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Recent developments in the tensile properties of natural fibre reinforced composites: A review

N. S. Balachandran, N.Badri Narayan Mehta, M.P.Jenarthanan,
School of Mechanical Engineering, SASTRA Deemed University, India. 613401.
jenarthanan@mech.sastra.edu

Abstract

Natural fibre reinforced composites dominate the field of engineering in the past few years. Many researchers do a lot of work in NFCs, trying increasing their mechanical performance especially make them suitable for day-to-day applications. Among the properties, tensile properties influence much as they aid design process, reduce material costs, and achieve lean manufacturing goals. Therefore, this review paper intends to administer an overview on the tensile properties of natural fibre reinforced polymer composites and explains achievements made with them. The study started by analysing and understanding the tensile properties of different natural fibre composites and modifications made in them to improve their tensile properties as expressed by several authors through their articles. The various experimental setups, resins, matrices and specimens used were noted and briefly explained here. It was found that by increasing the tensile strength value of NFCs, their application can be increased. Still, further work can be carried out to improve tensile strength of natural fibre composites. NFCs play a major role in automotive industry, building and construction, fishing nets, wall decorators etc.

Keywords: Fibre loading, Surface modification, reinforcement, hardness, strength, tensile strength.

1. Introduction

A polymer matrix imbedded with high-strength fibres yields a fibre reinforced polymer (FRP). Since natural fibres have advantages over conventional glass and carbon fibres they are used as an alternative reinforcement in polymer composites in the past few decades. Some examples for natural fibres are flax, hemp, jute, sisal, kenaf, coir, kapok, banana, vetiver, basalt, sugar palm etc. Some advantages of natural fibres include low cost, low density, comparable specific tensile properties, non-abrasive to the equipments, renewability, recyclability and bio-degradability. These composites are widely used for aerospace, construction, sport, packaging and automotive industries as mentioned earlier. There are many factors that can influence the performance of natural fibre reinforced composites. They are Fibre selection, Matrix selection, Interface strength, Fibre dispersion, Fibre orientation, Manufacturing, and Porosity. Table 1 shows the review of different properties of different NFCs obtained from different research articles. To yield the optimum composite products, with desired properties, suitable processing techniques and parameters must be carefully selected. This article aims to review the reported works conducted by researchers on the effects of various parameters on tensile properties of natural fibre reinforced composites. (Taken in Table. 1)

2. Discussions

The most widely tested properties of natural fibre reinforced composites is tensile properties. Tensile strength can be defined as the ability of a material to withstand a pulling (tensile) force. It is measured in units of force per cross-sectional area (More conventionally N/mm^2 or M Pa). This is an important concept in material science, mechanical engineering and structural engineering. The fibre strength may influence selection of a specific natural fibre for a specific application. A tensile test reflects the average property through the thickness. The stresses in a tensile test are uniform throughout the specimen cross-section. From tensile test ultimate tensile strength, breaking strength, maximum elongation, Young's modulus, Poisson's ratio and reduction in area can be determined. Palmyra Palm 'petiole fibre' was prepared and characterized its tensile and surface characteristics. The reinforcement are untreated and treated palmyra palm petiole fibre. In Palmyra palm petiole chemically treated FRP composites, the highest tensile strength of 56.69 MPa, is achieved, and shown in figure 1. Whereas for untreated and chemically treated palmyra palm petiole fibres respectively, the tensile strength of 98.14, 156.13 MPa respectively is observed. This shows that the chemical treatment of the fibres resulted in increase in the tensile properties for all the specimens. Since poor bonding is present between the fibre and matrix, only with the reinforcement level of 12.19 %, the composites showed tensile strength of 50.15 Mpa which is higher than all other composites reinforced with untreated fibre at different volume fractions i.e. 20.18 – 33.22 %. (Nadendla Srinivasababu et al. (Taken in Figure. 1). The tensile strength values of chemically treated fibres composites are greater than the tensile strength of untreated composites and the tensile strength of composites where coupling agents are used further increased. The tensile strength of untreated composites with coupling agents increased by 26.05% compared to untreated composites devoid of coupling agents for 40% fibre content whereas diazo treated composites containing coupling agent showed 5.67% hike in tensile strength than diazo treated composites devoid of coupling agents for the same fibre loading. The tensile strength of untreated composites containing coupling agents increased by 77.50%compared to untreated composites devoid of coupling agents and diazo treated composites containing coupling agent showed 70.07% increment in tensile strength than diazotreated composites devoid of coupling agents for the same fibre loading in the case of 50% fibre content. Figure 2 shows the effect of fibre loading in the tensile strength of various PP composites. (Ramadevi Punyamurthy et al. (Taken in Figure. 2)

A new particle-reinforced composite was preparedusing defatted horn fibre (HF) and polypropylene (PP), characterised the physical, mechanical, thermal and micro-structural properties of HF/PP composites with varying fibre wt% (5%, 10%, 15% and 20%) and compared with the properties of pure PP and pure HF. HF/PP composites show an increase in, tensile yield strength by 15.74% when compared to pure PP. The stress-strain graphs obtained from tensile test is shown in figure 3. It shows that specimen A is ductile, and on the other hand specimen F is brittle and specimens B, C, D and E contain both the behaviour. Due to clustering effect of the particles it is noticed that the tensile yieldstrength of HF/PP composites increases up to 15 wt% and decreases for higher fibre loading. That is clear from the stress-strain graph. Also, pure PP show less tensile yield when compared with the HF/PP composites, showing good bonding between them. (Kumar D et al.,

(Taken in Figure. 3)

An experimental investigation of the effects of temperature and atmosphere on the tensile behaviour of basalt fibreswas carried out(Figure 4). The failure originated from the fibre surface which is evident from scanning electron images of fibre fracture surfaces after tensile tests. Experimental results show that with conditioning temperature, the modulus of thermally treated basalt fibres increased.(Fabrizio Sarasini

(Taken in Figure. 4)

The mechanical properties of biocomposite using available theoretical methods and experimental verification of mechanical properties was identified. They used parallel & series models, Halpin-Tsai models and Hirsch models for the evaluation of mechanical tensile properties. They used universal testing machine for carrying out experimental mechanical characterization and found that increase in the fibre volume fraction as well as fibre length increase the tensile strength. (Yashwant S. Munde et al

(Taken in Figure. 5)

The experiments conducted by scientistsreveal that the tensile strength and stiffness related properties of certain natural fibres vary. If the uncertainty associated with the material properties of natural fibres is not evaluated in a standardised manner, a designer may run into predicamentin designing a natural-fibre-based product. This means that the continuous product development using natural fibres must be up held by an uncertainty quantification system. (Milanese AC

A study on tensile properties of sugar palm fibre (SPF) reinforced high impact polystyrene (HIPS) composites was carried out. In order to obtain Short SPFs long fibreswere cut with pulverisette tool and filtered using a sieve. The composites are fabricated by mixing Five differentfibre loadings of 10, 20, 30, 40 and 50% by weight with HIPS polymer with the help of melt mixer and hot press. Instron machine was employed for tensile tests of theComposites. The tensile strength of short SPF-HIPS composites decreased compared to neat HIPS (0% loading) on adding 10 to 30% by weight. It can be seen that the average tensile strength was 19.3 MPa for the composite with 30% fibre content; whereas it is lower by just approximately 35.5%from that of neat HIPS. Similar results have been found by Antich et al. where there was a decrease of the tensile strength values when they added 5 to 25% by weight of short sisal fibres in HIPS. The decrease in the tensile strength was about 46% to that of neat HIPS when 25% of fibre content was added thereby concluding that the decrease of tensile strength values was due to the weak fibre-matrix interface due to differing polarities of the hydrophilic sisal fibres and hydrophobic HIPS matrix. However, S.M. He found that the increase in the tensile strength valueswas due to the increase in fibre loadings from 40 to 50% indicating the possibility of better dispersion and greater interaction in the HIPS matrix of the fibres due to good bonding between fibre and matrix. (S.M. Sapuan et al

(Taken in Figure. 6)

Neng Sri Suhartya[8] et al evaluated the tensile strength and Flexural Strength of rPP (C0) as a raw material to be 21.25 MPa and 23.61 MPa, and for PP/Hall the tensile strength to be 32.32 MPa which is a 52% increment and flexural strength to be 26.07 MPa (10% increment). They found that the increment resulted because of the effect of the adding of 20% (w/w) Hall as a first reinforcement (C1). When C2 is used as reinforcement in the presence 20% (w/w) the tensile strength was found to be 34.26 MPa and on the other hand the flexural strength to be 30.11 MPa. The increment in strength further raised to 61% in TS and 28% in FS. Meanwhile, when 20% (w/w) Hall is used as a first reinforcement and 20%`` (w/w) KF as a second reinforcement (C3), the corresponding tensile and flexural strength values of rPP/Hall/KF were 38.28 MPa and 33.48 MPa. Also, the strength increased 80% in TS and 41% in FS compared to the rPP.

(Taken in Figure. 7)

Dilli Babu G et al[9] carried out an experimental study to investigate the tensile and wear characterization of polymer composites made by reinforcing Calotropis Gigentea fruit fibre as a new natural fibre into a polyester resin. The Calotropis Gigentea fibres extractedby manual processes are fabricated up to a maximum volume fraction of fibre of 0.35. The tensile strength increased with increase in fibre content. It was clearly evident the increased strength was due to the fact that the polyester resin transmits and distributes the applied stress to the Calotropis Gigantea fruit fibre. Therefore, the composite can sustain higher load before

failure. At 0.35 volume fraction of fibre the tensile strength of the composites increased by 52.26 % compared to the pure polyester. Hence, Calotropis gigantea fruit fibre which is abundantly available in nature, can be incorporated in many applications especially low cost housing and civil engineeringstructures.
(Taken in Figure. 8)
R.Panneerdhass [10] et al fabricated luffa fibre and Ground nut reinforced epoxy polymer hybrid composites by hand lay-up technique and evaluated the properties such as tensile, compressive, flexural, impact energy and water absorption characteristics with different volume fraction of fibres as in 1:1 ratio (10%, 20%, 30%, 40% and 50%). They also studied the effects of volume fraction on the various properties. The Figure shows the effects of volume fraction on the tensile strength which varies from 10.35 MPa to 19.31 MPa. At 40% of fibre volume fraction,the optimum mechanical properties were obtained.
(Taken in Figure. 9)
Nadendla Srinivasababu et al [11] made use of Thysanolaena Maxima (Broom Grass) fibres and reinforced into the polyester matrix and evaluated the mechanical and dielectric properties of the composites as per ASTM procedures. The tensile strength of untreated fibres were 45 MPa. The highest tensile strength of 82.39 MPa, is obtained for broom grass CT – 1 fibres.The broom grass FRP composites achieved higher tensile strength values for with CT – 2, and 3compared to the raw broom grass composite. The tensile strength of the fibre increased due to the chemical treatment of the fibre.
(Taken in Figure. 10)
D. Chandramohan [12] et al developed polymer bio-composites using powdered coconut shell, walnut shells and Rice husk as reinforcements with bio epoxy resin. The tensile strength of the fabricated composites were evaluatedinbothwithmoistureandwithout moisture as per ASTM standards. The hybrid composite has far better properties than single fibre glass reinforced composite. The hybrid of walnut shell and coconut shell composite showed more tensile strength than other two hybrid composites. In both with and without moisture it has a value of 68.8 KN and 69.5 KN respectively as shown in the figure. The hybrid of walnut shell and coconut shell composite failed at 9.12 kN in tensile test with moisture, and in the case of without moisture, it is 9.75 kN in tensile test. The specimens possess good mechanical properties and in both with and without moisture test results, there is not muchsignificant difference. However the properties are improvedwith the incorporation of walnut shell and coconut shell.
(Taken in Figure. 11)
Yahaya et al [13] computed the tensile strength values to be 145.8 MPa for woven kenaf composites. The intermediate and lowest tensile strength recorded were 115.36 MPa and 101.56 MPa respectively. The tensile properties of the composites is influenced by the orientation of kenaf fibre which is clearly shown in Figure 12.
(Taken in Figure. 12)
Majid Niaz Akhtar et al [14] found the tensile strength, with different kenaf fibres loading for the untreated and treated PP kenaf composites, and are presented in Fig. 7. The tensile strength of the composites improved with increase in the fibre loading of kenaf. However, thealkaline-treated kenaf/PP composites exhibited higher tensile strength than PP and the untreated kenaf/PP composites owing to the pull out of fibres and thede-bonding of the untreated kenaf fibres from the PP matrix. Also it was found that the theoretical rule of mixture worked well for the mechanical properties of short fibres.
(Taken in Figure. 13)
Wassamon Sujaritjun [15] focused on the tensile properties of natural fibre reinforced polylactic acid composites. They made use of untreated and flexible epoxy treated bamboo fibre, vetiver grass fibre and coconut fibre as reinforcement for PLA bio composites. They found that the flexible epoxy surface treatment improved the tensile strength of bamboo fibre and coconut fibre reinforced PLA composites when compared with untreated composites. Surprisingly, in their results, in order to improve the tensile properties,bamboo fibre proved to be the most effective reinforcement.
(Taken in Figure. 14)
Ma X [16] et al. studied the properties of natural fibres-reinforced thermoplastic starch composites and found the dependence of tensile properties of micro winceyette fibrereinforced thermoplastic corn starch composites on fibre contents. The tensile strength was approximately trebled to 150 MPa with the increase fibre content from 0% to 20 wt % showing progressive increment. However, the elongation of the composites decreased with increasing fibre loading. The elongation gave up considerably between fibre loading of 0–10% by weight; after this, the drop was very marginal. On the contrary, the energy dwindled to some extent from neat resin to 5 wt % of fibre at break of the composites and dropped noticeably from 5% to 10% by weight of fibre and after this, there was a minor increase.
(Taken in Figure. 15)

3. Results and Conclusions

Natural fibre composites have been proven alternative to conventional composites in many applications in automotive, transportation industries owing to their eco-friendly, abundant availability. Many researches are going on to improve the mechanical properties of composites, especially the tensile properties as they are very good and could be of potential use to replace the conventional fibres such as glass,carbon in reinforcing plastic materials. Therefore methods of improving the tensile properties have been carried out by researchers. This paper reviews the various methods to increase the tensile properties of NFCs. It was found that the tensile properties can be increased by numerous methods like chemical treatment of the fibres, mathematical modelling,uncertainty quantification,the effects of volume fraction,increasing the fibre content etc., From this review, it is concluded that among all the methods increase in fibre loadings of the composites proved to be the effective solution to increase the tensile strength. Also, itis being carried out by a large number of researchers. Here, the work is limited only to plant fibres composites and further research can be extent to animal fibers which is also available in abundant quantity.

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