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Critical review on Thermal and Mechanical properties of Natural fibres and nano-materials based polymeric Hybird Composites

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ABSTRACT:
Mixing of two or more different types fillers is a potential way to enhance and improve the desired properties of hybrid polymer composites. The hybridization is a desired process for making sustainable use of the easily and freely available natural fibers. Nano material as a filler provides more surface area for mixing and have excellent nucleating properties. Composite produced with natural fibers are environmental friendly and biodegradable which increase their demand in the market. This papers features and highlight the potential use of natural fibers and nanomaterial in hybrid composite materials for their abundant and friendly properties.
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I. INTRODUCTION:

Polypropylene is one of the important thermoplastic polymers as it is light weight, excellent mechanical properties, good heat and chemical resistance. It is easily processable and economical, and have good impact resistance. Due to these better properties polypropylene is fastest growing thermoplastic in commodity and engineering applications.

Polypropylene has excellent crystallization behaviour due to its regular chain structure .The most important industrial polypropylene is isotactic one. Isotactic polypropylene has been studied extensively for its polymorphic characteristics and crystallization behaviour since 1960 [1] and the results of these studies were reported in many publications [2-4], its crystalline structure influences the overall properties.

The effects of additives on the crystallization of polypropylene have been well observed in mineral filler like talc, $CaCO_3$, mica, and in various pigments like carbon black etc. Many results are also reported on fibre reinforced composites [5] which gives enhancement in material properties and cost saving possibilities in polymer based composites.

Polypropylene is a non-biodegradable thermoplastic. Due to the increased environment concern a new class of biodegradable polymer appeared produced from biomaterial [6].The biodegradables opened the way for new opportunities of waste management as these materials are designed to degrade itself under environmental conditions.

1.1 Composites with Natural Fibres

In composite material polypropylene takes an important role since its recyclability represents an advantage from energy saving point of view. It has been demonstrated that the PP/natural fibre composite have the potential to replace PP/glass fibre composite [7-13].

Natural fibres reinforced thermoplastics are also entering the global market of composite materials. Natural fibre composites consist of bio degradable or easily recyclable polymer and different natural fibres reinforcement [14-15].

Natural plant fibres like flax, hemp, kenaf which are renewable alternative to traditional glass fibre reinforcement due to increased concern about environment and energy saving attitude. The lower density of natural fibres as compared to higher density of glass fibres helps in to produce lightweight structures especially in automobile sector which is a desired point for automobile sector. Further natural fibre have high specific modulus as compared to glass fibres.

The future research on natural fibres reinforced polymeric composites mainly focused on a cost effective modification of natural fibres. The report related to the comparison of life cycle assessment of natural fibre composite with glass fibre reinforced composite, have found that natural fibre composites are superior in the specific automobile applications due to their low density and easily recyclability [14-18].

Thermoplastic composites are very much in use due to cost effective, improved mechanical properties and environmentally friendly.$CaCO_3$ as filler in thermoplastic reduces the production cost of moulded products. High filler content further can adversely affect the processisibility, ductility and strength of composites. To enhance the durability and appearance of composites, additives such as elastomers, coupling agents, surface agents, ultraviolet agents and antioxidants may be added in the polymer composites.

Talc, mica and kaolin are used to enhance the stiffness and strength of filled polymers. The properties of polymer composites are determined by component properties(matrix and filler).In addition to the matrix /filler properties, the mechanical characteristics of these materials are significantly influenced by the inter facial interaction which depends on the size of the interface and strength of the interaction [19]

Fibrous filler can usually improve the tensile strength and plate like filler increases rigidity. Talc and kaolin are plate like filler. Filler with high specific surface area will contribute to more surface contact between the filler and matrix, herby increasing the mechanical properties of the composites.

Natural fibre filled polymer composite are cheaper and biodegradable, despite these advantageous natural fibre has low compatibility with polypropylene. To overcome this disadvantage and to improve the surface characteristics of the composite, the application of compatabilizer is suggested, Compatibilizer is a compound used as coupling agent to improve compatibility between polymer matrix and natural fibre. Oxidized polypropylene or maleic anhydride grafted polypropylene can be used as compatibilizer.

1.2 Nano Composites

Nano material is extensively used in polymer to enhance their properties as shown by number of review articles. Nano dimensions particles effects the transition zone between the macro-level and molecular level resulted in large modification in the properties of polymer nano composite materials [20-22].

The driving force for the increasing research work in the field of polymer Nano composites was the report from the Toyota research group in the 1990 of a Nylon-6/montmorillonite nano composites [23] for which very small amount of silicate loading resulted in large improvements of thermal and mechanical properties.

The improvement in different properties of nano composites are related to the modifications of structure and dynamics of the polymer at and near the particle surface. Nano material increases the surface area to a great extent; this fraction of polymer contributes, significantly to the improvement of properties of the whole nanocomposite. In this respect, polymersn nano composites are somehow similar to semi crystalline polymers where the crystals can be considered as nano fillers [24].

In nanotechnology, polymer nano composites are defined as solids consisting of a mixture of two or more phase separated fillers, where one or more constituents phase is in Nano scale in a plyometric matrix. Materials can be referred to as nano scaled when their size, at least one of the dimensions lie in the range of 1nm to 100nm. [25].

There are number of nano particle that has been used in Nano composite. These particles are divided in fibres (1D), platelets (2D) nano particles (3D) depending upon the number of dimensions they display in nano scale [26]. .Performance of Nano composite depends on various features of nano particle such as the size, specific surface area, aspectratio, compatibility and dispersion in polymeric matrix.

The nano particle dispersion can be characterized by different states at Nano, micro and macroscopic scales. For example Nano clay based composites can show three different types of morphology; immiscible, intercalated or exfoliated (miscible) composites [27].

Nano composites are prepared by adding sufficient nano particles to polymer matrix to improve its performance due to the nature and properties of the Nano scaled particles. This produces high performance composites when good dispersion of the particles is achieved then the properties of the Nano scale particles are better than those of the polymer matrix [28].

Nano particles are used in polymer matrix to enhance mechanical properties like strength and stiffness by reinforcement mechanism. It is proved that properly dispersed and aligned clay particles are very effective to improve stiffness of polymer matrix [29]. The modifications of mechanical properties of the polymer matrix with clay seems to be a proper way due to their ability to act as a nucleating agent, clay particles may induces changes in crystallinity of the polymer matrix like PA6 or PP [30, 31].

Talc qualifies as good reinforcement filler alternate to clay because it is layered mineral with a high aspect ratio (particle diameter/thickness 20:1) this is due to its plate type structure having micron sized dimensions on length and width with nano metric thickness. The effects of talc on polymer have been well studied. It was demonstrated that talc improves mechanical properties and macromolecules orientation of polypropylene [32].

In addition to compatibilizer that improves mechanical and thermal properties of the composites, nowadays nano particles have received attention as a filler for polymer composites to further increase the properties like mechanical and thermal. The addition of Nano –clay particles and compatibilizer in the composite produced from bamboo fibres and polyethylene polymer were studied by Han et al [33] and concluded that the addition of 1% nano clay increases the flexural elasticity modulus, dynamic elasticity modulus and thermal stability.

1.3 Hybrid composite

In hybrid composites we reinforced polymer matrix with natural fibre and Nano material for getting enhanced mechanical and thermal properties [34-36].

Natural fibre composite are available at low cost and their friendly environment character, are the main reasons for an increase in interest in their development. Further the natural fibreshybrids composite are recyclable and biodegradable [37].

1.4 Properties of Hybrid Composites

The mechanical properties of hybrid composites depends strongly on the filler morphology, filler content, dispersion / distribution of filler material into matrix and filler/matrix adhesion. Fillers dispersion into hybrid polymer matrix is an indication of the relatively homogeneous nature as seen in SEM. Liu and Wu [38] studied the mechanical performance of Polyactide 66(PA66) nanocomposite and found that the tensile strength increased rapidly from 78 MPa for PA66 to 98 MPa for Polyactide66-clay nano composite (PA66CN)but the magnitude of this increase value diminished when the clay content was above 5%.

M.Alshabanat [39] studied the mechanical properties of intercalated Talc/PP nanocomposite and observed that best mechanical properties were obtained at talc content of 10 %.During observation it was found that impact strength of pure PPwas 23J/m as compared to talc filled PPwas 31.7J/m, .they also observed that yield stress also increases from 35 MPa to 39 MPa. Results indicated that composite became tougher and stronger but at the same time it became brittle.

Ammar O. et al [40] studied the thermal properties of PP/Talc and found that melting temperature remain unchanged at 165 ^{o}C but crystallization temp increased from 120 to 128 ^{o}C, indicating that talc is a good nucleating agent, they also observed 100 % increase in elastic modulus value of composite. However the ultimate elongation decreases with the addition of talc from 63% to 10%. Therefore addition of talc reduces the ductility and material became brittle.

Hajar Reisi Nafchi et al [41] studied the effects of oxidized PP as a compatibilizer and nano clay particles and concluded that by using oxidized PP thermal properties of the composite improved and releases less energy during thermal degradation and shows more thermal resistance and stability.

Han et al [42] studied the composite of bamboo fiber ,polyethylene polymer with nano clay particles and found that the addition of 1% nanoclay increases the flexural elasticity modulus, dynamic elastic modulus and thermal stability.

The hybrid composite properties are characterized by using various test such as: Scanning electron microscopy to know about morphology of the composite which give an indication of relatively homogeneous nature of the composite. Fourier Transform Infrared Spectroscopy (FTIR), illustrate the chemical structural properties and also shows the interaction between the various filler constituents. The mechanical properties are tested by tensile, flexural and impact testing on Universal Testing Machine (UTM) and Impact tester.

The thermal stability of hybrid composite is determined by using Thermo gravimetric Analysis (TGA). The initial weight loss in the range 100-200^{0}C may be due to the evaporation of water contained in the natural fiber. The thermal decomposition of all natural fibers consist of following steps:

Hemi cellulose degradation in temperature range 180-310^{0} C

Cellulose decomposition in temperature .range 320-340^{0} C

Lignin degradation in temperature range 440-480 $^{\mathbf{0}}$C

The variation of the thermal degradation peak temperature is due to the variation of the composition of the natural fibers which depends upon season, , region, part of plant, maturity of plant etc [43]

II. CONCLUSION:

In the present review the pre treatment of fibers is reported for proper adhesion and distribution of fiber with the polymer composite. The enhanced mechanical properties, thermal properties are also an added advantage. Hybrid composites are easy to decompose and produce less harmful effects on environment. Natural fibers are more easily available and cheaper as compared to synthetic fibers. Natural fibers are available at low cost, recyclable, light weight and eco friendly in nature. Hybrid composites have more stiffness. The hybrid composite finds extensive use in automobile sector due to advanced properties and low density. Further it can be used for any type of environment in hazardous chemical industry. This material can also be used for constructional and furniture items due to their toughness.

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