CHAPTER III

EXPERIMENTAL WORK

3.1 Raw Materials Used

3.1.1 Virgin High Impact Polystyrene

HIPS under the tradename of Styron(R) 486B by Dow Chemical Company was used in this study. The mechanical properties of Styron(R) 486B is shown in Table 3.1.

Table 3.1 : Properties of Styron(R) 486B.

PROPERTY	ASTM METHOD	VALUE
Yield Tensile Strength, MPA	D638	20.34
Ultimate Tensile Strength, MPA	D 638	18.62
Ultimate Elongation, %	D 638	45
Flexural Modulus, lbf/in^2	D790	280,000
Modulus of Elasticity in Tension, Lbf/in^2	D 638	250,000
Izod impact Strength, J/m	D 256	85.42
Vicat Softening Point, ^{o}C	D1525	102
Melt Flow Rate, g/10 min	D 1238	2.5
Specific Gravity	D 792	1.05

3.1.2 High Impact Polystyrene Scraps

HIPS scraps used in the present study are classified into two types namely Scrap A and Scrap B. Scrap A is commercial waste obtained from the manufacturer of HIPS. It does not contain any additives at all. Scrap B is industrial waste obtained from post-processing articles which had been rejected because they are below the acceptable standard. Inevitably, scrap B had earlier been compounded with colorants, ethyl vinyl acetate which acts as the film liner and probably some other additives prior to its processing.

3.1.3 Impact Modifier

Styrene Butadiene Styrene (SBS) block copolymer was selected as an impact modifier because the styrene base components makes it compatible with HIPS while the butadiene rubber is expected to enhance the impact properties. Two types of SBS block copolymers, SBS-I and SBS-II were selected for the present study. The SBS-I has 29% of plasticizer oil content while the SBS-II has no oil content. They are used extensively because of their thermoplastic and elastomeric property combinations. Properties of SBS-I and SBS-II are shown in Table 3.2.

Table 3.2 : Properties of SBS block copolymer.

Property	unit	SBS-I	SBS-II
Tensile Strength	psi	2750	4600
300 % Modulus	psi	250	400
Elongation	%	1300	880
Hardness	Shore A	47	71
Specific Gravity	N/A	0.93	0.94
Brookfield Viscosity (Toluene Solution)	cps at 77F	1000	4000
Melt Index	gm/10min	11	<1
Plasticizer Oil Content	%w	29	0
Styrene/Rubber Ratio	N/A	31/69	31/69
Physical Form	N/A	Porous Pellet	Porous Pellet

3.2 Sample Preparation

3.2.1 Mixes of Virgin HIPS and HIPS Scraps

A Series of mixture between virgin HIPS and HIPS scraps were prepared. Different ratios of virgin HIPS/HIPS scrap are 100/0, 80/20, 60/40, 40/60 20/80 and 0/100. Each formulation was mixed and repelletized by using a 30-mm single-screw extruder at 30 rpm. The extruder temperature at Zone 1, Zone 2, Zone 3 and Zone 4 are 185°C, 190°C, 195°C and 200°C respectively.

3.2.2 Passes of 100% HIPS Scrap Recycling

HIPS scrap in Section 3.1.2 is called the "first pass" recycling. Several recycling passes were prepared by firstly injection molded the 100% scrap. This is called the "second pass" recycling. The injected products were then ground by a grinder. The ground scrap was later injection molded again to generate the "third pass" recycling. The process was repeated until the "fifth pass" recycling is completed. The scrap sample from each pass was collected for further test in Sections 3.3 to 3.4.

3.2.3 Addition of SBS Block Copolymer to HIPS Scraps

Two types of scraps, A and B, and two kinds of SBS block copolymer, SBS-I and SBS-II, were used. A series of SBS block copolymer and HIPS scrap were prepared with various amounts of SBS block copolymer. The SBS block copolymer was added to Scraps A at 0, 3, 5, 7 and 10% w/w and to Scraps B at 0, 2, 3, 4, 5, 7 and 10% w/w respectively. Each formulation was mixed and extruded by a 30-mm single screw extruder at 30 rpm. The extruder temperature at Zone 1, Zone 2, Zone 3 and Zone 4 are 185 $^{\circ}$C, 190 $^{\circ}$C, 195 $^{\circ}$C and 200 $^{\circ}$C respectively. After extrusion, the extrudate was cooled in a water bath and pelletized.

3.3 Mechanical Tests

3.3.1 Tensile Properties

Tensile Properties, which is a measure of the ability of a polymer to withstand pulling stress, are determined by pulling a dumbell sample at both ends of the specimen. To prepare the tensile specimen, hot pressed sheets of scraps A and B

were compressed at a temperature of 200 °C by using a compression machine. The test specimen is clamped between two jaws of the test apparatus as shown in Figure 3.1. One jaw is stationary and the other moves at a constant rate. Tensile strength at yield by this procedure is defined as the maximum load sustained by a test sample divided by its cross-sectional area. Tensile strength at rupture is defined as the load required to pull the sample until it breaks. In this study, the tensile properties was performed according with the test method set in ASTM D638. The crosshead speed was set constant at 5 mm/min. All specimens were tested at standard testing conditions of 23 ± 2 °C and 50 ± 10 % relative humidity.

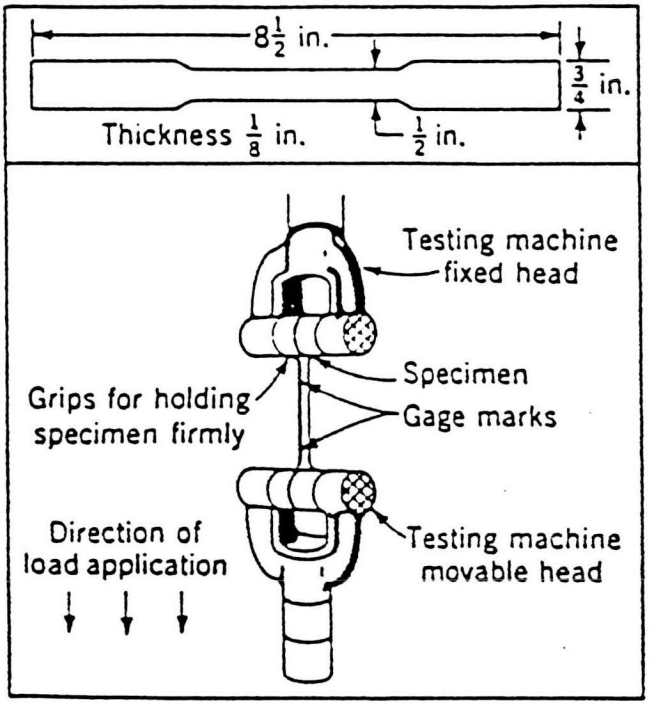

Figure 3.1 : Typical tensile apparatus.

3.3.2 Izod Impact Strength

The Izod impact specimens of both scraps A and B were prepared by using the molded-plate and were compressed at 200 °C. A "v"-notch was then introduced in each sample. The notch shape and sample size is show.ı in Figure 3.2.

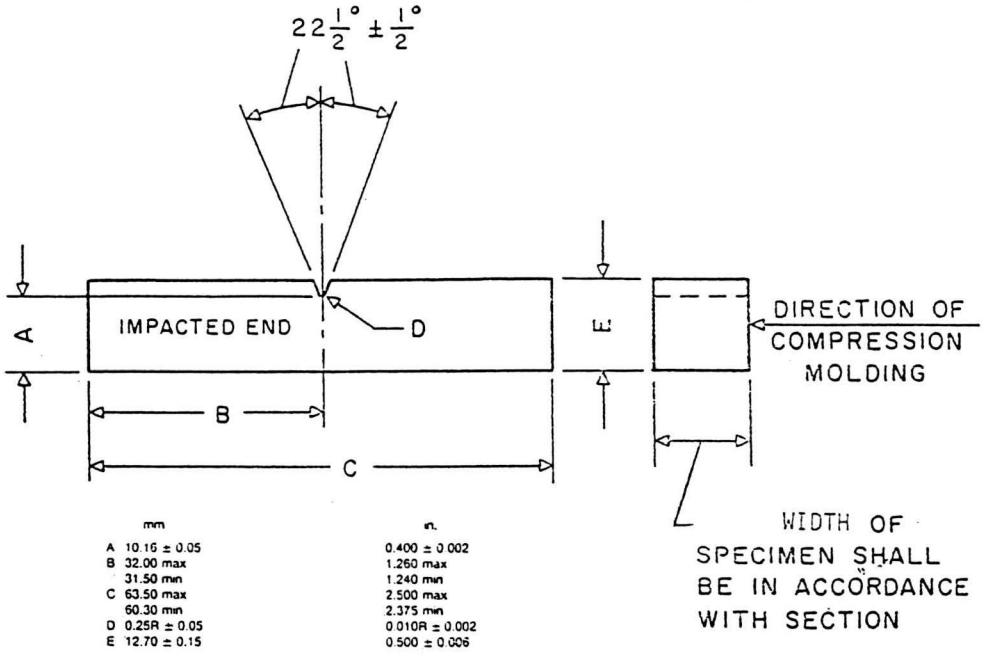

Figure 3.2 : Dimensions of the Izod test specimen.

The Izod impact test indicates the energy required to break notched specimens under a high rate of loading. In the test, a vertically held notched-sample is impacted with a pendulum from a fixed position. The notch in the sample faces the direction of impact. The Izod impact machine is shown in Figure 3.3.

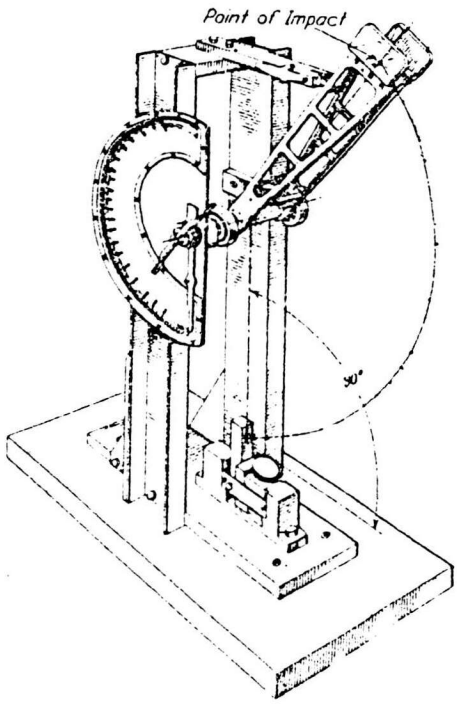

Figure 3.3 : Izod impact machine.

3.4 Thermal Properties

3.4.1 Melt Flow Rate

Melt Flow Rate is a measure of relative polymer melt viscosity. It is defined as the weight of polymer that flows in 10 minutes through a die of specific length and diameter under constant temperature and load. For HIPS, the temperature used is 200 °C, the load is 5.0 Kg. The die size is of 2.0955 mm in diameter and 8.000 mm in length. The test method is as set out in ASTM D 1238.

3.4.2 Vicat Softening Point

Vicat softening point is the temperature at which a flat-ended needle penetrates a test sample to a depth of 1 mm under a 1000 gram load and at a uniform heating rate of 120 °C/hr. This study complies with ASTM D 1525.

3.5 Physical Properties

3.5.1 Molecular Weight

Size Exclusion Chromatography was used to determine the molecular weight of the polymer molecule. Samples were dissolved in Tetrahydrofuran (THF), centrifuged and injected into the gel permeation chromatograph. The molecular weight was determined from the chromatograms with a calibration curve that had been obtained by using polystyrene standards.

3.5.2 Color

The color of the sample was measured by using the CIE Lab testing method. Granules was directly placed into the cups, then the Lightness index (color L*) and the yellowness index (YI) were estimated. Color L*, having a scale from 0 to 100, means black to white. The YI indicates the yellow color in the sample. Each sample was measured for 5 times and each reporting result is the average of five measurements.

3.5.3 Hardness

Hardness is defined as the resistance of a material to deformation, particularly permanent deformation, indentation, or scratching. The hardness of the samples in this study is determined by using a Durometer hardness test type D which complies with ASTM D 2240. Durometer hardness is often used for thermoplastic rubbers. The test method is based on the penetration of a specified indentor forced into the material under the specified conditions. In the present study, a load of 5 kg was applied as the indentor force. All specimens were tested at ambient temperature.

3.5.4 Specific Gravity

Specific gravity is defined as the ratio of the weight of a given volume of material to that equal volume of water at a state temperature. The temperature selected for determining the specific gravity of plastic is 23 $^{\circ}$C.

The test method is as set out in ASTM D792 method A. The test specimen of any convenient size is weighed in air. Next, the specimen is suspended from a fine wire attached to a balance and it is then immersed completely in distilled water. The weight of a specimen in water is determined. The specific gravity of the specimen is calculated as follows:

$$\text{Specific gravity} = a / [(a+w)-b]$$

where a = weight of specimen in air;

b = weight of specimen and wire in water;

w = weight of totally immersed sinker and partially immersed wire.

3.6 Morphology

The fracture surface of plastics was examined by using a Scanning Electron Microscope (SEM). The samples was immersed in liquid nitrogen and cracked. The cleaned fractured surface was then coated with gold prior to an observation of fracture morphology.