CHAPTER 3

LITERATURE SURVEY

3.1 INTRODUCTION

In recent years, nanoparticles have been attracting attention in the fiber reinforced nanocomposite community as they are capable of improving the mechanical and physical properties of traditional fiber reinforced composites. The studies to develop and characterize the behaviour of carbon nano particles have attracted considerable attention from researchers. Compared to other particulate additives, carbon nano materials offer more advantages. The addition of small size and low loading of carbon nano materials, without increasing the weight of the structure, can enhance the matrix-dominated properties of composites, such as stiffness, fracture toughness and interlaminar shear strength. Intensive survey on published research papers is carried out on the preparation and characterisation of carbon nano particles to acquire knowledge in the topic.

Although significant improvements have been made towards predicting the functional and performance properties none has been successful in predicting all of the important aspects of fiber reinforced polymer carbon nanocomposite response under a wide range of loading conditions. The observed change in properties of nanocomposite specimens caused by compositional changes due to inclusion of carbon nano particles have been explained in research journal papers. Both theoretical and experimental approaches are reported in literature to analyse the performance
characteristics and functional properties of carbon based nano particles in the FRP composites. Effect of carbon nano particle inclusion in FRP nanocomposite is widely reported. Very limited literatures are available in the hybrid resin area. Accelerated ageing studies are the most commonly followed method for storage life prediction of solid propellants. A significant amount of the work on the mechanical characterisation of FRP nanocomposite has been published separately. Good deal of effort has been spent in recent years to develop and demonstrate the intermediate velocity low mass projectile impact analysis of FRP carbon nanocomposite panel. It is found to be very difficult to survey sufficient number of research papers in this area, especially in continuous fiber reinforced hybrid resin carbon nanocomposite. Cantilever strip vibration analysis of composite and nanocomposite at different carbon nano particle loadings carried out by many researchers to study the damping characteristics gives insight into the composition kinetics of the nanocomposite under consideration. Some useful literature reports related to the work done have been summarised here.

3.2 PREPARATION AND CHARACTERISATION OF CARBON NANO CRYSTAL PARTICLES (CNCP)

The initial development of carbon nano materials through complicated and lengthy processes are being reported since 1970s. Several methods are used to develop the carbon nanomaterials. This type of nano materials are other way called as carbon blacks or carbon soot or carbon nano particles. The carbon black (CB) is the raw material for much needed carbon nano tubes (CNT). Harris and Weiner (1985) discussed about the morphology of carbon black. They observed the cluster of spheres in the black soot containing $10^5$ carbon atoms and $10^4 – 10^5$ hydrogen atoms. Many industries are still using carbon black (CB) in the raw form as fillers to improve the mechanical, thermal and electrical properties of high performance materials.
Carbon black is a material composed essentially of elemental carbon in the form of quasi-spherical particles in nano size (10 nm to 100 nm) that are fused together into aggregates. It is obtained by partial combustion or thermal decomposition of hydrocarbons. Several kinds of CB such as furnace blacks, channel blacks, thermal blacks, or Lamp-blacks can be obtained through different processes as enumerated by Donnet et al (1993). Many journal publications correlated the soot formation with fuel type, flame geometry, flame temperature or flow field. Manfred Kluüppel et al (2007) gave idea of using the carbon black as flexible filler network and strong polymer filler couplings.

Iijima (1991) used arc discharge method to prepare the carbon nanomaterials. These nano structures contain one or more tubular walls with open or closed ends with geometrical disorders. Plasma assisted pulsed laser deposition method was used to prepare the carbon nano particles by Suda et al (2002). The authors investigated the importance of controlling the ambient parameters which influenced the size of the nano particles and structure. Li Yajiang et al (2002) studied the microstructure in the welding zone of heat-resisting steel by means of transmission electron microscopy (TEM). The carbon products developed through various costly and complicated methods contained impurities like industrial contaminants, catalytic impurities and oxides. An exclusive and lengthy method for purifying the carbon products was also been reported by Vivekchand and Govindaraj (2003). Murr et al (2004) prepared aggregated nanomaterials when fuel-gas combustion was taking place and investigated through analytical instruments. Here the natural gas, propane, and methane were combusted and the aggregates were collected indoor and outdoor with lot of impurities. Cowley et al (2004) studied and gave clear idea about the structure of carbon nano crystals for cell dimension and phase with crystal planes. Prashanth et al (2005) prepared water soluble carbon nanotubes out of carbon soot extracted from burning of mustered oil in
a traditional lamp. Noriaki Sano et al (2004) reported a process which was being externally heated with the help of external heating facility (forced convection). The authors observed the increase of nano particle yield to a considerable level.

The thermal stability and combustion capability of nano particles were analysed by Yang Li et al (2005) with the help of thermo gravimetric analysis (TGA). The quantification of carbon nano particles is increased in a process by giving extra heat externally by forced convection. Even though, carbon nano particles are the significant derivatives but these products posse with impurities and defects. Fazio et al (2005) paid much attention to synthesis and characterisation of carbon nano materials, particularly MWCNT and SWCNT. Harris (1997) and Gautam (2006) carried out an exclusive TEM experimental study to reveal the range in dimension of the carbon nano particles developed from various processes. The dependency of nanomaterials on most of the properties, particularly on geometry and helicity of the atomic structure was investigated by Lambin, et al (2006). Development of carbon nanomaterials by the catalyst influenced pyrolysis of phenol formaldehyde resin was done by Ioan Stamatin et al (2007). The authors used the catalyst in order to prepare the carbon nano materials. Yadav and Ritesh (2008) thoroughly investigated the carbon products particularly fullerenes for their structural properties and applications. The pulsed laser ablation of carbon showed the particle surface profile with dimension of the order of 100 nm deposited on the substrate together with large amount of amorphous carbon phase.

Deng et al (2009) investigated the internal crystal structure of angled Te Nano Crystals and the growth direction of the arms by means of high-resolution transmission electron microscopy (HRTEM). Thermolysis method, a catalyst free process, was used by Bystrzejewski et al (2010) to
develop the carbon nanomaterials in the presence of buffer gas. The carbon extract collected through this method contained carbon-onions, amorphous carbons and impurities. The variation in size of the nanomaterials along with impurities due to the influence of catalyst had been cited in the research article published by Ganlin et al (2010). The carbon nano materials continue to gain the more importance for many potential applications because of their mechanical, electrical and electronics properties. The present study explains a process (MTP) with catalyst free preparation of carbon nano particles in order to avoid catalytic impurities in the product.

3.3 FUNCTIONALISATION

Significant review has been given on the surface chemistry of carbon blacks and other carbon nano particles. The main part has been devoted to surface oxides with emphasis on the chemical methods used in the assessment and identification of surface functional groups. Boehm (1994) suggested chemical reaction kinetics with free organic radicals for the functionalisation of carbon surfaces of carbon nano particles. Defects in carbon nano particles are important in covalent chemistry, because they can serve as anchoring groups for achieving functionalisation. Tianqi Liu et al (2005) reported the functionalisation of carbon nano particle (carbon black) surface with atom transfer radical polymerization (ATRP). The authors conducted experiments to achieve water-dispersible carbon nano particles. Liu et al (2005) suggested the opening and closing mechanism for free radicals favouring the polymer chain growth. The spontaneous chemical functionalisation of carbon nano particle by reaction with 4-nitrophenyl diazonium cations was investigated by Mathieu and Daniel (2008). The carbon nano particles were oxidized by nitric acid to introduce oxygenated functionalities. A reducing agent was added to a solution containing 4-nitrobenzene diazonium tetrafluoroborate to generate 4-nitrophenyl radicals
homogeneously in the bulk solution. Lines (2008) studied some processes for the preparation of nano materials and functionalising them. Mechanochemical Processing (MCP) technology, a relatively new technique being developed, is a novel, solid-state process for the manufacture of a wide range of nanopowders. The surface of these nano powders is modified with acid treatment in order to achieve functionality. Vesali Naseh et al (2009) experimentally investigated functionalisation process of carbon nano materials using two separate methods. The nitric acid treatment and subsequent drying of the carbon nano particles in the furnace functionalised the carbon nano materials. The functional groups were formed in the walls of the nano particles. Varga et al (2010) investigated the functionality of the composite system by adding novolac resin to have OH and COOH groups. On the other hand, among these functional groups, the physical or chemical interaction was further developed in order get nano particles linked to any fiber surfaces.

Herein, a simple, Indian modified traditional and low cost process is reported to prepare the carbon nano particles from two different oil bases, i.e. animal and vegetable bases. The developed process and products are free of the draw backs discussed above. The modified traditional process (MTP) involves the controlled combustion of base oil in a traditional earthen lamp enclosed by combustion chamber which can be externally heated. The temperature can be controlled as per the yield requirements. The combustion chamber temperature is compulsorily augmented or maintained during any adverse climatic condition. It is necessary to functionalise the developed CNCP samples in order to get the good dispersibility in the polymer resins. It is the process of attaching certain molecules, or functional groups, physically or chemically with the CNCP without significantly changing the properties. Oxidation is the method used here to functionalise the CNCPs to ensure the better mixing quality in binary polymers for active bonding sites on the
surface. For structural uses, CNCPs can be functionalized by attaching functional molecules, such as OH, COOH, etc. to them. Then they can usefully mimic certain structural functions, such as dispersion in the resin, solubility in water, etc., and bind to resin molecules.

### 3.4 HYBRID RESIN

During the preparation of a composite structure, the volume of a thermoset polymer changes, owing to a combination of thermal (expansion/contraction) and chemical effects (shrinkage). These alterations significantly affect the development of residual stresses in the composite, potentially resulting in distortion of parts. For this reason, it is essential to fully understand how the volume of a polymer varies in the course of curing to predict and reduce shape distortion and residual stresses, and to improve the properties of the composite structure. Measuring shrinkage is particularly challenging because it develops as the thermoset resin changes from a liquid to a rubbery and finally a glassy (stiffened) state.

There is a need for a curable thermo setting resin composition which has improved tensile strength, tensile modulus and glass transition temperature while adequate tensile strain is maintained, over that of pure epoxy or pure polyester resin. Robert et al (1990) used epoxy and polyester resin blend at different proportions and investigated the tensile properties. The authors concluded for considerable improvements (appendix 2). Youming et al (2001) measured the internal stress of modified epoxy resins with of polyester using steel ring method. The results showed that the internal stress of cured epoxy resins greatly depended on the addition of polyester in an optimal proportion and the minimum value of internal stress emerged with the addition of 16 phr polyester with no sacrifice of mechanical properties and heat-resistance.
The binary or hybrid matrix is the mixture of polyester and epoxy resin. The ternary (reinforcing fiber + matrix + nano particles) composite is made by mixing low fraction nano particles in a binary matrix. The experimental study on the preparation and properties of ternary composite were carried out by Cao et al (2002). The high strength and toughness were the results of the investigations carried out by the authors. The binary matrix system is remarkably superior to unmodified epoxy resin. Xiu et al (2006) carried out the synthesis and characterization of hyper branched polyester (HBP) with different molecular weight. The effect of HBP on the modification of epoxy resins was mainly discussed. The investigation shows that HBP can improve the toughness by forming copolymer networks between epoxy resins and HBP. Ramakrishna and Rai (2006) studied tensile, flexural, compression and impact strength of granite powder-epoxy composites on toughening epoxy with unsaturated polyester and unsaturated polyester with epoxy resin. The water absorption test was carried out by authors and observed the better toughening effect. The inter-facial region of composite was studied.

Considerable number of research works has been carried out on the epoxy and polyester blend and the improvement in the properties are observed. Yousef Jahani (2007) studied the effect of epoxy and polyester resin blend on mechanical and Rheological properties, and moisture absorption of wood flour polypropylene composites (WPCs). The reactive mixing of epoxy and polyester blend with 30, and 40 wt% wood flour and polypropylene (PP) was carried out by the author. The tensile strength of composites decreased slightly, and elastic modulus and moisture absorption increased with increasing epoxy resin content. The modified epoxy resin showed minimum water absorption with highest elastic modulus. The modification of epoxy resin with polyester and other particulates has been carried out. Yousef Jahani and Morteza Ehsani (2009) performed reactive
mixing of polypropylene (PP) and talc with epoxy-polyester blend hybrid resin and the rheology, morphology, crystallization behavior, and mechanical properties of composites were evaluated. The authors observed that the epoxy resin had suppressed the nucleation effect of fillers while the degree and rate of crystallization increased. The homogenous mixture of epoxy and unsaturated polyester resin in different proportions was prepared by Venkatesh and Venkata (2011) to have natural fiber reinforcement into this hybrid matrix. The compressive strength and chemical resistance of composite were observed excellent and to be increasing. In this work, epoxy resin has been modified with unsaturated polyester resin and used as binary (hybrid) matrix for making the fiber reinforced hybrid resin carbon nanocomposite specimens.

3.5 MECHANICAL BEHAVIOUR OF FRP NANOCOMPOSITES

The fiber reinforced binary matrix nanocomposites has revealed clearly the property advantages that nanomaterial additives can provide in comparison to both their conventional filler counterparts and fiber reinforced polymer matrix composites. Properties which can be investigated to undergo substantial improvements include mechanical properties e.g. strength, modulus and dimensional stability in tensile, flexure and impact modes. The nanocomposite consists of a resin matrix, which is continuous and providing the additional reinforcement such that the resulting composite property depends on matrix, fibre and filler. The polymers are the most widely used matrix materials because of their low specific gravity, chemical stability and ease fabrication. Polymers are also viewed as a viable substitute for other engineering materials with a different and formidable end product when processed.

This new type of binary resin was proposed by Robert et al (1990). The effect of epoxy-Polyester hybrid resin on mechanical and properties were
investigated. The tensile strength of the composite materials decreased but elastic modulus and moisture absorption increased with epoxy content. Many researchers studied the use of natural fibres with considerable interest in last decades. The most common concerns about the use of these fibres regard their coupling with a polymeric matrix, which needs to be compatible with the cellulose contained in the fibres. A number of thermoplastic and thermoset matrices were used with this aim. However, Ray et al (2001) conducted experiments with polyester and some phenolic resins and reported the better mechanical properties of the laminate. Yang et al (2004) and Oksman et al (1998) used rice husk and wood flour as fillers in the matrix and secondary reinforcement in the fibre reinforced polymer matrix composites, thus yielding composites with better dimensional stability and improved mechanical properties. Florian et al (2005) discussed the effect of content of the nano materials in the composite to have improved mechanical properties. The appropriate fabrication process was adapted by Thostenson et al (2005) to make the new type of composite materials. The aggregated particles could be exfoliated and dispersed uniformly in the matrix by Tsai et al (2006). In-Plane mechanical properties based on volume fraction and fibre orientation with constant percentage of polyester resin were studied by Satish et al (2010).

The reflection of some important characteristics of the components in composites at atomic level should be required. Liu et al (2005) fabricated carbon nano material based nanocomposites which form a new class of light weight and strong functional material for structural and energy storage application. The improved elastic properties of materials could be attained by adding very small volume fraction of carbon nano materials (CNM) without increasing the weight of the structure. Roy Xu et al (2007) studied the poor interfacial interaction developed in nanocomposites which fetched only the moderate increase of the mechanical strength. Haque et al (2003) experimentally studied the effect of dispersion of the organo clay on
improvement of inter laminar shear strength of nanocomposites up to 44% along with flexural properties. Yong (2009) reported the effect of modifying matrices and nano architecturing the interfaces at atomic level could improve the mechanical properties of nanocomposites to a considerable level. The investigation of absorbed energy in the specimens gave better knowledge on toughness measurement in both Charpy and Izod tests. Fu et al (1999) reported the increase of toughness linearly up to volume fractions of 20-30% of fiber reinforcing either polyester or epoxy matrices. Ebtisam et al (2010) carried out the experiments on notched specimens’ impact tests using Charpy impact test set up. The author noted the trend of increasing impact resistance with the increase of weight fraction of reinforcements.

In this project, it is intended to develop a new type of composite material with woven glass fiber as primary reinforcement along with traditionally prepared CNCPs as secondary reinforcement in hybrid resin as binary matrix. Here, the basic mechanical properties are evaluated for newly developed fiber reinforced nanocomposite specimens and compared the results with that of published research articles. A systematic investigation to understand the effect of traditionally self prepared animal and vegetable base carbon nano crystal particles (CNCP) on tensile, flexural and impact behavior of glass fiber/(HEP) hybrid resin/nanocomposites. A curable thermosetting resin composition with improved tensile strength and modulus is used as binary (Epoxy with Polyester resin in the ratio 3:2 – HEP) resin matrix in the fabrication of laminates. However, the effects of polyester resin in the epoxy on the mechanical properties of carbon nano particle/glass-fiber/binary systems have not been fully explored so far.

3.6 HEAT TRANSFER CHARACTERISTICS OF NANOFLOUIDS

It has recently been proposed that, in order to overcome poor heat transfer rates in conventional heat transfer fluids, a possibility might be to
disperse in it, small amounts of nanoparticles. Such a fluid with nanosolids dispersed in it, is called a "nanofluid". Such materials are, strictly multiphase and the property which we shall refer to as the thermal conductivity is, properly an effective property of the multiphase system. During the recent years the study of the enhancement of the thermal conductivity of nanofluids owing to the presence of nanoparticles, has attained considerable interest.

A temperature oscillation technique was used by Sarit Kumar Das (2003) for the measurement of thermal diffusivity and thermal conductivity was calculated from it. Singh, (2008) revealed that the thermal conductivity of various nanofluids was depending on the size of nanoparticles dispersed in the base fluid. The rheological properties were studied and considered by Kiyuel Kwak and Chongyoup Kim (2005) for nanofluids made of CuO particles of 10-30 nm in length and ethylene glycol in conjunction with the thermal conductivity enhancement. The thermal conductivity of nanofluids was studied experimentally by Assael et al (2006) using the transient hot-wire method and it was shown that significant increase could be obtained. The methods for prediction and correlation of the thermal conductivity were discussed.

The effective thermal conductivity is based on the volume fraction of the particles dispersed in the base fluid. Gandhi (2007) conducted experiments and observed increase in thermal properties of nanofluids. An expression had been derived for the effective thermal conductivity of nanofluids. A good idea had been obtained about the dependency of the thermal conductivity of the solid and liquid and their relative volume fraction. Xue and Wen-Mei Xu (2005) discussed in detail about the particle size and interfacial properties. The shearing flow dependency is one of the factors that govern the thermal conductivity enhancement. Detailed study had been carried out by Milivoje Kostic and Haibo Tong (1999) for measuring thermal
conductivity under the condition of motionless fluid and moving fluid. The effective thermal conductivity of liquid with nano solid suspensions, a modified Maxwell equation had been established and discussed by Yu and Choi (2003).

Choi et al (2006) measured the thermal conductivity of individual multiwalled carbon nanotubes by specialist method based on the fact that the third harmonic amplitude and phase are a response to the applied alternate current at fundamental frequency which could be expressed in terms of thermal conductivity and diffusivity. New mechanisms that were capable of explaining the enhancement of thermal conductivity obtained through experiments had been discussed in detail by Mohorianu and Agop (2006). The experimental observations of the thermal conductivity of nanofluids prepared by dispersing nanoparticles of SiO$_2$ and CuO in water and ethylene glycol at various concentrations were discussed by José et al (2008) with a technique. That method allows a very accurate determination of the enhancement in the thermal conductivity of the fluids due to the presence of dispersed nanoparticles.

A new approach was taken for the modeling and the prediction of the thermal behaviour of oil based as well as water based CNT nanofluids, which were quite different from each other in thermal characteristics. The experimental data for different combinations of CNT nanofluids with varying concentrations were studied by Patel et al (2008). Lee et al (2008) reported about the low volume concentrations of Al$_2$O$_3$ nanoparticles which showed that the viscosity was decreasing with increase of thermal conductivity. A model of nanofluids with effective thermal conductivity based on dimensionless group was observed by Moghadassi et al (2009). The thermal conductivity of TiO$_2$ nanoparticles in de-ionised water was investigated by
Turgut et al (2009) up to a volume fraction of 3%. Thermal conductivity was measured by 3\(\omega\) method.

An intensive review has been carried out about the determination of thermal conductivity of nanofluids. The enhancement in thermal conductivity was noticed with the increase in volume fraction of the particles by Ravikanth and Debendra (2009). Warrier and Teja (2011) investigated the improvement of thermal conductivity of nano fluids with metallic nano particles. Warrier and Teja (2011) investigated the improvement of thermal conductivity of nano fluids with metallic nano particles. The effect of particle size in the prepared nanofluids played a major role to control enhancement of thermal conductivity of metallic nano particles.

The nano-particles have pronounced and significant influence on the boiling process deteriorating the boiling characteristics of the fluid. It has been observed that with increasing particle concentration, the degradation in boiling performance takes place which increases the heating surface temperature. Critical heat flux (CHF) is directly related to the performance of the system since CHF limits the heat transfer of a heat transfer system. Significant enhancement of CHF allows reliable operation of equipment with more margins to operational limit and more economic cost saving.

Das et al (2003) conducted similar nanofluids pool boiling tests, under the same conditions as their previous study, using three smaller diameter size heaters. As was the case for the 20-mm-diameter cylindrical heater, the smaller heaters also showed heat transfer degradation with increasing nanoparticles concentration. Similar results were obtained by Vassallo et al (2003) who measured significant critical heat flux (CHF) enhancement of silica-water nanofluids. A dramatic 200% enhancement of CHF using Al\(_2\)O\(_3\)-water nanofluids at a 0.025 g/L concentration (0.0007% vol. concentration) has been reported by You et al (2003). A subsequent study
was carried out by Kim et al (2004) and the comparison of boiling characteristics of water and Al\textsubscript{2}O\textsubscript{3}-water nanofluids at different concentration were investigated. Bang and Chang (2005) studied boiling heat transfer performance and phenomena of Al\textsubscript{2}O\textsubscript{3}–water nano-fluids from a plain surface in a pool.

Additionally, Kim and Kim (2007) studied that the latent heat contribution constituted more of the total heat flux for Al\textsubscript{2}O\textsubscript{3}-water nanofluids compared to water. The authors confirmed the remarkable enhancement on CHF of the nanofluids. Milanova and Kumar (2005) experimentally investigated the nanoparticle deposition on the heater surface and a significant CHF enhancement. The authors reported that nanofluids could actually have a lower CHF than the pure fluids.

In this work, it can be revealed that, the self developed animal base (AB) and vegetable base (VB) CNCPs employed to have nanofluid samples, a wide distribution of particle size and stability, which show absolute enhancement of thermal properties and boiling characteristics. This fact may account for the different and enhanced results in relation to past literatures cited.

3.7 LOW MASS BULLET IMPACT ANALYSIS

Structural impact problems have become increasingly important for the modern aircraft industry. In design of aircraft structures, account is taken of accidental or sudden loads such as dropped objects, foreign object impacts, collisions, explosions and penetration by fragments. Most of these accidental loads are also pertinent in design of protective structures in the aircraft process industry. The energy absorption and crashworthiness are now critical issues in the design process of vehicles, vessels and aircrafts. In addition, many of the problems found in structural impact are also relevant in material
Beaumont and Phillips (1972) studied the fracture mechanism due to any impact. The experiments showed that the fracture in laminated plates depends on the percentage of nano particles inclusion and crack size. Takamatsu et al (1986) developed a three dimensional finite element code to predict impact damage in composite laminates. The extensive reviews on impact behaviour of composite and laminated structures for single point impacts were carried out and recorded by Cantwell and Morton (1991). The experimental works on impact and the physics of the phenomenon supported by the associated model were studied by Hamaide et al (1991). Bullet proof cloth of a relatively light and flexible character for protecting the wearer from a high speed projectile, such as a bullet from a handgun or a rifle, and which was capable of not only stopping passage of bullets, but reduced the damage caused by the impact resulting from the bullet trapped within the armor. A clear experimental study was made by Groves (1992) to understand the penetration behaviour of bullet in to a target. Jeng et al (1994) carried out experiments on plain woven glass fiber/epoxy laminate panels for their bullet impact response. The ballistic limit was predicted for WGF/Epoxy composite laminates hit by 14.9 gm bullet with hemispherical nose. The incident velocities were around 153 m/s. Series of hits were performed to assess the progressive damages. The delamination and fiber breakage were assessed and reported by Jeng et al (1994). Grace (1995) indicated the necessity of the evaluation of shear deformation and large deflection of low velocity impact tests. Results provided by the author, had expected penetration rates into plate targets, as well as unpenetrated target thickness (plug or spall) and residual penetrator length, mass, and velocity.
Major damage mechanisms like matrix cracking, debonding and fiber failure had been discussed elaborately by Hancox (1996). Zaera and Sánchez-Gálvez (1997) examined the essential physical processes in the perforation of metal backed ceramic armours which include projectile erosion, fracture of the ceramic tile and ductile deformation of the metal backing plate. The impact of projectiles onto alumina and aluminium nitride ceramic materials was studied by the authors. Karaoglan et al (1997) investigated the vulnerability of conventional laminates to delamination under impact and subsequent local buckling failure under in-plane compression. Woven composite materials responded well under the impact loading. Results of a study on the performance of 10 mm low alloy, rolled-homogeneous armour (RHA) plate when impacted by 20 mm diameter steel ogive-shaped projectile at 15, 30 and 45° angles of attack in the sub-ordnance velocity regime were investigated by Dikshit (1998).

A mathematical model based on energy balance principle and resistive forces acting on the projectile during perforation was developed by Sutherland and Soares (1999) and Ganesh Babu et al (2008) to calculate the ballistic limit. Small dent left on the impacted surface could have been underlying significant damages, which might include all the fracture mechanisms reported by Li et al (2000) and Helms et al (2001). Jain and Ramachandra (2003) developed explicit finite element code to predict blade damage caused due to 0.9 kg bird mass at critical flight velocity. The failure of centrifugal stiffened blades, radial unbalance and axial forces on engine bearing due to transient impact forces were studied. A time domain approach for the detection of cracks in beam structures had been investigated by Majunder and Manohar (2003). Chen and Li (2003) proposed a coupled shear-bending solution for a circular plate struck by a rigid mass and gave an explicit expression for the ballistic limit. Yu and Ruan (2003) formulated the problem that a cantilever beam was impacted at its tip by a moving free-free
beam. Some analytical results were analysed using general purpose commercial FEM software by Choi and Lim (2004). The effect of the repeated impacts on a plane laminate and nano laminate were studied by Sugun and Rao (2004).

The effect of medium velocity impact on sandwich structures was reported by Suvorov and Dvorak (2005). The focus was on the evaluation of contact forces and deflection of face sheet and foam core interface. The impact caused extensive damages on the face sheet and soft core materials. It was known that most of the kinetic energy was absorbed by the soft core material. The projectile’s contact time with the target was the critical factor to determine the dissipation of the kinetic energy. The various fracture mechanisms were reported by Wetzel et al (2006). The structural components are often very susceptible to foreign object damage due to impact loads. Their vulnerability due to intermediate velocity impact is widely known since these are not quite visually conspicuous. Ajayan et al (2006) studied interfaces between the nanotubes and matrix material and they predicted that they played an important role in nanocomposites for their properties. The interface area was larger in case of nanoparticle / matrix combination. Poor load transfer was sensed between the nanoparticle and the matrix. The interfacial slippage caused the poor damping capacity. The study was carried out by Jonghwan and Koratkar (2007) to know about the interfacial slip of nanoscale fillers in the polymer and epoxy matrices. The various effects with respect to weight fractions and geometry were studied. The response of laminated composites subjected to high velocity multi-site impacts was studied. The sequential and simultaneous multi-site high velocity impacts were experimentally studied by Shane and Uday (2007) to know about the energy absorption, new surface creation, and failure mechanisms in order to assess additive and cumulative effects of damages.
Velmurugan et al (2008) experimentally investigated damping ability of hybrid nanocomposites by low velocity impact. The authors reported improvement in damping coefficient and damping time with respect to nano particle loadings. A considerable variation in the result due to nano particle addition was observed. The prediction of the critical perforation energy of metallic plates struck by rigid projectiles in the sub-ordnance regime was investigated by Aly and Li (2008). Main factors affecting the critical perforation energy were identified and valid conditions for each empirical formula were compared by the authors. The work increases the confidence of using the empirical formulae and can be regarded as a quick guide for ballistic protection design of metallic shields and steel armour plates. Experimental work for short projectile in the sub-ordnance velocity regime revealed that the harder the projectile is the less the critical perforation. Maksim et al (2008) revealed through their experiments that the impact toughness and damping behaviour were the key factors for the quantification of the results. Grujicic et al (2010) impacted the target plate by a solid right circular cylindrical projectile. The results were analysed that the fracture-mechanics enriched meso-scale composite laminate material model, the fracture-mechanics character of micro-cracking was included within a damage mechanics formulation.

The influences of the several parameters such as CNT proportion, type of carbon nano particles and frequency of vibration dependency were explored by Song et al (2002) along with vibration control of a composite laminate. Rajoria and Nader (2005) investigated the material stiffness and vibration damping properties of CNT included composites for use in structural applications particularly in vibration prone areas. Mehmet ÇOLAKOĞLU (2006) predicted the modes of vibration of polymer matrix composite damping properties with the help of surrounding temperature, elastic properties, mass and geometry of the material. The functional
relationship between the surrounding parameters and damping properties were studied by the authors.

The influence of multi – wall carbon nanotubes (MWCNTs) on the low velocity impact and after impact behaviour of carbon fiber reinforced polymer laminates were studied by Kostopoulos et al (2010). The citation gave clear idea for the 0.5% inclusion of MWCNTs in the epoxy matrix. The mechanical and electrical performances of self – sensing conductive polymer composites were studied experimentally by Sertan Yesil et al (2010). Authors improved tensile, fatigue and impact damage sensing capability of nanocomposite panels by adding carbon nano particles in pre-defined proportions. Considerable dispersing ability of CNTs can be increased by the surface treatment of the CNTs with hexamethylene diamine. A 6% improvement in absorbed impact energy was observed by Fawad Inam et al (2010) that with small addition of CNTs (0.025, 0.05, and 0.1 wt %) to epoxy resins for the fabrication of multiscale carbon fiber nanocomposites. Hybridization of carbon fiber-reinforced epoxy using CNTs resulted in a reduction in dampening characteristics. Authors observed the presence of micron-sized agglomerates in the nanocomposite.

Relevant ASTM standards are referred to know about the procedure for NDT of flat panel composites. Many research scholars have carried out experimental and numerical investigations to study ultrasonic response of composite surface and sub-surface defects. In connection with NDE of composites good amount of reviews have been made. The estimation of severity and extent of damage zone due to bullet impacts can provide better inputs for further effective fabrication of composite laminates. There are several NDT techniques which are capable of identifying extend of damages to composites laminates. The methods are used to quantify defects generated during fabrication or in-service.
A computer controlled ultrasonic scanning and data collection systems were used by Jones (1985) in order to assess the damages imposed by impact. The authors recorded the best results. Preuss and Clark (1988) used the principle of ultrasonic C-Scanning for detection, sizing and characterization of defects in carbon-fibre composite components. The experiments were connected to both a physical nature of excitation signals and a type of inspected materials. Attenuation of ultrasonic waves in composites, depends on the thermal conductivity of fibers, type of structure (sandwich or laminar), as well as material quality. The analysis of the corresponding physical phenomena is of a primary interest because they decide about a proper choice of a NDE technique, especially if to take into account that the number of failure scenarios is vast. Adams and Cawley (1988) studied and reported the corresponding experimental results for the most expected failure modes. Henneke (1990) carried out many investigations to study the behaviour of composite laminates under bullet impacts. Authors used NDE methods to assess the damage caused by impact on the composites panel. Authors reported the result of experimental work on damage of carbon fibre reinforced plastic laminates due to low velocity impact. Both drop weight and low velocity projectile impacts were carried out at energy levels varying from 3 to 30 joules. The automated C-Scan inspection method for composite materials was used by Fahr and Kandeil (1992). Authors insisted on capabilities and limitations of ultrasonic techniques in testing flat panel composite laminate. Hosur et al (1998) determined delamination damage due to impact by using immersion type ultrasonic C-Scan conducted in pulse echo mode. Hosur et al (1998) gave better idea about evaluation and characterization of defects and damage in a composite panel. The study was carried out by the authors on different layups over different thickness. The ensuing delamination damage was observed by ultrasonic C-Scan procedure using pulse echo immersion method for both projected and layer wise
distribution. High strain rate impact behaviour and non-destructive evaluation (NDE) of impact damages were addressed.

Datta et al (2004) performed the impact by repeated dropping of weights on the GFRP panels and assessed the damage by immersion type ultrasonic C-Scan in pulse echo mode. Ertuğrul Çam et al (2005) investigated about the location and depth of cracks in beams and analysed after impact shocks. Authors compared the signals obtained in defect-free and cracked beams in the frequency domain. Authors determined the location and depth of cracks by analyzing the vibration signals. The concept of penetration analysis of a steel projectile in ceramic composite armour was discussed by Shokrieh and Javadpour (2008). The peridynamic method had been applied successfully by Jifeng Xu et al (2008) to damage and failure analysis in composites. Authors predicted in detail the delamination and matrix damage process in composite laminates due to low velocity impact, and the simulation results of damage area correlated very well with the experimental data. The composites are finding wide usage in defense applications for fabrication of body armours for protection against projectile or splinter impacts. Estimation of the extent of post-impact damage zone is important to provide valuable inputs for effective design and fabrication of such armours. Samanta et al (2009) investigated the damaged area of armours after impact by small arms ammunition of caliber 7.62mm with the help of the immersion type ultrasonic C-Scan at locations of impact. The response of a bonded carbon-fibre-reinforced plastic composite panel to impact, penetration, and perforation by a high-velocity steel sphere, was experimentally studied by Hazell et al (2009). The energy absorbed per unit thickness of laminate and the level of damage was measured by a C-Scan system. The modern approach to the detection of various types of defects in composite structures used in aerospace was investigated by Dragana and Swiderski (2010).
The details of test equipment, test methodology, instrumentation and test parameters, past and recent work were studied by Uday (2011). Alireza et al (2011) investigated high velocity impact performance of glass reinforced polyester (GRP) resin composite plates with different type of reinforcement. Five different types of E-glass fiber reinforcement were used, including chopped strand mat (CSM), plain weave, satin weave, unidirectional and cross-ply unidirectional fiber reinforcements. The projectile used was a sharp tipped (30°) conical head with total length of 30 mm and with weight of 9.74 g. A gas gun set up was used to conduct high velocity impact tests in the velocity range of 80–160 m/s.

The present work is to sense insight knowledge regarding the important issues of aerospace engineering in the field of intermediate velocity projectile impact and vibration damping characteristics of MWCNTs and AB and VB CNCPs included WGFR hybrid resin nanocomposite structure.

3.8 VIBRATION ANALYSIS

In order to vibrate a system, elasticity and mass are the two parameters required for all solids. Vibration can cause problems for the structures, and much effort may be spent in reducing unwanted vibration. Unwanted vibration causes two main problems; they are fatigue failure and failure due to excessive deformation. Considerable knowledge has been acquired by reviewing the publications to choose a proper choice of insert material of very little in quantity so as to improve the damping capacity of material.

The possibility of improving the damping capacity of cantilever strips by using high-damping inserts had been studied experimentally by Rahmathullah and Mallik (1979). Lu et al 1979 discussed about the analytical results which were determined by finite element approximations. The
dependence on frequency and temperature of the dynamic properties of the viscoelastic materials were the key factor for consideration. The basics of vibration and its mechanisms like the dissipation of energy were deeply discussed by Meirovitch (1986). Armanios and Badir (1995) extended their work to calculate the free vibration analysis of anisotropic thin-walled structures. The effect of cracks upon the dynamic behaviour of cracked beam was analysed by Krawezuk and Ostachowicz (1995). The authors further investigated cracked plates for their dynamic behaviour. Nobuo et al (1997) experimentally studied the damping properties of hybrid fiber reinforced plastic composite laminate. The authors understood that the damping characteristics were controlled by good heat conducting fibers. The fiber itself acted like adaptive material so as to accommodate the surrounding effects. Zapfe and Lesieutre (1997) developed an iterative process to refine successively the shape of the stress/strain distribution for the dynamic analysis of laminated beams. The iterative model was used to predict the modal frequencies and damping of simply supported beams with integral viscoelastic layers. Patel and Ganapathi (1999) developed the finite element procedure to solve free vibration behaviour of rotating isotropic, orthotropic, laminated composite and sandwich beams.

Jones (2001) enumerated the process of evaluating the hysteretic damping factor in the force – displacement field. Theoretical and experimental results were noted for damped composite plates made up of a thin viscoelastic layer sandwiched between two elastic layers. Also, Volnei et al (2001) proposed a procedure to estimate the dynamic damped behaviour of fiber reinforced composite beams in flexural vibrations. Authors conducted dynamic experiments in order to investigate the natural frequencies and modal shapes of the composite beams. Ronald and Hui (2001) had shown that simultaneous improvements in vibration damping and fracture toughness in
composite laminates by incorporating polymeric interleaves between the layers.

Some experiments conducted by Nayfeh et al (2002) indicated that a low-density granular fill could provide high damping of structural vibration if the speed of sound in the fill is sufficiently low. The experiments indicated that the damping at high frequencies was essentially a linear phenomenon. Jaehong and Kim (2002) developed a model based on classical lamination theory to analyse the dynamic behaviour of I-shaped composite beam. The Dynamic Finite Element (DFE) procedure was used by Boreman and Hashemi (2003) to calculate the exact natural frequencies for free vibration analysis of homogeneous beams, blades and beam like structures. Amplitude-fluctuation electronic speckle pattern interferometry (AF-ESPI) was used by Hsien-Yang Lin (2003) to investigate the force-induced transverse vibration of an angle-ply laminated composite embedded with a piezoceramic layer. The piezolaminated plates were excited by applying time-harmonic voltages to the embedded piezoceramic layer and the authors observed clear fringe patterns only at resonant frequencies.

A damping interleaved layer in laminate composites is an alternative way to control vibrations. Himanshu and Nader (2005) analysed the damping effect of multiwalled carbon nanotubes as fillers of an interleaved layer. Kireitseu et al (2005) described two important concepts, functionality and generality, for designing to be modular and extensible, the Virtual Reality Environment for damping / dynamics. The natural frequencies of a system are a function of its elastic properties, dimensions and mass. Mehmet ÇOLAKOĞLU (2006) used half-power band width technique to determine the damping properties in frequency domain. The author established functional relationship between temperature and damping properties. Jihua et al (2006) fabricated the nanocomposites through
integrating highly entangled carbon nanofiber paper into traditional glass fiber reinforced composites. This carbon nanofiber paper was employed as an interlayer and surface layer of composite laminates to enhance the damping properties. Mesut and Memduh (2007) experimentally studied the damping behaviour of MWCNT included nanocomposite under various frequencies. Authors understood that the frequency was affecting significantly the damping ability of the material with respect to temperature. Chandradass et al (2007) carried out experiments on nanoclay dispersed composites over vinyl ester-glass fiber composite for their vibration damping characteristics. The authors discussed the hybridization effect of nanoclay dispersion in matrix-fiber composite. Enhanced mechanical, thermal and vibration properties were observed. Mahmoodi et al (2008) reported the nonlinear vibration analysis of a directly excited cantilever beam modelled as an inextensible viscoelastic Euler–Bernoulli beam. Authors observed that if increasing excitation amplitude or decreasing damping ratio could cause a minor decrease in the nonlinear resonance frequency despite the significant increase in the amplitude of vibration due to reduced damping.

The effects of stacking sequences of composite laminated beams on natural frequencies were studied by Gökmen et al (2009) using the differential quadrature method (DQM). Authors developed a theoretical DQM model for the laminated composite beam. Authors used DQM directly to achieve desired natural frequencies and respective mode shapes without changing its geometry drastically or without increasing its weight. Silvio et al (2009) used the SMA wires into the polymer matrix to sense the vibration and subsequently to give damping ability. The authors measured the vibration modes using vibrometry. Leticia et al (2009) used SSI (stochastic subspace system identification) for the determination of the dynamic parameters of a cantilever beam with a tip mass, starting from the knowledge of output-only data of the system obtained experimentally through impact loads applied to
the beam. The extruded specimens were subjected to free vibration test to evaluate the damping ability and natural frequency. Umashankar, et al (2010) fabricated and investigated the damping properties of nano particulate composite. The authors suggested that the mixing and compaction parameters had to be standardized for each base material and MWNT weight percentage in order to realize improvement in damping and stiffness properties.

In this work, three types of carbon nano particles (MWCNT, AB CNCP and VB CNCP) are used in binary matrix (hybrid resin) to fabricate fiber reinforced hybrid resin carbon nanocomposite specimens. Vibration analysis of the fabricated cantilever specimens are carried out to study the damping characteristics of these fiber reinforced nanocomposite specimens.