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A review on the effect of fibre loading on mechanical strength of natural fibre reinforced polymer composites.

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Abstract: *This paper is a review on the effect of fibre loading on mechanical properties of natural fibre reinforced polymer composites. Recently, there has been a rapid growth in research and innovation in the natural fibre polymer composite (NFPC) area. Natural fibre composite is used as alternative to synthetic fibre composite due to their good mechanical properties, eco-friendly, high specific strength, non-abrasive, bio-degradability, renewable, low density, low cost, low machine wear. However, in development of these composites, the incompatibility of the fibres and poor resistance to moisture often reduce the potential of natural fibres. The mechanical properties of natural fibre reinforced polymer composite are mainly influenced by the interfacial adhesion between the matrix and the fibres. Therefore, chemical modification of natural fibre are employed to improve the interfacial matrix–fibre bonding resulting in the enhancement of mechanical properties of the composites. The mechanical strengths of the natural fibre reinforced polymer composites increase with increase fibre content up to a maximum or optimum value, after that the mechanical strength will drop.*

Keywords: *Natural fibre polymer composite (NFPC), Fibre loading, Mechanical properties, Biocomposite, Fibre– matrix adhesion.*

I. INTRODUCTION

A mixture of more than two materials, i.e. reinforcement and resin, which differs in structure or composition on a macroscale, is known as composite material. Natural fibres have recently attracted the attention of scientists and technologists because of the advantages that these fibres provide over conventional reinforcement materials, and the development of natural fibre composites has been a subject of interest for the past few years.

A fibre reinforced polymer (FRP) is a composite material consisting of a polymer matrix with high-strength fibres, such as glass, aramid and carbon. Generally, polymer can be classified into two classes, thermoplastics and thermosettings. Thermoplastic materials currently dominate, as matrices for biofibres; the most commonly used thermoplastics for this purpose are polypropylene (PP), polyethylene, and poly vinyl chloride (PVC); while phenolic, epoxy and polyester resins are the most commonly used thermosetting matrices. In the recent decades, natural fibres as an alternative reinforcement in polymer composites have attracted the attention of many researchers and scientists due to their advantages over conventional glass and carbon fibres. These natural fibres include flax, hemp, jute, sisal, kenaf, coir, kapok, banana, henequen and many others.[19]Conventionally, in aerospace, automotive, leisure, construction, sport and packaging industries synthetic fibre reinforced composites are widely used as they are having greater toughness and rigidity. But synthetic fibres are expensive and not ecofriendly. Therefore, biofibres are replacing to synthetic fibres. The constituents of natural fibres contain hydroxyl groups which make these fibres hydrophilic and increases moisture sensitivity, where as matrix material is hydrophobic in nature. However, the certain drawback of natural fibres/polymers composites is the incompatibility between the hydrophilic natural fibres and the hydrophobic thermoplastic matrices.As a consequence the interfacial bonding between fibre and matrix will not be so strong. The main role of matrix is to transfer the load on to the fibres at the interface.

Efficient load transfer is possible if there is proper bonding between fibre and matrix. Poor adhesion does not give optimum properties for the composites. Compatibility between fibre and matrix can be enhanced by suitable chemical treatments. Some of the natural fibre and man made fibres properties are given in Table 1. There are many factors that can influence the performance of natural fibre reinforced composites. Apart from the hydrophilic nature of fibre, the properties of the natural fibre reinforced composites can also be influenced by fibre content/amount of filler. In general, high fibre content is required to achieve high performance of the composites. Therefore, the effect of fibre content on the properties of natural fibre reinforced composites is particularly significance. It is often observed that the increase in fibre loading leads to an increase in tensile properties up to maximum, then it will drop.[18]

Composites were a need in the evolution of engineering materials because by a combination of materials it is possible to overcome, for instance, brittleness and poor processability of stiff and hard polymers. The simplest combination is of only two materials where one acts as the reinforcement and the other as the matrix.

Table 1 Properties of selected natural and manmade fibres [14]

Fibre	Density (g/cm^3)	Elongation(%)	Tensile strength (MPa)	Elastic mo-dulus (GPa)
Cotton	1.5-1.6	7-8	400	5.5-12.6
Jute	1.3	1.5-1.8	393-773	26.5
Flex	1.5	2.7-3.2	500-1500	27.6
Hemp	1.47	2-4	690	70
Kenaf	1.45	1.6	930	53
Ramie	1.5	3.6-3.8	400-938	61.4-128
Sisal	1.5	2-2.5	511-635	9.4-22
Coir	1.2	30	593	4-6
Softwood kraft pulp	1.5	4.4	1000	40
E-glass	2.5	0.5	2000-3500	70
S-glass	2.5	2.8	4570	86
Aramid	1.4	3.3-3.7	3000-3150	63-67
Carbon	1.4	1.4-1.8	4000	230-240

In principle, any isotropic material can be reinforced; the reinforcing material is usually stiffer, stronger or tougher than the matrix and there has to be a good adhesion between the components. Natural vegetable fibres, characterized by a rapid renewability, are environmentally friendly materials at all stages of their life cycle; that is to say, during extraction, production, processing, and disposal. Composites containing vegetable fibres such as sisal present soundproofing properties, the ability to absorb vibrations, and good impact properties due to their better elasticity, especially when modified with crushed fibres. Sisal reinforced polyester composites may be considered ecological materials because when burnt they produce less CO_2, CO, and toxic gases than their unreinforced counterpart; also, one has to consider the benefits of all oxygen emissions from the sisal plantation. The application of vegetable fibres to biocomposites is, however, limited by poor resistance to high temperatures, weak bonding to synthetic polymers, and variability of fibre properties with plant age, part of the plant, extraction method, etc. The cellulose and lignin contents of sisal varied from about 50 to 61% and 3 to 4%, respectively, depending on the plant age. The effects of surface modification on the properties of biocomposites have been recently studied in order to overcome some of the inconvenience associated with the use of lignocellulosic fibres.

II. LITERATURE REVIEW

Gowthami A. et al.,[1] investigated the effect of silica on thermal and mechanical properties of sisal fibre reinforced polyester composites. Experimental result showed that the tensile strength, young's modulus, impact strength of composite with silica is higher than that of the composite without silica and pure resin.

Bindal Amit . et al.,[2] studied the effect of jute fibre on mechanical properties of glass fibre reinforced polyester composite and result showed that by incorporating the optimum amount of natural fibres, the overall strength of synthetic fibre reinforced polyester composite can be increased and cost saving of more than 20% can be achieved. Results revealed that natural fibre content is limited up to 25–35% for 30% and 40% overall reinforcement.

Ramesh U.et al.,[3] studied that the effect of fibre loading on mechanical properties of aluminium, borassus flabellifer fibre and polyester composites. Tensile strength of fabricated composites increases with increase in weight of fibre. The tensile strength of pure polyester is 35.2 N/mm^2.The tensile strength of a composite is 64.51 N/mm^2 for maximum fibre loading(2.5g). The tensile module of a untreated fibreed composite is 1030.6 N/mm^2 for maximum loading fibre and tensile module of a Treated fibreed composite is 1244.4 N/mm^2 for maximum loading fibre.

Njoku R.E. et al.,[4] studied that the effects of variation of particle size and weight fraction on the tensile strength and modulus of periwinkle shell reinforced polyester composite. The tensile strength and elastic modulus improved with decreasing particle Size. Both tensile strength and Youngs modulus of the composite material increase with increasing weight fraction of periwinkle particles in the composite.

Ratna Prasad A.V. et al.,[5] carried out the experiments of tensile and flexural tests on composites made by reinforcing jowar,sisal and bamboo into polyester resin matrix. The mean tensile strength of jowar fibre composite at highest volume fraction(0.4) of fibre is much higher than that of sisal composites and is nearly equal to that of bamboo composite. It is also concluded that the mean tensile modulus of jowar fibre composite is higher than those of sisal and bamboo fibre composites at highest volume fraction of fibre. As the volume fraction of fibre increases in the composite the specific tensile strength of jowar fibre composite is higher than that of sisal composite and the specific tensile modulus is also higher than those of sisal and bamboo fibre composites.

Sangthong Supranee et al.,[6] studied the mechanical property improvement of unsaturated polyester composite reinforced with admicellar-treated sisal fibres. The composite with the best mechanical properties can be obtained by using 30 vol% fibre loading with fibre length of 30 mm.

Girisha C. et al.,[7] prepared sisal empty fruit bunch banana fibres reinforced epoxy composite. Alkali treatment of natural fibre composites improved the quality of the fibre-matrix interface as well as better adhesion. Maximum tensile strength of hybrid composite was found 63MPa for the 25-30% fibre loading.

Zhao Da and Zhou Zhou[8] were studied the application of light weight composites in automotive industries. Light weight composites produced from renewable and biodegradable materials. In automotive industries, natural fibre reinforced composites have extensive attention as alternative to replace traditional composite. Natural fibre such as sisal, jute, hemp, kenaf and flax have used as reinforcement in composite for automotive parts like door panels, headliners, floor mats, seat cushions and dashboards. Natural fibres have significant cost effective compare to synthetic fibres. Also, energy consumption of the production of natural fibres for composites is about 60% lower than glass fibre composites. Moreover, natural fibres present many advantages over synthetic fibres such as lower tool wear, cheaper cost, safer to handle, wider availability and biodegradability. There are also shortcomings like low moisture resistance, low thermal stability, low microbial resistance and a lack of quality consistency.

Kolybaba M.et al.,[9] developed biopolymer materials, which has been underway for a number of years and continues to be interest for many researchers. There are large number of areas such as agriculture, automotives, medicine and packaging all require environment friendly biodegradable polymers. Industry point of view greatest advantage of using biopolymers derived from renewable stocks is their low cost and easily availability.

Hargitai Hajnalkaet al.,[10] studied the effect of hemp fibre loading on the properties of polypropylene composites. Young's modulus of the composite increases with increase in the fibre loading, maximum value at a 50% fibre content and decrease thereafter at 70%. Optimum tensile strength obtain at 40% fibre content. The mechanical properties were weaker in perpendicular direction compared to parallel direction and the water uptake was the same in both direction.

Ahmad Ishak et al.,[11] studied that the effect of fibre loading and extrusion rates of twaron fibre thermoplastic natural rubber composite. The composite are prepared by two different composition of natural rubber/linear low density polyethylene matrix, 60/40 and 40/60. Result showed that the impact strength, tensile strength, hardness and young's modulus increase with increase in fibre loading, but the strain at break decreases. Optimum mechanical properties are found at 20% loading in both blend. While increasing the extrusion rate, there are no significant effect on the mechanical properties.

Khoathane M. C.et al.,[12] investigated the effect of fibre loading on the mechanical and thermal charactristics of hemp fibre polypropylene composite. Result showed that an increase in fibre content lead to increase in tensile strength, elastic modulus and flexural strength.

Ramakrishnan S. et al.,[13] studied the mechanical properties of vinylester resin reinforced with different weight fraction (10%, 20%, 30%, 40%) of natural fibres by mathematical modeling and ANSYS simulation. Result showed that the increase fibre content in vinylester matrix with improved mechanical properties of composite. Mathematical model and ANSYS result are correlate with each other for the same fibre loading. 40% fibre loading showed maximum tensile modulus, tensile strength, impact strength and toughness.

Ku. H. et al.,[14] investigated the mechanical properties of natural fibre reinforced polymer composite. The tensile strength and modulus increase with increasing fibre loading up to a certain amount. If the fibre loading increases below optimum value, load is distributed to more fibres, which are well bonded with resin matrix resulting in better tensile properties. Further increment in fibre loading has resulted in decreased tensile strength.

Eaysmine Shamima et al.,[15] studied that bioabsorbable polymer composites (starch/PVA and starch/PLA) constitute different composition (pure,3%,6%,9%,12%,15% of PVA and PLA respectively) and measure Tensile strength (TS), percentage of elongation at break (Eb), and tensile modulus (TM),Vicker's hardness (VH) and yield strength (YS). Result showed that the addition of 3%starch into PVA, the TS, Eb, and TM of the composite decreased. However, addition of more starch up to 15% increased the TS than that obtained from 3% starch/PVA composite. 6% starch/PLA showed the highest VH (20%) and YS (7MPa). Starch/PVA composites showed a better mechanical properties (TS: 19.7 MPa, Eb: 169%, and TM: 95 MPa) over the starch/PLA composites(7.2 MPa).

Gupta A.P. et al.,[16] studied that investigated the effect of starch loading on low density polyethylene composite. Result showed that the tensile strength reduced slightly from 10.0N/mm^2 to 8.6N/mm^2 while starch addition was increased to 5%; there after reduction in tensile strength 6.0N/mm^2 at 20% then increase 6.4N/mm^2 at 25% and finally lowest 4.0N/mm^2 at 30% starch concentration. Change in percentage elongation with 5% potato starch showed excellent composite results.

Sadhu Susmita Dey et al.,[17] studied that potato starch is used to prepare the film. This starch has been blended with PVA (Polyvinyl Alcohol) at different ratios (Starch:PVA=30:70(A),50:50(B),70:30(C), A+1%cloisite30B(AN1),A+3%cloisite 30B (AN2)). Nanoclay has also been mixed with the blend at 1%, 2% and 3% weight ratios. The blend with sample C shows the best mechanical strength. On addition of nanofiller the mechanical strength has increased significantly in all the samples. Sample with 70% starch shows maximum increase in strength compared to the unfilled sample. But the AN1shows maximum strength among all the 1% nanoclay filled samples. 1% clay loading is the maximum strength of composite beyond 1% clay loading the strength of the composite decreases. Increasing filler loading the transparency decreases.

III. CONCLUSION

Natural fibres are low cost, renewable, recyclable, low density and eco-friendly material. Their tensile properties are very good and can be used to replace the synthetic fibres such as glass, carbon in reinforcing plastic materials. A major drawback of using natural fibres as reinforcement in plastics is the incompatibility of fibre and matrix, resulting in poor adhesion between natural fibres and matrix, subsequently lead to low tensile properties. In order to improve fibre– matrix interfacial bonding and enhance tensile properties of the composites, novel processing techniques, chemical and physical modification methods are developed. Also, it is obviously clear that the strength and stiffness of the natural fibre polymer composites is strongly dependent on fibre loading. The tensile strength and modulus increase with increasing fibre loading up to a certain amount. If the fibre loading increases below optimum value, load is distributed to more fibres, which are well bonded with resin matrix resulting in better tensile properties. Further increment in fibre loading has resulted in decreased tensile properties.

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