

CHAPTER II

THEORY AND LITERATURE REVIEW

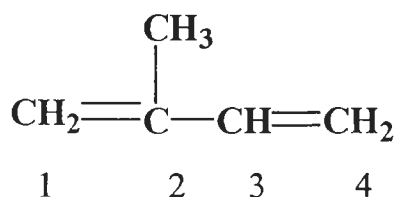
2.1 Natural Rubber

Natural Rubber (NR) is found in about 2000 plant species all over the world. Only Para rubber tree, *Hevea brasilliensis* is the rubber producing plant of commercial significance for over 99% of the world's natural rubber production. Other plants that contain rubber is guayule, balata and gutta percha tree⁴.

It has already been noted that natural rubber has the chemical name of polyisoprene. The rubber from *Hevea brasilliensis* and guayale is *cis*-1,4-polyisoprene, while the rubber from balata and gutta percha is *trans*-1,4-polyisoprene.

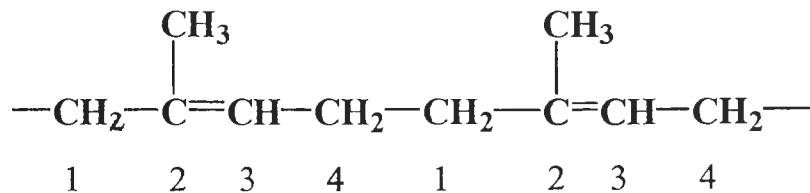
2.1.1 Chemical Formula

The chemical name for natural rubber is polyisoprene, which is a homopolymer of isoprene. Isoprene has the formula C₅H₈, which its structure is as follows:



Isoprene

Natural rubber is a polymer of isoprene, in which essentially all the isoprene units are linked together at carbon atoms 1 and 4 in a head-to-tail arrangement.



Head-to-tail Arrangement of Polyisoprene

2.1.2 Pre-vulcanized Natural Rubber Latex

Pre-vulcanized natural rubber latex⁵ is the form in which rubber is extruded from the *Hevea brasiliensis* tree as an aqueous emulsion, as rubber and non-rubber particles dispersed in an aqueous serum phase. Latex is harvested from the tree by a process called tapping. Freshly tapped latex (field latex) has a pH of 6.5-7.0, a density of 0.98 g/cm³, and a surface energy of 4.0-4.5 μJ/cm³ (0.96-1.10 μcal/cm³).

The rubber particles are usually spherical in shape with a diameter ranging from about 0.01 μm to 5 μm. The particles in latex are mainly rubber hydrocarbon surrounded by concentric spherical shells, first of phospholipid and then of protein. The probable structure of pre-vulcanized natural rubber latex particle is shown in figure 2.1

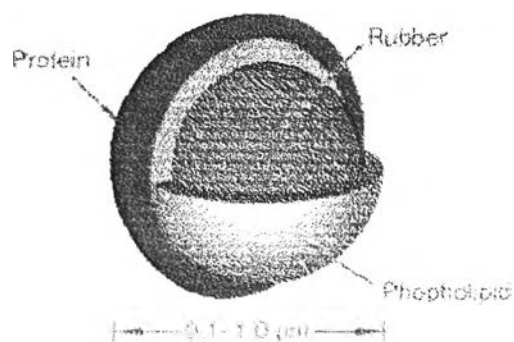


Figure 2.1 Diagrammatic representation of probable structure of pre-vulcanized natural rubber latex particle.

Table 2.1 Typical composition of the rubber phase.

Composition	%
Rubber hydrocarbon	86
Water (dispersed in the rubber hydrocarbon)	10
Proteins substances	1
Lipid substances	3

Trace amounts of metals, notably magnesium, potassium, and copper are also associated with the rubber particles to an aggregate extent of approximately 0.05%.⁶

2.1.3 The Preservation of Pre-vulcanized Natural Rubber Latex

The preservative protects the latex against spontaneous coagulation by suppressing the activity and growth of microorganisms, enhancing colloid stability,

and deactivating trace metals by sequestration in solution or precipitation as insoluble salts.

The most widely used preservative for natural rubber latex is ammonia. Short-term preservation (0.2% of ammonia) is sufficient to ensure that the latex remains in a liquid condition before being processed into the various forms of dry rubber. Short-term preservation (0.7% of ammonia) will keep the latex intact and free of decay during transportation and storage in country of final use.

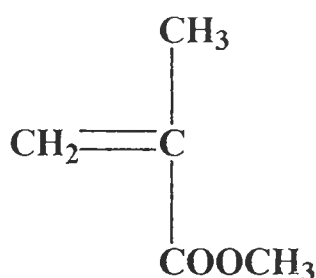
2.1.4 The Concentration of Pre vulcanized Natural Rubber Latex

Pre vulcanized natural rubber latex⁷⁻⁸ as it emerges from the tree (field latex) has a dry rubber content (DRC) of about 30% to 40%, the average being about 33%. Although field latex can be preserved with ammonia or fixed alkali, its low rubber content and high non-rubber solid content severely limit its usefulness. Hence it is necessary to increase the DRC in natural rubber latex to 60% or more to reduce transportation costs and enhance suitability for various latex processes. Concentrated latexes are economically useful as they contain less water to be shipped from the plantations, they are also more efficient in the manufacture of finished products directly from latex. Additionally, latex concentrates tend to be more uniform in quality than do field lattices. This is due in part to the partial removal of non-rubber constituents in several concentration processes.

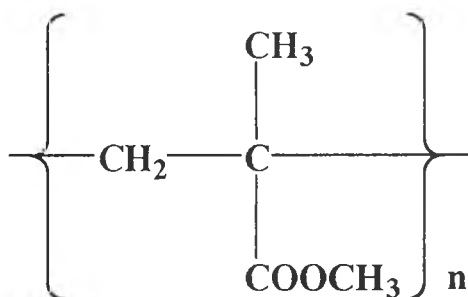
Four methods are used for concentrating natural rubber latex; centrifugation, creaming, evaporation, and electrodecantation. Of these processes, centrifugation is the most widely used.

2.2 Poly(methyl methacrylate)(PMMA)⁹

PMMA is polymerized by solution, suspension, and emulsion processes. PMMA is completely amorphous but has high strength and excellent dimensional stability due to the rigid polymer chains ($T_g = 105^\circ\text{C}$).



Methyl methacrylate
(MMA)



Poly(methyl methacrylate)
(PMMA)

The best known and remarkable property of PMMA is probably its excellent transparency. PMMA is the most resistant of all transparent plastics to ultraviolet radiation and moisture. The outstanding transparency, light piping qualities, colorability, and dimensional stability of PMMA coupled with the retention of these properties in outdoor applications over long periods of time make this resin useful in many industries. The chemical resistance of PMMA is noticed from the effect of various environments upon the acrylics in general. It is essentially unaffected by weak solutions of oxidizing acids, but deteriorates rapidly in highly concentrated solutions of oxidizing acids.

PMMA is used for aviation parts, including pilot's canopies and windows on commercial aircraft because it is free from optical distortion, resistance to light

and weathering, resistance to shattering, and able to withstand high pressure and temperature differences. Other uses include safety glass interlaying, glazing, dentures, contact lenses and various coatings and finishes.

2.3 Interpenetrating Polymer Networks (IPNs)

Interpenetrating polymer networks (IPNs)¹⁰ are defined as a combination of two or more polymers in network form, at least one of which is synthesized or crosslinked in the immediate presence of the other. The two networks share the same region of space, that is the macroscopic volume of the sample. This blend of two network polymers is “physical” in nature; ideally, there are no chemical grafts between them. Yet IPNs must be made “chemically” since physically blending two networks is not possible without breaking chemical bonds. So at least one polymer must be polymerized and/or crosslinked in the immediate juxtaposition of the other. When two or more polymers are mixed, the resulting composition can be called a multicomponent polymer material. There are several ways to mix two kinds of polymer molecules. Simple mixing, as in an extruder, results in a polymer blend. If the chains are bonded together, graft or block copolymer result; bonding between some portion of the backbone of polymer 1 and the end of polymer 2, the result is called a graft copolymer; chain bonded end to end result in block copolymer. Other types of copolymers include AB-crosslinked copolymer, where two polymers make up one network, and the IPNs, and semi-IPNs (SIPNs). An IPN is distinct from simple polymer blends, block or grafts in two ways: it swells but does not dissolve in solvent, and creep and flow are suppress.

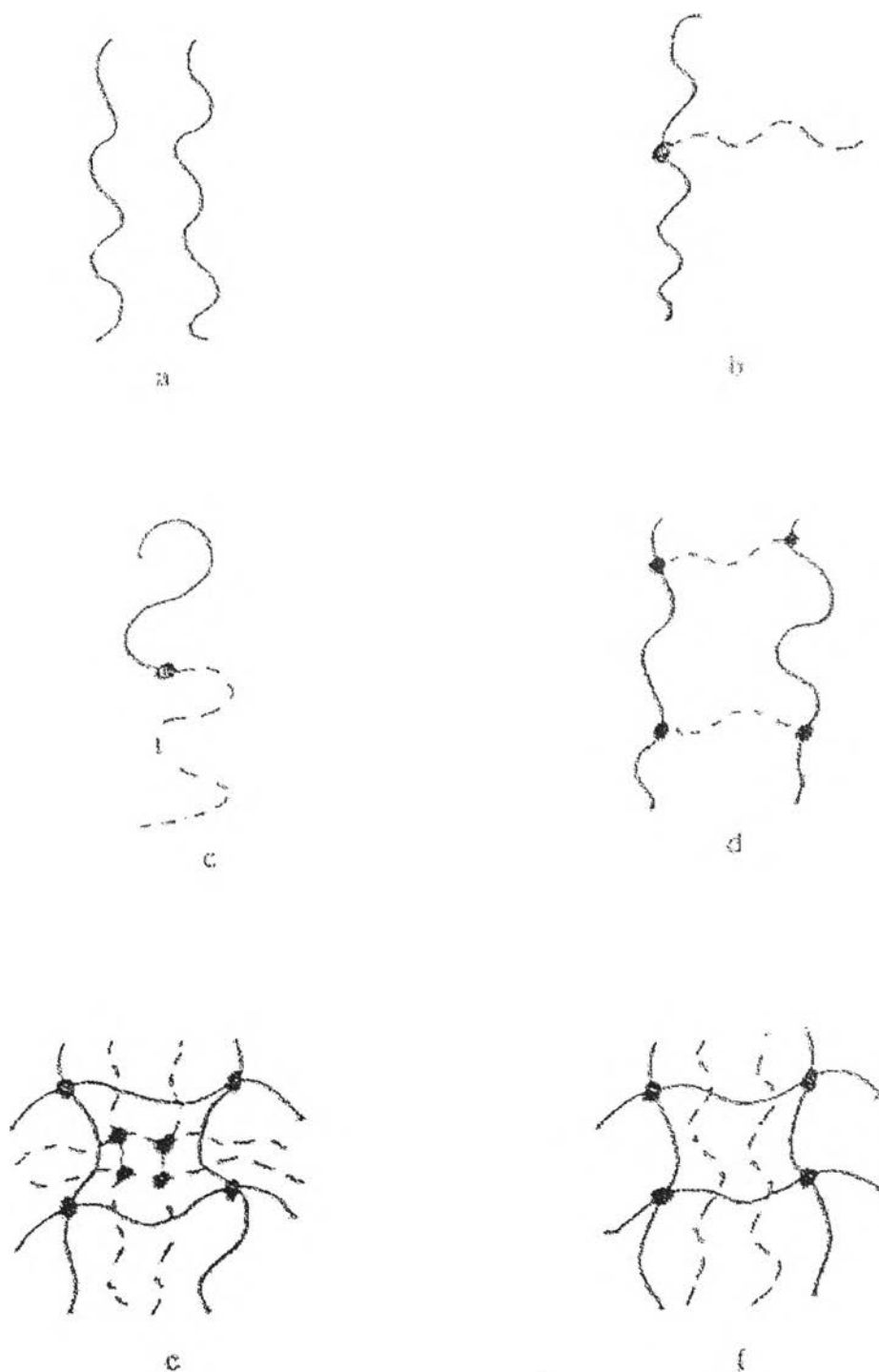


Figure 2.2 Six basic combinations of two polymers; a, Polymer blend, no bonding between chains; b, a graft copolymer; c, a block copolymer; d, an AB-graft copolymer; e, an IPN; f, a semi-IPN. Structures a–c are thermoplastic; structures d–f are thermoset.

2.3.1 IPNs Classification

1) IPN Classification by Synthesis

1.1) Sequential IPNs

1.2) Simultaneous Interpenetrating Networks(SINs)

2) IPN Classification by Structure

2.1) Semi-IPNs

2.2) Gradient IPNs

2.3) Latex-IPNs

2.4) Thermoplastic IPNs

2.5) Homo IPNs

Table 2.2 Classification of IPNs¹

Category	Definition
<ul style="list-style-type: none"> • Sequential IPNs • Simultaneous Interpenetrating networks (SIN) • Latex IPNs 	<ul style="list-style-type: none"> • Polymer network 1 is made. Monomer 2 plus crosslinker and activator are swollen into network 1 and polymerized <i>in situ</i>. • Monomers or prepolymers plus cross-linkers and activators of both networks are mixed. The reaction is carried out simultaneously, but by noninterfering reaction. • The IPNs are made in the form of latex, frequently with a core and shell structure. A variation is to mix two different latexes and then form a film, which crosslinks both polymers. This variation is sometimes called an interpenetrating elastomer network (IEN).

Category	Definition
<ul style="list-style-type: none"> • Gradient IPNs • Thermoplastic IPNs • Semi IPNs 	<ul style="list-style-type: none"> • Gradient IPNs are materials in which the overall composition of crosslink density of the material varies from location on the macroscopic level. For example, a film can be made with network 1 predominantly on one surface, network 2 on the other surface, and a gradient in composition throughout the interior. • Thermoplastic IPN materials are hybrids between polymer blends and IPNs that involve physical crosslinks rather than chemical crosslinks. Thus, these materials flow at elevated temperatures, similar to the thermoplastic elastomers, and at use temperature, they are crosslinked and behave like IPNs. • Composition in which one or more polymers are crosslinked and one or more polymers are linear or branched.

In this research, an attempt was made to prepare interpenetrating polymer networks between prevulcanized natural rubber latex with poly(methyl methacrylate). TPEs are generally used for making automobile parts. Since these materials find uses in a variety of application.

2.3.2 Latex IPNs

The IPNs are made in the form of pre-vulcanized natural rubber latex frequently with a core and shell structure. A variation is to mix two different latex and then form a film, which crosslinks both polymers. Composite latex particles based on pre-vulcanized natural rubber latex have been synthesized to yield materials which may be formally regarded as interpenetrating polymer networks and semi-interpenetrating polymer networks. Methyl methacrylate was added to a carefully stabilized pre-vulcanized natural rubber latex and polymerized. The morphology of the materials was determined both by transmission electron microscopy.

The modification of NR while still in the pre-vulcanized natural rubber latex form is clearly more challenging than in the dry state. The pre-vulcanized natural rubber latex particles were swollen with a monomer, methyl methacrylate (MMA), which was then polymerized. The free-radical initiator can lead to some crosslinking of the original pre-vulcanized natural rubber latex particles, such materials could be classified as latex semi-IPNs. An IPN is formed when a pair of networks are synthesized in such a manner that at least one of the networks has been formed and/or crosslinked in intimate juxtaposition with the other. IPNs are classified into a number of categories including latex IPNs. Semi-IPNs is formed when only one of the component polymers is crosslinked. Normally latex IPNs are made in two stages. The first pre-vulcanized natural rubber latex is formed and then the second monomer is incorporated and polymerized. The morphology of the materials was determined both by transmission electron microscopy and scanning electron microscope.

The problem also may be avoided if the polymers are prepared by seeded emulsion polymerization, leading to latex IPNs. Monomer II and its coreactants may be swollen into the latex seed particles of crosslinked polymer I, followed by an *in situ* polymerization. This results in an IPN structure in each latex particle, frequently with domains of polymer II in polymer I, or sometimes with characteristics of core-shell particles. The latex can be later coagulated and molded in any desired shape. If crosslinking or final postcuring is conducted after film formation, leading to interparticle crosslinking, the material becomes a thermoset and can no longer be molded.

2.3.3 Seeded Emulsion Polymerization (Core-Shell)

Latex particles with different morphological structures can be prepared from a seeded emulsion polymerization technique¹². These particles typically comprise an inner soft polymer sphere, i.e., the ‘core’ and an outer hard polymer ‘shell’. Although particles may be prepared in two consecutive stages, a core-shell structure does not necessarily result. In the literature, many examples of other phase arrangements like, e.g., ‘raspberrylike’, ‘acornlike’, ‘sandwichlike’, ‘poow’, and inverted structures are found.

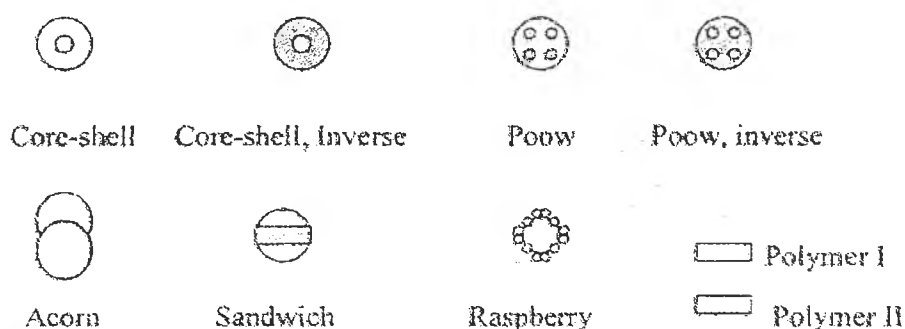


Figure 2.3 Possible morphologies of composite latex particles.

Many different parameters, e.g. the monomer addition sequence, the hydrophilicity of the monomers and polymers, the used initiating systems, and the viscosity within the monomer swollen seed latex particles, have to be taken into account. The last factor is primarily determined by the reaction temperature, the degree of crosslinking of the polymer chains, the monomer concentration in the seed latex particle during the reaction, and the molecular weight of the polymer. Furthermore, thermodynamic and kinetic aspects have to be considered. Morphology with the lowest free energy G is only achieved when the mobility of polymer chains is not too much reduced by a very high viscosity within the monomer swollen latex particle.

Core-shell, polymers such as polybutadiene (PB), styrene-butadiene rubber (SBR) and poly (butyl acrylate) (PBA), are usually chosen as the soft components, whereas the polymers of methyl methacrylate (MMA), styrene (St), acrylonitrile (AN), vinyl chloride (VC), vinyl acetate (VAc), and so on are chosen as the hard components. They exist as graft polymers on the interface between the core and the shell. Polymers with a soft core and a hard shell are used as impact modifiers, toughened plastics, and damped oscillation materials, whereas polymers with a hard core and a soft shell are usually applied in the coating and adhesive fields.

2.3.4 Chemical Crosslinking¹³

The most severe mechanism for decreasing molecular freedom is chemical crosslinking that combines the polymer chains together through covalent or ionic bonds to form a network. Occasionally the term curing is used to denote crosslinking. There are a number of ways crosslinking can be brought about, but basically they fall into two categories: crosslinking during polymerization by use

of polyfunctional instead of difunctional monomers crosslinking in a separate processing step after the linear (or branched) polymer is formed.

The crosslinks may contain the same structure feathers as the main chains, which is usually the case with the former, or they may have an entirely different structure, which is more characteristic of the latter.

A number of extreme changes accompany crosslinking. If previously soluble, the polymer will no longer dissolve (except in the case of some ionically crosslinked polymers). In the presence of solvent, a crosslinked polymer swells as solvent molecules penetrate the network. The degree of swelling depends on the affinity of solvent and polymer for one another, as well as on the level of crosslinking. It may be recalled that a solvent-swollen crosslinked polymer is called a gel. Covalently crosslinked polymer also loses their flow properties. They may still undergo deformation, but the deformation will be reversible; that is, the polymer will exhibit elastic properties. However, ionically crosslinked polymers will flow at elevated temperatures. With network polymers it is common to speak of the crosslink density, that is, the number of crosslinked monomer units per main chain. The higher the crosslink density, the more rigid the polymer. Very high crosslink densities lead to embrittlement. Because crosslinking reduces segment motion, it is frequently employed to increase the glass temperature.

2.3.5 Physical Crosslinking

When polymer chemists use the term crosslinking, they invariably mean covalent chemical crosslinking. Covalent crosslinking has certain disadvantages, however. Once crosslinked, a polymer cannot be dissolved or molded. One approach has been to investigate thermally labile crosslinks that is chemical

crosslinks that break apart on heating and reform on cooling. Ionic crosslinks fall into this category. The other approach has been to introduce strong secondary bonding attraction between polymer chains such that the polymer exhibits properties of a thermosetting material while remaining thermoplastic. Crystalline polymer fit into this category. Because of the very strong secondary forces arising from close chain packing, many of the mechanical and solution properties of crystalline polymers resemble those of crosslinked amorphous polymers. Certain materials intermolecularly associated through hydrogen bonds also behave like crosslinked polymers.

In recent years, the technology of block copolymers has been applied to the area of physical crosslinking. The method involves synthesis of block copolymers of the ABA type in which the A and B blocks differ substantially in structure. Consider, for example, a long-chain “flexible” polymer such as polybutadiene, capped at each chain end with short blocks of a “rigid” polymer such as polystyrene.

2.4 Polymer Blends

The term polymer blend is used in two ways. First, it involves all multicomponent polymer materials composed primarily of two or more polymers. Second, it is used specifically to describe combinations of two or more polymers that are not bonded chemically to each other. Important combinations of two or more polymers bonded together include graft copolymers, block copolymers, AB-crosslinked polymers, and interpenetrating polymer networks (IPNs).

The blending of polymers has become an important industrial technique that is an economic and versatile way to produce materials having a wide range of

properties. Their enhanced, especially adapted property profiles provide advantages to the processor and end user such as extra ease of processing, better low temperature impact performances, higher strength, higher or lower gloss, reduced flammability, and higher transparency, often in combination with a lower price.

2.4.1 Polypropylene Blends

Polypropylene (PP)¹⁴ is used as homopolymers, random copolymers and block copolymers. Polypropylene is the thermoplastic polymer. PP is one of the most widely used commodity plastics. It has a good chemical resistance, excellent thermal stability, a low price and high flowability, which find extensive use in the field of industrial materials, construction, automobile industry, electrical and household. Although, polypropylene is excellent material when considered generally, their Impact Strength (NI) and rigidity are relatively poor and this often narrows the range of application. A usual method for improving the impact strength is to blend thermoplastic polymer with rubber to eliminate this defect. The polymer has three drawbacks: (1) it is sensitive to oxidation during processing and use, (2) it has a poor resistance to UV-induced degradation, and (3) it is rather brittle even though its glass transition temperature (-10°C) is below room temperature.

Thermal oxidation problems have been solved by use of specially developed additive packages. Impact performance can be improved by chemical modification (copolymerization) or blending. Comonomers are mainly ethylene and higher olefins. Rubbers such as ethylene propylene diene monomer (EPDM) are

frequently used for blending. The miscibility between polyolefins is extremely limited in spite of their great chemical similarity. However, due to the small interfacial tension, the dispersibility is acceptable. Nevertheless, when blends of PP and other polyolefins are being made, they often require a compatibilizing block copolymer to provide the necessary degree of dispersion and to maintain morphological control during processing. The latter is essential for obtaining the desired mechanical properties of the product. Morphological stability can be further enhanced by *in situ* crosslinking of the dispersed phase (dynamic vulcanization). Since the composition of this research has remarkably improved FS while maintaining other mechanical properties. Therefore, it would contribute to wider applications, for example automotive parts especially car bumpers.

Table 2.3 Typical data of polypropylene copolymer grade 2500 TC

Typical Data	Unit	Value	Test method
MFI 2.16 kg/230 °C	g/10min	45	ASTM D1238
Tensile Strength at Yield	N/mm ²	21	ASTM D638
Charpy Notched Impact Strength	mJ/mm ²	5.5	DIN 53453
Shear Modulus	N/mm	430	DIN 53457
Ball Indentation Hardness	N/ mm ²	53	DIN 53456
Heat Distortion Temperature	°C	90	ASTM D648

2.4.2 Processing Technique

Mixing of Rubber

Open Mill Mixing

An open mill consists of two parallel rollers, adjustable for nip distance setting. Sizes range from approximately 12 inches long for use in laboratories to as long as 84 inches. Common mill sizes are 60 inches and 84 inches. Roller speeds vary from an even speed to ratios as high as 1:1.2 for grind purposes. Common speeds for general purposeful work are approximately 1:1.05.

The open mill mixing process is to masticate the polymers until an even and smooth band is formed around the front roller. The fillers and oils are added alternately by small additions and finally followed by the vulcanizing materials. During the whole operation, cutting and blending by hard rolling are carried out. With those compounds containing mixed polymers, the best dispersion and blending them together should be while they are still hot. The addition of the fillers and other component can then carry out subsequently in a usual way.

A two-roll mill is selected for blending PP and IPNs products of this research. The mill generates a high shear rate in a narrow nip between two heated rolls, which counter-rotate with slightly different velocities. In commercial mills, the rolls are about 1 ft. in diameter by 3 ft long. Once the polymer has banded on one of the rolls, the ingredients are added to the bank between the rolls. The band is cut off from the roll with a knife, rolled up, and fed back to nip at right angles to its former direction. This is done several times to improve mixing.

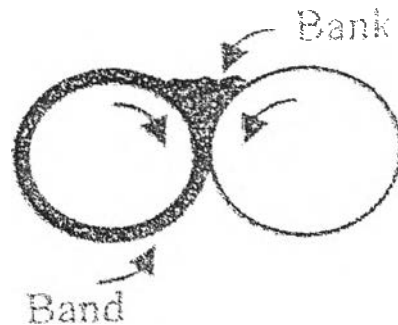


Figure 2.4 Characteristic of two-roll mills.

2.4.3 Morphology

The morphology of a material is its organization on a supermolecular scale, i.e., the form, size, orientation of its crystallites, domains, the structure of group of molecules in the specimen and their boundaries, and the degree of crystallinity. Most of polymer blends are heterogeneous, and the sizes and shapes of the phase domains control mechanical and transport properties. This is especially relevant for elastomeric systems, as many of these are rubber blends, thermoplastic elastomers, thermoplastic olefins and dynamic vulcanite. The measurement of interfacial tension, which controls phase separation and growth and thus morphology, is also important.

The Scanning Electron Microscopy (SEM) is used to investigate the morphology of blend products. SEM is becoming the most popular method of observation of polymer blends. The great advantages of this technique are its rapidity, range of readily accessible magnifications, and depth of field.

2.5 EPDM-PP thermoplastic IPNs

The most important commercial system involves ethylene-propylene-diene-monomer (EPDM) in combination with isotactic-polypropylene (i-PP). The EPDM is blended with the PP under condition where the EPDM undergoes crosslinking through the diene moiety. Fischer invented this new class of IPNs in the early 1970s. Fischer blended i-PP and EPDM during the shearing action. The two phases in this system have remarkably different properties. The first phase is the disperse phase, it contains a component which is above its glass transition temperature (T_g) and melting temperature (T_m), so that chain is very mobile. Another phase is the matrix phase, it contains segments which are rigidity locked in place, because the service temperature is below both T_m and T_g . The result is a series of leathery materials that have great energy absorbing capacity. End use includes automotive bumpers.

2.6 Ethylene-1-Octene Copolymer (ENGAGE)

Engage polyolefin elastomers are ethylene copolymer produced using “INSITETM”, a catalyst and process technology that allows extraordinary control over polymer structure, properties and rheology, by controlling molecular architecture, “INSITETM”, designed to process like thermoplastics and perform like elastomer. The unique characteristics of “INSITETM” are flexibility, hardness, elasticity, clarity and other key properties. These properties can be further improved through compounding and the use of filler. When crosslinked, it also offers excellent compression set and heat resistance. Engage is the enabling polymer in a broad range of thermoplastic elastomer (TPE) compounding and

imparts a unique combination of processability and toughness when used to modify rigid TPO blends for exterior bumpers and fascias.

Table 2.4 Typical properties of ethylene-1-octene copolymer

Typical Properties	Range of Values
Density, g/cc. (ASTM D-792)	0.864-0.913
Flexural Modulus, 2% Secant, MPa (ASTM D-790)	7-19
Elongation, % (ASTM D-638)	700
Melting Point, °C	50-100
Hardness, Shore A (ASTM D-2240)	65-95
Melt Index, dg/min (ASTM D-1238)	0.5-30

2.7 Applications

The IPNs have many applications, both proposed and in practice. Many types of IPNs, semi-IPNs are available as commercial products. These IPNs products can be used for car bumper, mudguard, rubber floor tiles and car floor rubbers, etc.

2.8 Literature Reviews

Natural rubber (NR) has been modified in many different ways, and modified forms have been available commercially. Several monomers can be grafted onto natural rubber latex (e.g., styrene (St), vinyl acetate, acrylonitrile, and

methyl methacrylate (MMA)). Emulsion polymerization is used in the synthesis and peroxides or hydroperoxides are used as initiators.

Das et al.¹⁶ studied sequential IPNs, which were synthesized using NR and PS as elastomer and plastomer components, respectively. Benzoyl peroxide was used as the polymerization initiator, dicumyl peroxide (DCP), as the crosslinker for NR and divinyl benzene as the comonomer/crosslinker for PS. Both full IPNs and semi-IPNs were prepared by using dry NR that was masticated in a two-roll mill with crosslinking and cured. Then cured NR sheets were swollen in distilled styrene monomer containing the initiator, and crosslinking took place before polymerization occurred. Morphology of IPNs was studied through scanning electron microscopy. Crosslinking of the plastomer component induced better miscibility and finer morphology. IPNs products were characterized by evaluating their mechanical properties. Full IPNs showed higher tensile strength, modulus, and tear strength than the corresponding semi-IPNs, while the latter exhibited higher elongation at break and toughness.

Schneider et al.¹⁷ studied different emulsion polymerization processes allowing a variation in the microstructure of composite NR-based latex particles. A prevulcanized and no crosslinked natural rubber latex were coated with a shell of crosslinked PMMA or PS. The bipolar redox initiating system *tert*-butyl hydroperoxide / tetraethylene pentamine promoted a core-shell arrangement. Furthermore PS subinclusions were introduced into the NR core. The initiators used for the subinclusion synthesis were azo-bis-isobutyronitrile at high temperatures and a redox initiator system consisting of *tert*-butyl hydroperoxide / dimethylaniline at low temperatures. TEM and SEM characterized the morphology of the resulting latex IPNs. Different staining methods allowed an

increase in the contrast between the NR phase and the secondary polymers in the composite latex particles. A semi-continuous feeding process decreased the PS subinclusions sized by a factor of 6 in comparison with a batch reaction. Differential scanning and DMA confirmed two or three phase particle morphology.

Asaletha et al.¹⁸ studied compatibility of NR/PS blend that is poor and can be enhanced by the addition of a graft copolymer of NR-graft-PS. The effect of homopolymer molecular weight, copolymer molecular weight, copolymer concentration, processing condition and mode of addition on the morphology of the dispersed phase have been investigated by means of optical microscopy. The addition of a small percentage of the compatibilizer decreases the domain size of the dispersed phase. The effect levels off at higher concentrations than the leveling off could be in indication of interfacial saturation. The addition of the graft copolymer improves the mechanical properties of the blend and attempts were made to correlate the mechanical properties with the morphology of the system. Attempts were also made to understand the conformation of the morphology of the graft copolymer at the interface.

Pieroni P.¹⁹ This work presents results obtained for ternary blends of polypropylene (PP), a linear low-density polyethylene (LLDPE) and two ethylene-propylene-norbonene terpolymer (EPDM) of different viscosity. The effect of LLDPE added to the PP/elastomer blends is analyzed in terms of morphological features and impact properties. Press molded specimens were used throughout this work. The LLDPE disperse effect is verified independently of the elastomer viscosity. Ternary blends containing more than 50% EPDM in the disperse phase showed better impact strength than the corresponding binary PP/EPDM blend.

Dietmar et al.²⁰ studied the influence of comonomer incorporation on morphology and thermal and mechanical properties of blends based upon isotactic metallocene-polypropylene and random ethylene/1-butene copolymers. Blends of isotactic polypropylene (i-PP) with random ethylene/1-butene (EB) copolymers were prepared in order to examine the influence of the EB molecular architecture on the morphology development as well as on the thermal and mechanical properties. Compatibility between i-PP and EB increased with increasing 1-butene content in EB to afford single-phase blends at a 1-butene content exceeding 82 wt%. The morphology was investigated using AFM and TEM. Improved compatibility accounted for enhanced EB dispersion and interfacial adhesion and highly flexible as well as stiff blends with improved toughness were obtained.

Chotikunpisarn²¹ studied the flexural strength improvement of PP/EPDM. The composites prepared by mixing various amounts of PP, and EPDM, reinforced additives on two-roll mills and subjected the composites to compression molding to obtain the specimens for testing. X-ray fluorescence spectroscopy, differential scanning calorimeter (DSC), and SEM were used to study the elements, melting temperature and dispersion of the composites, respectively. The addition of EPDM increased the impact strength while the flexural strength, melt flow index and hardness decreased. The addition of talc gave specific improvement on flexural strength and hardness, while clay provided almost no improvement on properties.

Charmondusit²² studied the graft copolymerization of MMA and styrene onto NR in the emulsion process. The optimum conditions were 100 parts by weight of monomer per 100 parts by weight of NR latex, the emulsifier concentration of 1.5 parts by weight, the initiator concentration of 1.5 parts by

weight and temperature at 70 °C for 8 hours. The grafted natural rubber product was used as an impact modifier in PVC. The tensile strength and hardness decreased with increasing grafted natural product content, but the elongation at break and impact strength increased with increasing grafted natural rubber content. The appropriate amounts of grafted natural rubber product used were 10 and 15 phr.

Anuntathanawanich²³ studied the interpenetrating polymer networks of styrene onto prevulcanized natural rubber latex in the emulsion process. The optimum condition were the initiator concentration of 1.5 phr, the crosslinking agent concentration of 0.25 %wt of the monomer, emulsifier concentration of 1.5%wt of monomer and temperature at 60 °C for 2 hours. The IPNs composite was used as an impact modifier in PP. The effects of IPNs product content on tensile strength and hardness decreased with increasing the IPNs product content, but impact strength increased with the increasing IPNs product content. The appropriate amounts of IPNs products used were 10 and 15 phr.