	Mean	12.89	2.98	184.1
	S.D.	-	-	1.99

Table A-4 (continued)

Composition	Specimen	Width (mm)	Thick (mm)	Tensile strength (kgf/cm^2)
HIPS with 5% of M/L 5048	1	12.88	2.98	200.4
	2	12.85	2.97	198.7
	3	12.85	2.97	204.3
	4	12.85	2.97	200.3
	5	12.88	2.98	204.9
	Mean	12.86	2.97	201.7
	S.D.	-	-	2.72
HIPS with 15% of M/L 5048	1	12.89	2.98	173.0
	2	12.89	2.98	179.9
	3	12.89	2.98	174.4
	4	12.89	2.98	177.1
	5	12.89	2.98	180.2
	Mean	12.89	2.98	176.9
	S.D.	-	-	3.22
HIPS with 5% of M/L 6038	1	12.86	2.98	207.9
	2	12.88	2.98	207.0
	3	12.87	2.98	207.9
	4	12.85	2.97	207.3
	5	12.85	2.97	207.3
	Mean	12.86	2.98	207.5
	S.D.	-	-	0.40
HIPS with 15% of M/L 6038	1	12.89	2.98	168.6
	2	12.89	2.98	168.4
	3	12.88	2.98	168.7
	4	12.88	2.98	168.1
	5	12.89	2.98	168.1
	Mean	12.89	2.98	168.4
	S.D.	-	-	0.28

Table A-5 Tensile strength of LDPE and LDPE blends with Universal Masterbatches (M/H 4058, M/H 5048, M/H 6038, M/L 4058, M/L 5048 and M/L 6038)

Composition	Specimen	Width (mm)	Thick (mm)	Tensile strength (kgf/cm^2)
LDPE NATURAL	1	12.65	2.95	155.5
	2	12.63	2.95	155.5
	3	12.65	2.94	156.5
	4	12.65	2.96	157.0
	5	12.64	2.96	158.0
	Mean	12.64	2.95	156.5
	S.D.	-	-	1.06
LDPE with 5% of M/H 4058	1	12.65	2.95	163.0
	2	12.65	2.94	164.0
	3	12.63	2.95	169.0
	4	12.64	2.95	169.0
	5	12.65	2.96	170.0
	Mean	12.64	2.95	167.0
	S.D.	-	-	3.24
LDPE with 15% of M/H 4058	1	12.68	2.94	140.0
	2	12.66	2.94	140.0
	3	12.68	2.94	144.0
	4	12.65	2.94	143.0
	5	12.65	2.93	140.0
	Mean	12.66	2.94	142.7
	S.D.	-	-	1.95
LDPE with 5% of M/H 5048	1	12.65	2.92	177.0
	2	12.68	2.93	163.0
	3	12.63	2.93	166.0
	4	12.65	2.92	169.0
	5	12.65	2.92	163.0
	Mean	12.65	2.92	167.6
	S.D.	-	-	5.81

Table A-5 (continued)

Composition	Specimen	Width (mm)	Thick (mm)	Tensile strength (kgf/cm^2)
LDPE with 15% of M/H 5048	1	12.64	2.93	142.0
	2	12.65	2.93	147.0
	3	12.64	2.93	142.0
	4	12.64	2.93	147.0
	5	12.65	2.93	141.0
	Mean	12.64	2.93	143.8
	S.D.	-	-	2.95
LDPE with 5% of M/H 6038	1	12.65	2.93	161.0
	2	12.65	2.93	162.0
	3	12.65	2.93	164.0
	4	12.65	2.93	165.0
	5	12.65	2.93	170.0
	Mean	12.65	2.93	164.4
	S.D.	-	-	3.51
LDPE with 15% of M/H 6038	1	12.64	2.93	146.0
	2	12.62	2.93	144.0
	3	12.64	2.93	144.0
	4	12.66	2.93	143.0
	5	12.64	2.93	147.0
	Mean	12.64	2.93	144.8
	S.D.	-	-	1.64
LDPE with 5% of M/L 4058	1	12.65	2.93	155.0
	2	12.65	2.93	153.0
	3	12.65	2.93	159.0
	4	12.65	2.93	154.0
	5	12.65	2.93	163.0
	Mean	12.65	2.93	156.8
	S.D.	-	-	4.15
LDPE with 15% of M/L 4058	1	12.66	2.94	147.0
	2	12.67	2.94	155.0
	3	12.64	2.94	152.0
	4	12.65	2.93	158.0
	5	12.66	2.93	147.0
	Mean	12.66	2.94	151.8
	S.D.	-	-	4.87

Table A-5 (continued)

Composition	Specimen	Width (mm)	Thick (mm)	Tensile strength (kgf/cm^2)
LDPE with 5% of M/L 5048	1	12.65	2.93	153.0
	2	12.66	2.93	151.0
	3	12.66	2.93	150.0
	4	12.66	2.94	155.0
	5	12.67	2.93	155.0
	Mean	12.66	2.93	152.8
	S.D.	-	-	2.28
LDPE with 15% of M/L 5048	1	12.66	2.94	153.0
	2	12.65	2.94	150.0
	3	12.68	2.94	152.0
	4	12.66	2.94	159.0
	5	12.64	2.94	155.0
	Mean	12.66	2.94	153.8
	S.D.	-	-	3.42
LDPE with 5% of M/L 6038	1	12.65	2.93	156.0
	2	12.64	2.94	154.0
	3	12.65	2.94	159.0
	4	12.65	2.94	155.0
	5	12.64	2.94	158.0
	Mean	12.65	2.94	156.4
	S.D.	-	-	2.07
LDPE with 15% of M/L 6038	1	12.64	2.93	155.0
	2	12.66	2.94	156.0
	3	12.68	2.93	151.0
	4	12.65	2.94	164.0
	5	12.68	2.93	158.0
	Mean	12.66	2.93	156.8
	S.D.	-	-	4.76

Table A-6 Izod impact of ABS and ABS blends with Universal Masterbatches (M/H 4058, M/H 5048, M/H 6038, M/L 4058, M/L 5048 and M/L 6038)

Composition	Specimen	Thickness (cm)	Swing up angle	Izod Impact (kg-cm/cm^2)
ABS NATURAL	1	0.318	115.5	13.9
	2	0.318	114.2	15.0
	3	0.317	114.8	14.5
	4	0.320	114.2	14.9
	5	0.319	114.4	14.8
	Mean	-	-	14.6
	S.D.	-	-	0.44
ABS with 5% of M/H 4058	1	0.317	118.6	11.2
	2	0.318	118.0	11.7
	3	0.318	117.8	11.9
	4	0.318	119.0	10.9
	5	0.318	118.6	11.2
	Mean	-	-	11.4
	S.D.	-	-	0.37
ABS with 15% of M/H 4058	1	0.319	122.1	8.3
	2	0.319	122.7	7.8
	3	0.319	121.8	8.5
	4	0.320	123.4	7.2
	5	0.321	122.7	7.7
	Mean	-	-	7.9
	S.D.	-	-	0.51
ABS with 5% of M/H 5048	1	0.317	119.2	10.7
	2	0.317	118.5	11.3
	3	0.318	119.1	10.8
	4	0.317	119.6	10.4
	5	0.317	118.6	11.2
	Mean	-	-	10.9
	S.D.	-	-	0.37

Table A-6 (continued)

Composition	Specimen	Thickness (cm)	Swing up angle	Izod Impact (kg-cm/cm^2)
ABS with 15% of M/H 5048	1	0.318	123.6	7.1
	2	0.319	123.8	6.9
	3	0.319	122.2	8.2
	4	0.319	122.9	7.6
	5	0.320	122.6	7.8
	Mean	-	-	7.5
	S.D.	-	-	0.53
ABS with 5% of M/H 6038	1	0.318	119.4	10.5
	2	0.318	119.6	10.4
	3	0.318	119.2	10.7
	4	0.318	120.2	9.9
	5	0.319	119.4	10.5
	Mean	-		10.4
	S.D.	-	-	0.30
ABS with 15% of M/H 6038	1	0.319	123.3	7.3
	2	0.319	123.3	7.3
	3	0.318	123.1	7.5
	4	0.319	123.0	7.5
	5	0.318	123.1	7.5
	Mean	-	-	7.4
	S.D.	-	-	0.11
ABS with 5% of M/L 4058	1	0.318	116.5	13.0
	2	0.319	116.6	12.9
	3	0.318	117.6	12.1
	4	0.318	117.1	12.5
	5	0.318	117.8	11.9
	Mean	-	-	12.5
	S.D.	-	-	0.48
ABS with 15% of M/L 4058	1	0.319	118.2	11.5
	2	0.319	118.5	11.3
	3	0.319	119.0	10.9
	4	0.320	118.1	11.6
	5	0.319	118.3	11.4
	Mean	-	-	11.3
	S.D.	-	-	0.27

Table A-6 (continued)

Composition	Specimen	Thickness (cm)	Swing up angle	Izod Impact (kg-cm/cm^2)
ABS with 5% of M/L 5048	1	0.318	117.5	12.2
	2	0.318	117.2	12.4
	3	0.318	117.8	11.9
	4	0.318	118.5	11.3
	5	0.319	118.1	11.6
	Mean	-	-	11.9
	S.D.	-	-	0.44
ABS with 15% of M/L 5048	1	0.319	119.5	10.4
	2	0.319	119.0	10.8
	3	0.319	118.8	11.0
	4	0.319	119.4	10.5
	5	0.319	118.6	11.2
	Mean	-	-	10.8
	S.D.	-	-	0.33
ABS with 5% of M/L 6038	1	0.320	116.2	13.2
	2	0.318	115.9	13.5
	3	0.318	116.6	12.9
	4	0.319	116.1	13.3
	5	0.318	116.8	12.8
	Mean	-	-	13.1
	S.D.	-	-	0.29
ABS with 15% of M/L 6038	1	0.319	117.8	11.8
	2	0.319	117.2	12.4
	3	0.320	116.8	12.7
	4	0.319	117.0	12.5
	5	0.319	116.7	12.8
	Mean	-	-	12.4
	S.D.	-	-	0.39

Table A-7 Izod impact of PP and PP blends with Universal Masterbatches (M/H 4058, M/H 5048, M/H 6038, M/L 4058, M/L 5048 and M/L 6038)

Composition	Specimen	Thickness (cm)	Swing up angle	Izod Impact (kg-cm/cm^2)
PP NATURAL	1	0.316	122.3	8.2
	2	0.316	120.0	10.1
	3	0.316	120.2	9.9
	4	0.316	121.6	8.8
	5	0.316	122.5	8.0
	Mean	-	-	9.0
	S.D.	-	-	0.96
PP with 5% of M/H 4058	1	0.318	119.2	10.7
	2	0.318	119.6	10.4
	3	0.318	119.2	10.7
	4	0.317	119.2	10.7
	5	0.320	119.8	10.1
	Mean	-	-	10.5
	S.D.	-	-	0.27
PP with 15% of M/H 4058	1	0.317	115.5	13.9
	2	0.317	114.5	14.8
	3	0.317	115.0	14.4
	4	0.317	115.0	14.4
	5	0.317	114.0	15.2
	Mean	-	-	14.5
	S.D.	-	-	0.49
PP with 5% of M/H 5048	1	0.319	119.6	10.4
	2	0.318	119.5	11.4
	3	0.319	118.0	11.7
	4	0.318	119.0	10.9
	5	0.319	118.0	11.7
	Mean	-	-	11.2
	S.D.	-	-	0.56

Table A-7 (continued)

Composition	Specimen	Thickness (cm)	Swing up angle	Izod Impact (kg-cm/cm^2)
PP with 15% of M/H 5048	1	0.317	116.2	13.3
	2	0.317	115.0	14.4
	3	0.317	116.1	13.4
	4	0.317	115.1	14.3
	5	0.317	115.1	14.3
	Mean	-	-	13.9
	S.D.	-	-	0.54
PP with 5% of M/H 6038	1	0.317	118.8	11.1
	2	0.317	118.8	11.1
	3	0.319	118.3	11.6
	4	0.317	118.0	11.7
	5	0.316	118.8	11.1
	Mean	-	-	11.3
	S.D.	-	-	0.30
PP with 15% of M/H 6038	1	0.317	115.9	13.6
	2	0.317	115.2	14.2
	3	0.317	115.4	14.0
	4	0.317	115.8	13.7
	5	0.317	115.8	13.9
	Mean	-	-	13.9
	S.D.	-	-	0.24
PP with 5% of M/L 4058	1	0.317	120.2	9.9
	2	0.318	120.0	10.0
	3	0.318	120.5	9.6
	4	0.318	119.3	10.6
	5	0.318	120.0	10.0
	Mean	-	-	10.0
	S.D.	-	-	0.36
PP with 15% of M/L 4058	1	0.317	111.1	17.8
	2	0.317	113.2	16.0
	3	0.317	113.0	16.1
	4	0.317	111.6	17.4
	5	0.317	111.0	17.9
	Mean	-	-	17.0
	S.D.	-	-	0.92

Table A-7 (continued)

Composition	Specimen	Thickness (cm)	Swing up angle	Izod Impact (kg-cm/cm^2)
PP with 5% of M/L 5048	1	0.319	119.2	10.7
	2	0.318	119.2	10.7
	3	0.317	119.0	10.9
	4	0.317	119.5	10.5
	5	0.318	119.0	10.9
	Mean	-	-	10.7
	S.D.	-	-	0.17
PP with 15% of M/L 5048	1	0.317	112.7	16.4
	2	0.317	111.0	17.9
	3	0.317	112.6	16.5
	4	0.317	113.2	16.0
	5	0.317	111.4	17.6
	Mean	-	-	16.9
	S.D.	-	-	0.82
PP with 5% of M/L 6038	1	0.318	119.4	10.5
	2	0.318	119.2	10.7
	3	0.318	119.3	10.6
	4	0.317	119.5	10.5
	5	0.318	119.0	10.9
	Mean	-	-	10.6
	S.D.	-	-	0.17
PP with 15% of M/L 6038	1	0.317	115.4	14
	2	0.317	115.1	14.3
	3	0.317	114.0	15.2
	4	0.317	114.0	15.2
	5	0.317	114.6	14.7
	Mean	-	-	14.7
	S.D.	-	-	0.54

Table A-8 Izod impact of HDPE and HDPE blends with Universal Masterbatches (M/H 4058, M/H 5048, M/H 6038, M/L 4058, M/L 5048 and M/L 6038)

Composition	Specimen	Thickness (cm)	Swing up angle	Izod Impact (kg-cm/cm^2)
HDPE NATURAL	1	0.315	127.0	4.4
	2	0.315	127.0	4.4
	3	0.315	127.0	4.4
	4	0.315	126.8	4.6
	5	0.315	127.0	4.4
	Mean	-	-	4.4
	S.D.	-	-	0.09
HDPE with 5% of M/H 4058	1	0.316	126.8	4.6
	2	0.316	126.9	4.5
	3	0.316	126.9	4.5
	4	0.316	126.9	4.5
	5	0.316	121.0	4.4
	Mean	-	-	4.5
	S.D.	-	-	0.07
HDPE with 15% of M/H 4058	1	0.315	127.0	4.4
	2	0.316	127.0	4.4
	3	0.316	127.0	4.4
	4	0.316	127.0	4.4
	5	0.316	127.1	4.3
	Mean	-	-	4.4
	S.D.	-	-	0.04
HDPE with 5% of M/H 5048	1	0.316	127.0	4.4
	2	0.316	127.0	4.4
	3	0.316	127.0	4.4
	4	0.316	127.0	4.4
	5	0.316	127.0	4.4
	Mean	-	-	4.4
	S.D.	-	-	0.00

Table A-8 (continued)

Composition	Specimen	Thickness (cm)	Swing up angle	Izod Impact (kg-cm/cm^2)
HDPE with 15% of M/H 5048	1	0.315	127.2	4.3
	2	0.315	127.1	4.3
	3	0.316	127.1	4.3
	4	0.316	127.2	4.3
	5	0.316	127.0	4.4
	Mean	-	-	4.3
	S.D.	-	-	
HDPE with 5% of M/H 6038	1	0.316	127.0	4.4
	2	0.316	127.0	4.4
	3	0.316	127.0	4.4
	4	0.316	127.0	4.4
	5	0.316	127.0	4.4
	Mean	-	-	4.4
	S.D.	-	-	0.00
HDPE with 15% of M/H 6038	1	0.315	127.0	4.4
	2	0.315	127.0	4.4
	3	0.315	127.0	4.4
	4	0.315	126.9	4.5
	5	0.315	127.0	4.4
	Mean	-	-	4.4
	S.D.	-	-	0.04
HDPE with 5% of M/L 4058	1	0.316	127.0	4.4
	2	0.316	127.0	4.4
	3	0.316	127.0	4.4
	4	0.316	127.0	4.4
	5	0.316	127.0	4.4
	Mean	-	-	4.4
	S.D.	-	-	0.00
HDPE with 15% of M/L 4058	1	0.315	127.6	4.0
	2	0.314	127.2	4.3
	3	0.315	127.1	4.3
	4	0.315	127.2	4.3
	5	0.315	127.2	4.3
	Mean	-	-	4.2
	S.D.	-	-	0.13

Table A-8 (continued)

Composition	Specimen	Thickness (cm)	Swing up angle	Izod Impact (kg-cm/cm^2)
HDPE with 5% of M/L 5048	1	0.316	127.0	4.4
	2	0.316	127.0	4.4
	3	0.316	127.0	4.4
	4	0.316	127.0	4.4
	5	0.316	127.0	4.4
	Mean	-	-	4.4
	S.D.	-	-	0.00
HDPE with 15% of M/L 5048	1	0.315	127.2	4.3
	2	0.315	127.3	4.2
	3	0.315	127.2	4.3
	4	0.315	127.3	4.2
	5	0.315	127.2	4.3
	Mean	-	-	4.3
	S.D.	-	-	0.05
HDPE with 5% of M/L 6038	1	0.316	127.0	4.4
	2	0.316	127.0	4.4
	3	0.316	127.0	4.4
	4	0.316	127.0	4.4
	5	0.316	127.0	4.4
	Mean	-	-	4.4
	S.D.	-	-	0.00
HDPE with 15% of M/L 6038	1	0.315	127.2	4.3
	2	0.315	127.3	4.2
	3	0.315	127.4	4.1
	4	0.315	127.3	4.2
	5	0.315	127.4	4.1
	Mean	-	-	4.2
	S.D.	-	-	0.08

Table A-9 Izod impact of HIPS and HIPS blends with Universal Masterbatches (M/H 4058, M/H 5048, M/H 6038, M/L 4058, M/L 5048 and M/L 6038)

Composition	Specimen	Thickness (cm)	Swing up angle	Izod Impact (kg-cm/cm^2)
HIPS NATURAL	1	0.317	121.2	9.1
	2	0.317	121.1	9.1
	3	0.317	121.9	8.5
	4	0.317	121.9	8.5
	5	0.317	121.6	8.7
	Mean	-	-	8.8
	S.D.	-	-	0.3
HIPS with 5% of M/H 4058	1	0.317	122.2	8.2
	2	0.317	122.6	7.9
	3	0.317	122.4	8.6
	4	0.318	121.8	8.2
	5	0.318	122.3	8.4
	Mean	-	-	8.3
	S.D.	-	-	0.26
HIPS with 15% of M/H 4058	1	0.318	125.3	5.7
	2	0.318	125.3	5.7
	3	0.317	125.3	5.7
	4	0.317	125.3	5.7
	5	0.317	125.3	5.7
	Mean	-	-	5.7
	S.D.	-	-	0.0
HIPS with 5% of M/H 5048	1	0.317	122.6	7.9
	2	0.318	122.7	7.8
	3	0.318	122.4	8.0
	4	0.317	122.6	7.9
	5	0.318	122.5	8.0
	Mean	-	-	7.9
	S.D.	-	-	0.08

Table A-9 (continued)

Composition	Specimen	Thickness (cm)	Swing up angle	Izod Impact (kg-cm/cm^2)
HIPS with 15% of M/H 5048	1	0.317	126.4	4.9
	2	0.317	126.3	4.9
	3	0.317	126.3	4.9
	4	0.317	126.2	5.0
	5	0.317	126.2	5.0
	Mean	-	-	4.9
	S.D.	-	-	0.05
HIPS with 5% of M/H 6038	1	0.318	122.6	7.9
	2	0.318	122.6	7.9
	3	0.318	122.6	7.9
	4	0.318	122.6	7.9
	5	0.318	122.6	7.9
	Mean	-	-	7.9
	S.D.	-	-	0.00
HIPS with 15% of M/H 6038	1	0.317	127.8	3.8
	2	0.317	127.6	3.9
	3	0.317	127.9	3.7
	4	0.317	127.6	3.9
	5	0.318	127.8	3.8
	Mean	-	-	3.8
	S.D.	-	-	0.08
HIPS with 5% of M/L 4058	1	0.318	122.2	8.2
	2	0.318	122.2	8.2
	3	0.317	122.4	8.1
	4	0.318	122.2	8.2
	5	0.318	122.3	8.1
	Mean	-	-	8.2
	S.D.	-	-	0.05
HIPS with 15% of M/L 4058	1	0.318	127.1	4.3
	2	0.318	127.0	4.4
	3	0.318	127.1	4.3
	4	0.318	126.9	4.5
	5	0.318	127.1	4.3
	Mean	-	-	4.4
	S.D.	-	-	0.09

Table A-9 (continued)

Composition	Specimen	Thickness (cm)	Swing up angle	Izod Impact (kg-cm/cm^2)
HIPS with 5% of M/L 5048	1	0.317	123.1	7.5
	2	0.318	123.2	7.4
	3	0.317	123.1	7.5
	4	0.317	123.2	7.4
	5	0.318	123.2	7.4
	Mean	-	-	7.4
	S.D.	-	-	0.05
HIPS with 15% of M/L 5048	1	0.318	127.6	3.9
	2	0.317	127.8	3.8
	3	0.317	7.5	4.0
	4	0.317	127.7	3.9
	5	0.317	127.6	3.9
	Mean	-	-	3.9
	S.D.	-	-	0.07
HIPS with 5% of M/L 6038	1	0.317	122.8	7.7
	2	0.317	122.9	7.7
	3	0.317	123.0	7.6
	4	0.317	122.7	7.8
	5	0.317	123.0	7.6
	Mean	-	-	7.7
	S.D.	-	-	0.08
HIPS with 15% of M/L 6038	1	0.317	128.1	3.5
	2	0.316	128.2	3.5
	3	0.316	128.2	3.5
	4	0.316	128.2	3.5
	5	0.318	128.4	3.3
	Mean	-	-	3.5
	S.D.	-	-	0.09

Table A-10 Izod impact of LDPE and LDPE blends with Universal Masterbatches (M/H 4058, M/H 5048, M/H 6038, M/L 4058, M/L 5048 and M/L 6038)

Composition	Specimen	Thickness (cm)	Swing up angle	Izod Impact (kg-cm/cm^2)
LDPE NATURAL	1	0.314	85.9	42.2
	2	0.314	92.2	39.3
	3	0.314	91.9	36.4
	4	0.314	85.1	43.0
	5	0.314	88.5	39.7
	Mean	-	-	40.1
	S.D.	-	-	2.61
LDPE with 5% of M/H 4058	1	0.313	91.9	36.5
	2	0.313	90.1	38.2
	3	0.311	90.2	38.4
	4	0.312	92.0	36.5
	5	0.313	91.9	36.5
	Mean	-	-	37.2
	S.D.	-	-	0.99
LDPE with 15% of M/H 4058	1	0.314	90.1	38.1
	2	0.314	85.5	42.6
	3	0.314	85.2	42.9
	4	0.314	90.2	38.0
	5	0.314	87.6	40.6
	Mean	-	-	40.4
	S.D.	-	-	2.35
LDPE with 5% of M/H 5048	1	0.313	91.9	36.5
	2	0.313	91.0	37.4
	3	0.313	90.9	37.5
	4	0.312	91.9	36.6
	5	0.313	91.1	37.3
	Mean	-	-	37.1
	S.D.	-	-	0.47

Table A-10 (continued)

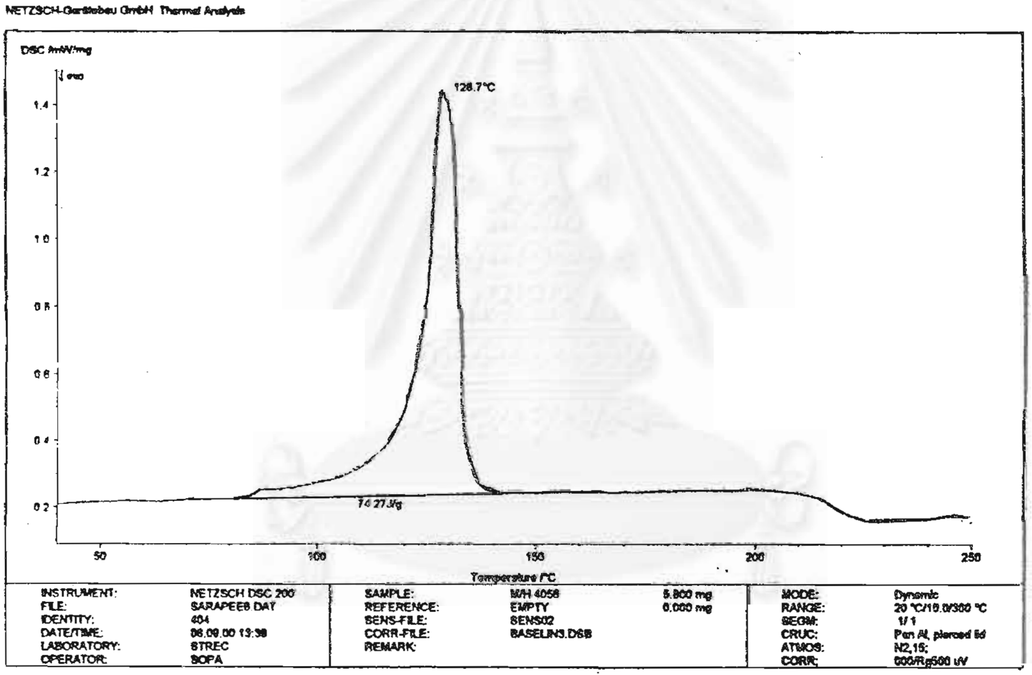
Composition	Specimen	Thickness (cm)	Swing up angle	Izod Impact (kg-cm/cm^2)
LDPE with 15% of M/H 5048	1	0.313	90.9	37.5
	2	0.312	90.0	38.5
	3	0.313	90.1	38.2
	4	0.313	90.9	37.5
	5	0.313	91.9	36.6
	Mean	-	-	37.7
	S.D.	-	-	0.74
LDPE with 5% of M/H 6038	1	0.313	90.8	37.6
	2	0.312	92.1	36.4
	3	0.312	91.2	37.1
	4	0.313	91.0	37.5
	5	0.312	89.9	38.6
	Mean	-	-	37.4
	S.D.	-	-	0.80
LDPE with 15% of M/H 6038	1	0.313	90.8	37.6
	2	0.312	91.0	37.5
	3	0.312	92.1	36.5
	4	0.312	89.4	38.9
	5	0.312	92.1	36.4
	Mean	-	-	37.4
	S.D.	-	-	1.01
LDPE with 5% of M/L 4058	1	0.313	96.0	32.5
	2	0.313	96.8	31.7
	3	0.312	97.8	30.8
	4	0.313	97.0	31.5
	5	0.313	98.1	30.4
	Mean	-	-	31.4
	S.D.	-	-	0.82
LDPE with 15% of M/L 4058	1	0.315	84.0	43.9
	2	0.314	86.2	41.9
	3	0.315	85.6	42.4
	4	0.313	85.2	42.9
	5	0.315	84.5	43.5
	Mean	-	-	42.9
	S.D.	-	-	0.8

Table A-10 (continued)

Composition	Specimen	Thickness (cm)	Swing up angle	Izod Impact (kg-cm/cm^2)
LDPE with 5% of M/L 5048	1	0.313	88.6	39.7
	2	0.313	88.5	39.8
	3	0.313	89.0	39.3
	4	0.312	89.2	39.3
	5	0.313	89.0	39.3
	Mean	-	-	39.5
	S.D.	-	-	0.25
LDPE with 15% of M/L 5048	1	0.312	88.9	39.6
	2	0.313	83.9	44.0
	3	0.312	85.4	42.9
	4	0.314	86.2	41.9
	5	0.312	86.7	41.3
	Mean	-	-	41.9
	S.D.	-	-	1.66
LDPE with 5% of M/L 6038	1	0.313	91.6	36.8
	2	0.312	91.2	37.3
	3	0.313	91.0	37.4
	4	0.314	92.0	36.3
	5	0.313	92.0	36.4
	Mean	-	-	36.8
	S.D.	-	-	0.50
LDPE with 15% of M/L 6038	1	0.312	88.9	39.6
	2	0.313	89.4	39.0
	3	0.312	88.9	39.5
	4	0.312	89.9	38.7
	5	0.313	88.5	39.8
	Mean	-	-	39.3
	S.D.	-	-	0.45

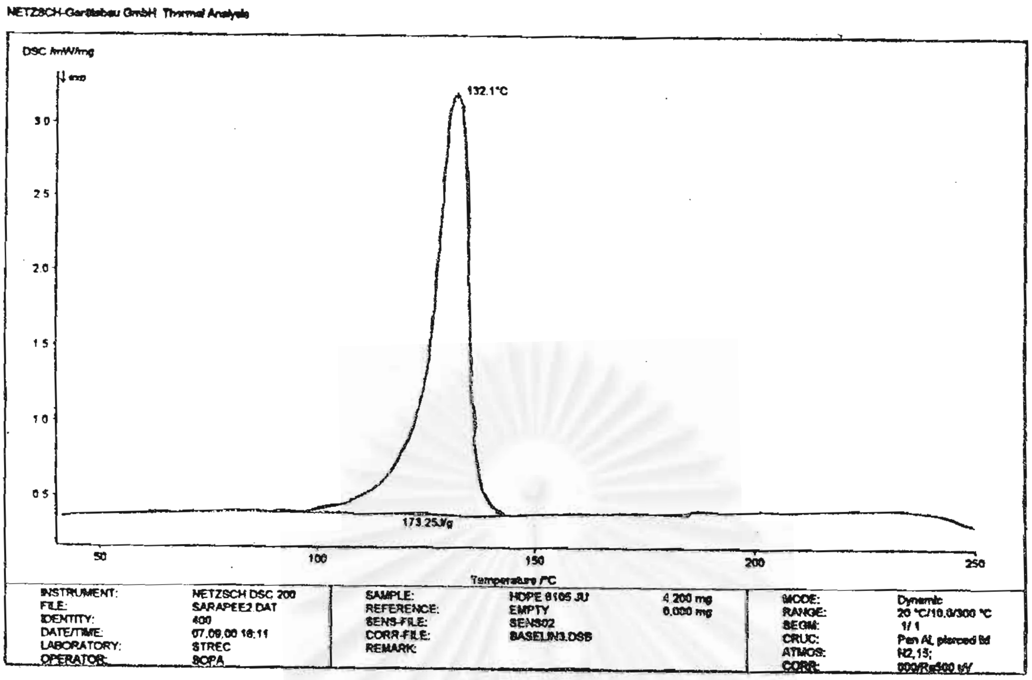
APPENDIX B

Differential Scanning Calorimetry (DSC) of M/H 4058, HDPE 6105 JU, LDPE ST 1018, PP 2300 K, HIPS 825-10, and ABS LUSTRAN 250 and their blends with M/H 4058 at 5%



INSTRUMENT:	NETZSCH DSC 200	SAMPLE:	M/H 4058	5.800 mg	MODE:	Dynamic
FILE:	SARAPEE8.DAT	REFERENCE:	EMPTY	0.000 mg	RANGE:	20 °C/10.0/300 °C
IDENTITY:	404	SENS-FILE:	SENS02		SEGM:	1/1
DATE/TIME:	06.09.00 13:38	CORR-FILE:	BASELIN3.DSB		CRUC:	Pan Al, pierced lid
LABORATORY:	STREC	REMARK:			ATMOS:	N2,15;
OPERATOR:	SOPA				CORR:	000/Rg500 uV

Figure B-1 DSC curve of M/H 4058

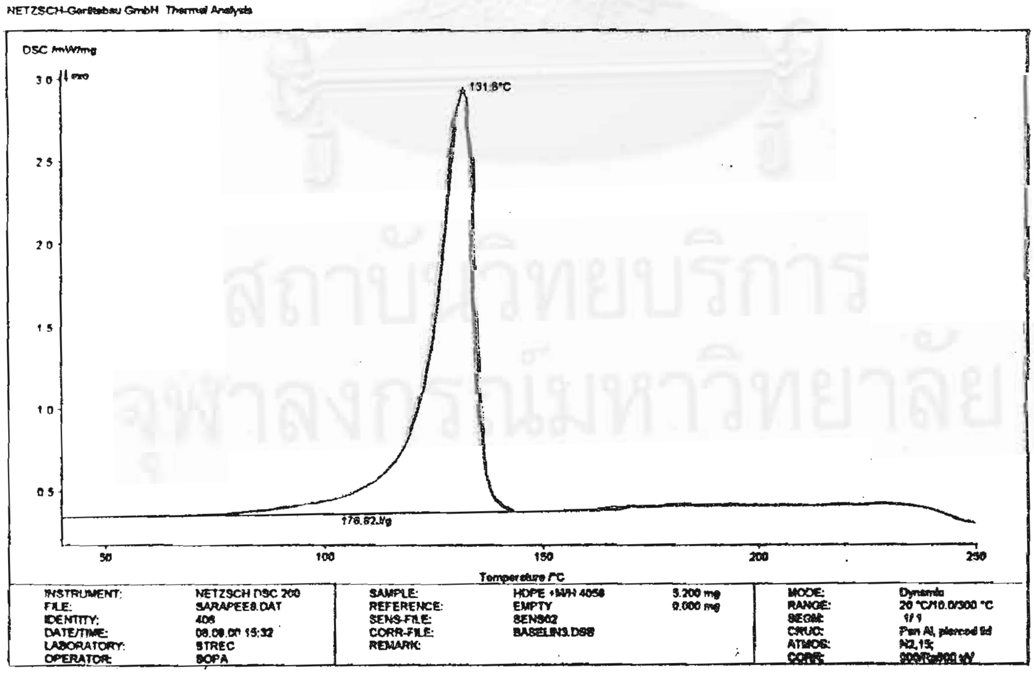


INSTRUMENT: NETZSCH DSC 200
FILE: SARAPEE2.DAT
IDENTITY: 400
DATE/TIME: 07.09.00 16:11
LABORATORY: STREC
OPERATOR: SOPA

SAMPLE: HDPE 6105 JU 4.200 mg
REFERENCE: EMPTY 0.000 mg
SENS-FILE: SENS02
CORR-FILE: BASELIN3.DSB
REMARK:

MODE: Dynamic
RANGE: 20 °C/10.0/300 °C
SEGM: 1/1
CRUC: Pan Al, pierced lid
ATMOS: N2,15;
CORR: 000/Rg500 uV

Figure B-2 DSC curve of HDPE 6105 JU

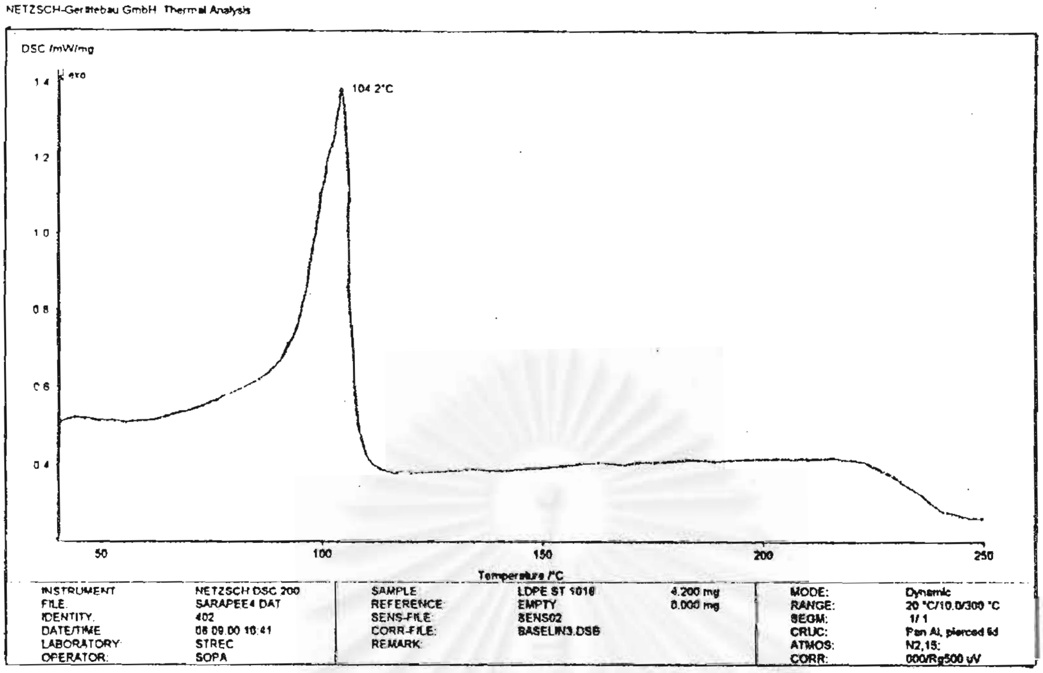


INSTRUMENT: NETZSCH DSC 200
FILE: SARAPEE8.DAT
IDENTITY: 406
DATE/TIME: 08.09.00 15:32
LABORATORY: STREC
OPERATOR: SOPA

SAMPLE: HDPE +M/H 4058 5.200 mg
REFERENCE: EMPTY 0.000 mg
SENS-FILE: SENS02
CORR-FILE: BASELIN3.DSB
REMARK:

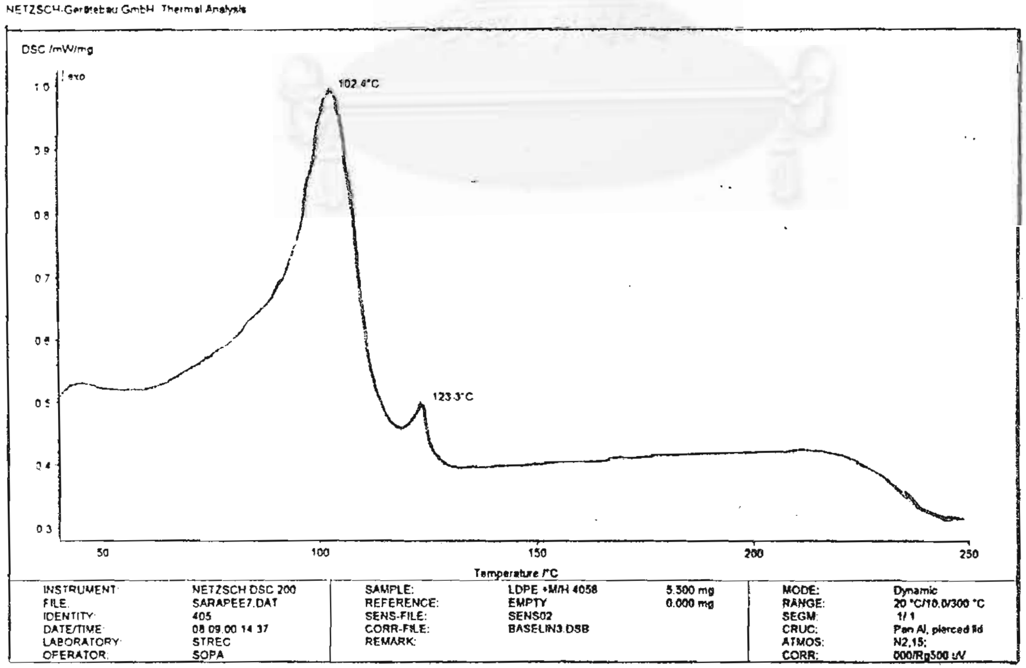
MODE: Dynamic
RANGE: 20 °C/10.0/300 °C
SEGM: 1/1
CRUC: Pan Al, pierced lid
ATMOS: N2,15;
CORR: 000/Rg500 uV

Figure B-3 DSC curve of HDPE 6105 JU blend with M/H 4058 at 5 %



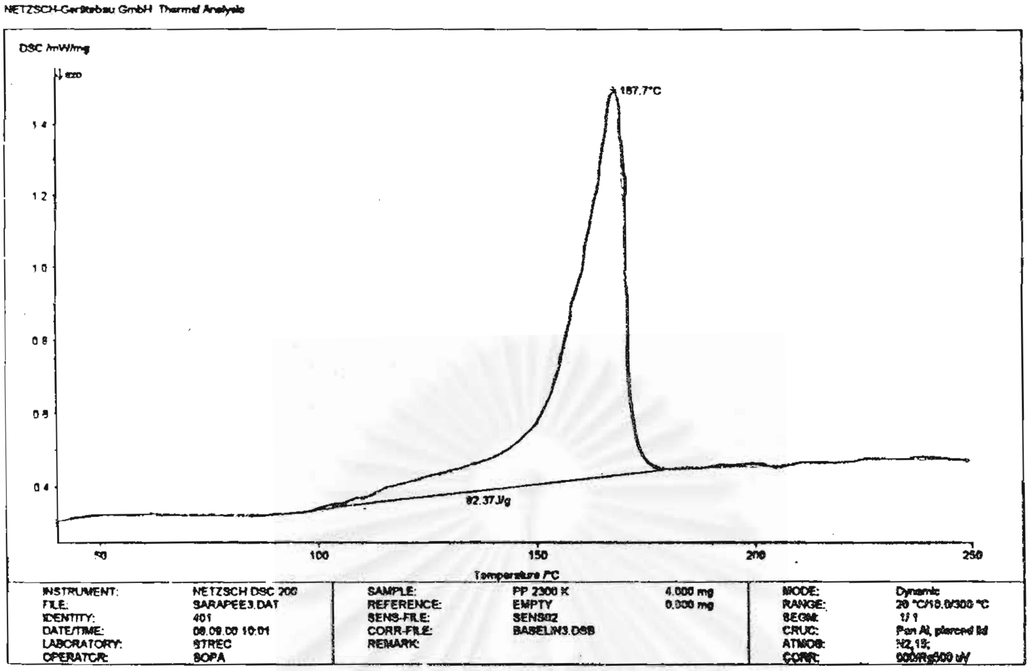
INSTRUMENT:	NETZSCH DSC 200	SAMPLE:	LDPE ST 1018	4.200 mg	MODE:	Dynamic
FILE:	SARAPEE4.DAT	REFERENCE:	EMPTY	0.000 mg	RANGE:	20 °C/10.0/300 °C
IDENTITY:	402	SENS-FILE:	SENS02		SEGM:	1/ 1
DATE/TIME:	08.09.00 10:41	CORR-FILE:	BASELIN3.DSB		CRUC:	Pan Al, pierced lid
LABORATORY:	STREC	REMARK:			ATMOS:	N2,15;
OPERATOR:	SOPA				CORR:	000/Rg500 uV

Figure B-4 DSC curve of LDPE ST 1018



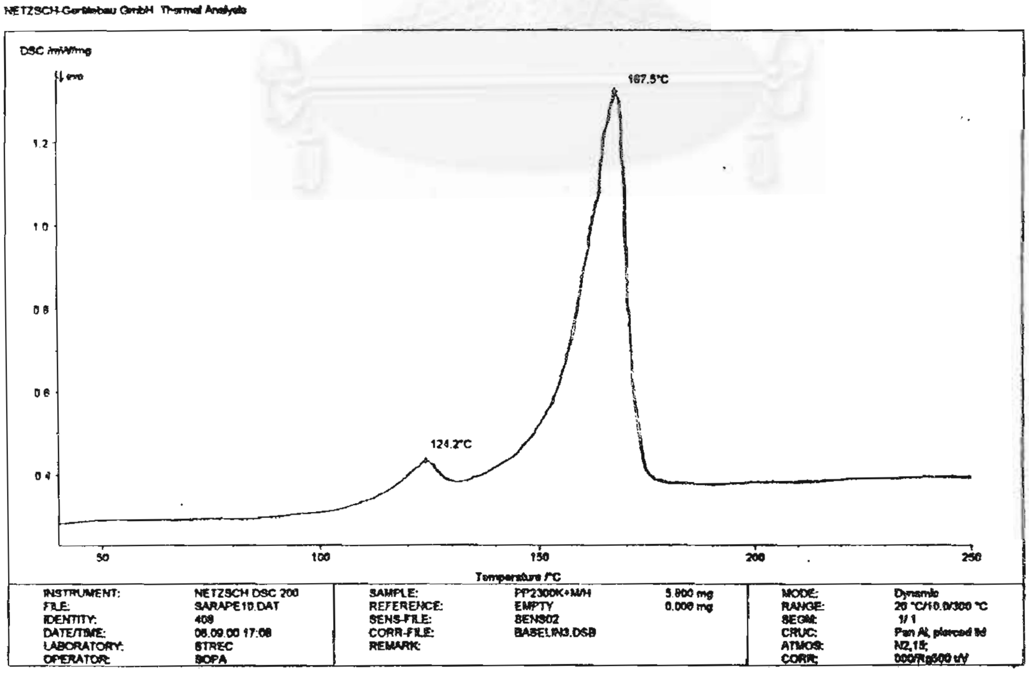
INSTRUMENT:	NETZSCH DSC 200	SAMPLE:	LDPE +M/H 4058	5.300 mg	MODE:	Dynamic
FILE:	SARAPEE7.DAT	REFERENCE:	EMPTY	0.000 mg	RANGE:	20 °C/10.0/300 °C
IDENTITY:	405	SENS-FILE:	SENS02		SEGM:	1/ 1
DATE/TIME:	08.09.00 14:37	CORR-FILE:	BASELIN3.DSB		CRUC:	Pan Al, pierced lid
LABORATORY:	STREC	REMARK:			ATMOS:	N2,15;
OPERATOR:	SOPA				CORR:	000/Rg500 uV

Figure B-5 DSC curve of LDPE ST 1018 blend with M/H 4058 at 5 %



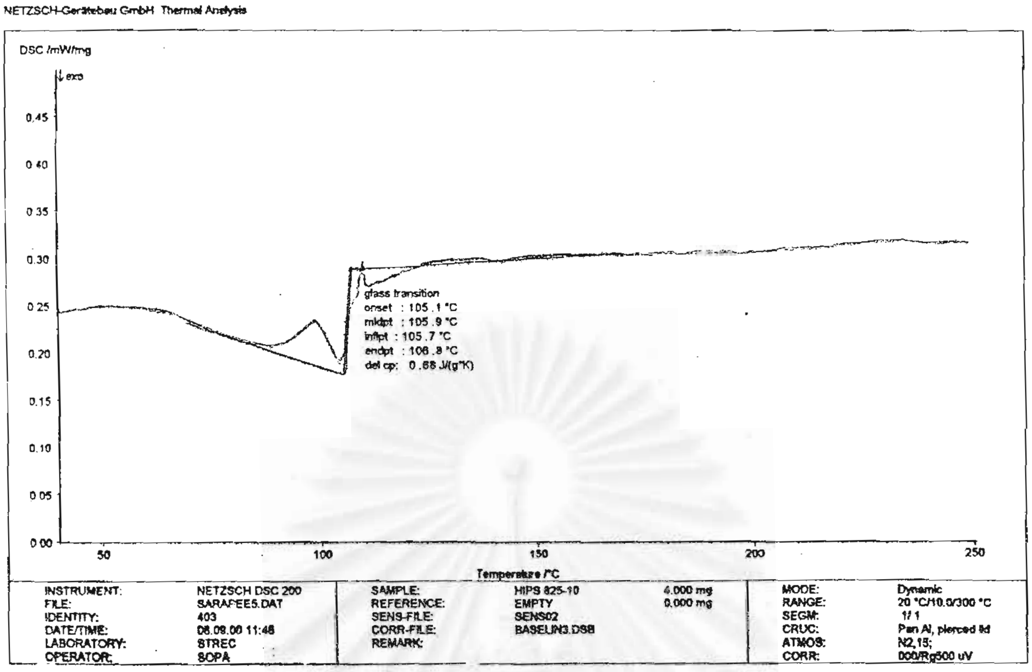
INSTRUMENT:	NETZSCH DSC 200	SAMPLE:	PP 2300 K	4.000 mg	MODE:	Dynamic
FILE:	SARAPEE3.DAT	REFERENCE:	EMPTY	0.000 mg	RANGE:	20 °C/10.0/300 °C
IDENTITY:	401	SENS-FILE:	SENS02		SEGM:	1/1
DATE/TIME:	08.09.00 10:01	CORR-FILE:	BASELIN3.DSB		CRUC:	Pan Al, pierced lid
LABORATORY:	STREC	REMARK:			ATMOS:	N2,15;
OPERATOR:	SOPA				CORR:	000/Rg500 uV

Figure B-6 DSC curve of PP 2300 K



INSTRUMENT:	NETZSCH DSC 200	SAMPLE:	PP2300K+M/H	5.800 mg	MODE:	Dynamic
FILE:	SARAPE10.DAT	REFERENCE:	EMPTY	0.000 mg	RANGE:	20 °C/10.0/300 °C
IDENTITY:	408	SENS-FILE:	SENS02		SEGM:	1/1
DATE/TIME:	08.09.00 17:08	CORR-FILE:	BASELIN3.DSB		CRUC:	Pan Al, pierced lid
LABORATORY:	STREC	REMARK:			ATMOS:	N2,15;
OPERATOR:	SOPA				CORR:	000/Rg500 uV

Figure B-7 DSC curve of PP 2300 K blend with M/H 4058 at 5 %

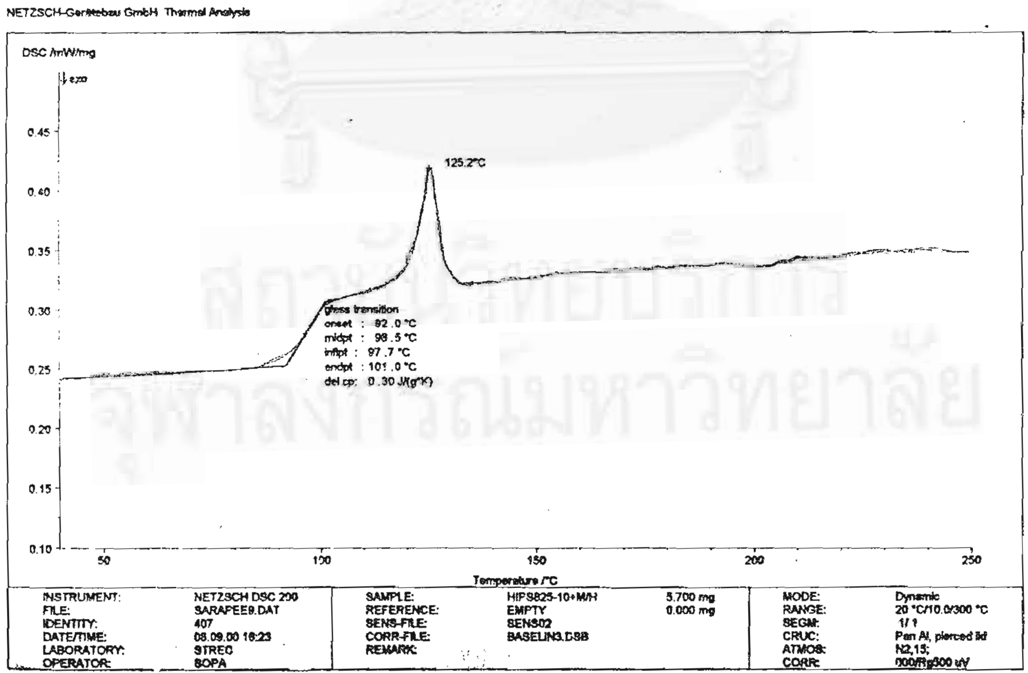


NETZSCH-Gerätebau GmbH Thermal Analysis

glass transition
onset : 105.1 °C
midpt : 105.9 °C
inflpt : 105.7 °C
endpt : 106.8 °C
del cp: 0.68 J/(g*K)

INSTRUMENT:	NETZSCH DSC 200	SAMPLE:	HIPS 825-10	4.000 mg	MODE:	Dynamic
FILE:	SARAPEE5.DAT	REFERENCE:	EMPTY	0.000 mg	RANGE:	20 °C/10.0/300 °C
IDENTITY:	403	SENS-FILE:	SENS02		SEGM:	1/1
DATE/TIME:	08.09.00 11:48	CORR-FILE:	BASELIN3.DSB		CRUC:	Pan Al, pierced lid
LABORATORY:	STREC	REMARK:			ATMOS:	N2,15;
OPERATOR:	SOPA				CORR:	000/Rg500 uV

Figure B-8 DSC curve of HIPS 825-10



NETZSCH-Gerätebau GmbH Thermal Analysis

glass transition
onset : 92.0 °C
midpt : 98.5 °C
inflpt : 97.7 °C
endpt : 101.0 °C
del cp: 0.30 J/(g*K)

INSTRUMENT:	NETZSCH DSC 200	SAMPLE:	HIPS825-10+M/H	5.700 mg	MODE:	Dynamic
FILE:	SARAPEE9.DAT	REFERENCE:	EMPTY	0.000 mg	RANGE:	20 °C/10.0/300 °C
IDENTITY:	407	SENS-FILE:	SENS02		SEGM:	1/1
DATE/TIME:	08.09.00 16:23	CORR-FILE:	BASELIN3.DSB		CRUC:	Pan Al, pierced lid
LABORATORY:	STREC	REMARK:			ATMOS:	N2,15;
OPERATOR:	SOPA				CORR:	000/Rg500 uV

Figure B-9 DSC curve of HIPS 825-10 blend with M/H 4058 at 5 %

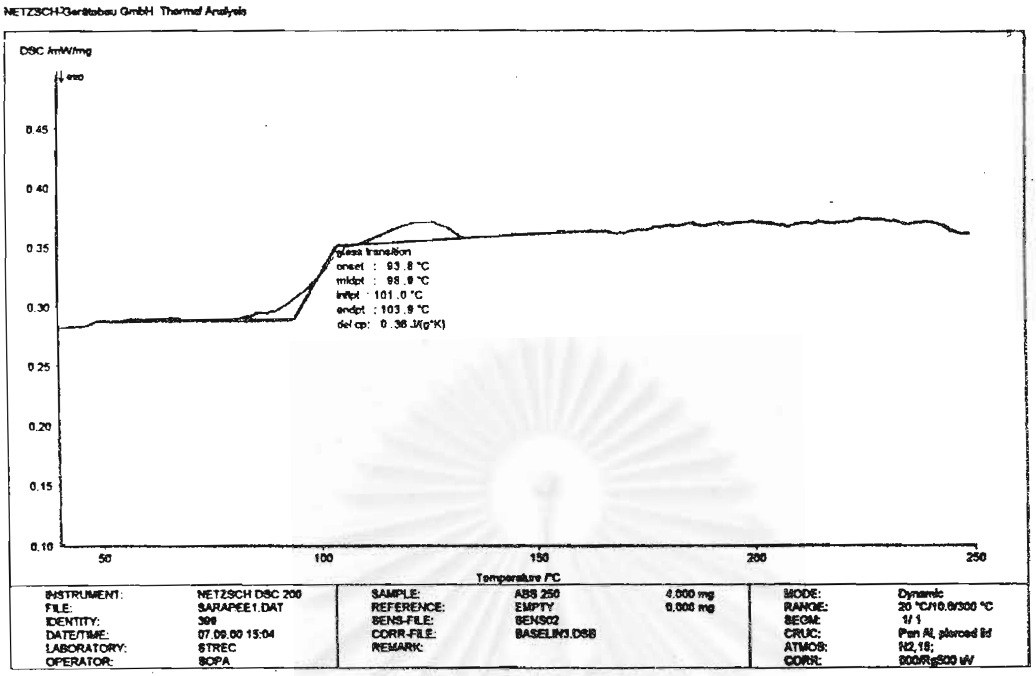


Figure B-10 DSC curve of ABS LUSTRAN 250

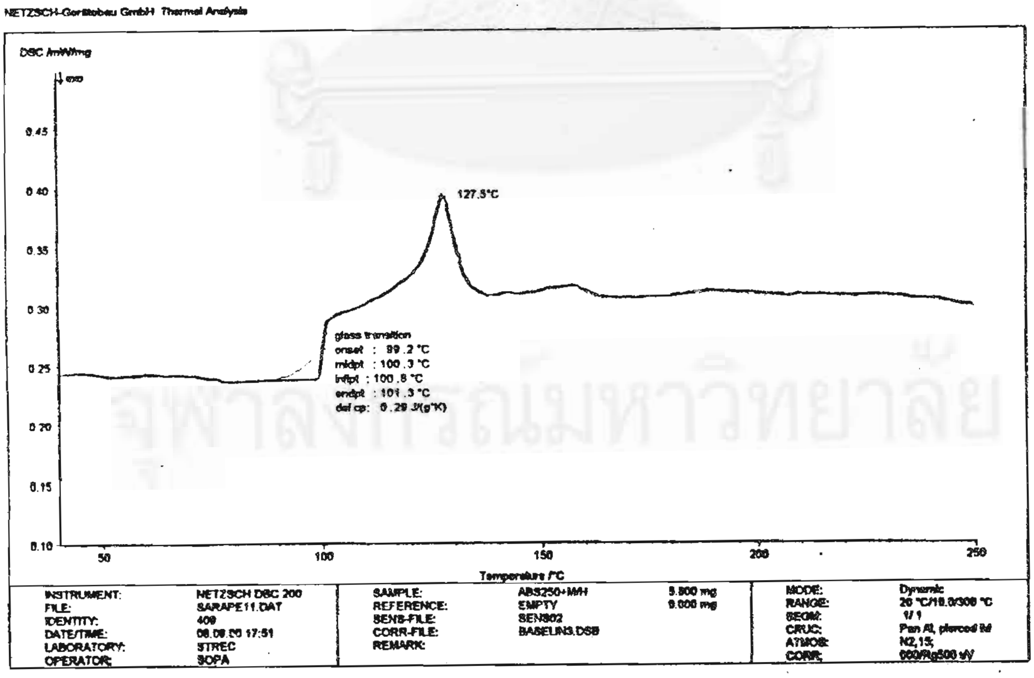
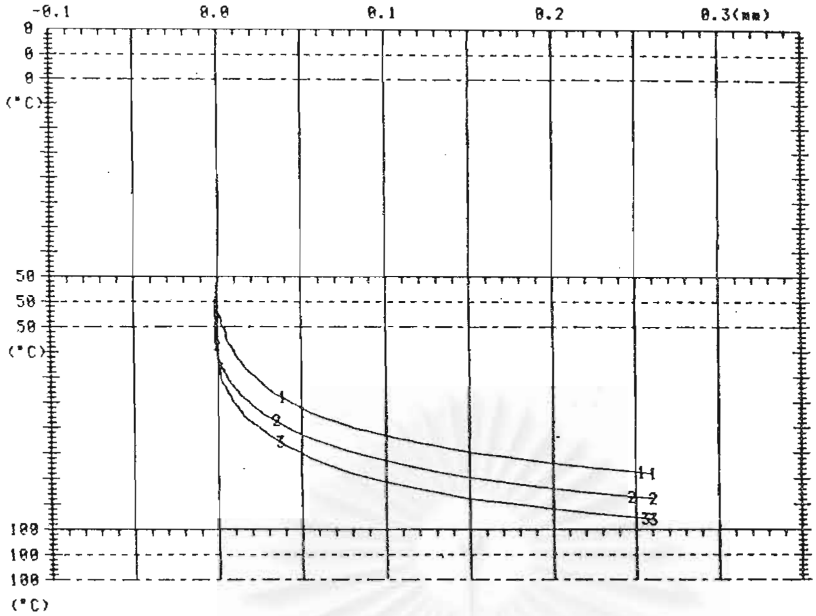
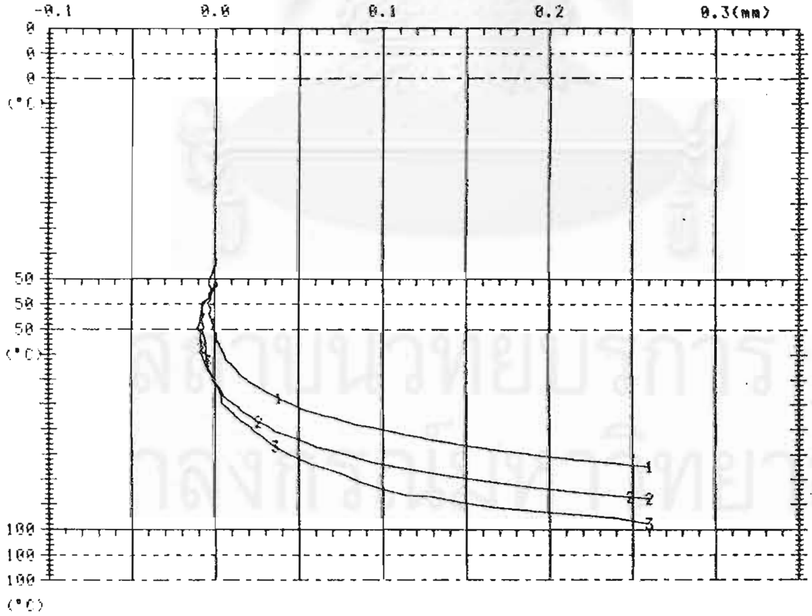


Figure B-11 DSC curve of ABS LUSTRAN 250 blend with M/H 4058 at 5 %



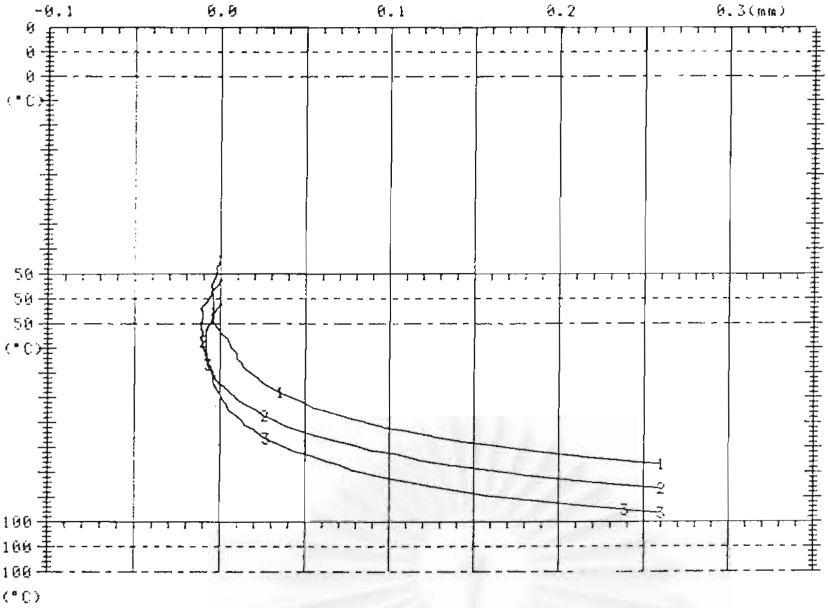
```
DISP      TEMPERATURE(°C)
(mm)     CH1     CH2     CH3
0.260  89.0    89.0    88.1
AVERAGE   88.7 °C
```

Figure B-12 HDT of ABS LUSTRAN 250



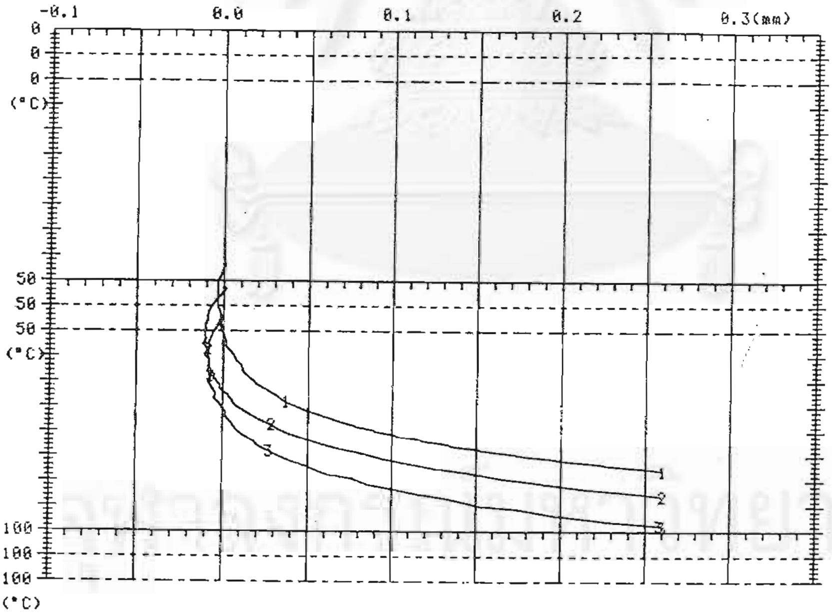
```
DISP      TEMPERATURE(°C)
(mm)     CH1     CH2     CH3
0.260  87.4    88.9    88.9
AVERAGE   88.4 °C
```

Figure B-13 HDT of ABS LUSTRAN 250 blend with M/H 4058 at 5 %



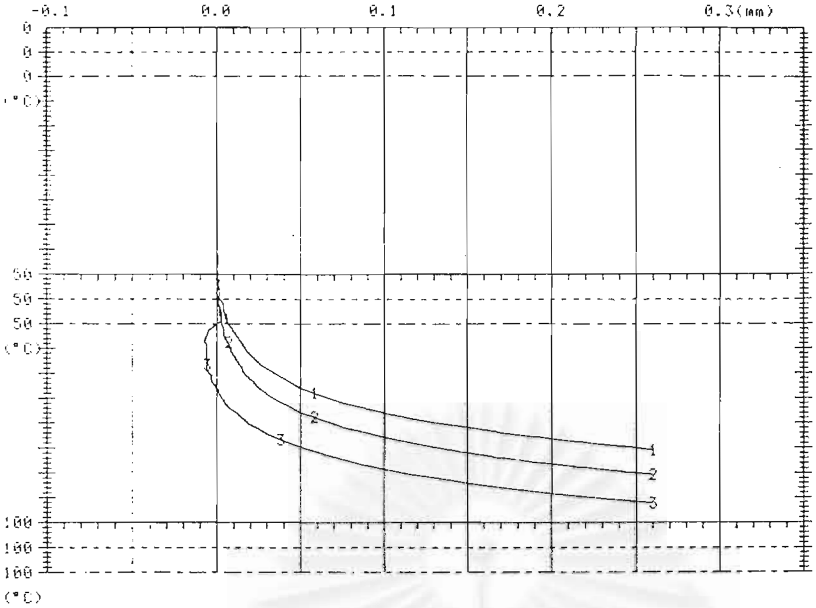
```
DISP       TEMPERATURE(°C)
(mm)       CH1     CH2     CH3
0.260     88.4    88.3    88.3
AVERAGE    88.3 °C
```

Figure B-14 HDT of ABS LUSTRAN 250 blend with M/H 5048 at 5 %



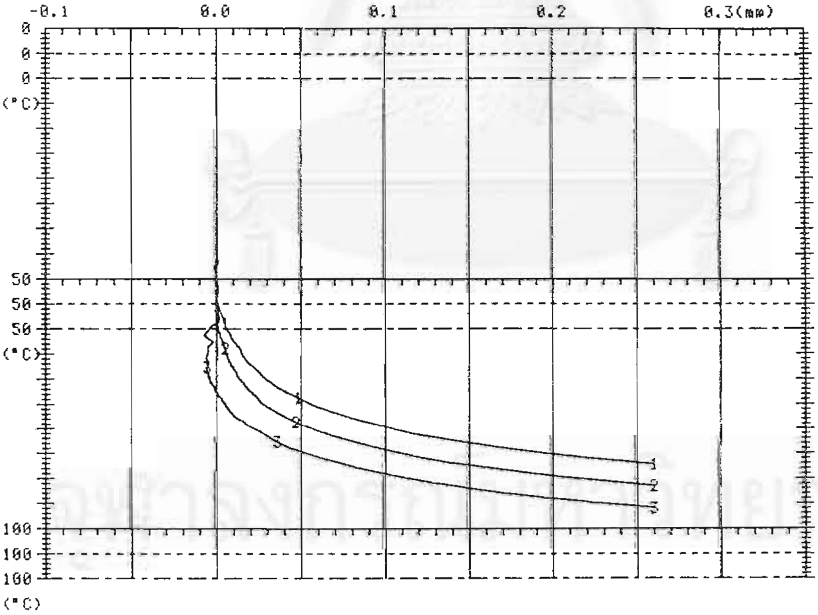
```
DISP       TEMPERATURE(°C)
(mm)       CH1     CH2     CH3
0.260     87.9    88.1    89.1
AVERAGE    88.4 °C
```

Figure B-15 HDT of ABS LUSTRAN 250 blend with M/H 6038 at 5 %



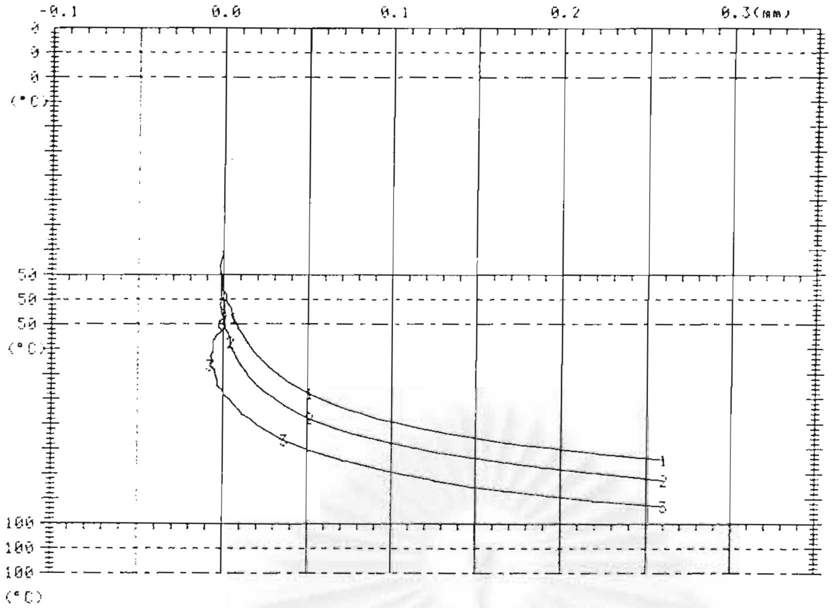
```
DISP      TEMPERATURE(°C)
(mm)       CH1      CH2      CH3
0.260   85.3     85.4     86.2
AVERAGE    85.6 °C
```

Figure B-16 HDT of ABS LUSTRAN 250 blend with M/H 4038 at 15 %



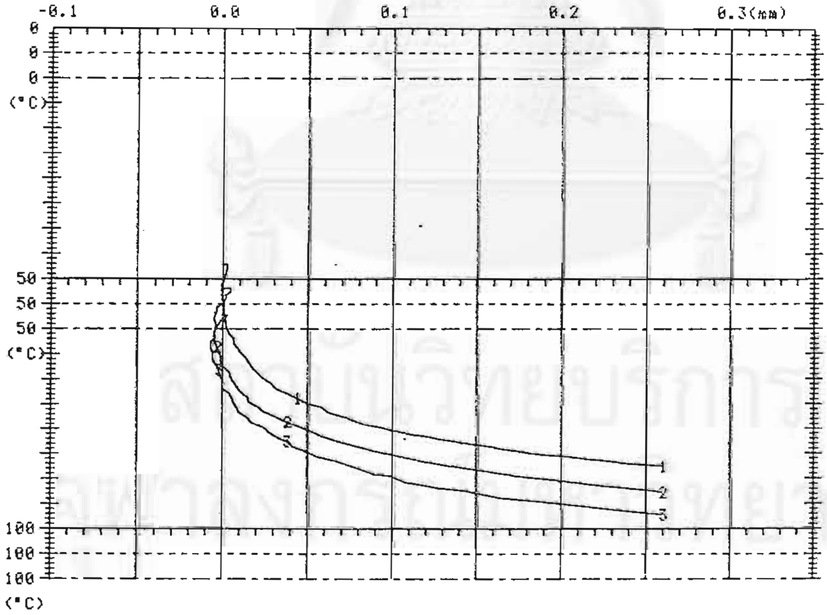
```
DISP      TEMPERATURE(°C)
(mm)       CH1      CH2      CH3
0.260   87.2     86.5     86.1
AVERAGE    86.6 °C
```

Figure B-17 HDT of ABS LUSTRAN 250 blend with M/H 5048 at 15 %



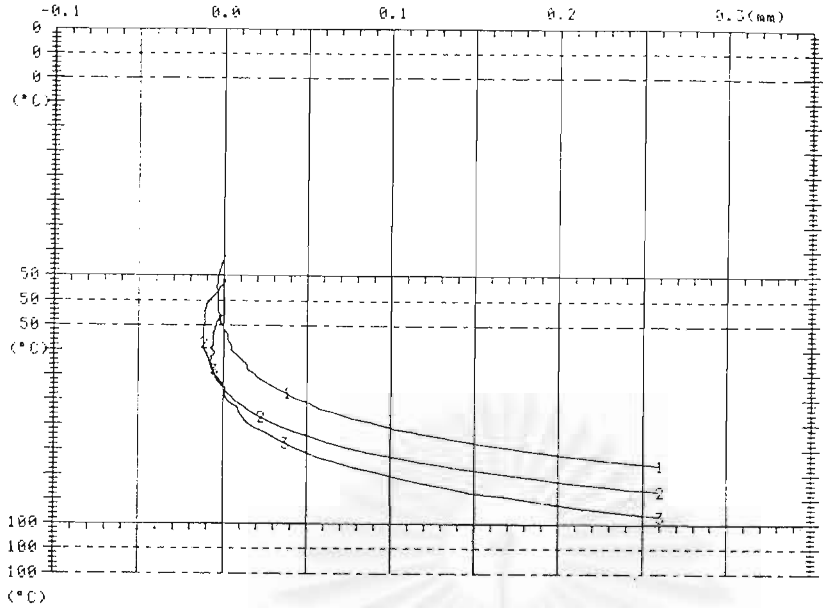
```
DISP     TEMPERATURE(°C)
(mm)     CH1    CH2    CH3
0.260  87.2   86.3   86.7
AVERAGE   86.7 °C
```

Figure B-18   HDT of ABS LUSTRAN 250 blend with M/H 6038 at 15 %



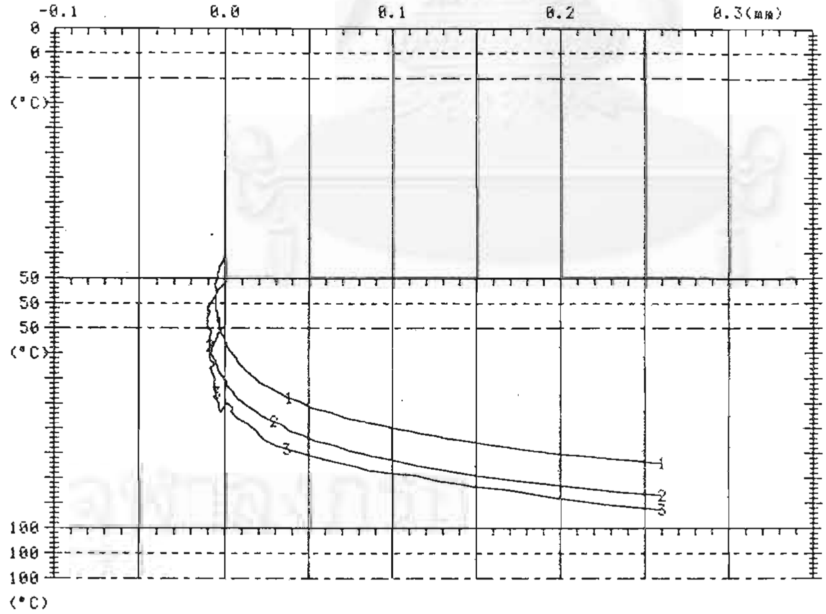
```
DISP     TEMPERATURE(°C)
(mm)     CH1    CH2    CH3
0.260  87.6   87.8   87.4
AVERAGE   87.6 °C
```

Figure B-19   HDT of ABS LUSTRAN 250 blend with M/L 4058 at 5 %



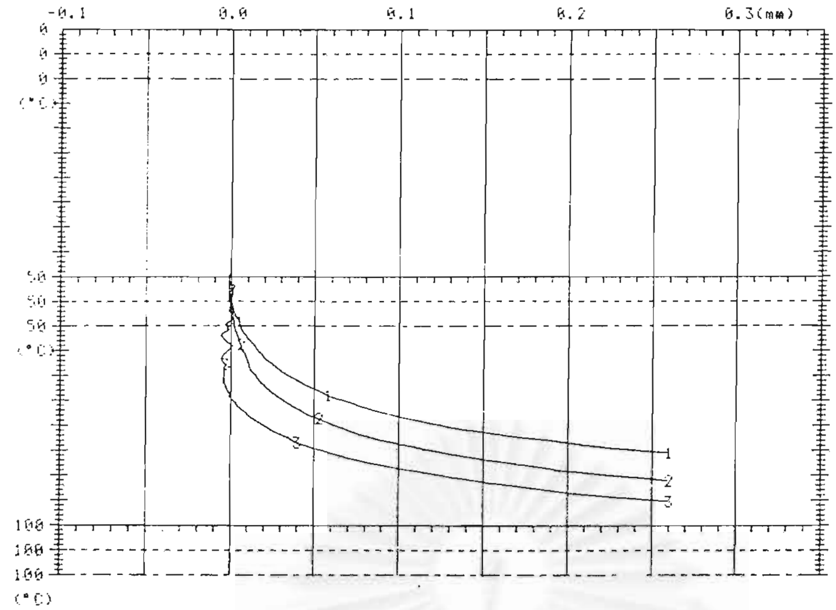
```
DISP      TEMPERATURE(°C)
(mm)      CH1     CH2     CH3
0.260  88.0    88.3    88.5
AVERAGE    88.3 °C
```

Figure B-20 HDT of ABS LUSTRAN 250 blend with M/L 5048 at 5 %



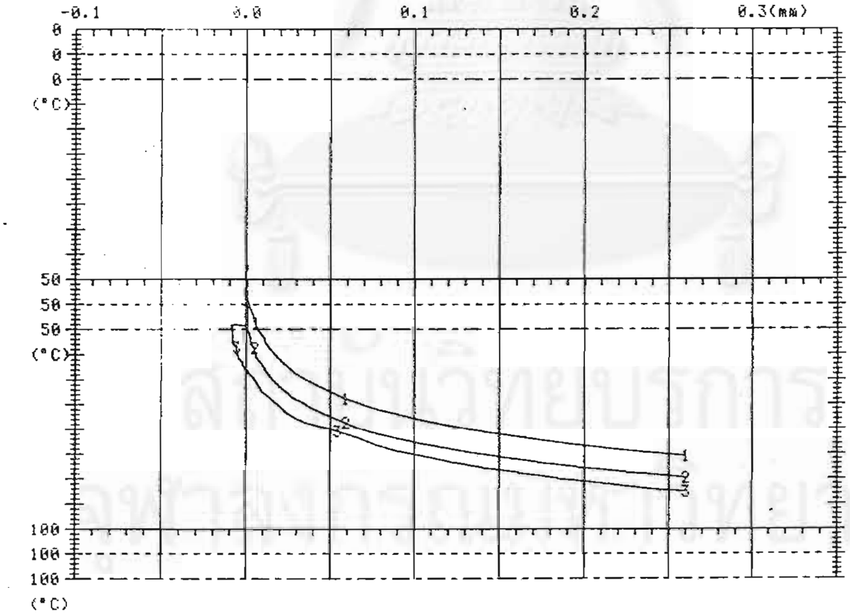
```
DISP      TEMPERATURE(°C)
(mm)      CH1     CH2     CH3
0.260  87.0    88.5    86.4
AVERAGE    87.3 °C
```

Figure B-21 HDT of ABS LUSTRAN 250 blend with M/L 4058 at 15 %



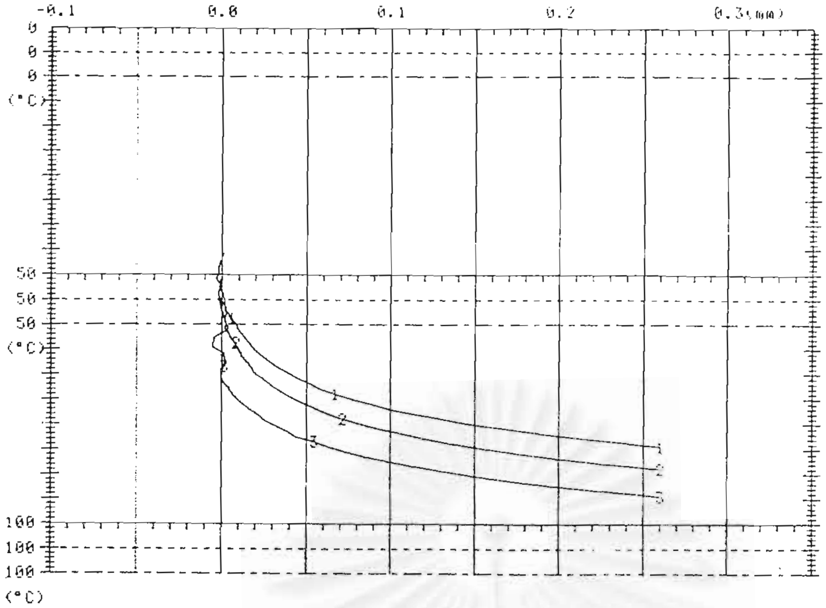
```
DISP      TEMPERATURE(°C)
(mm)     CH1    CH2    CH3
0.260   85.5   86.2   85.4
AVERAGE   85.7 °C
```

Figure B-22 HDT of ABS LUSTRAN 250 blend with M/L 6038 at 5 %



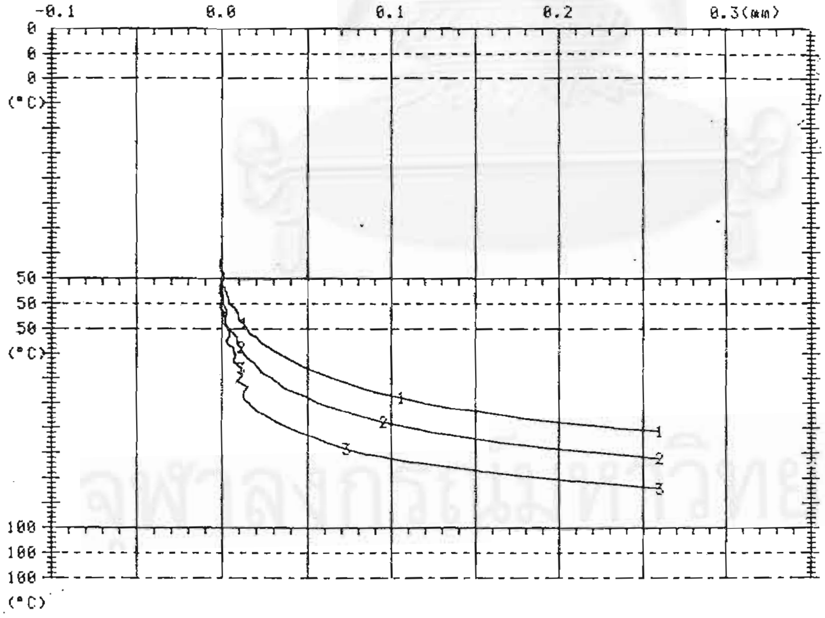
```
DISP      TEMPERATURE(°C)
(mm)     CH1    CH2    CH3
0.260   85.5   84.9   82.7
AVERAGE   84.4 °C
```

Figure B-23 HDT of ABS LUSTRAN 250 blend with M/L 5048 at 15 %



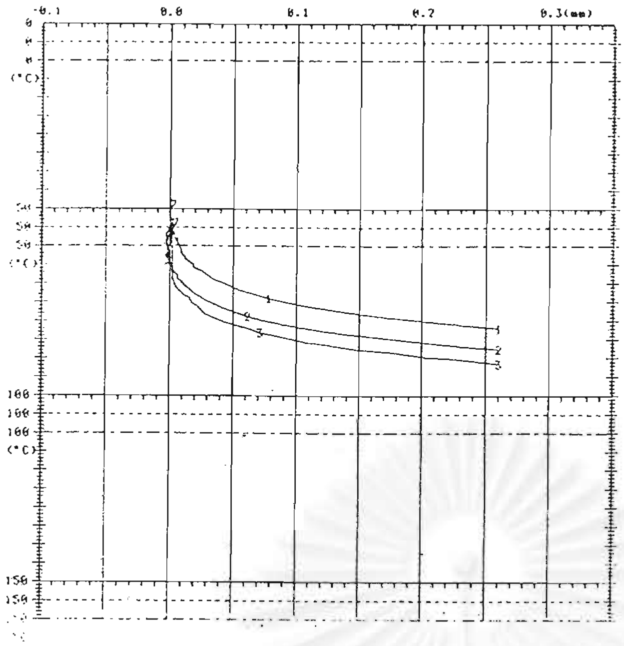
```
DISP      TEMPERATURE(°C)
(mm)     CH1     CH2     CH3
0.260  84.4    84.0    84.7
AVERAGE   84.4 °C
```

Figure B-24 HDT of ABS LUSTRAN 250 blend with M/L 6038 at 15 %



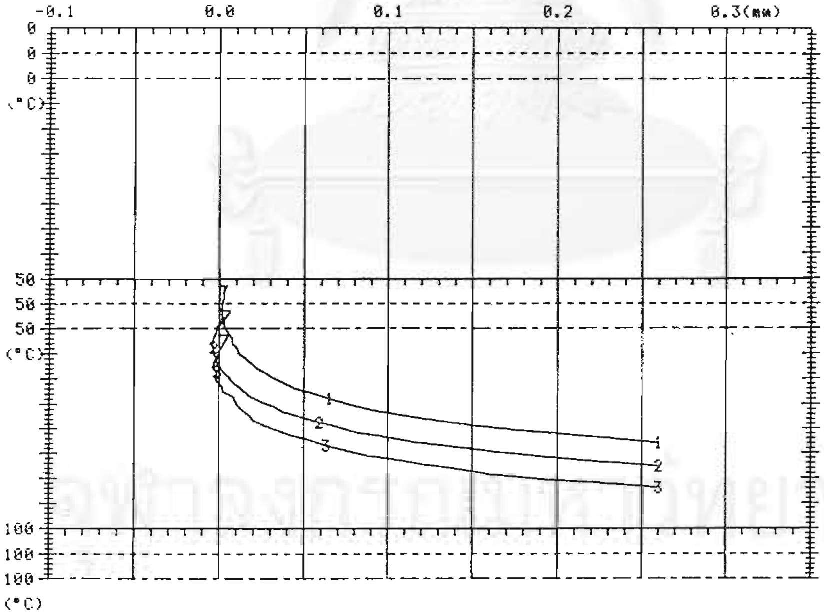
```
DISP      TEMPERATURE(°C)
(mm)     CH1     CH2     CH3
0.260  80.7    81.1    82.2
AVERAGE   81.3 °C
```

Figure B-25 HDT of HIPS 825-10



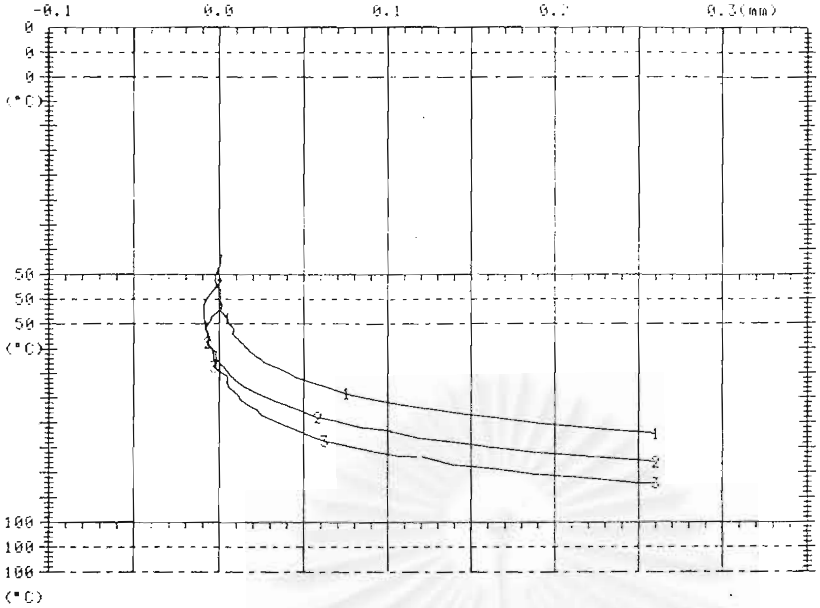
```
DISP      TEMPERATURE(°C)
(mm)     CH1     CH2     CH3
0.260  82.1    82.8    81.8
AVERAGE   82.2 °C
```

Figure B-26 HDT of HIPS 825-10 blend with M/H 4058 at 5 %



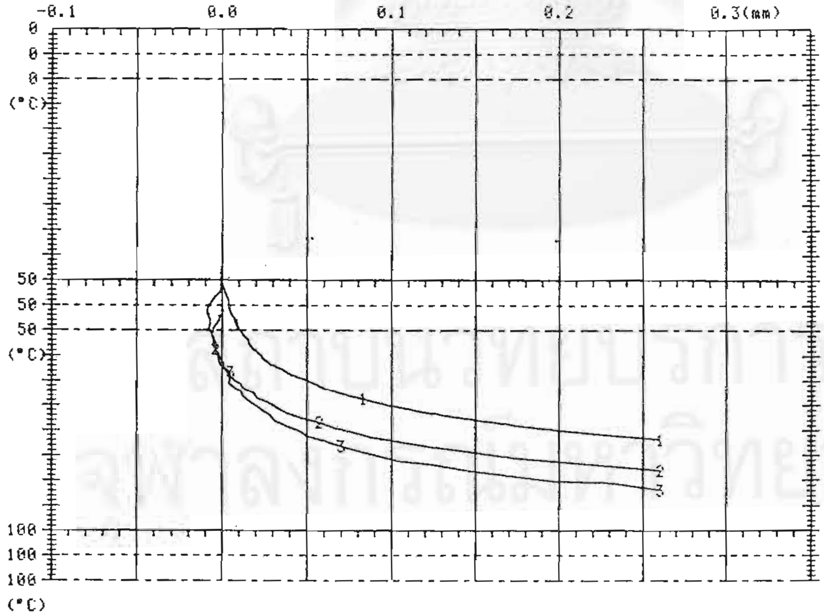
```
DISP      TEMPERATURE(°C)
(mm)     CH1     CH2     CH3
0.260  82.9    82.7    82.0
AVERAGE   82.5 °C
```

Figure B-27 HDT of HIPS 825-10 blend with M/H 5048 at 5 %



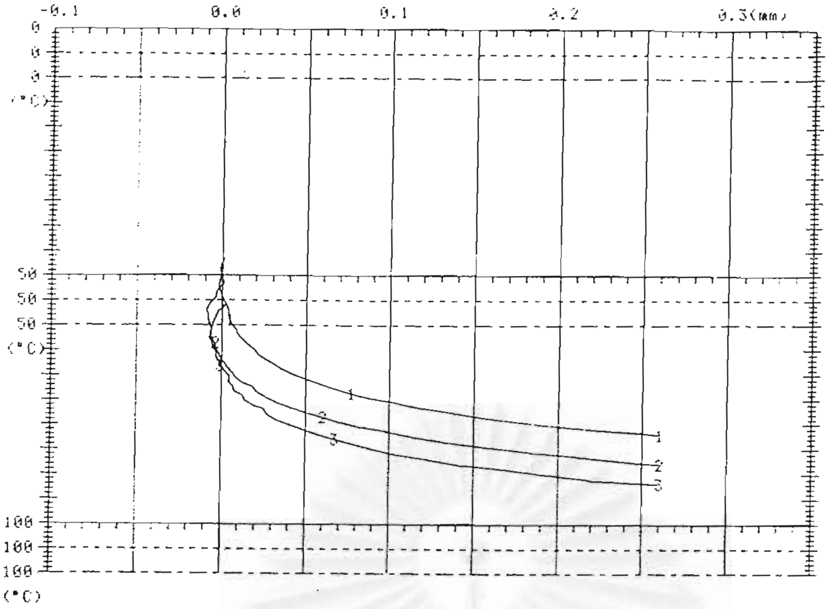
```
DISP     TEMPERATURE(°C)
(mm)     CH1     CH2     CH3
0.260   82.1    82.9    82.2
AVERAGE    82.4 °C
```

Figure B-28 HDT of HIPS 825-10 blend with M/H 6038 at 5 %



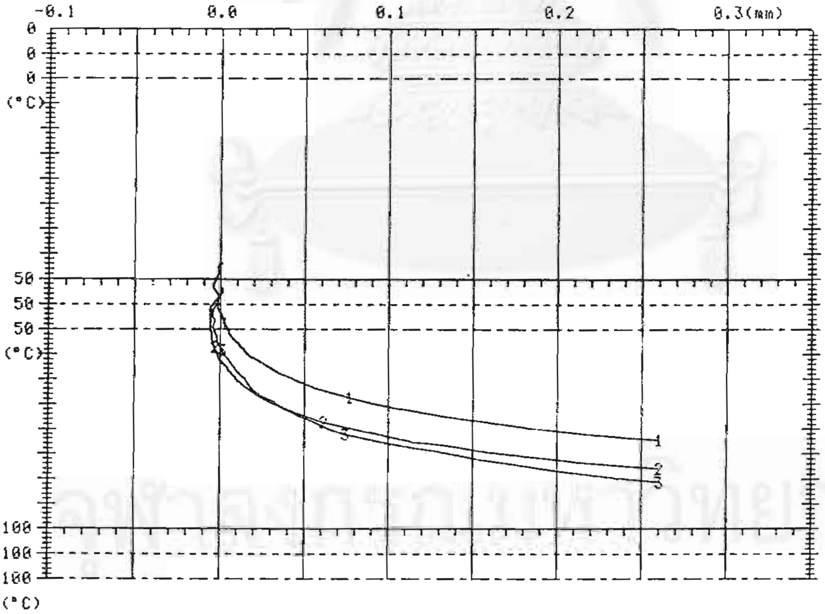
```
DISP     TEMPERATURE(°C)
(mm)     CH1     CH2     CH3
0.260   81.9    83.2    82.1
AVERAGE    82.4 °C
```

Figure B-29 HDT of HIPS 825-10 blend with M/H 4038 at 15 %



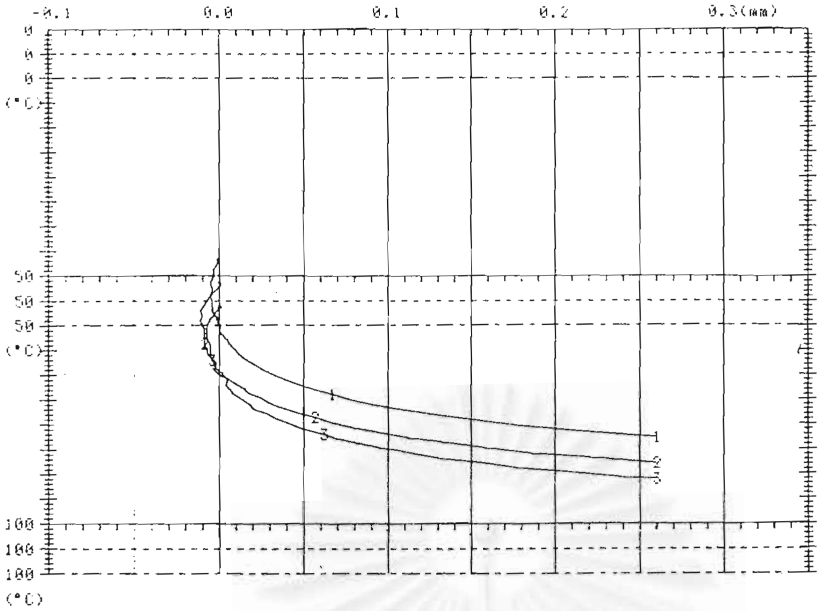
```
DISP      TEMPERATURE(°C)
(mm)     CH1     CH2     CH3
0.260   82.1    82.9    82.0
AVERAGE    82.3 °C
```

Figure B-30 HDT of HIPS 825-10 blend with M/H 5048 at 15 %



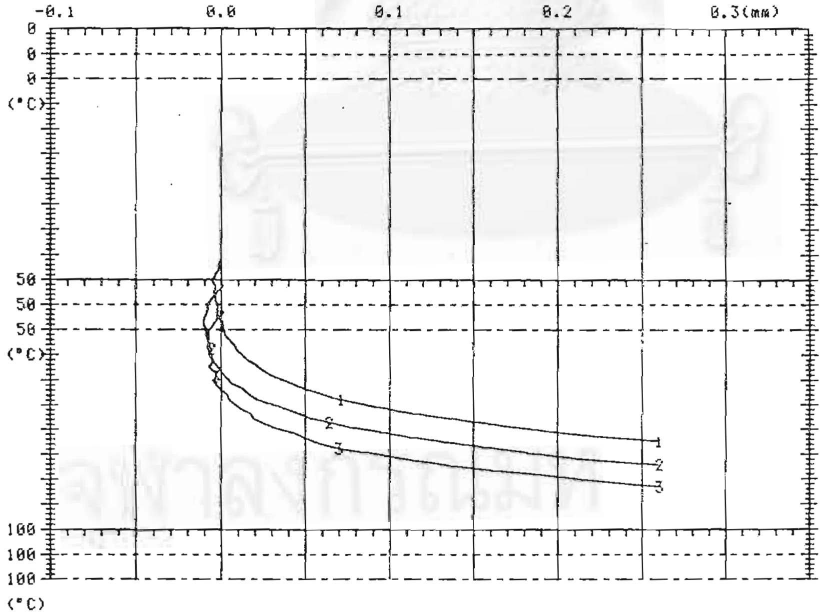
```
DISP      TEMPERATURE(°C)
(mm)     CH1     CH2     CH3
0.260   82.4    83.1    80.8
AVERAGE    82.1 °C
```

Figure B-31 HDT of HIPS 825-10 blend with M/H 6038 at 15 %



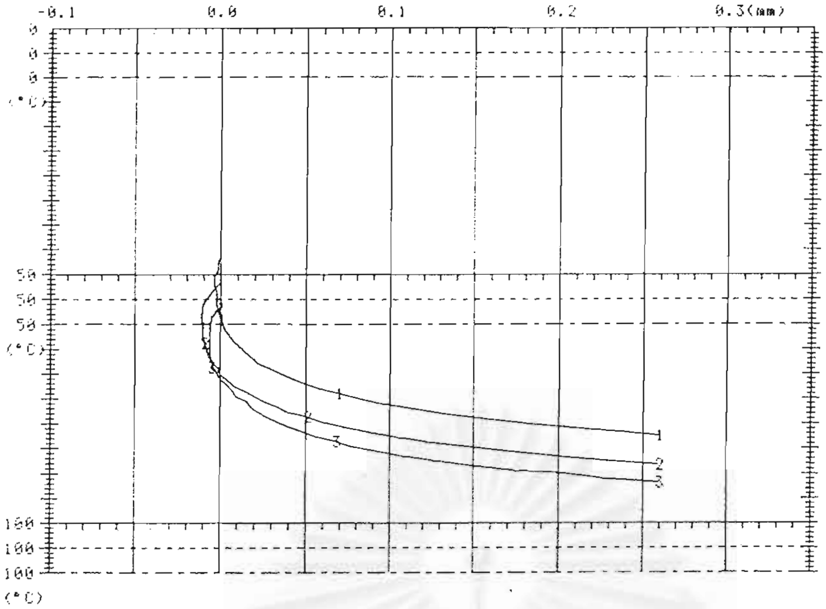
```
DISP      TEMPERATURE(°C)
(mm)     CH1     CH2     CH3
0.260  82.7    83.0    81.2
AVERAGE   82.3 °C
```

Figure B-32 HDT of HIPS 825-10 blend with M/L 4058 at 5 %



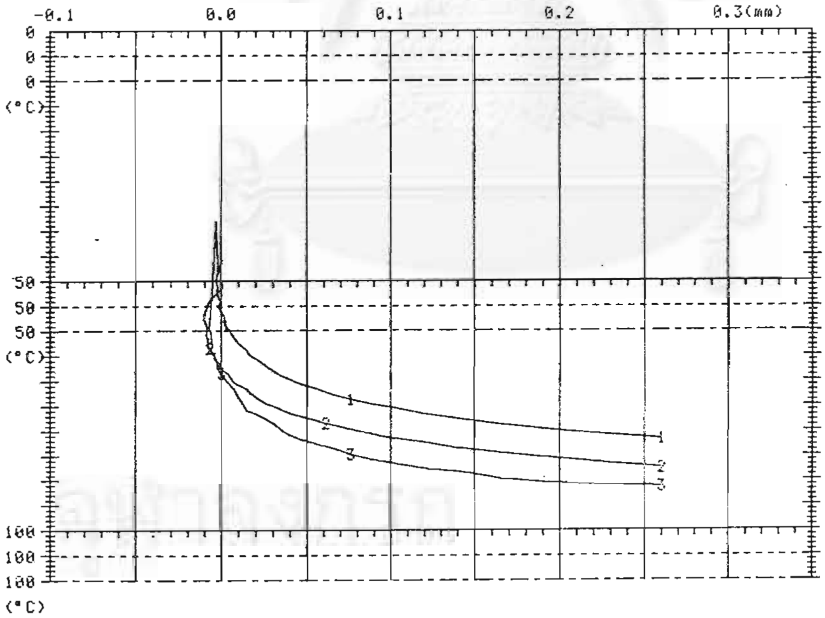
```
DISP      TEMPERATURE(°C)
(mm)     CH1     CH2     CH3
0.260  82.3    82.2    81.7
AVERAGE   82.1 °C
```

Figure B-33 HDT of HIPS 825-10 blend with M/L 5048 at 5 %



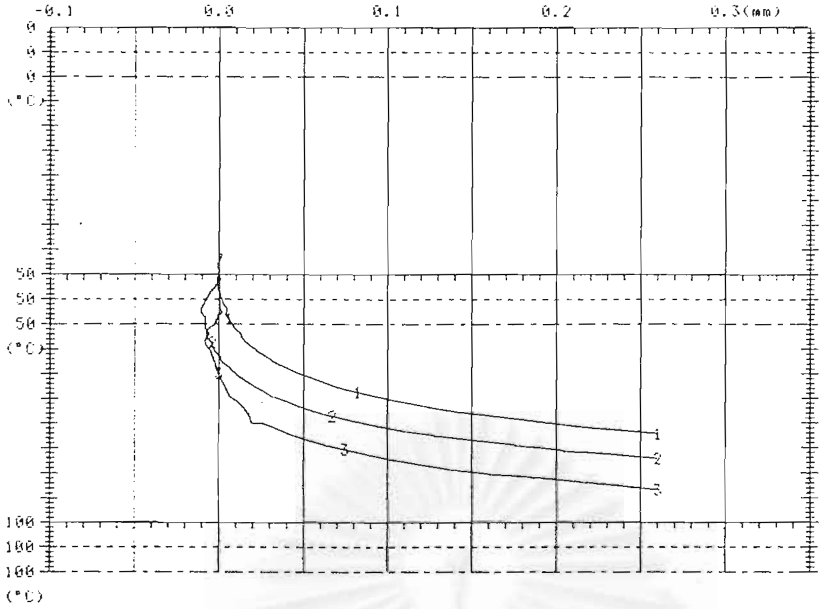
```
DISP      TEMPERATURE(°C)
(mm)      CH1     CH2     CH3
0.260   82.5    83.4    81.9
AVERAGE    82.6 °C
```

Figure B-34 HDT of HIPS 825-10 blend with M/L 6038 at 5 %



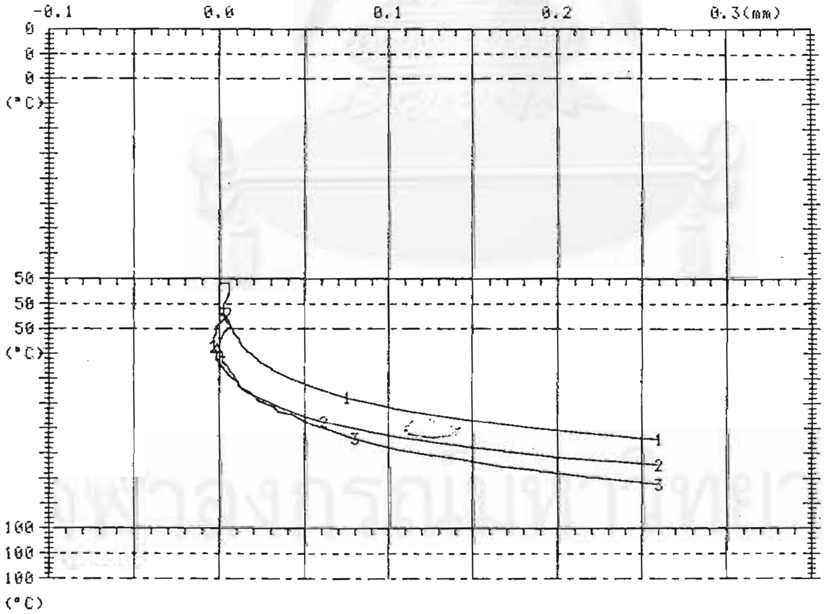
```
DISP      TEMPERATURE(°C)
(mm)      CH1     CH2     CH3
0.260   81.8    82.6    81.3
AVERAGE    81.9 °C
```

Figure B-35 HDT of HIPS 825-10 blend with M/L 4058 at 15 %



```
DISP      TEMPERATURE(°C)
(mm)     CH1     CH2     CH3
0.260  82.2    82.2    83.5
AVERAGE    82.6 °C
```

Figure B-36 HDT of HIPS 825-10 blend with M/L 5048 at 15 %



```
DISP      TEMPERATURE(°C)
(mm)     CH1     CH2     CH3
0.260  82.2    82.3    81.2
AVERAGE    81.9 °C
```

Figure B-37 HDT of HIPS 825-10 blend with M/L 6038 at 15 %

VITA

Miss Sarapee Thongsri was born on November 27, 1965 in Nakornsrithammaraj. She received her Bachelor of Science Degree in Chemistry from the Department of Chemistry, Faculty of Science, Prince of Songkla University in 1988. She began her master's degree studies in the multidisciplinary program of Petrochemistry and polymer, Faculty of science, Chulalongkorn University, in 1997 and completed the program in 2000.