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Understanding Mechanical Behavior of Kevlar Polymer Hybrid Composites : A Review

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ABSTRACT

A review of mechanical properties of Kevlar and different artificial based fibers/fillers/particles or nanotubes reinforced composites forming polymer hybrid in different capacities was carried out. Most of the composites were prepared by hand layup, compression and injection molded techniques. Many of the review works has concentrated on using Scanning electron microscopic analysis to be followed in order to evaluate surface morphology of the composites respectively. Normally the relationship between theoretical and experimental values was figured out using rules of mixture in the present papers studied for review. Mainly out of the analytical results showed good agreement with the experimental results. From the review, in Kevlar based composites, it is observed that, hybrid composites showed good results in terms of Impact strength, tensile strength, flexure strength, fracture toughness good energy absorption capacity, and compression after impact properties. The use of surface treatment or coupling agents have helped in improving the strength, adhesive, high strain properties in the materials. The use of fillers, particles, nano-tubes or nano clays has really enhances the Kevlar based polymer materials properties.

Keywords : Kevlar, Mechanical, Hybrid, Filler.

I. INTRODUCTION

This review is dedicated to Kevlar based polymer hybrid composite materials. A composite material is made by combining two or more materials to give a unique combination of properties. The above definition is more general and can include metals alloys, plastic co-polymers, minerals, and wood. Fiber-reinforced composite materials differ from the above materials in that the constituent materials are different at the molecular level and are mechanically separable. In bulk form, the constituent materials work together but remain in their original forms. The final properties of composite materials are better than constituent material properties [1].

Composites have emerged as important materials because of their light-weight; high specific stiffness, high specific strength, excellent fatigue resistance and outstanding corrosion resistance compared to most common metallic alloys, such as steel and aluminum alloys. Other advantages of composites include the ability to fabricate directional mechanical properties, low thermal expansion properties and high dimensional stability. It is the combination of outstanding physical, thermal and mechanical properties that makes composites attractive to use in place of metals in many applications, particularly when weight-saving is critical.

FRP composites can be simply described as multi-constituent materials that consist of reinforcing fibres embedded in a rigid polymer matrix. The fibres used in FRP materials can be in the form of small particles, whiskers or continuous filaments. Most composites used in engineering applications contain fibres made of glass, carbon or Kevlar [2]. Composite supplies are most commonly used because of their finer strength and/or stiffness at a given weight as Compared to conventional structural materials. Broad market for organic fibers is a direct outgrowth of applying the basic principles of polymer science to produce a new and exceptional engineering material. In polymers its chain fibers, very high stiffness, Strengths and use temperatures could be achieved [3].

Over 70% of the total production of thermoplastics is accounted for by the large volume, low-cost commodity resins: polyethylene's (PE) of different densities, isotactic polypropylene (PP), polystyrene (PS), and PVC. Next in performance and in cost are acrylics, acrylonitrile–butadiene–styrene (ABS) terpolymers, and high impact polystyrene (HIPS). Engineering plastics such as acetals, polyamides, polycarbonate, polyesters, polyphenylene oxide, and blends thereof are increasingly used in high-performance applications. Common thermosets employed in specialized applications are Bismaleimides, polyimides, and polybenzimidazoles. Thermosetting resins are usually low-viscosity liquids or low molecular weight solids that are formulated with suitable additives known as cross-linking agents to induce curing and with fillers or fibrous reinforcements to enhance both properties and thermal and dimensional stability.

It has been frequently stated that in view of their excessive brittleness many thermosets would have been nearly useless had they not been combined with fillers and reinforcing fibers [4]. Kevlar fiber is replacing glass fibers in some of these applications because of its higher tensile strength–weight and Modulus–weight ratios than those of glass fibers. Among the application areas are boat hulls, decks, bulkheads, frames, masts, and spars. The principal advantage is weight reduction, which translates into higher cruising speed, acceleration, Maneuverability and fuel efficiency [5].

The excellent properties of Kevlar result from both chemistry and physical microstructures. In both meta- and Kevlar, the aromatic rings in the backbone chain produce high thermal resistance. In addition, in Kevlar the orientation of the chain-extending bonds produces a polymer which is an extended-chain rigid rod [3].

Particulate-filled polymer composites have a long history and consequently newcomers to the field usually expect to find an area of well-understood science with few intellectual challenges remaining. However, they are usually amazed to find that this is far from the truth in many areas, with few reliable generalizations (but several unreliable ones) available and much basic information yet to be established. This is largely due to the way in which the technology has developed, with different filler and polymer combinations tending to be developed largely piecemeal to meet the specific demands of various industries.

The initial, and to some extent continuing, emphasis on cost reduction has also meant that many fillers have been poorly characterized [6]. The present work deals with the review on mechanical properties of Kevlar composites. Literatures reviews have been carried out on the mechanical behavior of Kevlar based hybrid polymer composites which involve the use of thermoplastic, thermosets, fillers/particulates or other reinforcements.

II. EXPERIMENTAL DISCUSSIONS

Kevlar fibers are made aromatic polyamides which are long polymeric chains and aromatic rings. They are structures in which six carbon s\atoms are bonded to each other and to combinations of hydrogen atoms. In Kevlar fibers, these rings occur and reoccur to form the fibers. They were initially used to reinforce automobile tires. Since then, they have also found other uses like bullet proof vests.

As high strength applications, their use in power boats is not uncommon. They have high tensile strength, high modulus and low weight. Impact-resistant structures can be produced from such fibers. The density of Kevlar fibers is less than that of glass and graphite fibers. They are fire resistant apart from being high-temperature resistant and unaffected by organic solvents fuels. But their resistance in acid and alkaline media is poor. They are supple and allow themselves to be woven into matrices by simple processes. Kevlar fibers have a negative coefficient of thermal expansion in the fiber direction and failure of Kevlar fibers is unique. When they fail, the fibers break into small fibers, which are like fibers within the fibers. This unique failure mechanism is responsible for high strength.

Following reviews on significance of mechanical properties on Kevlar composites. Bandaru et al. [7] conducted mechanical experiment on laminates prepared by Kevlar 29 fabrics reinforced with polypropylene resin following different fiber architecture of 2-D and 3-D types. It was found that, at 10% MAg-PP with 3-D laminates showed enhanced energy absorption values for its impact loading due to interfacial bonding and failure of material by matrix cracking, fiber breakage and delamination. Bandaru et al. [8] observed improvement in ballistic impact response of Kevlar 29 fabric with polypropylene hybrid composites due to the effect fabric architecture treated with the maleic anhydride coupling agent which also helped in reducing density and interfacial property of the material.

Kapoor et al. [9] investigated properties of Kevlar with polypropylene composites with MAg grafted by vacuum assisted compression molding process. It resulted in high strain rates values of laminates by SHPB method and SEM analysis was followed to understand the failure morphology in the material. Woo et al. [10] observed that, the high strain under compressive loading on carbon/Kevlar hybrid composites by SHPB method revealed low level damage in hybrid laminates at initial level and matrix failure with brittle carbon fiber under SEM.

Manero II et al. [11] showed improved toughness and energy absorption when tested under ballistic response condition of hybrid composites. This was due to matrix toughening and strengthening at fiber-matrix interfaces. Reis et al. [12] tested impact response property of Kevlar filled cork powder, nano clay cloisite 30B fillers, followed by silane treatment of the material, which indicated improved impact resistance with higher impact absorption energy. Valenca et al. [13] fabricated hybrid of Kevlar 49/S-glass reinforced epoxy composites and it showed highest mechanical strength and stiffness of the material along with SEM images revealing fractured area.

Ou et al. [14] investigated mechanical properties of Kevlar fiber with wood flour reinforced with high density polypropylene hybrid composites indicated improved strength and toughness of the laminates and failure zone was studied by SEM analysis. Gustin et al. [15] conducted flexural and after impact tests on Kevlar/carbon hybrid, which resulted in good mechanical properties due to presence of Kevlar at both the sides of material. Fu et al. [16] developed a hybrid of thermoplastic elastomer of olefin block co-polymer with Kevlar short fiber coated with maleic anhydride grafted polypropylene composite by compression and followed by injection processes, which resulted in improved interfacial interaction with good tensile properties.

Kang et al. [17] showed that, the Kevlar with multiaxial warp-knit fabric composite resulted in better fracture toughness with reduced delamination energy over other composites. Vachon et al. [18] observed no much effect of TiNi Kevlar thread based composite under flexural loading, but better in stiffness property of the composites. Zhu et al. [19] showed that Kevlar 49 fabric composite would behave highly non-linearly under tension applied in uniaxial and bi-axial directions, as well as under shear load also.

Zhu et al. [20] investigated on Kevlar 49 composites, which resulted in increased strain rate under dynamic loading which improved mechanical and toughness properties and influence of gauge length has adverse effect on tensile strength of the composites. Varelidis et al. [21] developed Kevlar epoxy coated with polyamide 6.6 to form composite fabricated by In-situ interfacial polymerization technique, which indicated an adverse effect on the materials interlaminar shear strength, but improved fractured toughness of coated fibers. Therefore, optimizing some of the properties will lead to direct and indirect improvements in the performance of such Kevlar based polymer hybrid materials [22].

III. CONCLUSIONS

Currently, a considerable amount of work is being published on Kevlar based polymer hybrid composites. Many experimental works in the area of such polymer composites has to found, there is yet to be a compromise on how micro, nano-sized or combined affect on the material properties. This is partly due to the novelty of the area, and the challenges in processing of filled composites, lack of structured experimental results, and insufficiency of theoretical studies. Moreover, some material properties have been studied more comprehensively than other, leaving gaps in the awareness on such composite behavior. The following sections will outline some of the experimental results that are available to-date and identify the trends that can be obtained from these results. The focus of this summary will be on different particles, matrix systems on strength and fracture toughness of the composites.

In an attempt to further understand the processing and properties analysis of such polymer composites has been based on selection of important and recent literature which has been chosen to highlight some of the parameters related to the preparation and mechanical behavior of composites with micro, nano-sized in comparison with combined filled polymer composites. Some of the literature review also involves surfaces modifiers, because for most the particulate fillers they have less tendency for dispersion into, and interaction with, polymers. Surface modifiers/ surface treatments can frequently improve this, and other filler properties. Sometimes materials which are effective surface modifiers will be found to have been added for filler manufacturing reasons. From the above discussions, some trends are observed but no proper patterns for the behavior of particulate polymer composites can be said in general. In general, the material properties of combined particles filled Kevlar based polymer composites are superior to that of micro or nano filled polymer. The effects of the nanoparticles are dependent on many variables such as particle size, shape, processing techniques and modifiers nature of the polymer matrix as well as the interaction between the filler and matrix.

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