

A Review on Mechanical and Thermal Properties of Binary and Ternary Thermoplastic Immiscible Polymer Blends

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ABSTRACT

Polymer mixes are a blend of at least two polymers that are mixed together to make another material with various physical properties. Binary polymer mixes have significantly affected the market in the prior years and demonstrated preferable properties over crude polymers. Ternary polymer mixes are of extraordinary significance and the investigations are as yet going on. This review is focused on thermoplastic-thermoplastic polymer mixes in which the chosen polymers are Polypropylene (PP), High-density polyethylene (HDPE) and Polystyrene (PS). The impact of melt handling conditions and compositional changes brings forth changes in the mechanical properties and in the behaviour of immiscible mixes. In HDPE: PP mixes, the addition of PP content increased the mechanical quality while PS: PP mixes indicated exceptional impact strength and better elastic modulus and PS: HDPE mixes not delivered great outcomes. A ternary polymer mix of reused PE/PP/PS showed better properties than the above binary polymer mixes. Thermal properties in view of the onset of degradation are additionally examined. A concise survey of mechanical and thermal properties of binary and ternary polymer mixes are presented in this paper.

1. INTRODUCTION

Polymers have contributed more to modern and innovative advancement. The purpose of the utilization of polymers is fundamentally a result of the simplicity of processibility, light weight, resistance to corrosion and so forth. Polymers with high molecular weight are called macromolecules and these are worked small molecules called monomers. The reaction of monomers to shape polymers is known as polymerization [1]. A few polymers have high level of polymerization is high and they are named as high polymers. The primarily manufactured polymer, named Bakelite was created in 1909 and this prompts the improvement of engineered fibre in 1911. Polymers demonstrate distinctive physical properties and synthetic structure, mechanical conduct, thermal qualities and so on. Polymers are classified based on its nature, thermal reaction, a method of arrangement, line structure, application and physical properties, tacticity, crystallinity, polarity, and chain length.

Mixing was additionally a procedure utilized by scientists to create polymer mixes and this makes an imperative zone these days. Analysts demonstrated better properties for polymer mixes and they are financially savvy than crude polymers. Numerous polymer mixes are immiscible in nature. It is observed that blending at least two polymers. Thermoplastic blends offer a wide variety of uses in the current market [2]. Generally used thermoplastics are polypropylene, high density polyethylene, and polystyrene. These days, ternary polymer mixes are of extraordinary significance and it makes a considerable measure of room for specialists to take a shot at. In genuine application cases, polyblends are normally utilized and mixed by melt blending process.

Melt preparing systems not require any solvents, but rather the suitable temperature and structure deliver best outcomes. [3]. Usually blended thermoplastic polymers are polypropylene (PP), high-density polyethylene (HDPE) and polystyrene (PS). Among this polypropylene is the widely utilized polymer in the market. Polypropylene has

good mechanical properties, ease and simplicity of handling and so on compared to other polymers. High-density polyethylene is generally essential for enhancing the mechanical properties. Polystyrene is a weak material with low impact quality and is utilized as a part of a few mixes to get the best outcomes contrasted with the crude.

Binary mixes of PP: PS, PP: HDPE, PS: HDPE are studied here. Their mechanical and thermal properties are discussed and a ternary mix of PP: HDPE: PS is also examined in this review paper.

2. LITERATURE REVIEW

2.1. Thermoplastic immiscible polymer blends

2.1.1. PP/HDPE Blends

1. S.Can and S. Tan demonstrate that PP/HDPE mixes indicate poor mechanical properties because of their incompatible nature. They done their experiment by ball mill processing and compared the results with the melt blending mix. Ball mill processing diminishes the crystallinity of polymers and melt blending didn't change the stiffness with the exception of the 75PP/25HDPE system. The processing parameters were maintained at 15 min, 45 rpm and 1900 C. From their investigations, plainly ball processing brings about a less hardened material than melt blended [4].
2. Sihama E. Salih¹, Abdulkhaliq F. Hamood¹ & Alyaa H. Abd al-salam uncovered that mechanical properties are significantly higher for HDPE: PP mixes than LDPE: PP blends. Mix proportion 20HDPE/80PP shows prevalent mechanical quality and both these mixes are immiscible. The parameters of the study were was 20 rpm, temperature (1400C, 1500C, 1600C). They concluded that mechanical properties increased with the addition of PP content. The mixes are found to be incompatible in nature. [5].
3. Jun Li et.al specified about the isothermal crystallization of polypropylene at a temperature where polyethylene stayed liquid. PP is solidified in PP-HDPE mixes in-phase isolated beads while PP was more scattered in LLDPE showed by contrast in crystallization. Crystallization rate of PP is same in PP-HDPE mixes as well as in unaltered PP. rate. PP was immiscible with HDPE and LDPE while it is miscible with LLDPE at 20% PP at elevated temperatures. [6].
4. J.Z. Liar & J. N. Nessb demonstrated that melt flow properties of PP were clearly enhanced when it was melt mixed with small amount of HDPE or LDPE. Their investigations focussed on PP/HDPE and PP/LDPE mixes and their end pressure losses, flow curves, the connection between the viscosities of the mix melts and the components. PP mixed with HDPE and LDPE by screw extruder and the composition was varied from 0 to 100. Blend of PP/HDPE did not show promising result. The similarity and miscibility are the imperative factors influencing the rheological qualities of the melts. Viscosity proportions of PP to HDPE mixes are high. The increment in the composition of PP increase the shear viscosities of PP/HDPE and PP/LDPE mixes. The shear stream did not comply with the flow curve law and the melts depends essentially understanding with Arrhenius condition [7].
5. Jia-Horng Lin et.al illustrated that PP and HDPE are incompatible and the chemical structure of PP did not affect by HDPE. They concluded that only physical mixing is happening in PP/HDPE blends. Stacking was the real reason and the tensile modulus and flexural modulus of PP/HDPE mixes diminish by an increment

in HDPE. As HDPE is incorporated in PP, Impact quality increased because of the particle form and particles show stress concentration and furthermore display plastic deforming to disseminate the impact energy. PP has higher melt flow record than HDPE, showing that HDPE has more viscosity. [8].

6. B. L. Schurmann et.al investigation demonstrated that 60HDPE/40iPP blend showed better properties than crude iPP. From the outcomes of SFM and TEM, strength was enhanced because of the expansion in the total interfacial volume. Young's modulus reliant on the PE composition and it diminishes with increment in the HDPE content. HDPE and iPP are immiscible polymers where epitaxial crystallization was occurring [9].
7. R.A. Shanksa, J. Lia, L. Yub showed that PP is just soluble in LLDPE. Isotactic polypropylene (iPP) has been mixed with High-density polyethylene (HDPE), Low-density polyethylene (LDPE), linear low density (LLDPE), Very low density (VLDPE) and Ultra-low density polyethylene (ULDPE). Mixes were blended utilizing a solitary screw extruder at 2000 C. The arrangement of the mixes was PP: PE (20:80) by mass. The noteworthy change in the rate of crystallization of PP was an identification of miscibility. The point when PP solidified from a homogeneous arrangement, which was the situation with LLDPE alone, wide diffuse spherulites formed and PP turned into a continuous phase [10].
8. C.M. Tai, Robert K.Y. Li, C.N. Ng recommended that the kind of effect test is additionally a factor that decides the effect quality. They considered two tests to be conventional and instrumental Izod impact testing in which the PP homopolymer is blended with HDPE and LDPE. Results demonstrated that PP homopolymer and PP/LDPE mixes have comparative impact strength, while PP/HDPE mix bring down impact strength. On account of instrumented Charpy impact test, both PP/LDPE and PP/HDPE indicates comparable impact quality and the qualities are lower than PP homopolymer. The estimations of impact quality of PP homopolymer is higher than the two binary mixes at 200 C and 00 C by Charpy impact test [11].
9. Walker Camacho, Sigbritt Karlsson conveyed the results that relied upon thermal and thermal oxidative quality of reused PP, HDPE and their blend containing 20 wt. % PP. The thermal steadiness of PE diminished with the reuse, which demonstrated that the shear forces amid handling instigate chain scission of the polymer spine essentially driving to shortening of the chains. The mix of PP and HDPE which was mechanically blended was found to be immiscible in nature. They also concluded that HDPE can bring stabilizing affect with PP [12].

2.2. PP/PS Blends

1. Ivonne Otero Navas and Uttandaraman Sundararaj studied the morphology of PP/PS mix with various blending times and with various compositional ranges. The handling parameters were taken for the investigation was 50 rpm, 15 min and 2000 C. The composition varies from 30 to 70 for the mixes. They also investigated the effect of nanoclays on blend behaviour. These mixes are immiscible and the augmentations of nanoclays will go about as intermediaries or extensions between PS spaces to group and blend [13].

2. L. Elias, F. Fenouillot, J.C. Majeste, and Ph. Cassagnau considers the addition of two types of silica particles to polypropylene/polystyrene (PP/PS) and polypropylene/poly (ethylene-co-vinyl acetate) (PP/EVA) mixes. The intensifying technique was set up by utilizing twin screw extruder and the screw speed is 120 rpm, time is 5 min, the temperature kept at 2000 C. The results demonstrated that the morphology of the virgin mix was essentially changed and particles estimate was drastically decreased upon the addition of silica nanoparticles. The nearness of silica nanoparticles in the mix changes the viscoelastic properties. When 3 wt. % of silica is included the mix, the relaxation of the PS beads is moved to bring down relaxation times contrasted and the perfect PP/PS mix was obtained. The quicker drop relaxation subjectively implies that the interfacial forces increment when silica fillers have been included the mix. With hydrophilic silica, the interface involved in the inorganic particles while hydrophobic silica thoroughly covers the interface and structures a 100 nm thick interphase [14].
3. Asha K. Krishnan et. al showed the fuse of nanoclays to PP/PS mixes. The investigations from a few researchers in the prior days demonstrated that the blends are unmistakably immiscible and don't get the adequate mechanical properties and additionally thermal properties. Nanocomposites arranged from adjusted fillers indicate enhanced elastic modulus and strength when compared with those prepared from unmodified clays. The parameters taken for the analysis was 50 rpm, 1800 C, and the composition was 80PP/20PS. Enhanced thermal stability of nanocomposites can be credited to the diminished porousness of oxygen caused by the incomplete peeling of the clay in the nanocomposites. SEM micrograph demonstrated better dispersion for PP/PS/N100V nanocomposites and the dispersion of the particles in polymer blends was affected by the strength of extent of dispersion of polymer and filler [15].
4. Fortelny et.al studied about the impact of the atomic structure of styrene– butadiene (SB) copolymers on the morphology, tensile properties, impact strength, and smaller scale hardness of PP/PS (80/20) mixes. The readied test with a composition of 80PP/20PS with processing parameters are 90 rpm and 2000 C and time was 8 min. Mixes containing PS particles with all around created honeycomb structure indicate bring down yield stress and higher plasticity than the mixes having PS particles with the basic structure. The tensile and impact strength was enhanced significantly by the addition of SB in mixes containing moderately little PS particles. [16].
5. Zhimin Xie, Jing Sheng, and Zhimin Wan investigated the morphology and mechanical properties, i.e., solidness and strength, of mixes of polypropylene (PP) and polystyrene (PS) inside the structure of micromechanics of composite materials. The Mori– Tanaka model would be a more powerful strategy for designing materials than Halpin– Tsai model. Based on the presumption that an ultimate strength will be controlled by the scattered stage when the mix has more than the minimum fraction. The minimum fraction of dispersed stage computed was discovered near the phase inversion region found by the mix morphologies. The Mori-Tanaka show most intently fits the information and would be a viable strategy for designing materials with the Halpin-Tsai display and the adjusted blend demonstrate in light of the fact that

there is no confinement on trial parameters. An ultimate strength was anticipated as far as pure part strength and composition, and the minimum fraction of scattered stage ascertained was discovered near the phase inversion region found by mix morphologies [17].

6. Reza Salehiyan et. al considered the morphological attributes of PP/PS blends loaded with various kinds of clays. The ratio for the investigation was taken as 80PP/20PS. All dried ingredients were blended in a blender at 50 rpm and 200 °C for 8 min at groupings of 1, 3, 5, 7, and 10 phr (parts per hundred resin). Small Amplitude Oscillatory Shear (SAOS) result demonstrated the addition of C20A initiated nonterminal conduct at bringing down frequencies, recommending that it went about as a PP/PS compatibilizer. C20A delivered the smallest PS beads and Large Amplitude Oscillatory Shear (LAOS) displayed solid strain-softening and articulated nonlinear conduct at C20A groupings of 3 phr or more [18].

2.3. PS/PE Blends

Iza M Bousmina M Jerome R recommended the rheological conduct of PS/PE blends. The viscoelastic immiscible mix compatibilized by two kinds of interfacial modifiers. 50/50 (wt./wt.) PS/HDPE mixes were set up by melt mixing in a Haake group blender at 180 °C and a rotor speed of 50 rpm for 10 min. With a specific end goal to assess the impact of a compatibilizer, 1 wt. % or 4 wt. % (in respect to the aggregate weight of the mix) was added to the mix amid the liquefy mixing. The immiscible mixes made out of it were consistent. It is a blend of prolonged particles and beads; with obviously forms some degree of interconnected stage structure. It is observed that the molecule concentration essentially diminishes with the addition of compatibilizer. The impact of copolymer change has little impact on dynamic and steady shear material elements of the mix. Shear stress was found to obey sensibly scaling laws built up by Doi-Ohta for both unmodified and copolymer modified mixes. No vast impact was seen on mass rheological properties of the mix altered with 1% compatibilizer.

2.4. Thermal Properties of Thermoplastics

The degradation of thermoplastics happens by four mechanisms: arbitrary chain scission, end-chain scission, chain-stripping, and different procedures, like cross-linking. Scission includes the cleavage of a carbon-carbon bond in the foundation of the polymer to create two radicals. This might start at any position all the polymer chain and offer ascent to a monomer and oligomers. It might be started entirely at the finishes of the chain in end-chain scission. End-chain scission brings about the select formation of a monomer and is started at unsaturated chain ends.

In TGA, a small amount of sample is heated under an inert environment, either isothermally or at a steady rate, and the mass of test is recorded as a function of either time or temperature. The degradation depends to some degree on the rate at which the temperature is increased and this must be considered in any analysis. In polyethylene (PE) and polypropylene (PP), in light of the fact that both of these have hydrogen particles on all carbons, one can expect that random scission will be the prevailing pathway of the degradation and consequently one can hope to discover

monomer and oligomers as the results of the degradation. The TGA of high-density PE seems to indicate comparative thermal stability qualities. The beginning of PP degradation starts at low temperature. The degradation of PE include ethylene and higher oligomers, which emerge from hydrogen exchange to various positions along the polymer chain. Similar degradation products are obtained from propylene are butene, pentene, hexene etc. The degradation of PP is more complex and a more extensive assortment of products is created. The real unpredictable items found in the degradation of PP, arranged by significance are 2, 4-dimethyl-1-heptene, 2-pentene, propylene, 2-methyl-1-pentene, and in considerably littler sum, isobutene.

In PP/PS mixes, the degradation begins at 384.760 C and the half loss of material at 426.60 C. The peak degradation temperature in which the material is completely degraded at 434.390 C and the residue acquired at 6000 C was 0.4561%. [15] In PP/HDPE mixes, the degradation begins at 3530 C and the half loss of material at 4590 C. The peak degradation temperature was at 4820 C [19].

2.5. Ternary thermoplastic polymer Blend

Nilton Equiza et. al investigated mixes of PE, PP, PS and HIPS which were acquired from virgin crude materials and reused plastic waste. The ideal conditions for preparations of these materials were found as 190 0C, 14 min and 3.5 wt. - % of compatibilizer (SEBS/EPR). The results demonstrated that the utilization of compatibilizer is imperative for getting good mixes as the arrangement of the concentrated plastic waste (PE/PP/PS; 70/20/10) is in a non-stable region. Subsequently, the utilization of SEBS/EPR as a compatibilizer to build the stage miscibility (similarity) was justified. Utilizing SEBS/EPR as a compatibilizer, the PE/PP/PS mixes demonstrated properties near that of PE/PP/HIPS. The whole mixes showed intermediate impact resistance esteems compared with those of virgin polymers. The mixes prepared from virgin polymers exhibited melt flow index lower than those from reused plastics. These distinctions can be because of the way that reused materials have just been prepared, and accordingly, their MFI values are higher than that of unadulterated polymers which is normal if the mixes are effectively handled. From the morphological analysis, three isolated stages were watched: 1) permeable structure; 2) nonporous semi-spherical structure; and, 3) superposed lacy structure. The pore, semi-spherical and lacy structures would speak to PS and PP scattered in PE lattice, separately; that is on the grounds that PE constitutes 70 wt. - % of the mix [20].

3. CONCLUSION

From the above papers, it is evident that PP, PE, and PS are incompatible and immiscible. Crystallization rate is additionally a sign of the miscibility of the polymers. PP: HDPE demonstrates great mechanical properties and PS: PP indicates better impact strength and great flexible modulus. But PS: HDPE blends not produced promising results. Compatibilizer assumes a vital role in the miscibility of polymers and nanoclays demonstrates better miscibility between the mixes. The processing parameters like blending rpm, time and temperature are an imperative part in the molding of better polymers. Thermal degradation temperature of the mixes is studied from the above research papers. Diverse processes deliver distinctive outcomes and one or more extrusions additionally

create a similar thing. Ternary polymer mixes of recycled polymers discussed in this paper demonstrated better tensile and impact strength than the binary polymer mixes. PP/PS/HDPE ternary mixes are a decent choice to meet the present prerequisites of the market in a financially savvy way.

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