JANUARY 2017 M.Sc. in Mechanical Engineering ARKAN JABBAR FARHAN

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VIBRATION, DAMPING PROPERTY, TENSILE AND FLEXURAL BEHAVIOR OF KEVLAR-CARBON/EPOXY/NANOSILICA COMPOSITES

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MECHANICAL ENGINEERING

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ARKAN JABBAR FARHAN
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Vibration, Damping Property, Tensile and Flexural Behavior of Kevlar-Carbon/Epoxy/Nano Silica Composites

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Assoc. Prof. Dr. Ahmet ERKLİĞ

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Arkan Jabbar FARHAN

ABSTRACT

VIBRATION, DAMPING PROPERTY, TENSILE AND FLEXURAL BEHAVIOR OF KEVLAR-CARBON/EPOXY/NANOSILICA COMPOSITES

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The purpose of this thesis was to study the effect of particle contents of nano-silica on the tensile and flexural properties of interaply hybrid carbon/Kevlar fiber reinforced epoxy matrix (CKFRE) composites. The nano-silica with particle contents of 0, 0.5, 1, 1.5, 2.5 and 3 wt% were used to produce six composite laminates. The specimens and tests were conducted according to ASTM standards. The results showed that the tensile and flexural strengths were increased with the increase of nano-silica content. The highest improvement of flexural strength was obtained at 1.5 wt% content of nano-silica with increment of 35.7%. The vibration and damping properties were also enhanced with the addition of nano-silica. Furthermore, the damping ratio of hybrid composite having nano-silica content of 3 wt% was obtained 18.3% higher than unmodified CKFRE composite.

Key Words: Carbon/Kevlar fiber, nano-silica, hybrid composite.

ÖZET

KEVLAR-KARBON/EPOKSİ/NANOSİLİKA KOMPOZİTLERİN TİTREŞİM, SÖNÜM ÖZELLİĞİ İLE ÇEKME VE EĞİLME DAVRANIŞLARININ BELİRLENMESİ

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Bu çalışmanın amacı, farklı oranlardaki nano-silika parçacığının, iç içe dokunmuş (interaply) hibrit karbon/Kevlar elyaf takviyeli epoksi matris (CKFRE) kompozitlerin gerilme ve eğilme özellikleri üzerine etkisini araştırmaktır. Ağırlıkça yüzde 0, 0,5, 1, 1,5, 2,5 ve 3 nano-silika parçacıkları ile altı farklı kompozit plakalar üretildi. Numuneler ve testler ASTM standartlarına göre gerçekleştirildi. Sonuçlar, nano-silika içeriğinin artmasıyla çekme ve eğilme mukavemetlerinin arttığını gösterdi. Eğilme mukavemetinde en yüksek iyileşme, ağırlıkça % 1,5 nano-silika içeriğinde % 35,7 artış ile elde edilmiştir. Titreşim ve sönümleme özellikleri de nano-silika ilavesi ile arttı. Ayrıca, ağırlıkça %3 nano-silika muhtevasına sahip olan hibrid kompozitin sönümleme oranı, modifiye edilmemiş CKFRE kompozitinden %18,3 daha yüksek olarak elde edildi.

Anahtar Kelimeler: Karbon/Kevlar elyaf, nano-silika, hibrit kompozit

*I dedicated this thesis to (**my dear father, my kind mother and my wife**), thank you for your unconditional support with my studies. I am honored to have you as my parents. thank you for giving me a chance to prove and improve myself.*

Arkan Jabbar FARHAN

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TABLE OF CONTENTS

Page

LIST OF FIGURES

Page

LIST OF TABLES

page

CHAPTER 1

INTRODUCTION

1.1 General Introduction

Composite materials have a large significance in many applications such as commercial, industrial, aerospace, marine and medical industries. Composite materials are made of at least two or more phases which have a place with the properties and superior. The result is more prominent than those of the constituent materials acting separately. Fiber reinforced polymer (FRP) composites consist of a fibrous reinforcement bonded together with a polymer matrix in order to improve the stiffness and strength of the composite laminate. The incorporation of rigid inorganic nano-particles within FRP composites can enhance the mechanical and vibration properties, in addition to increase the applications of the FRP composites such as production of military and medical equipment as well as manufacture some parts of airplane and big boats.

1.2 Introduction to Polymer

The term polymer derives from the ancient Greek word poly mean numerous; much and parts. Polymer is along chain of particles that is made of countless units of indistinguishable structure. Polymers can be seen everywhere. There is a part of the nature itself. Polymers have low weight and it can resist corrosion with low strength and stiffness and it is not appropriate for use at high temperatures. The polymers are moderately cost and framed into various shapes, extending from plastic sacks and mechanical apparatuses to shower tubes. A specific polymer, for example, proteins and silk are found in nature while different sorts, for example, polystyrene and nylon are created just by manufactured courses. Sometimes, normal happening polymers can likewise be created by manufactured techniques. One of the imperative case is common elastic; known as polyisoprene in its manufactured frame [1, 2].

Polymers have properties of high expansion under encompassing conditions which are found critical applications with elastomer. Notwithstanding regular polymers, there are a few critical engineered elastomers, for example, nitrile and butyl elastic. Different polymers may have properties that allow for their arrangement into long filaments and appropriate for material applications as well. The engineered strands are primarily nylon and polyester are great substitutes for happening filaments, for example, cotton and fleece. Engineered polymers today discover its way in application in about each industry and region of life. It utilized generally as cements and greases, notwithstanding auxiliary parts for assembling kids' toys to flying machine [3, 4]. As opposed to the utilization of the term polymer, those business materials other than elastomers and strands that originated from manufactured polymers are named plastics. From the universe of polymers, we see a regular business plastic sap may contain at least two of polymers notwithstanding unique added substances and fillers. These materials added to enhance a specific property, for example, handle capacity, and warm or ecological steadiness, or the sorts of the last item. Today, polymeric materials utilized as a part of almost all regions of everyday life and their generation and manufacture in major overall ventures.

1.3 Thermoplastics and Thermosets

Polymers can be separated into two noteworthy classes depending up on their warm preparing conduct as thermoplastics and thermosets (Table 1.1). Thermoplastics and thermosets can be significant at the point when warmth is connected. With thermoplastic case the material will mollify and expel from the warmth brings about solidifying case, while with a thermoset, warm causes the material to smolder and decay with no softening. The iota’s in a thermoses shape with three-dimensional structure of chains with cross-interfaces between chains as well. The chain and its bonds connecting are solid and it is not easy to break. In this way, the chains impractical to slide more than each other accordingly so, thermosetting polymers are stronger and stiffer than thermoplastics. Thermoplastics show the possibility of heating and then can be pressed into to the required forms. Thermosets can not be dealt with. The processes thermosetting polymer can be shaped in where the product is formed by the chemical process.

Material is in the shape of the cross-connected chains is delivered. Thus, the outcome is a polymer molded as the frame by the shape. There are no further procedures other than perhaps some machining likely happens [5-6].

Table 1.1 Difference between thermoplastics and thermosets.

Thermoplastics	**Thermosets**
Mellow on warming and weight, and hence simple to repair	Break down on warming
High strains to disappointment	Low strains to disappointment
Inconclusive timeframe of realistic usability	Distinct timeframe of realistic usability
Can be reprocessed	Can't be reprocessed
Not shabby and simple to handle	Cheap
Short cure cycles	Long cure cycles
Higher creation temperature and viscosities have made it hard to prepare	Lower fabrication temperature
Great dis solvable resistance	Fair solvent resistance

1.4 Definition of Composite Materials

Composite materials primarily are witness for the development of the science and technology of materials. They mixed the best properties of numerous materials originating from the most up-to-date technologies, which permit them with exceptional physical and mechanical characters. This investigation of composites is a sort of logic of materials outline, that mean to enhance both the piece of materials themselves and their structure. Technology and a science, requiring firm interaction between different study materials, such as process engineering, mechanics of materials, and study of relevant materials. There is an ongoing demand for new and developed materials, due to the speed of technological developments and lead to a force for the progress of composite materials. Due to high cost of developed composites is less expensive. The advances in technology field led to the quest for access to modern and more advanced materials.

Where this progress and innovation in composite materials play an important and major role in the science of composite materials. Thus, the high cost of composite materials, which demanded for the use of less expensive materials and with the higher resistance and performance. States of a composite result from components of its constituents, and from the designing and dispersion of the stage. The volume (or weight) fraction of the reinforcement fibers can be considering a standout amongst the most significant parameters. The appropriation of the reinforcing conveys the arrangement of its elements. Minimal uniform of the support, not coordinating the material and the highest point of the likeness of the disappointment in the most helpless, though the geometry and direction of the reinforcement conflict on the anisotropy of the framework. The composite stages prompt couple of developments and depend on the class and completing of the composite itself. In the expressions of black out or center execution composites, reinforcement made consistently, and made out of abbreviated fibers or particles, which take into account particular stiffness and, advancing the material just locally. They are habit made out of consistent fibers constructing the edge work of the material and convey it solidness and resistance toward the fiber course. The lattice arrange exchanges the demonstration of protection, upgrade the fibers, and transmit of nearby push from a fiber to another. The between stage, despite its minor shape in measurement, can assume a high part in controlling the disappointment systems [7]. At present time, we can observe a fast advancement and development in composite material technology, and this will supply the market with new products of these material. The expense of the materials can be reduced due to the reaction to the increasing requirement [8]. So, fiber-reinforced composites are quickly got the market share, but more growth be limited with their lack of stiffness.

Lightweight construction has been turning out to be progressively huge in many industries, particularly in aerospace, what's more, car ingenuities. This previously mentioned material composites are draw more consideration for these weight-touchy determinations as their fabulous strength and solidness are joined with a low thickness. Sadly, the cost of their restricted durability is coming at the high solidness and strength of these composites. As most materials, fiber reinforced polymer (RFP)composites additionally experience issues in reinforce versus unpleasant with troublesome cases.

Throughout the years, roughing of fiber- reinforcement polymer composites are still a region of exceptionally dynamic study. A variety of procedures have been proposed to make these materials more harmed safe and less delicate as well. A standout amongst the broadest looked into system is roughing of the polymer grid by agreement the polymer science, by rubbers, thermoplastics and so on. What's more, by this procedure, the risen network sturdiness has huge part on the lattice principle composite properties and the building composite characters [9-10]. Through looking for new toughening components there is still an expanding enthusiasm for structure property relations of characteristic composites which are particularly adaptable to disappointment [11-12].

1.5 Advantages and Disadvantages of Composites

Composite materials bring a significant advantage by collecting the original properties of the contained material. Today, composite materials produced in system to ensure adaptation with outstanding features include the difficult working cases. Superior features are expected from a material generally is as below:

• High strength,

• High rigidity,

• High fatigue resistance,

• Excellent wear resistance,

• High temperature capability,

• High consumption resistance,

• High warm conductivity,

• Formability,

• Low thickness,

They limited the number of complex parts because of the produced part as a single. Thus, the reduction in production time has been shortened. All of features mentioned above in a composite material can got it if it is considering to suitable matrix/reinforcement element pairs, manufacturing techniques, the strength shapes of the components and other factors. The act of choosing of suitable matrix/reinforcing elements is important due to the mechanical and physical characters of the system. For a composite material, the interface bond between matrix and reinforcement elements should be strong to transmit the load from matrix to reinforcing element. This depends upon the harmony of pair. Besides, apart from the production technique selection, the homogeneous distribution of the reinforcing elements in the matrix/resin depends upon the choice of matrix alloy and reinforcing element too [13-14]. Besides the above-mentioned excellent properties, some disadvantages will also be there for composite materials. These are as follows:

• Production difficulties,

• It is expensive,

• There is no recycling for composite material,

• Operating problems,

• High operating costs,

• It is difficult to reach to the required surface roughness,

• The air particles in the polymer based on composite materials adversely effects on the fatigue properties of material [15-16].

1.6 Definition of Hybrid Composite

The hybrid composite is the most part used to draw a grid containing no less than two sort of reinforcement or more**.** The disappointment durability and strain may be critical to rise if fragile fibers are utilized rather than malleable fibers. In this situation, metal fibers will be have high solidness and huge disappointment strain as well, however these are restricted by its high densities. Polymer fibers, then again, this has low densities and can be pliable, yet are constrained by their low stiffness and little temperature quality. Due to the drawbacks of these toughening strategies and the strong require for new lightweight materials with enhancement and toughness, the research interest in ‘‘hybridization’’, is resuscitating [17-18]. Hybrid composites are entrancing structures materials, since the composite properties can be blended or worked to be good to the requests. This implies hybrid composites molded of at least two sorts of reinforcements or frameworks or the two one. By brushing two unique filaments, it may conceivable to join the benefits of two distinct strands while coincidently diminish the effect on their less attractive qualities. Normally, one of the filaments in a hybrid composite will be with high cost, , and high modulus fiber for instance carbon/graphite, and the other fiber more often than not will be a low modulus, little cost fiber, for example, Kevlar, S-glass, or E-glass [18-19]. Hybrid composites including four major kinds.

- According to a specific result, reciprocal hybrids, which are compose of plies from two or more that move towards one direction composites stacked.
- Reciprocal hybrids, made of two or more different fibers mixed in the same layers.
- Reciprocal hybrids, in which can be built due to a given result.
- Huge hybrids, which are resin-matrix composite plies organized in accord with certain arrangements.

It is known that hybrids composite may be obtained more effective in case of the cost, using fibers which has low cost and better mechanical and physical properties. in other words, hybrids composite in the field of polymer which contain mixing of the different materials in a resin-matrix. It is cleared, using hybrids composite which has high strength, stiffness and good damping properties.

Therefore, hybrids composite materials are divided according to common reinforcement materials such as, fibers, particles, flacks and layers [20-21]. It is known that the properties and the features of type of the composite materials are limited, where many components can be affected and depended on the kind of the fiber reinforced materials, distribution of reinforced phase in additional to the comprising of polymer, where the amount of reinforced materials and the nature of interface area can be between the reinforced phase and supplemental phase [18]. From these issues, which must be known that the composite materials can be composed of one or more than main phase and a fiber reinforced material by the sake of getting many compounds as an outcome, by bonding the reinforced materials and main materials resulted from the hybrid composite materials [22].

1.7 Composite Material Properties

The general uses and engineering of the composite materials broadly relied on the mechanical properties, for example, flexural, Tensile, impact, fatigue, buckling and vibration properties, etc. All these materials are depended on the component of polymer (Epoxy, polyester), the particle weight and reinforcement. Hence, these materials are widely centered on the reinforcement materials and added materials such as, the practical [23].

1.8 Definitions of Tensile and Flexural Strength and Vibration Damping

Tensile stress occurs when tensile (object is controlled to forces which make the object extends. Tensile strength can be described as the limit of a material to resist tensile stress without causing failure on the material. General instance of tensile stress is lengthening a rubber band and if the stress is further its strength, then the rubber band will fail.

1.8.1 Tensile strength

Tensile strength is considered as measure of susceptibility condition of the materials upon stabled force which will be done on pull and break it. The fibered composite materials contain fibers which are strong and brittle submerged by the main material which are described being more ductile. The composite material with extending as a line at the beginning corresponding to the shed efforts by continuing loading by this method, turning is occurred as result for reaching the main materials to a yielding point. Meanwhile, the fibers continue by extending until its resistance is demolished. When the main material demolished, the composite materials will have failed [23].

1.8.2 Flexural strength

The properties of flexural is regarded as measure for the strength bending. It can be described to maximum settled loading which can be shed on the paradigm test before to produce or break. When the flexural strength is shed on the layered composite material, so the similar efforts be balanced with elasticity properties for the layers by arranged inside the composite materials. The different in properties of layers' lead to the beginning of the failure inside the layer more than in exterior surface as it be done with the integrated material properties [23]. In the meantime, the flexural strength can be characterized as the cutoff of a material to oppose flexural push without disappointment. In the event that a protest is subjected to flexural push, it will move under strain and pressure conduct because of twisting minute. Flexural strength of a material will rely on either its elasticity or compressive strength, which is lesser. Most common instance of a flexural stress is by bending into a U shape. The upper surface of the specimen will be subjected to compressive stress action while bottom surface will undergo tensile stress. If you bend it further, you may see the bottom surface of the specimen will start to move to crack, which indicates that it the stress applied to it after its flexural strength limitation.

1.8.3 Vibration and damping

Vibration can be characterized as perpetual development for a protest or framework, as it were unpredictable question are expelled from the balanced place [24]. The mass and flexible protest object can be perfect to vibration where most technology and designing composite struggle with degrees of vibration.so, they need in comprising and design them and we must take into consideration frequency conduct [24]. Damping is defined as a mechanism that dissipates vibratory energy in another form of energy (e.g. heat in the case of viscoelastic damping). In the transportation industry, vibration damping solutions are used to reduce the vibration level of the different panels. This gives an improvement of the long-term reliability of the different parts and an increase of the acoustical comfort of the passengers [25].

1.9 Significance of the Study

The technological interest in producing lighter and higher quality materials is due to the possible reduction of the costs and this prompt pull in new clients. The composite strength depends on the stages that it required furthermore on the procedure. Fiber development in various weft and twist grants to an assortment of mechanical properties and can be created for a given part plan and lead to attract new customers. The composite strength is based on the phases that required and also on the process. Fiber construction in different weft and warp permits to a variety of mechanical properties and can be generated for a given part design CKFRE fibers are widely known reinforcement substance for their excellent characteristics such as the ideal mechanical ability and modulus of elasticity, low density, and good flame resistance. It makes carbon fiber irreplaceable in wide sectors of engineering technology such as for automobile, aircraft, ships, construction works, and sport equipment. However, Kevlar- carbon fiber composites are rather susceptible to stress concentration due to the brittleness of carbon fiber. In addition, carbon fiber needs costly production. One way to improve the weakness of carbon fiber reinforced plastic (CFRP) composite is by replacing some layers of the carbon fiber and by ductile fibers such as Kevlar fiber. More tough and less flexural influenced materials can be touched base with the utilization of hybrid composite material. Material dispersion in layers, required number of layers to stay away from flexural and can be resolved.

1.10 Methods and Outline of the Study

In this work, preparation of intraply hybrid composites was achieved by selecting carbon/Kevlar fibres reinforcements while epoxy resin used as matrix. The following must be prepared based on ASTM standard: hybrid composite laminates are kinds for tensile, flexural tests and vibration damping. There are five chapters in this study. In chapter one important concepts and definitions about the composite materials, hybrid composites, tensile, flexural strengths and vibration damping are presented. As well as, advantages of this work and thesis outline are presented in this chapter. Literature review is given in chapter 2. Also, chapter two discussed important factor that effect on the mechanical properties of the hybrid composites materials. Chapter three explain task of production unit and production methods of the composite and hybrid composites. Additionally, this chapter explained the mechanical properties of CKFRE and analysed the test methods that used to determine these properties. Chapter four present the tensile, flexural, vibration damping experiments and discussing the results that obtained from these experiments and also study the effect of the configuration on the mechanical properties. Important conclusions and suggestion idea for future work are presented in chapter five.

CHAPTER 2

LITERATURE SURVEY

2.1 Introduction

In the literature survey, some investigation is observed about effects of different fillers on mechanical, thermal and some other properties of composite material. Presented study is about effect of particles on the mechanical properties of composite material hence, similar studies in literature are investigated prior to any work. A brief literature related to composite, hybrid composite materials, tensile, flexural strength and vibration damping of composite materials is presented in this chapter. Literature survey has been grouped in four areas: concentrates on composite overlays and a few variables impact on their attributes are explored in section 2.2, general mechanical properties of fiber-strengthened composite plates are checked in section 2.3, hybridization effect on tensile and flexural strengths of carbon, glass and Kevlar fibers reinforced composites plates are surveyed in section 2.4, conclusion on literature review is assessed in section 2.5.

2.2 Studies on Particle Filled Composites

Particulate reinforced polymer composite materials are used for various engineering applications as well as production of electrical products, computer housings, etc. In order to provide unique physical and mechanical properties with a low specific weight, the particles used in composites are borax, perlite, silicon carbide, fly ash, sewage sludge ash, silica, etc. The filler morphology, size, particle amount and the dispersion homogeneity influence extensively the composite' performance.

Sayer [26] studied the effects of the various ceramic particles on elastic properties and load carrying capabilities of E-glass/epoxy composite plates. Effects of particles on mechanical properties were determined experimentally and numerically.

The composite plates are filled with 0% (unfilled), 5%, 10% and 15% particle weight fractions (based on the weight of composite), of silicon carbide (SiC), which has two particle sizes, aluminum oxide (Al_2O_3) and boron carbide (B_4C). The outcomes showed that the heap conveying capacity of composites are impacted by molecule weight divisions, distinctive molecule sizes and diverse earthenware particles (fillers). Accordingly, the load carrying capabilities of composites filled with 10 wt% ceramic particles were found higher for small particle sizes. Moreover, the addition of 10 wt% boron carbide (B_4C) particles to composites increases the critical buckling load value of composite up to 42 %.

Asi [27] examined the mechanical properties of glass-fiber strengthened epoxy composite loaded with various extents of Al_2O_3 particles. As a correlation, the mechanical properties of unfilled glass-fiber strengthened epoxy composite was likewise assessed under indistinguishable test conditions. Compared with the flexural properties of the unfilled glass-fiber strengthened epoxy composite, with the addition of 10 wt% of Al_2O_3 particles in the matrix flexural strength and flexural modulus were increased by 33 and 78 %, individually.

Setsuda et al. [28] considered the effects of fly ash in composites created by injection molding. The outcomes showed that the substance of fly ash debris is profoundly huge and contributive to the shrinkage proportion and bowing strength. The shrinkage proportion, bending strength and flexural modulus of LDPE composites containing crude fly ash powder were found to progress. The shrinkage proportion and flexural modulus of PP composites containing ground fly slag were additionally found to move forward.

Gu et al. [29] prepared epoxy composites filled with fly ash having different volume fractions and investigated damping properties of prepared composites. Fly ash volume fractions were 30, 40, 50 and 70 vol%. The maximum value of damping of the composite was obtained with 30 vol % fly ash addition. All volume fractions of fly ash give higher damping ratio than unfilled epoxy composite. They found that the addition of fly ash certainly enhances the damping capacity of epoxy resin.

The nano-sized silica (30 nm in size) particulates reinforced poly (ether ketone) (PEEK) composites were fabricated by Lai et al. [30]. The dynamic modulus of the

PEEK nanocomposites showed over 40% increment in thermomechanical properties of the PEEK matrix

Ruse et al. [31] examined the effects of zinc powders on high density polyethylene (HDPE) composites in terms of mechanical and thermal properties. Volume fractions were used zinc powders as 0 to 20 %. They found that, addition of zinc powder reduced mechanical properties, but density and hardness of HDPE/zinc composites increased as compared to unfilled HDPE composite. Also, thermal stability of HDPE/zinc composites is better than unfilled composite.

Patnaik et al [32] investigated effects of different ceramic particles on mechanical properties of glass fiber reinforced polyester composites. Fly ash, Al_2O_3 and SiC ceramic particles were used as filler materials. It has been found that type and ratio of particles affected tensile strength, flexural properties, interlaminar shear strength, density and hardness of the composites. Addition of these fillers drastically reduced the tensile strength of composites, but 10 wt% addition of fly ash increased flexural strength compared to all other fillers.

2.3 Composite Laminates and Some Factors Effect on Their Characteristics

There are many factors that effect on the properties of laminated composites which cannot be confined to such research, but some of them mentioned. Ann et al [33] investigated the failure analysis of composite materials of unidirectional woven fiber which used in airplane control rod by experimentally and numerically. Specimens having many unlike geometries (formed changing the width to hole diameter and the edge distance to the hole diameter ratios, considering hole size constant) were used in the test. Failure modes and loads were determined by testing under pin loading and effects of different geometries were obtained. Also, numerical analyses were done and results were compared. It was found that these different geometries have a huge effect on the composite properties.

Aktas and Karakuzu [34] investigated the effects of temperature on mechanical properties (tensile, compressive, shear) of glass/epoxy composite plates. The used temperatures of experiments were 20°C, 40°C, 60°C, 80°C, and 100°C. Laminated composite plates were cured at constant pressure of 250 KPa with a constant temperature of 120 °C and a curing time of 2 h. After that, laminated composite plates were cooled to room temperature at constant pressure of 250 KPa. It was shown that reduction of mechanical properties caused by increasing of temperature.

Zou and Lam [35] investigated the effect of layer numbers, lamina thickness, ratio of Young's modulus in plane and lateral direction and fiber orientations (cross-ply and angle-ply) on buckling were researched using FEM (using high-order shear deformation theory of buckling). It was found that these factors have a huge effect on the composites.

Sun et al [36] studied numerically the delamination effects on compressive failure response of composites. Von Karman's equations used to include nonlinearities was used to find buckling, post buckling, contact influences of delaminated region, progress of delaminated region, fiber and matrix cracking. Progress of delaminated region was considered by using a fracture theory which controls energy dissipated during fracture along delaminated region. It was concluded that delamination growth is influenced extremely from boundary types, and stiffness deterioration have considerable effects on buckling strength.

Krishna et al. [37] studied the mechanical properties of granite powder as a filler of composite material. The granite powder was added at different weight percentages (30, 35, 40, 45, 50, 55 and 60 wt%) to the epoxy resin. It was found that, the elasticity and effect strength were at a greatest for the half rock powder-strengthened epoxy composite, while they diminished at 60wt%. The concoction resistance test demonstrates that the composite materials are impervious to acidic corrosive, concentrated hydrochloric corrosive, sodium hydroxide, benzene, carbon tetrachloride, and n-hexane at half support of stone powder.

Sheer et al. [38] dealt with the investigation of mechanical properties of Potassium strengthened epoxy based Polymer Matrix Composites (PMCs). Epoxy composites loaded with PTW in different substance of 0, 5, 10, 15 and 20 wt% were prepared using the casting technique. Thickness, hardness and warmth redirection temperature of epoxy were found to increase with increasing of Potassium content. However malleable and flexural properties of the made composites showed a changing example concerning Potassium content. Epoxy stacked with 10 wt% of Potassium showed awesome change in flexibility and flexural strength. It was watched that

Potassium is not useful in upgrading the impact nature of epoxy. Composites with 20 wt% of Potassium showed minimum effect strength.

Nitin and Singh [39] studied the mechanical behavior of reinforcing epoxy matrix by walnut particles at different weight percentages 10, 20, 30 and 40 wt%. Increment of wt% of walnut particle from 10 wt% to 20 wt% was especially successful for misfortune in extreme elasticity and pick up in rate of lengthening, in contrast with increment in 20-40% wt. Impact on modulus of versatility was practically reliable. The thickness acquired is exceptionally appropriate for light weight application

2.4 Hybridization Effect on General Mechanical Properties of Fiber Reinforced Composite Plates

Sarasini et al. [40] studied the effects of basalt fiber hybridization on low velocity impact behavior of carbon/epoxy laminates. Hybrid samples with two distinctive stacking successions (sandwich-like and intercalated) were produced. Results demonstrated that hybrid overlays with intercalated configuration (substituting succession of basalt and carbon textures) have better effect vitality ingestion ability and upgraded harm resilience as for the all-carbon covers, while mixture covers with sandwich-like configuration (seven carbon texture layers at the focal point of the overlay as center and three basalt texture layers for every side of the composite as skins) present the best flexural conduct.

Peijs and De Koki [41] studied the elastic and exhaustion conduct of unidirectional carbon-elite polyethylene/epoxy crossover composites including the effect of hybrid outline and surface treatment of the superior polyethylene (HP-PE) filaments. Results showed that the ductile conduct of carbon-HP-PE hybrids in both monotonic and exhaustion testing can be translated. Receiving the traditional 'consistent strain' demonstrate for hybrid composites. hybrid effects under tractable stacking conditions were in sensible concurrence with computations representing measurable impacts and stretch fixations as dictated by limited component investigations.

Shan et al. [42] studied environmental fatigue and life expectation of unidirectional glass–carbon/epoxy hybrid composites. The results indicated that a much better performance in fatigue can be achieved for glass–carbon hybrid composite by incorporating appropriate amount of carbon fibers in glass fiber composite.

Gustin et al. [43] investigated impact, compression after impact, and tensile stiffness properties of carbon fiber and Kevlar (CKF) sandwich composites. CKF hybrid composite plates were prepared considering impact side. Carbon fiber was kept in the bottom side (tensile side) of plates due to its high flexural stiffness. The focus of this research was to determine if any improvement in impact properties existed as a result of replacing the impact-side face sheet layers of carbon fiber with Kevlar or hybrid. Impact tests were conducted on different sample types to obtain information about absorbed energy and maximum impact force.

Yadav et al [44] improved fracture toughness of carbon fibre epoxy composite with Kevlar reinforced interleave. Flexural modulus declined up to 12% by interleaving and improved up to 6% by increasing amount of Kevlar.

Kitano et al. [45] researched the effect two different fibers on the mechanical properties of HDPE matrix. Long and short glass fibers and one of the organic fibers such that Kevlar-49, fluid crystalline polymer (LCP) and vinylon in hybrid composites. The main objectives of the paper are the analysis of the effects of fiber loading, their length and hybrid mixing ratio on the properties of the composites.

Fonseca et al. [46] investigated the properties of polyethylene-(pine/agave) fibers based hybrid composites made with two characteristic fibers: agave and pine. The outcomes showed that expansion of agave fibers enhances affect, elastic and flexural strength, while pine fibers diminishes water take-up.

Ramesh et al [47] produced hybrid composites made of sisal–jute–glass fibers and their tensile, flexural and impact strengths are measured. It is found that the usage of sisal–jute fiber with GFRP can developed the mechanical properties.

Fernandes et al [48] fabricated composites from HDPE filled with fitting powder and coconut short fibers. The extension of coconut fiber to cork–HDPE composites extended the adaptable modulus and inflexibility by 27% and 47% independently, stood out from cork–HDPE composites.

Boopalan et al. [49] observed the effect of adding banana fiber to jute-epoxy composites and obtained increased mechanical properties with lower moisture absorption.

Naik et al. [50] explored impact and post impact compressive attributes of carbon-glass/epoxy hybrid composites with different stacking arrangements. In their concentrate, plain weave E-glass and twill weave T-300 carbon have been utilized as reinforcing materials. Likewise, containing covers just glass and carbon reinforcement have been considered for examination. Trial examines have been done on instrumented drop weight impact test. It was observed that hybrid composites are less sensitive compared to only-glass or only-carbon composites. Moreover, carbon-outside/glass-inside collected hybrid arrangement gives lower impact sensitivity compared to the other hybrid arrangements.

Pandya et al [51] examined hybrid composites made of 8H satin weave T300 carbon and plain weave E-glass fabrics under in-plane quasi-static tensile and compressive loading. It’s reported that putting glass layers in the outside and carbon layers in the inside give highest tensile strength.

Sevkat et al. [52] explored the repeated impact effects on hybrid composites made of S2-glass and IM7 graphite fibers with epoxy resin. Impact tests were repeated at 32 J by a 6.15-kg, 16-mm diameter hemispherical drop-weight steel impactor. It’s found that, hybridization of graphite/epoxy composite with glass layers changed the progressive damage of the hybrid composite.

Hwang and Mao [53] investigated buckling characteristics of inter-ply hybrid composites (E-glass /Epoxy and Carbon/Epoxy) including delimitation. It was found that nonlinear buckling analysis gave near results with experimental results.

Önal [54] studied the buckling analysis of symmetrical and antisymmetric cross-ply layered hybrid composites (Boron/Epoxy and E-glass /Epoxy) plates having inclined crack. The buckling characteristics were determined using finite element and first order shear deformation theory.

Hosur et al. [55] researched impact response of hybrid composites using impact testing machine–Hybrid composites were produced with plain weave S-glass and twill weave carbon fibers. Square plates having dimensions 100 mm × 100 mm and thickness 3 mm were exposed to low velocity impact loads at 4 energy levels of 10, 20, 30 and 40 J. Experimental studies showed that there is an important increase in load carrying capability of hybrid composited with small decrease in stiffness compared with carbon/epoxy composite.

Belingardi et al. [56] used a hybrid biaxial intraply glass–carbon fiber reinforced epoxy matrix composite. its bending fatigue behavior laminae as well as biaxial glass laminae and biaxial carbon laminae was considered.

Marom et al. [57] examined the effects of stacking sequence and hybridization level on impact strength of hybrid composites. Hybrid composites were produced with carbon and Kevlar fibers and epoxy resin. When one carbon layer was putted between two Kevlar layers, positive hybrid effect was seen.

Duran et al. [58] evaluated effect of drilling to delimitation formations. Two types of laminates (Carbon/Epoxy and Glass/Epoxy) were drilled using different machining parameters and comparing drill geometries. Results showed that the importance of a careful selection of machining parameters when drilling of composites is involved.

2.5 Tensile, Flexural, Vibration and Damping Properties of Hybrid Composite

Park and Jang [59] examined the position effect of polyethylene (PE) fibers in carbon-PE/vinyl ester hybrid composites on mechanical performance. They used PE fibers because of its high elongation at break, and high specific strength and stiffness. They concluded that the mechanical properties of hybrid composite strongly depended on the reinforcing fiber position, such that, when carbon fiber was positioned at the outermost layer, the hybrid composite showed the highest flexural strength.

Guru Raja and Hari Rao [60] examined tensile properties of glass / carbon - epoxy composites for different ply angles. The accompanying conclusions were drawn and recorded: (a) The glass strands come up short rapidly than the carbon filaments. The five layers of glass utilizes at front restricted the connected load more prominent than the five layers of glass handles at back in woven glass/carbon hybrid composites. (b) Incorporation of woven glass/carbon in outrageous handles of composites upgrades the enhanced mechanical properties of hybrid composites. (c) Failures of composite materials incorporate the break of filaments, crack of lattice in pressure typical to the strands. Scanning electron micrographs demonstrated that the fiber hauls out began from glass filaments and great interfacial security was created between woven glass and epoxy tar grid. In any case, some micrographs are uncovered the nearness of voids, in this way debasing the quality.

Subgiant et al. [61] investigated the effect of different stacking sequences of carbon and basalt fabrics on the flexural properties of hybrid composite laminates. The hybrid composites were manufactured using vacuum bagging. Their outcomes demonstrated that all the stacking arrangements demonstrated a positive hybridization impact. The exchange hybrid composite with carbon fiber at the compressive side displayed higher flexural strength and modulus than when basalt fiber was put at the compressive side.

Ary Subgiant and Kim [62] researched the flexural properties of the carbon-basalt/epoxy hybrid composites according to number of basalt layer and stacking sequence. Experimental studies showed that position of carbon and basalt fiber on laminate directly affecting the flexural properties of hybrid composites. Carbon fiber in tension side have the highest flexural strength in accordance to hybrid configurations.

Li et al. [63] investigated the compressive and flexural behavior of ultra-high-modulus polyethylene fiber and carbon fiber hybrid composites. Hybrid composites were produced with different hybrid ratios. The results showed that the joining of a direct measure of carbon fiber into an UHMPE-fiber-strengthened composite incredibly enhances the compressive strength, flexural modulus and flexural strength while the increase of a small amount of UHMPE fiber into a carbon reinforced composite essentially improves the flexibility with just a little reduction in the compressive strength .

Dong and Davies [64] concentrated on the flexural properties of hybrid composites reinforced by S-2 glass and T700S carbon fibers. It was demonstrated that flexural modulus increases when span to depth ratio increases from 16 to 32 They proposed the simple formula for prediction of flexural modulus of hybrid composites.

Davies [65] searched flexural properties of unidirectional carbon fiber-reinforced polymer matrix composites. Composite plates were tested using concentration of epoxy (45–65 wt%) within an acetone solution for wetting the carbon fibers. It was found that the maximum flexural strength was of 1292 MPa by using 50 wt% of epoxy resin content.

Diharjo et al. [66] researched the replacement of glass fibers with carbon fibers on both upper and lower sides symmetrically of hybrid composites. Produced specimens were tested using four-point bending method. The outcome demonstrated that increase of carbon fibers are increased the flexural strength and modulus of hybrid composites. When weight percent of carbon fiber reached to 90%, maximum flexural strength is gathered.

Pavia et al. [67] studied flexural, shear, tensile and compressive tests of carbon fiber reinforced composites (CFRC) based on tow epoxy resin systems (8552^{TM} and F584 ^{TM}) and 2 carbon fiber fabric reinforcements (Plain Weave (PW) and Eight Harness Satin (8HS)). It was observed that the F584-epoxy matrix laminates give higher mechanical properties in the tensile and compressive tests than 8552 composites.

Do Rigato and Poretti [68] investigated the behavior of epoxy laminates Carbon, basalt and E-glass-balanced woven fabrics under fatigue conditions. indicated superior performances of BF laminates with respect to the corresponding GF composites.

Davis et al. [69] studied the improvements in tensile strength and stiffness and durability of carbon fiber reinforced epoxy composite laminates, with 0.2, 0.3 or 0.5 weight percent (wt%) fluorine functionalized ‘‘XD” carbon nanotubes (f-XD-CNTs) strategically incorporated at the fiber fabric–matrix interfaces.

Ho and Lau [70] hybridized short silk fibers with the woven glass fiber reinforced polymer composites to obtain hybrid composite which has better Young's modulus and impact resistance properties. As a result of experimental studies 0.4 % wt. addition of short silk fiber had better tensile and impact strengths.

Ratnakar and Shivanan [71] studied experimentally the strength and stiffness of glass-graphite/epoxy fiber reinforced composites under flexural loading. The fundamental discoveries of this examination that thickness of hybrid composites is directly affecting flexural strength.

Dong et al. [72] studied the flexural strength of hybrid epoxy composites reinforced by S-2 glass and T700S carbon fibers in an intra-ply configuration, several stacking configuration of carbon fiber and glass fiber laminas were considered. The flexural strength was acquired from the three-point bending test. It is seen that increase of percentage of S-2 glass fibers decreased flexural modulus. Positive hybrid effects occurred when carbon fibers take placed with glass fibers.

Petruccianiet al. [73] studied hybrid laminates, including a basalt fiber core, proved interesting to suggest which combinations of the three reinforcements, glass fibres and two ligno-cellulosic fibres, hemp and flax to improve the tensile, flexural and interlaminar shear strength tests (ILSS). The mechanical performance of all the hybrid laminates appears superior to pure hemp and flax fiber reinforced laminates and inferior to basalt fiber laminates.

Almeida et al. [74] investigated the effect of hybridizing glass and curaua fibers on the mechanical properties of their composites. Composite specimens have been produced using hot press from pure glass, pure curaua and hybrid of them with different volume fractions. It can be derived from experimental studies; mechanical performance of vegetable/synthetic fiber can be increased with addition of glass fibers.

Zhang et al. [75] investigated the strength of hybrid composite laminates using varying ratio of glass woven fabric and carbon woven fabric in an epoxy matrix. It is shown that better the best flexural properties when the carbon layers are at the exterior, hybrid composite laminates with 50% carbon fiber reinforcement provide while the alternating carbon glass lay-up provides the highest compressive strength.

Wan et al. [76] evaluated the mechanical properties of unidirectional and three-dimensional (3D) braided carbon/Kevlar hybrid fibers. It was found that the hybrid composites showed significant improvements in flexural strength and interfacial adhesion strength (IAS) after two-step surface treatment, suggesting this process was efficient.

Valença et al. [77] studied the mechanical properties of epoxy matrix (DGEBA) reinforced with Kevlar fiber plain fabric and Kevlar/glass hybrid fabric plate. It showed that Composites with Kevlar/glass hybrid structure in the reinforcing fabric give better specific mechanical strength.

2.6 Conclusion on Literature Review

The selection of these literatures was focused on the behavior of composites by reinforcing them with different types of reinforcement materials, modifying of particulate reinforcing and the mechanical tests that related to our work. The concluded remarks from the literature survey are as follow:

- In the above survey, there are numerous studies on polymer grid composites and some mechanical tests are carried out on them, e.g. tensile and flexural.
- From the above literature, there are few studies deal with carbon/Kevlar fibers. Moreover, Particle reinforcement had not been used with carbon/Kevlar fibers for improving mechanical properties.
- The particle used in reinforcement of composite namely: fly ash, clay, borax, perlite, Al_2O_3 and SiO_2, carbon nanotube etc. are mostly in micro and nano scale.
- The presence of hybrid effects is still a question due to the changed results. This study expects to expand on these outcomes by using distinctive setups of twill woven carbon/Kevlar fiber, layers and researches did not covers many issues about the tensile, flexural, vibration and damping behavior.
- In this study, the CKFRE composite contains 8 layers of (CKF)as reinforcements with addition of nano-silica within epoxy have been produced in order to obtain the tensile, flexural, vibration and damping properties.

CHAPTER 3

EXPERIMENTAL STUDIES PRODUCTION OF COMPOSITEPLATES AND DETERMINATION OF MECHANICAL PROPERTIES

3.1 Introduction

This chapter demonstrates the production of composite plates and determination of mechanical properties of these laminates.

3.2 Materials

In the production of composite plates, twill 2/2 woven carbon-Kevlar fabric having 210 g/m^2 areal density have been used. MGS L285 epoxy resin and MGS H285 hardener were used at a ratio of (1/0.285) and nano-silica particle in the production of composite plates.

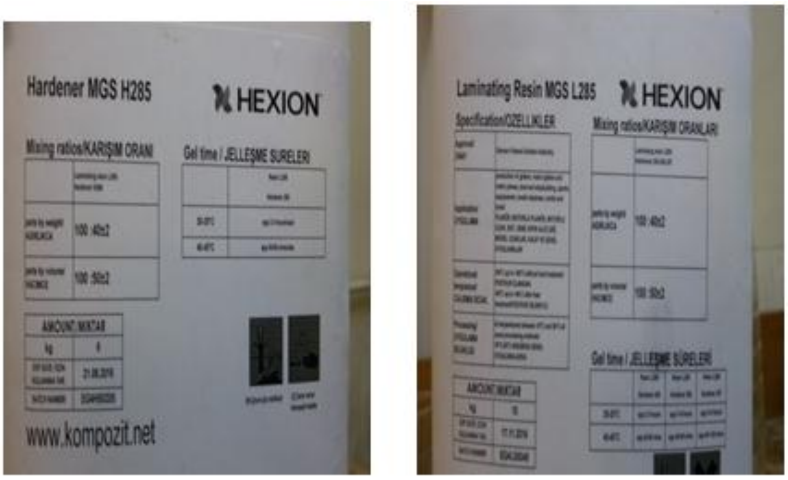


Figure 3.1 Epoxy resin & hardener

3.2.1 Nano- silica

Nano-silica (NS) particular sufficiently uniform dispersed in polymer material– which can be overall improved in performance comprising. NS is an inorganic chemical material commonly known as silica, since the ultrafine nanometer size rang 1-100nm, and therefore has many unique properties to the other inorganic material. NS was supplied from Grafen Chemical Industries, Turkey with a high purity 99.5%, average particle size is 15 nm, specific surface area is 300 m^2/gr and bulk density is 0.05 gr/cm^3. SEM image of NS particles is shown in Figure 3.2.

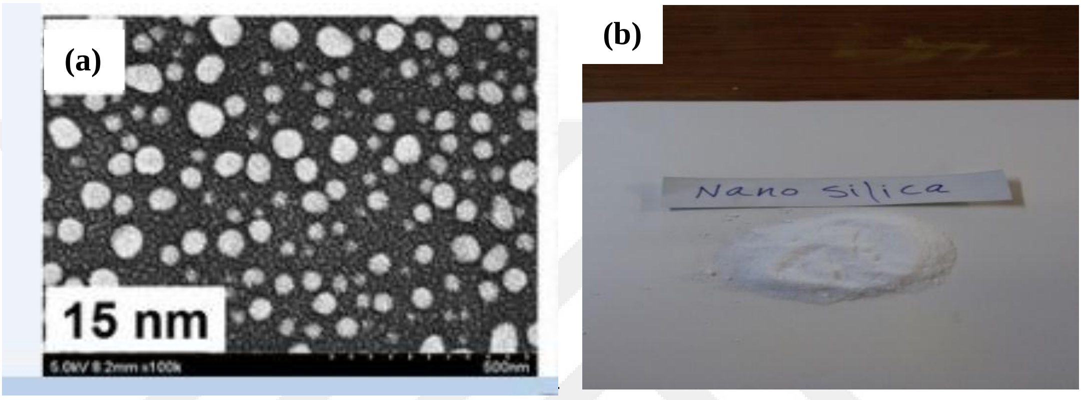


Figure 3.2 (a) SEM image of NS particles, (b) NS particles

3.2.2 Carbon/Kevlar fibers

Carbon Kevlar hybrid fabrics are used in aerospace and marine applications, in construction, transportation, and for decorative purposes. An example of using hybrids in aerospace applications is to utilize the natural toughness of Kevlar to offset the brittleness of typical carbon fiber. 2x2 twill weave carbon/Kevlar hybrid fabric as shown in Figure 3.3 (3K Carbon and 158 Tex Aramid in warp and weft) having areal density of 210 g/m^2, thickness of 0.23 mm was supplied from Dost Kimya Co., İstanbul, Turkey.

Figure 3.3 Carbon/Kevlar fiber used in this study.

3.3 Production of Hybrid Composite Laminates

Fibers were cut to the dimensions of 300 mm × 260 mm by using EC fiber cutter as shown in Figure 3.4. Particle and epoxy resin were mixed with a mixer at constant speed (800 rev/min) for 20 min in a bowl before hardener was added at a ratio of 0.285 by mass of epoxy. After addition of hardener mixer was continue to mixing process for 5 minutes to get homogeneous mixture. Composite laminates were produced by hand lay-up process at room temperature (25°C). Epoxy and nano-silica mixture has been laid to the fabric layer by layer with the use of brush. Plastic plate was used for each layer to prevent air bubbles and voids in the composite (Figure 3.5a). This process is repeated till all the 8 layers were placed. After that the wetted composite laminate was transferred to the production unit shown in the Figure 3.5b.

Figure 3.4 Cutting fibers by EC, Carbon/Kevlar fiber.

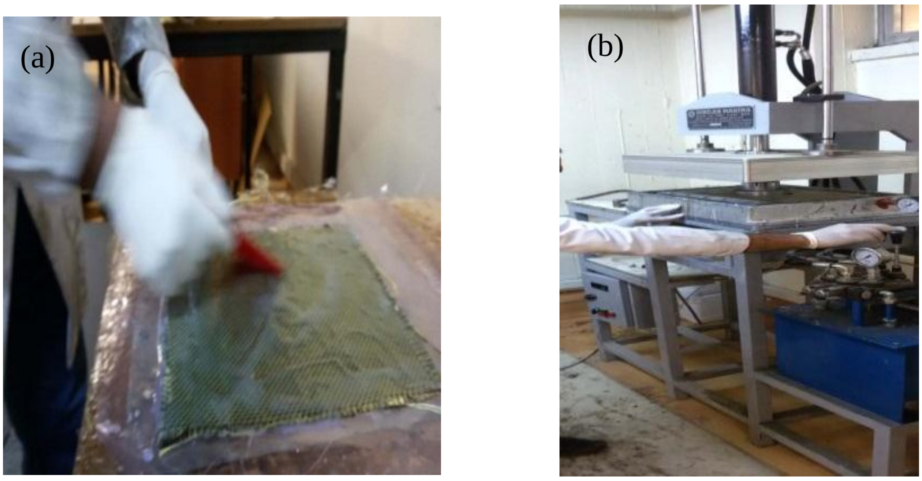


Figure 3.5 Composite production (a) resin application (b) production unit.

The wetted composite laminate was cured in the production unit for 1 hour at a temperature and pressure of 80 °C and 0.16 MPa respectively. At that point, the composite laminate was cooled to room temperature under pressure for three hours.

Finally, the cured laminate removed from the mold. This process was repeated for all of the nano-silica filled hybrid composite laminates. A flow chart used in the fabrication of hybrid composites and curing process is given in Figure 3.6. Composite plate thickness was average 2.5 mm.

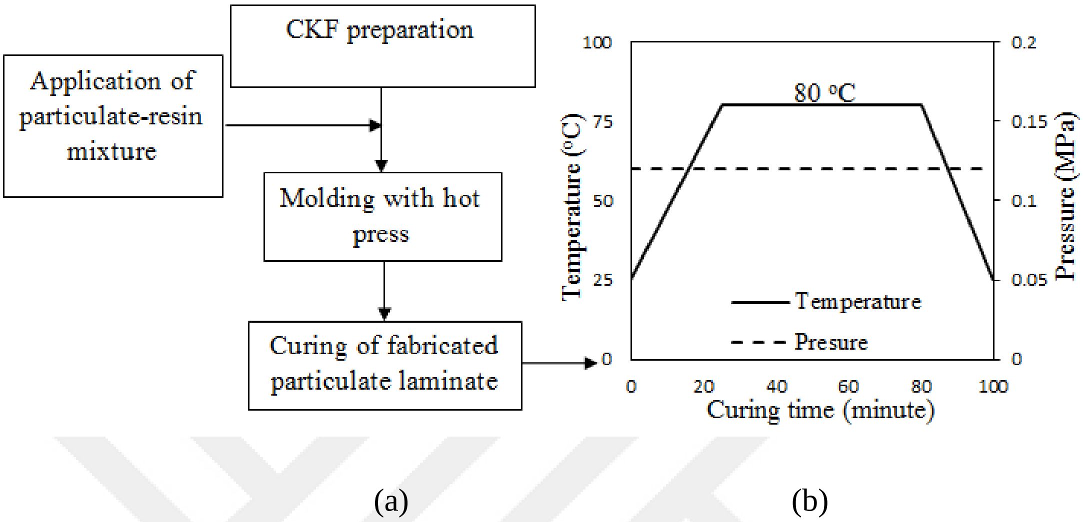


Figure 3.6 (a) Process flow outline utilized as a part of the manufacture of hybrid composites, and (b) The curing procedure.

Produced laminates (Figure 3.7) were cut using CNC machine (Figure 3.8) to produce tensile, flexural and vibration tests samples. The edges of the produced composite specimens were finished with emery paper.

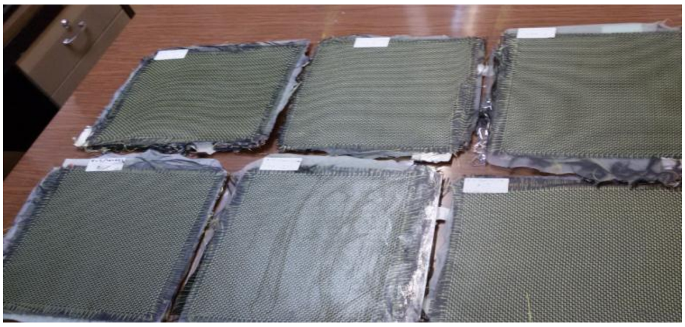


Figure 3.7 Examples of produced composite and hybrid composite plates.

3.4 Tensile Testing

Tensile test specimens were cut according to ASTM D638-10 [78] standard and flexural test specimens were cut according to ASTM D790 [79]. The commonly used specimens for tensile test are the dog-bone type, generally performed on flat and the straight side type. The produced tensile and flexural specimens are shown in Figure 3.9

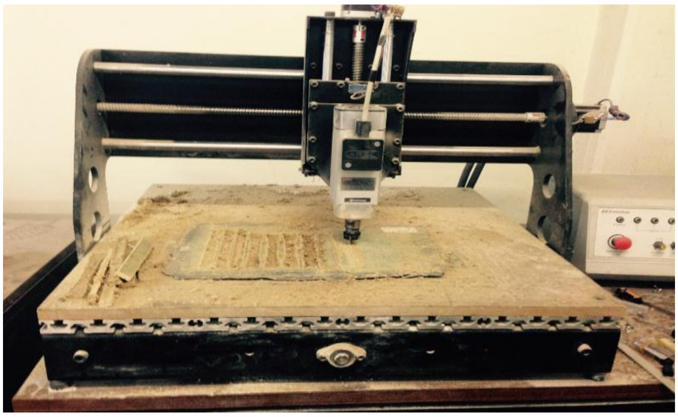
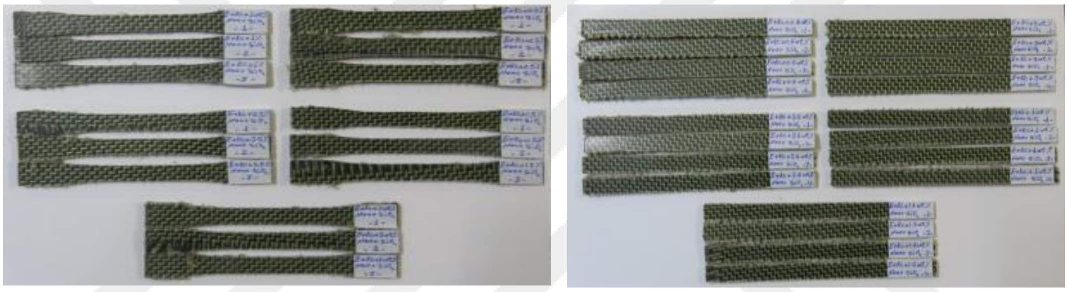


Figure 3.8 CNC Machine



(a) (b)

Figure 3.9 CKFRE-NS composite specimens for (a) tensile test, (b) flexural test.

Type 1 configuration of ASTM 638-10 standard have been used considering specimen dimensions as width of narrow section 13 mm, length of narrow section 57 mm, overall width 19 mm, overall length (LO) 165 mm, gage length (G) 50 mm, distance between grips (L) 115 mm and radius of fillet (R) 76 mm shown in Figure 3.10.

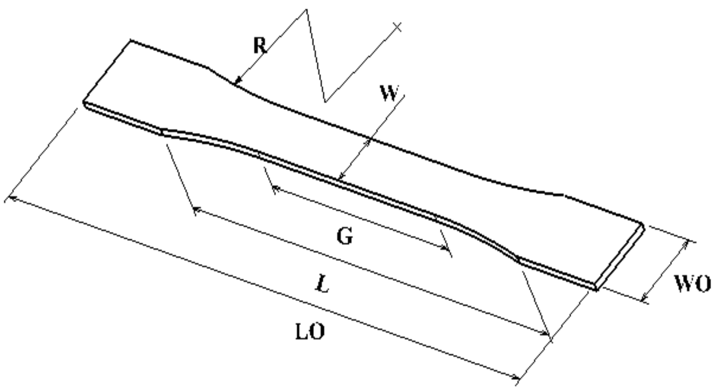


Figure 3.10 The dimensions of the tensile specimens according to ASTM 638-10

Tensile tests were carried out by 300 kN load capacity Shimadzu AG-X tensile testing machine (made in Japan) shown in Figure 3.11. Tensile load was applied with a 2 mm/min crosshead speed according to the standard.

Figure 3.11 Tensile test set-up Shimadzu AG-X arrangement testing machine.

3.5 Flexural Test

Three-point bending test of specimens were carried out according to ASTM D790 standard test using Shimadzu AG-X tensile testing machine as shown in Figure 3.12. Flexural specimen length is 200 mm and width is 12.7 mm laid on two cylindrical rods as shown in Figure 3.13. The load was applied with crosshead speed of 3 mm/min. Span-to-thickness ratio was selected as 32:1. Bending load was applied until failure occur on the specimens. Load-displacement curves were got for each tested specimen and at least three specimens were tested for each content ratios of nano-silica in the laminate. The flexural properties of the samples (Flexural strength (σ_F), flexural modulus (E_F) and failure strain (ε_F)) were determined from the output data by using the following equations [80]

$$\sigma_F = \frac{3P_{max}\,L}{2bh^2}\left[1 + 6\left(\frac{D}{L}\right)^2 - 4\,\left(\frac{h}{L}\right)\left(\frac{D}{L}\right)\right] \quad (3.1)$$

$$E_F = \frac{m\,L^3}{4bh^3} \quad (3.2)$$

$$\varepsilon_F = \frac{6\mathrm{Dh}}{\mathrm{L}^2} \quad (3.3)$$

Where L, b and h are the length, width and thickness of the specimens, respectively. P is flexural load and D is mid-span deflection and *m* is slope of the tangent to the initial straight-line portion of the load-deflection curve.

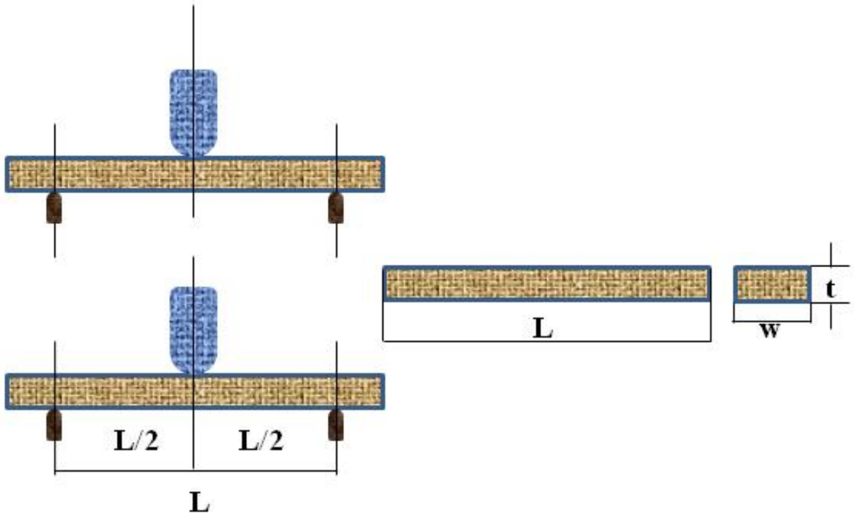


Figure 3.12 The dimensions of the flexural specimens according to ASTM D 790

Figure 3.13 Flexural test set-up Shimadzu AG-X arrangement testing machine.

3.6 Vibration Test

Dynamic properties of composites were measured according to ASTM E756 [81] standard using experimental setup shown in Figure 3.14. Output signal acquisition was taken from a general-purpose PCB 352C03 ceramic shear ICP® accelerometer (Brüel & Kjær Sound & Vibration Measurement A/S, Nærum, Denmark). Stimulus force signal was applied by a PCB 086C03 general purpose modal impact hammer. Data acquisition was acquired by National Instrument product NI 9234 data acquisition device with LABVIEW software. Specimen dimensions are 200 mm in length and 12.7 mm in width. Specimens are clamped in one end with 45 mm and one end is free to vibrate. Accelerometer was sticked near the fixed part of composite. LABVIEW software was run in order to plot FRF on monitor, then impact hammer was struck three times on the specimen for better excitation. FRF and time signal graph were plotted on a computer by using LABVIEW software and natural frequencies were plotted on the screen from FRF curves by the application of modal impact hammer. Three different specimens were tested and average of them were determined.

The main dynamic properties of composites were determined (e.g. natural frequency (ω_n), damping ratio ξ, storage modulus **È** and loss modulus **E′′**). Time-dependent acceleration responses of the samples were measured by the application of an impact hammer. Accordingly, natural frequency responses were determined by the application of fast fourier transforms. Frequency responses were extracted within the constant frequency range from 0 Hz to 500Hz.

3.6.1 Damping ratios

Half-power bandwidth method was used for determining the damping ratio. Maximum amplitude of first mode frequency was determined from the frequency response curve, then ω_1 and ω_2 frequencies corresponding to Z_1 and Z_2 points were found by dividing maximum amplitude value of first mode to the value of $\sqrt{2}$ as shown in Figure 3.14.

$$\xi = \frac{\omega_2 - \omega_1}{2\omega_n} \tag{3.1}$$

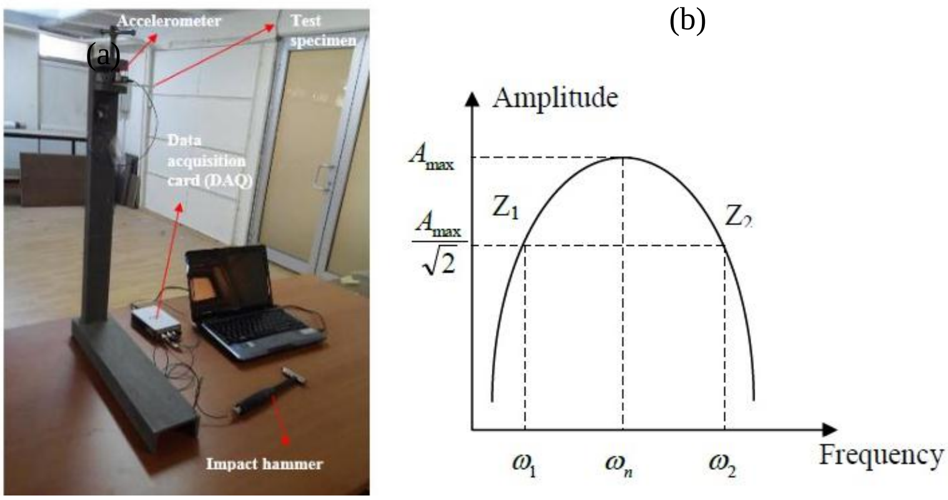


Figure 0.14 Vibration test mechanism. (a) Overall view of set-up, (b) Half power band-width method.

3.6.2 Storage modulus and Loss modulus

In addition of damping ratio, material storage modulus can be obtained from Euler–Bernoulli beam theory as equation (3.2).

$$\omega_1 = \frac{1.875^2}{2\pi L^2}\sqrt{\frac{E' I}{\rho A}} \qquad (3.2)$$

Loss modulus of the beam can be found using storage modulus. The relationship between loss and storage modulus is given in equation (3.3).

$$E'(\omega) = 2\,E''(\omega)\,\xi(\omega) \qquad (3.3)$$

Where

ω_1 = natural frequency of the first mode

ρ = density of the beam

A=cross-section of the beam

L =free length of the beam

I = moment of inertia

ω_n = natural frequency

E' = Storage modulus

ξ =Damping Ratio

E" = Loss modulus

The relationship between loss and storage modulus is given in Equation 3.3 is an impact inside or upon an oscillatory framework that has the impact of decreasing, limiting or keeping its motions. In physical frameworks systems, damping is delivered by procedures that scatter the energy put away in the wavering.

Illustrations incorporate viscous drag in mechanical frameworks, resistance in electronic oscillators, what's more, ingestion and disseminating of light in optical oscillators. Damping not in view of energy misfortune can be critical in other swaying frameworks, for example, those that happen in natural systems.

CHAPTER 4

EXPERIMENT RESULTS AND DISCUSSION

4.1 Introduction

The mechanical aspects of the composite material have a huge importance in using such materials. These aspects should be high and accepted in order to perform its work efficiently. Experimental studies have been carried out for carbon/Kevlar epoxy composite having different ratios of nano-silica particles. Tensile testing and three-point bending tests and vibration tests were made for the three different specimens and results were presented in this chapter.

4.2 Tensile Properties

Tensile test results are given in Table 4.1 and tensile stress and strain variation of CFRE specimens with different nano-silica ratios are shown in Figure 4.1. According to Figure 4.1 tensile stress and strain increased with the increase of nano-silica content this agree with [84] and [85]. In addition, whether it was filled or unfilled with nano-silica particles, the tensile samples were failed at higher stress. This suggests that the nano filler-matrix interaction is very strong therefore the nano-composites exhibited higher strength compared to the unfilled CKFRE composites. Maximum tensile strength value was 444.98 MPa with NS of 3 wt %. The addition of nano-silica gave maximum improvement of 46.8% as compared with pure CKFRE composite. Moreover, the elongation at break also was increased with the addition of nano-silica particles due to the chemical compatibility of it within composite system. Hence, the elongation at break increased by 32.5% compared with pure CKFRE composite with the addition of 3% wt. nano-silica. From the experimental study, it was observed that CKFRE composite has maximum tensile strength of 445 MPa, where Kevlar-carbon/epoxy composite has minimum tensile strength about 371MPa. Also, it is shown from the results that the hybrid CKFRE-NS composites strongly effects the tensile strengths of composites.

Table 4.1 Tensile Properties for CKFRE-NS composites.

Specimen	Elongation at break (mm/mm)	Max. Tensile Strength (MPa)	Average elongation at break	Average Tensile Strength (MPa)
PURE-1 PURE-2 PURE-3	0.0279 0.0257 0.0376	402.24 335.96 376.15	0.0304	371.74
0.5%- 1 0.5%- 2 0.5%- 3	0.0351 0.0345 0.0376	402.44 404.30 374.09	0.0357	393.60
1%- 1 1%- 2 1%- 3	0.0298 0.0321 0.0313	434.07 368.20 384.92	0.0310	395.21
1.5%- 1 1.5%- 2 1.5%- 3	0.0344 0.0332 0.0357	450.94 371.10 397.45	0.0344	405.48
2.5%- 1 2.5%- 2 2.5%- 3	0.0320 0.0311 0.0338	439.80 433.09 408.93	0.0323	427.27
3%- 1 3%- 2 3%- 3	0.0456 0.0473 0.0439	503.06 481.55 350.34	0.0455	444.98

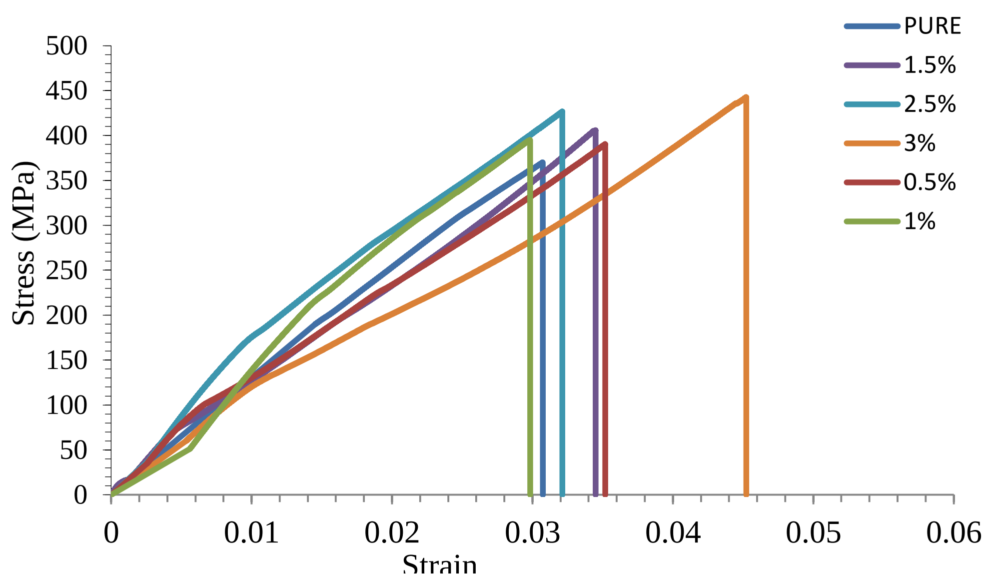


Figure 4.1 Tensile stress-strain curves of the CKFRE-NS composites.

The tensile strength was increased by increasing of the addition of (NS). The crack types are matrix cracking broken, fiber broken, layer delamination and fiber pull out.

The fractured surface of the tensile specimens was observed using SEM micrographs for NS particle content of 0.5, 1.5, 2.5 and 3 wt%, as presented in Figure 4.2 SEM images indicate the bonding among NS, epoxy and carbon/Kevlar fibers. The samples of 0.5 wt% NS was exhibited good adhesion of the NS/epoxy and the carbon/Kevlar fibers (Figure 4.2(a)). As obvious in Figure 4.2(b), (c) and (d) for the samples of 1.5, 2.5 and 3 wt% NS, respectively, the interface bonding was increased between the NS/epoxy and carbon/Kevlar fibers. In addition, these images show the fiber pull-out at low NS content of the CKFRE-NS composite systems.

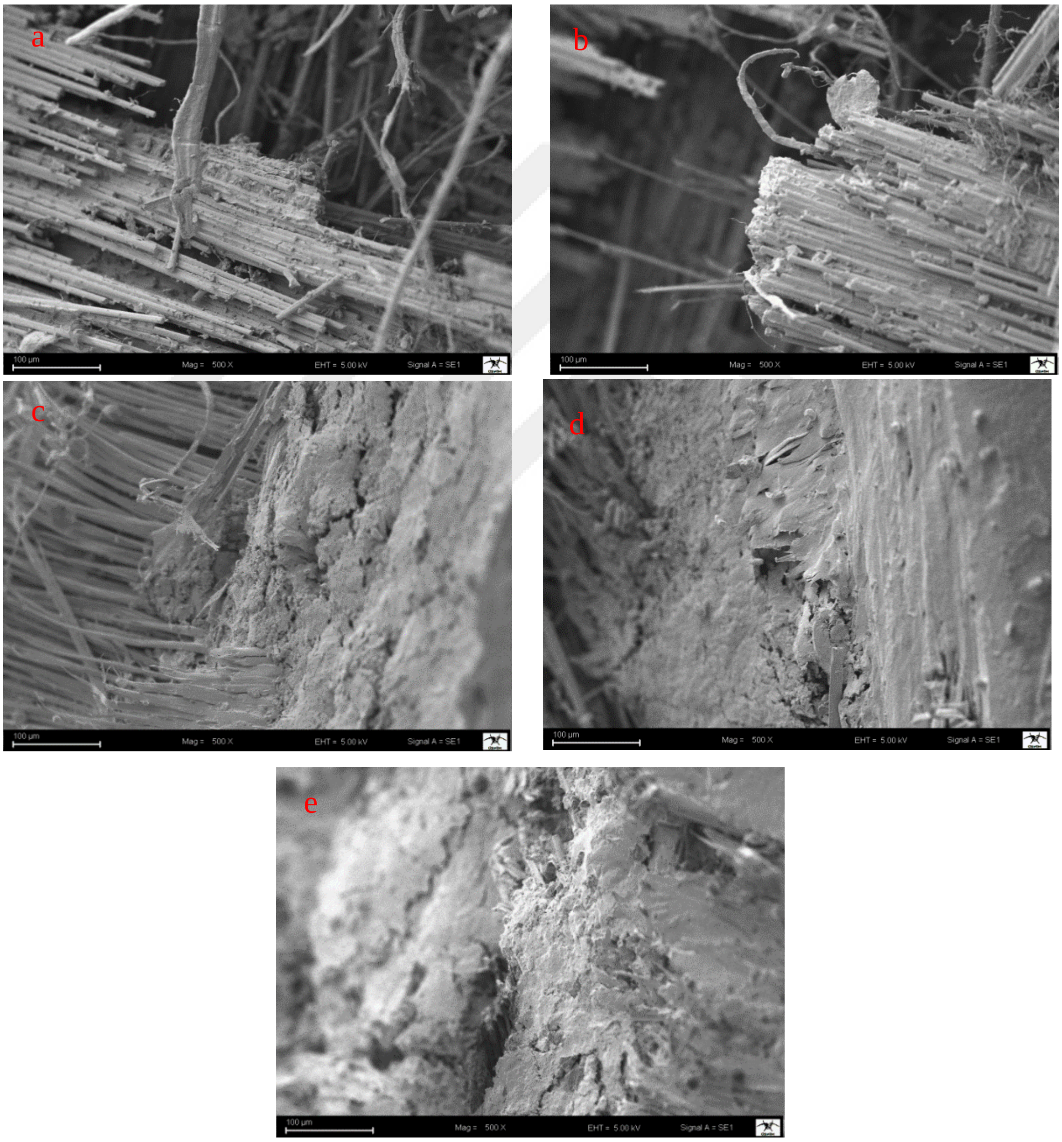


Figure 4.2 SEM of microscope photographs for cracked surfaces (a) 0.5wt% NS, (b) 1.5wt% NS, (c) 2.5wt% NS, (d) 3wt% NS

To show the effect of nano-silica content on tensile strength, the variation of the average tensile strength of CKFRE-NS is drawn in Figure 4.3. The tensile strength increased with the increasing of the NS content. The Figure 4.4 also shows the same effects. The results show clear increase in strength at high weight percentage of particles.

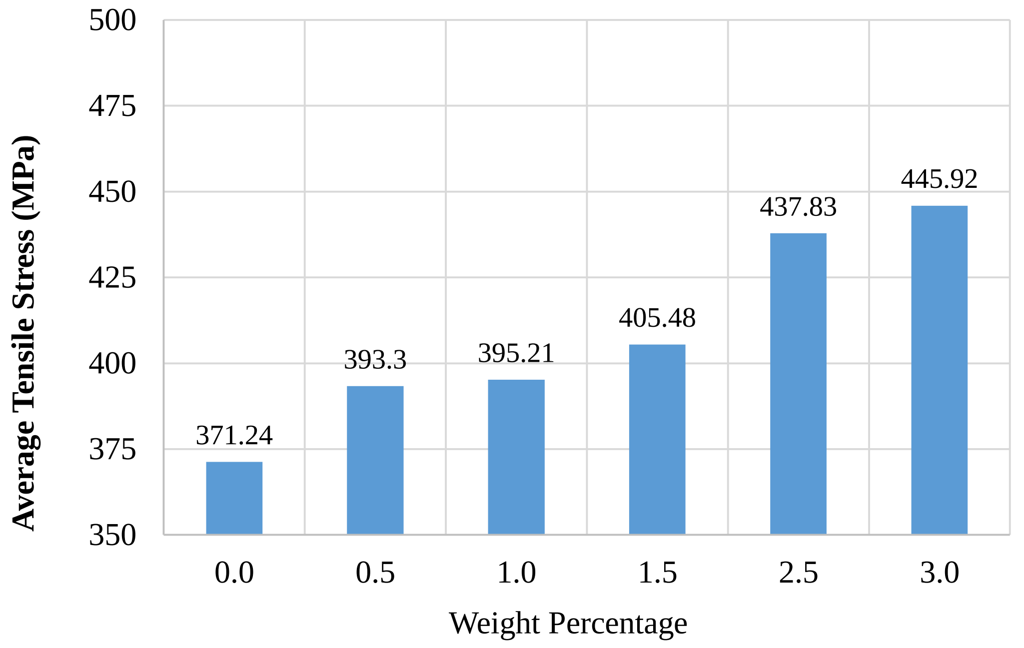


Figure 4.3 Relationship between average tensile strength & wt% of CKFRE-NS

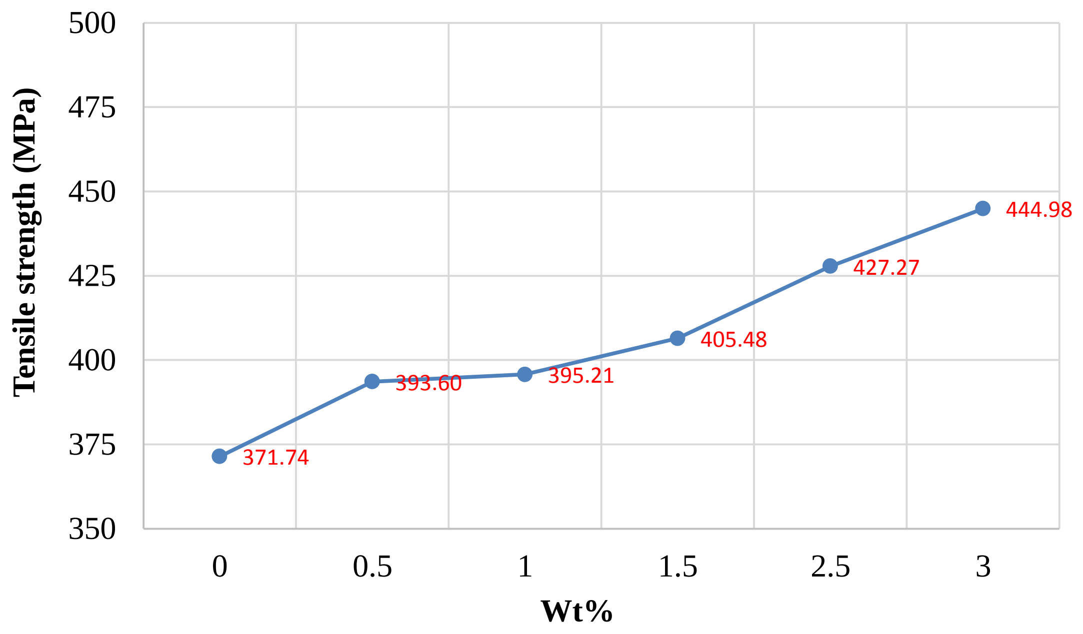


Figure 4.4 Relationship between average tensile strength & wt% of CKFRE-NS

As shown in Fig. 4.5, the specimens failed at the specimen center by tension load were mostly the crack type are fiber pull out that failure was started with matrix cracking then fibers breakage and carbon/Kevlar layers delamination start from surface.

Figure 4.5 Failure specimens of different composite laminates after tensile test.

4.3 Flexural Properties

The flexural results were obtained from the three-point bending test for composite specimens are tabulated in the Table 4.2. This table presents flexural strength, and flexural modulus of the hybrid CKFRE-NS composites.

The flexural tests showed a linear response of the load-displacement curves (Figure 4.6) of the studied composites, then the fracture was occurred and the flexural strength decreased suddenly. This figure also indicates that the failure strain was significantly increased with addition of nano-silica particles.

It noticed that values of flexural strength were increased with increasing of the weight ratio of (NS) until reaching to its highest value at particle content of 1.5 w%, then values of flexural strength get reduced. As shown in Table 4.2 and Figure 4.7, flexural strength has been improved by addition of nano-silica particles to the CKRE. Hence, the composite flexural strength was increased from 442.64 MPa for unfilled CKRE to reach 600.86MPa with nano-silica content of 1.5 wt%, afterword flexural strength follows the trend of decreasing to reach 496.79 MPa at content of 3 wt%. Therefore, the highest improvement of flexural strength was obtained at 1.5 wt% content of nano-silica with maximum increment of 35.7%. As shown in Figure 4.8, the specimens failed at the specimen center by bending load that failure was started with matrix cracking then fibers breakage and carbon/Kevlar layers delamination between compression and tension sides. The relationship between tensile strength, flexural strength and flexural modulus of CKFRE-NS are shown in Figure 4.9, which give relationship between tensile strength, flexural strength and flexural modulus of CKFRE-NS.

Table 4.2 Flexural properties for CKFRE-NS and interplay hybrid composites with different stacking configurations.

Composite specimens	Max. Force (N)	Flexural strength (MPa)	Average flexural strength (MPa)	Flexural modulus (GPa)
PURE- 1	239.60	465.73	442.64	9..03
PURE- 2	255.99	488.95		9..85
PURE- 3	242.09	373.24		7.74
0.5% - 1	258.68	557.99	508.62	7.13
0.5% - 2	247.58	496.11		7.75
0.5% - 3	275.61	471.76		10.06
1% - 1	266.47	482.00	547.41	11.06
1% - 2	283.81	585.86		10.32
1% - 3	265.93	574.37		10.09
1.5%- 1	321.24	668.01	600.86	07.70
1.5%- 2	347.22	662.99		10.15
1.5%- 3	278.37	471.58		08.65
2.5%- 1	295.94	511.96	585.95	08.89
2.5%- 2	278.33	554.14		08.19
2.5%- 3	309.69	691.74		09.47
3% - 1	257.01	438.97	496.79	07.94
3% - 2	259.20	470.33		08.28
3% - 3	243.18	581.07		08.76

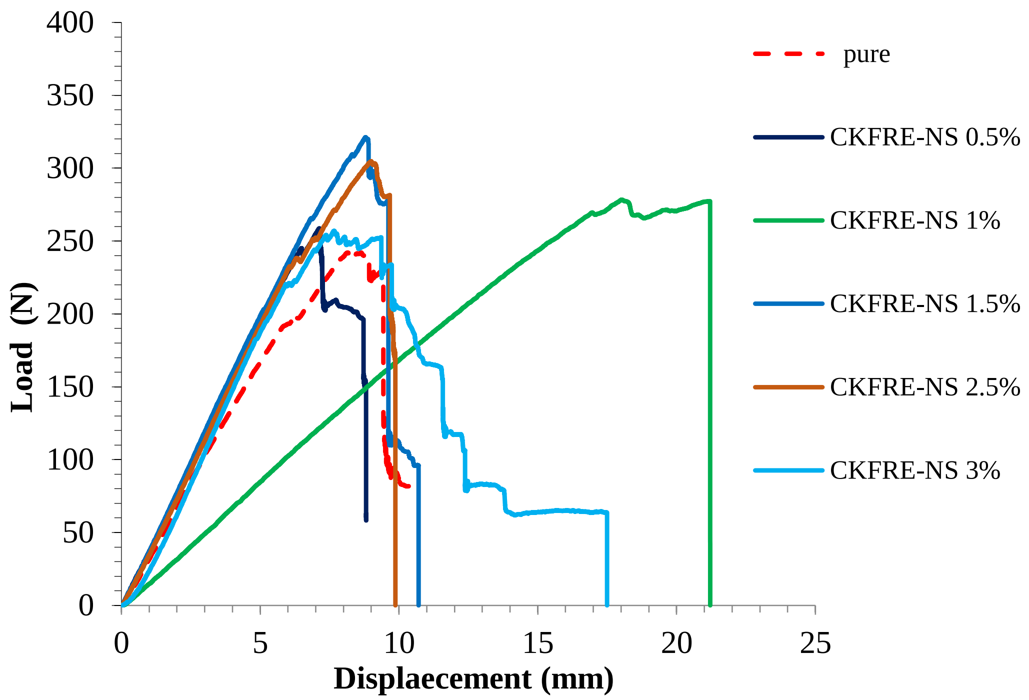


Figure 4.6 Flexural load-displacement curves for the CKFRE-NS composites.

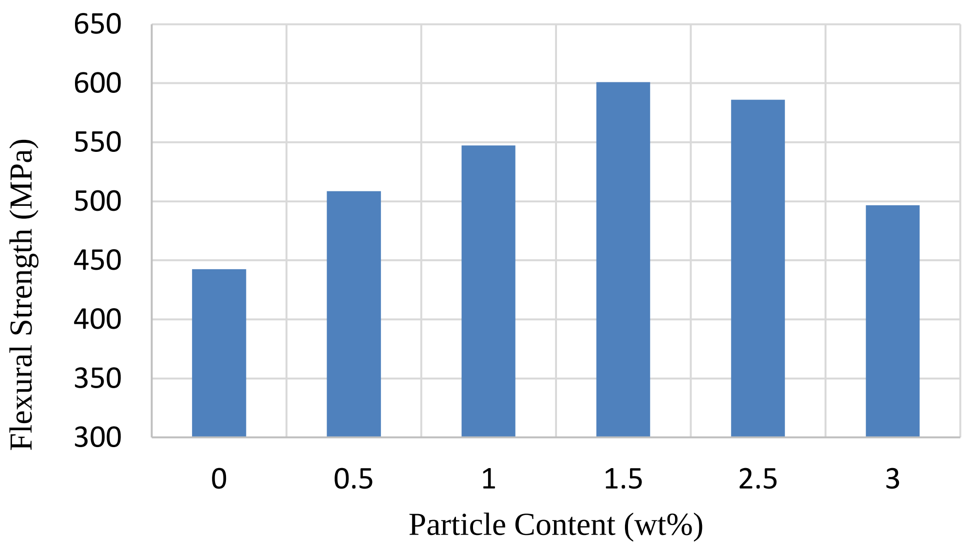


Figure 4.7 The relation between Flexural strength and NS particle content.

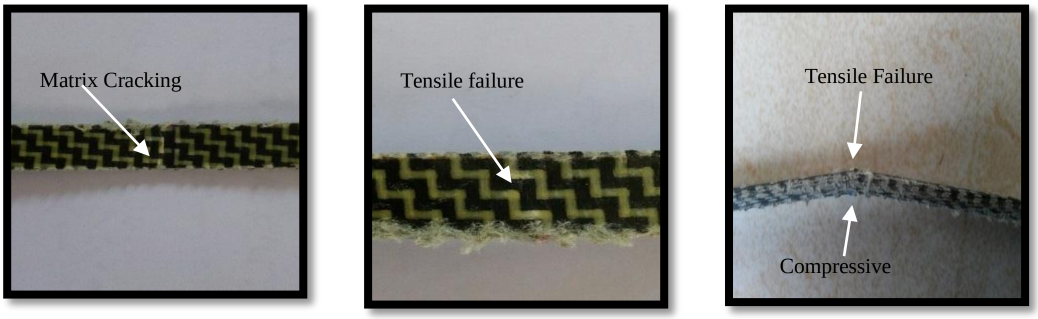
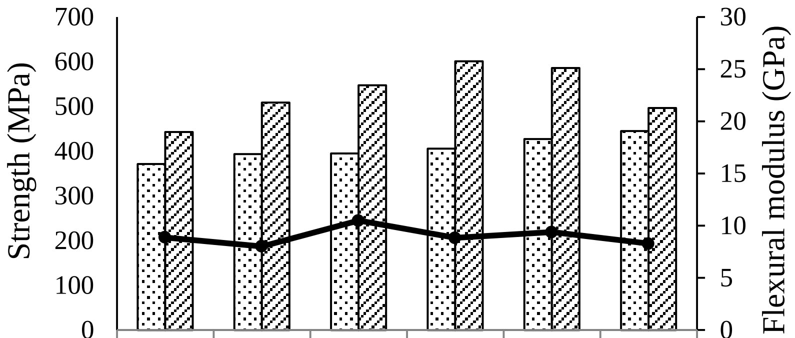


Figure. 4.8 Samples of specimen failed under flexural loading.

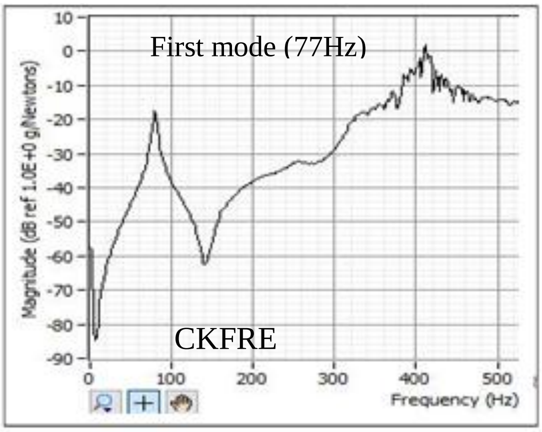


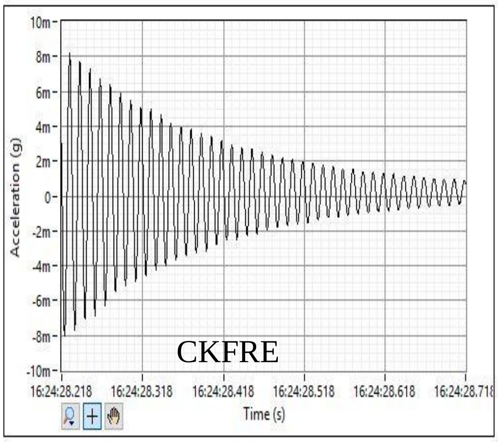
	0	0.5	1	1.5	2.5	3
Tensile strength	371.74	393.6	395.21	405.48	427.27	444.98
Flexural strength	442.64	508.62	547.41	600.86	585.95	496.79
Flexural modulus	8.87	8.02	10.49	8.83	9.38	8.28

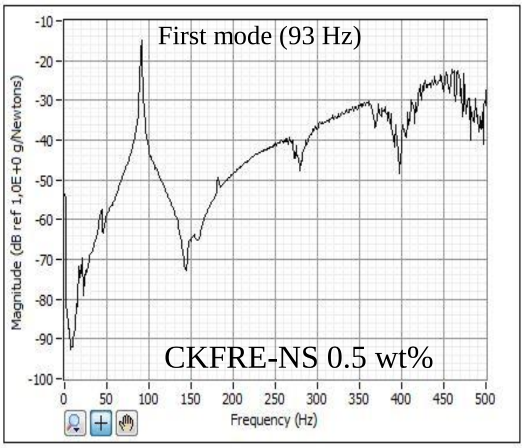
Figure 4.9 Relationship between tensile strength, flexural strength and flexural modulus of CKFRE-NS.

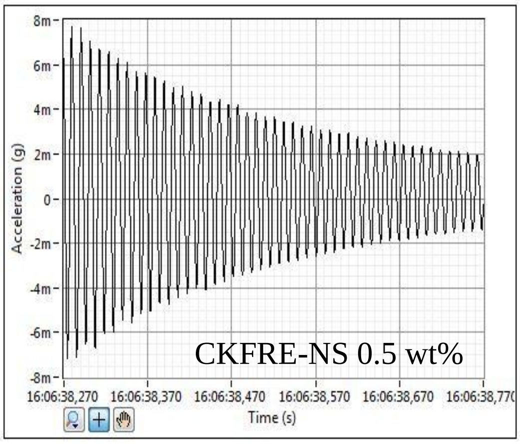
4.4 Vibration and Damping Properties

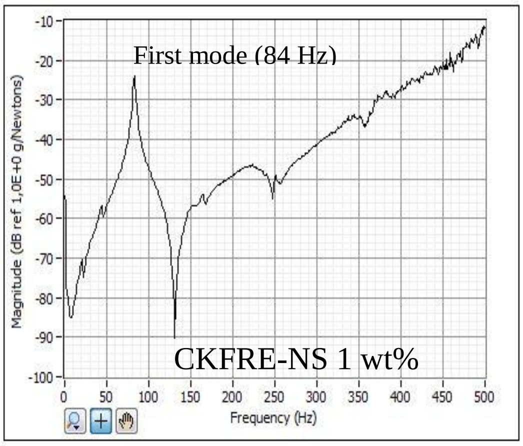
It was noticed damping properties of all composite materials have positive relationship between the modulus of elasticity and natural frequency of composite materials. Figure 4.10 shows the frequency and time dependent acceleration responses of CKFRE-NS composite specimens. According this variation natural frequency values are tabulated in Table 4.3. Highest natural frequency was obtained in 1.5 wt% ratio of NS. After this ratio natural frequency has decreasing trend.

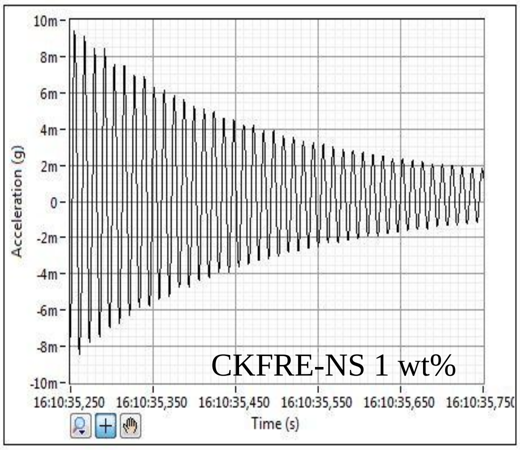

First mode (77Hz)
CKFRE
Magnitude (dB ref 1.0E+0 g/Newtons)
Frequency (Hz)


CKFRE
Acceleration (g)
Time (s)


First mode (93 Hz)
CKFRE-NS 0.5 wt%
Magnitude (dB ref 1,0E+0 g/Newtons)
Frequency (Hz)


CKFRE-NS 0.5 wt%
Acceleration (g)
Time (s)


First mode (84 Hz)
CKFRE-NS 1 wt%
Magnitude (dB ref 1,0E+0 g/Newtons)
Frequency (Hz)


CKFRE-NS 1 wt%
Acceleration (g)
Time (s)

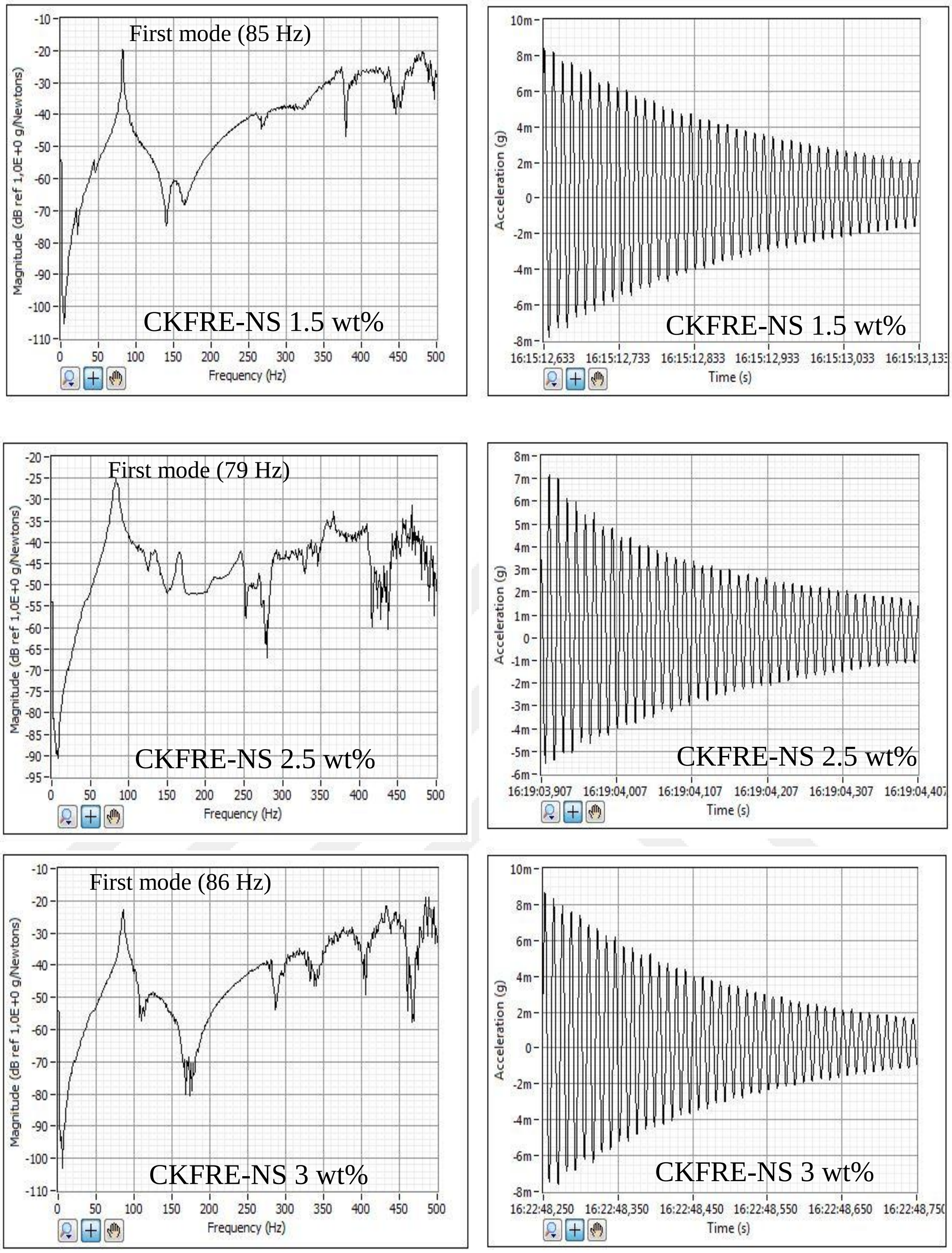


Figure 4.10 The frequency and time dependent acceleration responses of CKFRE-NS composite specimens.

Damping is characterized with the extent of discrepancy when resonating. The vibration system faces different kinds of damp forces as an internal partial friction. When the damping is low, its effect in the natural frequencies will be considerable as if there is no damping. The variation of first mode frequency values with damping properties of the composite laminates is given in Table 4.3. The results imply that the increase in stiffness causes a trend of increase in the natural frequency. However, increasing in stiffness may not lead to increase in the damping ratio, since the damping properties of the structures strictly depend on viscoelastic properties, which means the better absorption of vibration energy and good storage modulus. Where the study of the natural frequency improvement and compared with the proportion of suppressions damping ratio task whenever it increased the proportion particle ratio natural frequency value.

Table 4.3 Vibration and damping results of CKFRE-NS composite.

Composite type	**NS content (wt%)**	**Amplitude**	**W_1**	**W_2**	**Natural frequency, ω_n (Hz)**	**Damping ratio, ξ**
CKFRE	0	39.16	66.06	94.14	77.62	0.202
CKFRE-$NS_{0.5}$	0.5	65.51	54.50	104.05	75.97	0.163
CKFRE-NS_1	1	67.09	61.10	112.31	84.23	0.166
CKFRE-$NS_{1.5}$	1.5	63.21	64.41	112.31	85.88	0.182
CKFRE-$NS_{2.5}$	2.5	59.85	56.15	92.49	82.58	0.230
CKFRE-NS_3	3	48.63	66.56	104.44	79.27	0.239

The results showed that the addition of nano silica particles by loading significantly increased the damping ratio as in Table 4.3 and Figure 4.11. The natural frequency increased with increasing nano silica particle until reach maximum in 1.5wt% (85.88 Hz) and after that value be decreeing, while the amplitude decreased after reach maximum in 1wt% (67.09 g/N). With the addition of 1.5 wt % nano silica particles, natural frequency increased by 11 % in all nano silica/Kevlar-carbon /epoxy samples. The samples with 1.5 wt % nano silica particles content exhibited the highest natural frequency. it is concluded that stiffness of the specimens increases as the nano silica particles content increases. The difference of damping ratios can be attributed the matrix dislocations during the fabrication. In the same domain, we concluded that the increase of effective damping ratio could be result in the reduction of energy dissipated and responses by means of amplitudes, however the maximum damping ratio obtained from 3 wt% addition of NS particle. 3 wt% addition of NS increased damping ratio nearly18.3% compere unfilled CKFRE composite. It was concluded that addition of organically modified NS in the hybrid laminates increased the damping ratio due to the increased modulus. In addition, enhancement in damping factor NS filled laminates was observed up to 3% by weight of organically modified

NS. This was attributed the stiffness mismatch between the matrix, fibres. This increase may be occurred due to addition of rigid particles in epoxy matrix and also increasing stiffness of composite material.

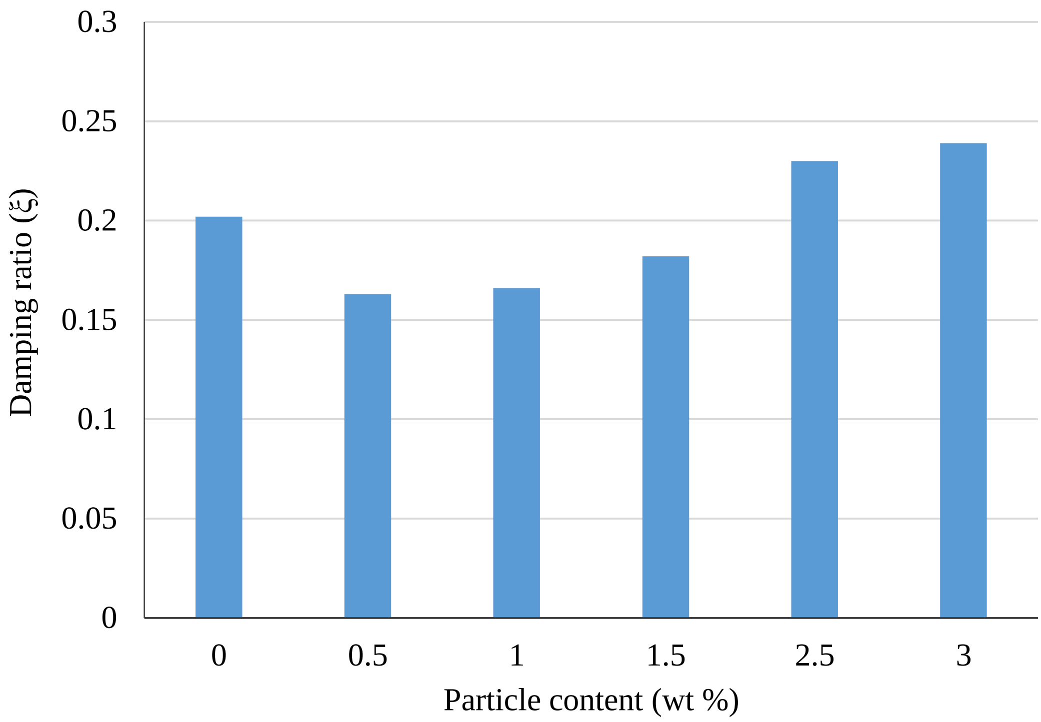


Figure 4.11 Relationship between (ξ) damping ratio and weight ratio of CKFRE-NS hybrid composite.

The Figure 4.12 shows natural frequency variations. which show further increase in nano silica, trend is followed by decrease in natural frequency, but resulting the increase of the damping ratio.

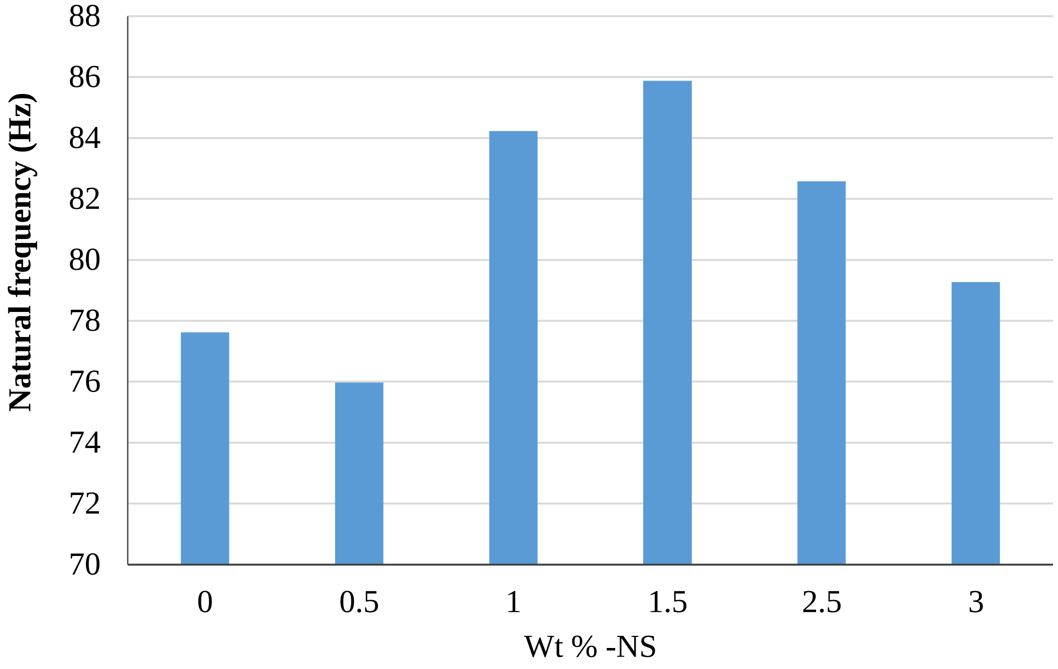


Figure 4.12 Relationship between natural frequency and weight ratio of CKFRE-NS hybrid Composite.

Loss modulus is relationship between damping ratio and natural frequency material however when increasing the damping ratio, the loss modulus be increase. The value loss models be high when the material stiffness and be low value when the material be ductility.

The results in Table 4.4 are drawn in Figures 4.13 shows storage and loss modulus of composite samples. It is found that the value of loss modulus increased with particle ratio until it reached the maximum value when the ratio (1 wt %), an increase of (20.09 GPa). The variation of storage modulus and natural frequency has revealed the maximum value at 1.5% of NS, but the maximum value of loss modulus is at 1wt% having maximum improve about, 31.7% and 85% respectively. It is observed that the first mode natural frequency was definitely dominant for all nano silica. It can be seen from this figure that the storage modulus exhibits a maximum at some intermediate composition this trend agrees with [82] and [83].

Table 4.4 Storage and loss modulus of CKFRE-NS hybrid composite.

NS content (wt%)	t (mm)	ρ (kg/m^3)	*I* (x10^{-11}m^4)	E\` (GPa)	E" (GPa)
0	2.4	1043.956	0.1498	26.758	10.810
0.5	2.4	978.053	0.1509	27.445	17.620
1	2.5	1198.815	0.1667	33.156	20.092
1.5	2.5	1269.531	0.1667	35.242	19.595
2.5	2.5	1242.983	0.1680	30.756	15.378
3	2.6	1333.513	0.1875	34.188	15.043

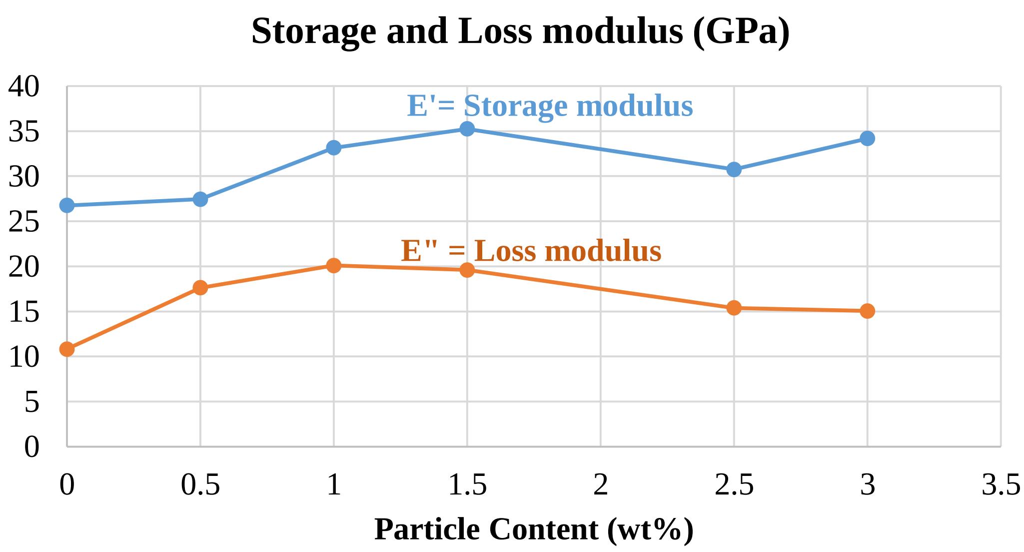


Figure 4.13 Relationship between loss modulus and storage modulus of CKFRE-NS hybrid composite.

CHAPTER 5

CONCLUSION AND FUTURE WORKS

5.1 Conclusion

This study explored the possibility of incorporating nano-SiO_2 within CKFRE composite and also, investigated the impact of stacking configurations on the tensile, flexural and vibration damping properties of the hybrid composite. Hand lay-up procedure was utilized to fabricate the hybrid KCFRE-NS composites. The hybrid composites containing 8 layers of CKFRE-NS were fabricated to evaluate tensile and flexural properties. The effects of Nano-silica particles with variety in substance on tensile and flexural properties of the CKFRE-NS composites were examined. The highest improvement of the tensile and flexural strength for CKFRE composites was obtained at nano-silica content of 3 and 1.5 wt%, with maximum increment of 19.9% and 35.7%, respectively. The flexural properties were degraded when Nano-silica content exceeded 1.5 wt%. Generally, the tensile and flexural failure strains of the KCFRE composites were increased. Indeed, the mechanical properties were improved with nano-silica addition.

As a result of vibration behavior, the addition of nano- silica improved the vibration and damping properties. The optimum ratio for vibration test is obtained at 3 wt% of Nano-silica as 0.239 and was 18.3% higher than CKFRE composite. Also the storage modulus and loss modulus to highest values at NS content of 1.5% ,1% wt respectively with maximum increase of 31% ,85% then followed the trend of decreasing.

This improvement of tensile, flexural and vibration properties attributed to the chemical compatibility of the nano-silica particles with epoxy resin and CKF fibers in the CKFRE-NS composite laminate systems.

5.2 Future Works

The following proposals are recommended for future work:

1. Concentrating on other mechanical properties of composite materials, (for example, weakness, wear… and so on).

2. Investigating the impact of utilizing other reinforcement materials, for example, ceramic particles (Nano graft, porcelain, Nano ceramic, and so on.) under different conditions.

3. The effect of using different sizes and shapes of particles on the mechanical properties of composite materials.

4. Reinforcing the polymers with different sorts of fillers (normal materials) and research their properties.

5. Producing this hybrid composite under different temperature degrees.

6. Setting up a polymeric mix from thermoplastic with thermoset polymers and contrast it in our work. Notwithstanding the way that carbon and Kevlar fibers are used as a piece of this study. The approach is sensible for other fiber sorts that assorted strains-to-disillusionment. Future work fuses multi-target headway study is relied upon to finish the best layout dependent upon the essential of perfect and toughness. In future, the study can be connected with new polymer composites having particular surface/system blends and the resulting trial disclosures can be further examined.

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