CHAPTER 1

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1.1 Composites

The concept of composites are ancient to combine different materials to produce a new material with high performance, which is unattainable by the individual constituents. An example for this is adding a straw to mud for building stronger mud walls. Some more recent examples before engineered materials became prominent are carbon black in rubber, steel rods in concrete, cement/asphalt mixed with sand and fiberglass in resin etc. In nature, examples abound are a coconut palm leaf, cellulose fibers in a lignin matrix (wood), collagen fibers in an apatite matrix (bone) etc.

A composite material consists of two or more physically and/or chemically distinct, suitably arranged or distributed phases, with an interface separating them. It has characteristics that are not depicted by any of the components in isolation. Most commonly, composite materials have a bulk phase, which is continuous, called the matrix, and one dispersed, non-continuous, phase called the reinforcement, which is usually harder and stronger. The essence of the concept of composites is this: the bulk phase accepts the load over a large surface area, and transfers it to the reinforcement, which being stiffer, increases the strength of the composite. Depending on the desired properties of composites, many matrix materials and fiber can be combined in countless ways.

The fibers available for the fabrication of composites are in different forms such as rovings, chopped fibres and fabrics. The fabric-reinforced polymer composites are often called as textile composites. The different types of fabrics available are woven, nonwoven and knitted fabrics. The nonwoven fabric is used in the manufacture of light-weight composites and it finds the application where the weight saving is an important issue. In addition to this, nonwoven fabrics are popular owing to the simplicity and economy of their production since the traditional weaving operations are not used; hence, less equipment, less space, and fewer personnel are required. Nonwoven fabrics can also be produced using waste fibers and useful characteristics can be obtained which may not be attainable by
woven or knitted fabrics. The present research utilized the nonwoven fabric as the fibrous reinforcement into different matrix materials.

1.2 Nonwoven fabrics

Nonwoven fabric is a class of textiles/sheet products, unique in industry, which is defined in the negative; that is, they are defined in what they are not. In nonwoven fabrics, the fibers present are not rigidly bonded and to a large degree act as individuals [1].

The definitions of the nonwovens most commonly used now a days are those by the Association of the Nonwovens Fabrics Industry (INDA) and the European Disposables and Nonwovens Association (EDANA).

INDA definition: Nonwovens are a sheet, web, or bat of natural and/or man-made fibers or filaments, excluding paper, that have not been converted into yarns, and that are bonded to each other by any of several means. The various methods for bonding are: (i) adding an adhesive, (ii) thermally fusing the fibers or filaments to each other or to the other meltable fibers or powders, (iii) fusing fibers by first dissolving, and then resolidifying their surfaces, (iv) creating physical tangles or tuft among the fibers and (v) stitching the fibers or filaments in place.

EDANA definition: Nonwoven fabric is a manufactured sheet, web or bat of directionally or randomly oriented fibers, bonded by friction, and/or cohesion and/or adhesion, excluding paper or products which are woven, knitted, tufted stitch bonded incorporating binding yarns or filaments, or felted by wet milling, whether or not additionally needled. The fibers may be of natural or man-made origin. They may be staple or continuous or be formed in situ.

1.2.1 Classification

The classification is made based on the techniques/methods involved in the formation and bonding of nonwoven fabric. Based on the formation [2-3], nonwoven fabrics are classified into (a) dry laid, (b) wet laid, (c) polymer laid and (d) composites. The textile-based processes through which nonwoven fabrics are manufactured are known as dry laid nonwovens. Papermaking process manufactured ones are called as wet-laid nonwovens. Nonwoven fabrics produced through fibre forming process is known as polymer laid nonwovens which are often called as spunbonded and melt blown nonwovens.
The bonding of dry formed nonwoven fabric is essential to impart the strength for further processing. The three main methods involved are thermal bonding, chemical bonding and mechanical bonding. Thermally bonded nonwoven fabrics can be obtained with the application of heat and pressure to the thermoplastic fibre networks. In chemical bonding of nonwovens, materials like adhesive are used to bond the loosely formed network of fibres. Mechanical bonding can be achieved by either entanglement of fibers or by a stitch-through bonding process. Entanglement of fibers can be accomplished by needle punching or water jets. The composite structures are produced using pre-formed fabrics. A schematic representation of the above discussion is shown in Figure 1.1. In the present research work, mechanically bonded dry-laid nonwoven fabric (through needle punching process) has been used to fabricate the composites. The advantages of needle punched nonwoven fabric are it offers unique strength in all directions, excellent delamination resistance, low cost, light-weight and high amount of matrix holding ability.

![Figure 1.1. Schematic flow diagram of nonwoven web forming and bonding techniques](image-url)
1.2.2 Needle punched nonwoven fabric

Needle punching is a bonding process to strengthen the dry formed textile fabric through carding process. The needle punching process is illustrated in Figure 1.2. Needle punching is a method of mechanically interlocking loose fibers to form a felt or nonwoven fabric [4-5]. The principle of needle punching process is the same as regardless of the fibers or the needles used. A web of fibers from a suitable source is conveyed under a beam which contains a board or bar with a multitude of barbed needles in a certain number and arrangement to produce the desired results. The needle board operates in an up and down motion at speeds up to about 2300 needle board lifts per minute.

As the needle board pushes the blades of the barbed needles into and partially through the web, each barb catches one or more fibers and pushes them into or through the body of the web. When the motion of the needles is reversed and the needles start to withdraw from the web, which is restrained by the stripper plate, the fibers, which were pushed down, come unhooked from the barbs. The degree of needle punching, and hence the strength imparted to the fabric, is determined by needle design, needle density, pattern on the needle board, needle penetrations per unit area of web, and depth of needle penetration into the web.

The resultant increased interlocking of fibers increases the interfiber reorientation and friction within the web, which in turn produces an increased dimensional stability or strength of the web as a whole. The cumulative effect of repeating this action many times in the same area of the web results in the mechanical interlocking of fibers and the production of fabrics with a wide variety of useful characteristics.

Virtually any fiber, including both natural and manmade fibers, can be formed into a nonwoven by the needle punching process. Needle punch machines upto 10 m wide are produced with machines designed specifically for manufacturing fabrics for different applications.

1.2.3 Fibers

Jute and cotton are the natural fibers generally used for the production of nonwoven fabrics as they are low cost and imparts biodegradability. The man-made synthetic fibers used are aramid, acrylic, polyester, polyvinyl chloride (PVC), polypropylene (PP),
polyethylene (PE), viscose rayon and nylon. Both natural and man-made fibers are being used for the production of dry laid nonwoven fabrics.

![Figure 1.2. Schematic representation of needle punching operation](image)

For the present research work, both synthetic and natural fiber based nonwoven fabric has selected. Because of the outstanding properties such as resilience, ultraviolet light resistance, dimensional stability, resistance to acids, organic solvents and weak alkalis, synthetic fiber has selected. The natural fiber is selected as because it offers biodegradability, absorption-desorption characteristics, excellent resilience and inexpensive.

1.3 Applications

The application of nonwoven fabric can be broadly divided into two groups: disposables (short-term applications) and durables (long-term applications). For disposable applications, the nonwoven fabrics themselves are sufficient without any polymer matrix. For durable applications, the nonwoven fabric alone is insufficient in strength to withstand the load in use. Hence, generally for such applications, composites were fabricated by impregnating a pre existing textile fabric in a polymer solution. Few examples for disposable and durable applications are given in Table 1.1. Recently, Smith [6] listed eighteen needle-punched nonwoven fabric composites/products.
Table 1.1. Some examples of disposable and durable applications of nonwoven fabric composites

<table>
<thead>
<tr>
<th>Disposable applications</th>
<th>Durable applications</th>
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<tr>
<td>Incontinence diapers</td>
<td>Abrasive pads, sheets</td>
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<tr>
<td>Incontinence pads</td>
<td>Accoustic sealing</td>
</tr>
<tr>
<td>Laundry softener sheets</td>
<td>Automotive headliners, interior trim</td>
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<tr>
<td>Medical/surgical: drapes, gowns,</td>
<td>Upholstery, vinyl roofs filters</td>
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<td>packs, masks</td>
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<td>Packing wraps</td>
<td>Bedding sheets</td>
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<tr>
<td>Absorbent pads</td>
<td>Shoe components</td>
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<tr>
<td>Floppy disk liners</td>
<td>Printed circuit board</td>
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<td></td>
<td>Tea bags</td>
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<td>Furniture and bedding</td>
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<td></td>
<td>Aerospace: shuttle tiles and brake pads</td>
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<td></td>
<td>Marine hulls</td>
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<td>Tennis court surfaces</td>
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1.4 LITERATURE REVIEW

The nonwoven fabric reinforced polymer composites are made by impregnating the nonwoven fabric in polymer matrix/binders to bind or to hold the fibers. The choice of fibers in the manufacture of nonwoven fabric is markedly dependent on intended end use. De Bruyne [7] and Stansny [8] reported on the primary fibre roughness and fibre cross-section area on the fiber-polymer bonding. The effect of multifiber substrate geometry and porosity on the adhesion of fiber-polymer was discussed by several researchers [9-12].

The end application decides the polymer to fiber ratio in the composite. As discussed in the previous section, the bonding of nonwoven fabric can be done by chemical, mechanical or thermal means [13]. The bonding of nonwoven fabric by chemical means involves polymer-based materials, wherein the polymers to fibre ratio is very low (less than 0.35:1) [14-22] and are often termed as chemically bonded nonwoven fabrics. On the other hand for some durable applications, the polymer to fibre ratio will be as high as 3.5:1 [23-28] and this type are known as nonwoven fabric reinforced composites or
resin bonded textile composites or impregnated nonwoven fabric composites. In both the cases, the knowledge on polymer-based binders/matrix is very essential. Based on the physical state, three broad types of binders have been proposed in the literature for nonwoven fabrics; (i) thermoplastic fibers, (ii) thermoplastic resins and (iii) polymer in liquid form, including latex.

Among the above types, the first one involves the addition of a small proportion of a thermoplastic fibre along with the principal fibers of the web. The heating of the blended fibre web effects fiber bonding provided that, the temperature is sufficiently high to cause the thermoplastic fibers to melt throughout the entire bulk of the web [29-34]. As the binder is already part of the web and no special impregnating equipment is necessary, the bonding of nonwoven fabric via the addition of thermoplastic fibre becomes an advantage. Winchester and Whitwell [35] have investigated the effects of fibre variables such as linear density, staple length and fibre post extension yield on the thermal bonding of polyester or polyvinyl chloride nonwoven fabrics. Lower fiber linear density found to significantly affect nonwoven tensile strength, tear strength and air permeability. The effect of fibre structure and morphology on the mechanical properties of thermally bonded nonwoven polypropylene (PP) fabrics was studied by Wei et al [36]. This study revealed that the mechanical properties of the fabrics were found to be greatly affected by thermal bonding temperature. The effect of bonding temperature and binder fibre distribution on the mechanical properties of the resultant thermally bonded nonwoven fabric was discussed in the literature by several researchers [37-42]. Harris [43] observed that the strength of nonwoven fabric of polyester binder fibers found to be dependent on the bonding temperature and the amount of binder fiber. Soszynski [44] described a laser technique for the production of spot-bonded acrylic and polyester fibre nonwovens, whose fabric properties (such as tenacity and heat resistance) were found to be significantly better than those produced by conventional thermal bonding techniques. Shimalla and Whitewell [29, 38] have discussed effect of crystallinity, elongation at break and initial modulus of fiber on the resultant tenacity of the bonded nonwoven fabric. In general finer fibres showed a higher specific strength, which would increase the nonwoven fabric mechanical properties. However, the factors such as the use of low molecular mass fibre to achieve low softening
point (reduces mechanical strength) coupled with its high cost made this system less popular.

The second type of binder system makes use of various thermoplastic resins in powder form for bonding nonwoven fabrics. The powders are blended with the fibre and the mixture is heated to a temperature sufficient to cause the resin to melt. Bonding takes place as the mixture cools down. Although some have been prepared commercially, the practice is very limited. The thermoplastic powders are excellent for bonding, but the problem of distributing the powder into the web and keeping it where it can bind the fibers efficiently make this process unattractive [45-46].

The third type of binder system involves the use of polymer in the form of either a solution in organic solvent or latex. The polymer solution in organic solvent becomes less popular because of the obvious reasons such as the cost of solvent recovery, hazardous nature [45] (fire and toxicity) and very low solution concentration (low solid content). With the low solid content systems, it is difficult to incorporate the required amount of polymer binder into the nonwoven fabric to achieve certain desired end properties. The most versatile and popular binders for the nonwoven fabrics are water based emulsion systems, which include polymer latices [47-55]. The principal requirements of the polymer latex used for impregnation should penetrate the substrate (nonwoven fabric) and then by further processing, be hardened on the surface with a controlled degree of flexibility [56].

The high molecular weight of the polymer latex and the presence of emulsifier in the polymer latex (which improves the fibre wetting essential to achieve the desired end properties in the nonwoven fabric) made this system popular over the thermoplastic fibre and powder system. Coke [57] and Bozzacco [58] have discussed the properties such as strength of binder, location of binder in nonwoven fibrous network and the specific adhesion between the fiber and binder. The wide range of latex properties available is contributed to the tremendous growth of chemical bonded nonwoven fabric. The polymer latex can be applied to the fabric either by impregnation or by spraying or by printing method [59]. The use of latex is to bond together a loose web of fibers into a coherent structure. The applied polymer latex is not present as a continuous film extending throughout the bonded fibers; rather, it is present as isolated droplets, which should be coherent and continuous within them [47].
The role of polymer latices is to bind the fibers depending on the nature of polymer which, impart specific and desirable properties such as resistance to deformation, better retention of mechanical properties, resistance to laundering, resistance to solvent, fire and weather. The choice and characteristics of a polymer latex is also depends on the nature of the fibre used for making the finished products [17-19]. Robert [20] discussed the requirements such as the polarity and surface tension properties of the polymer latices. According to Robert [20], the polar water-soluble animal glue will adhere to cellulose fiber, because (i) both the materials are highly polar and (ii) the reduction in surface energy between the fibre and adhesive by means of fibre wetting. But rubber adhesive will not adhere to cellulose.

Hardness and flexibility of chemically bonded nonwoven fabrics is dependent on the glass transition temperature ($T_g$) of the polymer/binder used. Depending on the end application of nonwoven fabric, the $T_g$ of the binder is adjusted by copolymerisation with different monomers. The effect of $T_g$ of a series of acrylic binders on strength properties of rayon nonwoven fabric was reported by Kirk [18]. Increase in the $T_g$ of the binder found to increases the tensile strength, burst strength and dynamic thrust moduli (DTM) of the chemically bonded rayon nonwoven fabric. The DTM shows a remarkable exponential fall in mechanical properties with increase in the $T_g$ of acrylic binder beyond 40°C. On the basis of $T_g$, an attempt has been made to classify different polymeric binders used for bonding the nonwoven fabrics.

The polymer latex binder used to chemically bond the nonwoven fabrics can be classified into thermoplastics and thermosets. Thermoset binders undergo chemical reaction (crosslinking or curing) with or without catalysts. This process transforms the binder into an infusible and insoluble state by providing necessary bonding. This type of binders are desirable for high performance nonwoven fabrics. The thermoplastic resin bonded nonwoven fabrics have the tendency to lose its mechanical properties at elevated temperature. In case of thermosets [60-65], no such negative dependence on performance characteristics was noticed with increasing the temperature.

The different thermoplastic polymer latices used as binders for nonwoven fabrics are discussed below;
(i) **Acrylics:** Acrylic polymers are the most widely used binder for nonwoven fabrics [66-70]. The T_g of the acrylic polymer is a key factor in selecting the binder [25]. Usually acrylates have more than four carbon atoms in the ester alkyl group yields a polymer with low T_g. High degree of tackiness in acrylic polymers has been correlated with low T_g.

A range of latices, including acrylic esters modified with rosin esters and ethylene-acrylic acid copolymers has been widely used for bonding of nonwoven fabric with polypropylene (PP) fibres and blends with viscose [71]. Impregnation of chromatography paper with different acrylic latices and cured at 150°C showed improved dry and wet tensile strength [72]. Nylon nonwoven fabrics with acrylic latex of particle size 0.15-0.25 Μm pigmented with TiO_2 exhibited an improved resistance to laundering and abrasion [73].

(ii) **Vinyl acetate polymers:** These binders are stiff in nature than acrylcs and do not have good washing and dry-cleaning resistance. However, the low price, good film forming ability, good color and heat sealability are attractive to use this as binder for nonwoven fabrics. Poly vinyl acetate (PVAc) bonded nonwoven fabrics cannot be used extremely at high temperature. The PVAc produces hard film, which has a T_g of 30°C. Acrylate based co-monomers are commonly used with vinyl acetate monomer to impart flexibility [74-77]. The common binders are vinyl acetate-acrylic ester copolymers and vinyl acetate-ethylene copolymer latices. A nonwoven fabric resistant to chlorinated organic solvents has been fabricated by treating the nonwoven fabric with butyl acrylate-vinyl acetate copolymer latex [74]. Viscose rayon nonwoven has been bonded with vinyl acetate-acrylic ester copolymer latex containing poly acrylic acid and pigment [78]. Coir fibre nonwoven webs (400 g/m^2) bonded with ethylene-vinyl acetate latex resulted a delamination resistant product [79].

(iii) **Butadiene copolymers:** Acrylonitrile-butadiene (NBR) copolymers in latex form are efficient binders for many textile fabrics. Oil and fat resistance can be improved using NBR as the binder for nonwoven fabrics [80-81].

(iv) **Polyurethanes:** The outstanding characteristics of polyurethanes (PUs) as binder made it as popular for nonwoven fabrics [82-83]. The properties such as high elastic film, stability to weathering and heat are the main characteristics of PUs.

It is appropriate to conclude this broad survey on different type of polymer latex used to produce chemically bonded nonwoven fabrics by noting that, for many
applications, these chemically bonded nonwoven fabrics alone are unsatisfactory, because the finished nonwoven fabric contains less than 25% binder content. In the present research work, the composites were fabricated by impregnating the needle punched nonwoven fabric in various types of polymeric latex wherein the binder content maintained was above 75%. The present research work utilizes the knowledge of the above literature survey on polymer latices to fabricate the composites.

**Fibre-polymer bonding**

In order to achieve a very good fibre-polymer bonding in composites, the theory of adhesion plays an important role. The three essential requirements for a good polymer-fibre bond are [84]; (i) the ability of the polymer to wet the fibre surfaces, (ii) solidification of the polymer (to provide resistance to shear), (iii) deformability (to reduce stress concentration). The establishment of polymer-fibre interfacial adhesive bond employing polymeric latex is complex. During the fabrication of nonwoven fabric impregnated polymer composites, when polymer latex is added to the nonwoven fabric, a film of the latex formed between two fibres as shown in Figure 1.3.

![Figure 1.3. Sketch of fiber-latex-fibre bond interface](image)

The wetting of the fiber is controlled by the wetting characteristics of the aqueous phase of the latex. The surfactants present in the polymer latex may interfere with polymer-fibre bonding. During drying of nonwoven fabric impregnated polymer latex composites, the evaporation of water present in the latex allows the latex particles to coalesce [85]. During the final stage of drying, particularly when the system is cured at elevated temperature, strength improvement may be increased as a result of continued latex coalescence and in some cases by cross-linking. Diffusion may also play an important role. Allan et al have explained the importance of functional groups to improve the fiber-binder adhesion [86]. Meath and McFarlane [87] and McLaughlin [88] have found that the incorporation of carboxyl functional groups to ethyl acrylate increased the tensile strength and elongation of
cellulose fibrous nonwoven structure by 110 and 43% respectively. Allan et al have
concluded that, the functional groups such as carboxyl, aldehyde, amide, cyanoethyl,
hydroxyalkyl and sulfonic groups will not yield improvement in bond strength, but rather
imparts low enthalpy hydrogen bonds. The important properties that affect adhesion are
particle size distribution, stabilizer level, viscosity, solid content and tack of the polymer
latex [89-91]. Touchette and Jenness [92] have studied the effect of surfactant present on
the interfiber bonding. According to them the tensile strength of the cellulose fibrous
network has reduced as a result of surfactant addition. White [93] has shown that the use of
oligomeric surfactant in the preparation of carboxylated latices improves the adhesion by
increasing latex surface tension. Polywet surfactant, which are polymeric in nature have
multiplicity of ionic charges along their chain in contrast to conventional surfactants
which, found to improve the stability of latex and also the interfiber bonding.

The main advantage of using the needle punched nonwoven fabric in the composite
fabrication is its ability to incorporate high amount of binder, fabrication flexibility and
low density [94-95]. In these composites, the binder properties dominate in the final
composite performance and the nonwoven fabric functions as a carrier for the binder.
These type of composites are also called as bonded textile composites. Needle punched
nonwoven fabric is one of the material popularly used for the fabrication of composites
since they possess a good blend of strength, light weight and flexibility compared to
conventional textile material [96]. Because of the excellent z-directional strength of
needled nonwoven fabric, a very high delamination resistant composite can be obtained. In
addition to this, ease of processing, economy of cost and recycling ability of the needle
punching process made needled nonwoven fabrics to become popular in the fabrication of
composite. The composites can be fabricated by employing the natural and man-made fiber
based nonwoven fabrics containing one or more types of polymer as reinforcement. The
fibre and polymer components have their own specific roles to fulfill, although synergistic
effects resulting from their combination during the manufacturing process. The end
products may vary from very low-density products to medium and high-density board like
products. The polymer reinforced nonwoven fabric composites provides the important
properties that are interrelated and they mainly depend on the fibre-polymer interfacial
bonding;
1. Dimensional stability
2. Resistance to chemical and environmental degradation
3. Ability to hold stitch, be riveted and nailed
4. Resistance to cracking, piping and wrinkling
5. Embossability
6. Resiliency (cushioning)
7. Moisture and vapor transmission
8. Cutting and edge characteristics
9. Biological inertness
10. Abrasion resistance
11. Thermal and electrical resistance
12. Noise control

Several research articles in the journals and patents described the development of needled nonwoven fabric impregnated polymer composites. Epstein et al [97] fabricated the composites using needled mats of polyester, polyethylene and p-aramid fibers with polyurethane (PU) matrix via structural reaction injection molding (SRIM). The authors have discussed the influence of parameters such as the fibre-surface characteristics, fiber dimensions, and fiber volume fraction on the strength of nonwoven composites. A new mold was developed by Epstein and Shishoo [98-99] for the fabrication of nonwoven fabric reinforced – polyurethane composites. The authors have used two-component PU system and reported that the performance of the composites found to dependent on fibre type, fibre dimensions and polymer/fibre ratio. Natural rubber (NR) latex, polyurethane (PU) and acrylic latex (Primal HA16) reinforced polyester nonwoven fabric composites have been reported by Epstein et al [100]. Lukic et al [101] fabricated the composites by impregnating the needle punched polypropylene (PP) fibre in carboxylated styrene-butadiene rubber (SBR) latex containing embedded particles of abrasive Al₂O₃. Rigidahl et al [102] studied the effect of acetone dissolved poly vinyl acetate (PVAc) solution and poly vinyl alcohol (PVA) on the performance of cellulose nonwoven fabric composites. Shonaike [103] conducted the experiments to investigate the effect of impregnation conditions on glass fiber-reinforced ethylene-vinyl-acetate (EVA) elastomer composites.
The author reported that the use of a specially constructed mold reduces the tendency of the matrix resin flowing out during compression molding and the bending properties are strongly dependent on the impregnation conditions [103]. Huguchi [104] et al have fabricated the composites by impregnating the needled nonwoven fabric in PU solution of dimethyl formamide.

Klaus et al [105] have simulated the stress-strain diagram of leather by impregnating the polyester-polyamide nonwoven fabric in acrylic latex binder containing polysiloxane. Sinn [106] developed a microporous sheet by impregnating the needle punched polyester/polyamide nonwoven fabric with acrylonitrile-butadiene (NBR) latex containing a silicone emulsion. Jackson [107] and Young et al [108] have discussed the use of water borne epoxy resin dispersions as effective binders for the fabrication of nonwoven fabric composite. Dever [109] discussed the comparison between the acrylic latex bonding and ultrasonic bonding of a polyolefin nonwoven fabric composite. An orthopedic support material was developed by Ensfeld et al [110] wherein, sufficient curable polyurethane resin was impregnated into the nonwoven fabric such that the resin represents from about 65-90% by weight of the total weight of the material. Brady et al [111] have reported the effect of binder add-on and glass Tg on the tensile strength and elongation properties of resin bonded polyester nonwoven fabric composites. Rigdahl et al [112] have discussed the improvement of dry formed non-woven fabric of cellulose fibers after incorporating PVAc. The effect of nonwoven fabric structure on the thermal protective properties for out door applications was reported by Nosov et al [113]. It was found by the author that, the binder content in the composite markedly affects the thermal resistance properties. Artemenko et al have used the glued nonwoven cloth as reinforcement for polymer composite by [114].

Comparison of different binders for jute nonwoven fabrics, suggested that, poly vinyl acetate (PVAc) latex is more satisfactory than natural rubber. Mitra et al fabricated the composite by impregnating the needle punched jute nonwoven fabric in phenol-formaldehyde (PF) resin. The authors found that the cashew nut shell liquid (CNSL) modified PF resin performed better in terms of reduction in moisture regain and strength of composite (tensile strength and three point bending) [115-117]. Mwaikambo et al [118] fabricated the hemp fibre based nonwoven fabric CNSL composites. They reported that the
NaOH treated hemp fibres exhibited enhanced fibre-matrix adhesion compared to untreated composites. Yachmenev et al [119] fabricated a moldable, cellulosic-based nonwoven composites having excellent thermal insulation properties from kenaf, jute, flax, and waste cotton using recycled polyester and PP. The composites of these fibers have excellent shape stability and high tensile and flexural properties coupled with economic and environmental benefits. Hagstrand et al [120] fabricated flax fiber nonwoven mat reinforced and particulate filled melamine-formaldehyde composites processed by compression molding are studied and compared to a similar MF composites reinforced with glass fibers. The use of flax fiber instead of glass fiber has a somewhat negative effect on tensile performance and the scanning electron microscopy (SEM) revealed that the micro cracking takes place mainly in the fiber cell walls and not at the fiber-matrix interface [120].

1.5 SCOPE AND OBJECTIVES OF THE PRESENT RESEARCH WORK

Today polymer reinforced nonwoven fabric composites and nonwoven fabrics alone are used in more than 40 components of car manufacture in automobile sector. Carpet related applications accounts for 43% with 20% for insulation and 23% for bonnet liners. The nonwoven fabric reinforced polymer composites are light in weight, allowing improved fuel efficiency, design flexibility and can be formed into complex shapes. The fibre composition can be tailored to specific requirements. The high specific energy absorption of nonwoven fabric-polymer composites allowed it to be used as crash absorbers. Light weight polyester based composites accounts for high acoustic insulation performance. Nonwoven fabric composites allow the manufacturers to improve the cost effectiveness of their materials by matching the strength and durability of the conventional products and providing better performance and consistency at lower cost. Further, these polymer reinforced nonwoven fabric composites can greatly contribute the manufacturers to have a goal constituting (a) 30% weight reduction and (b) 20% cost reduction [121]. The nonwoven fabrics from single fibres embedded with suitable matrix are well suited for paneling elements in cars, railways and aeroplane etc.

The main objectives of the present research work are to fabricate the composites through a simple and straightforward impregnation method. A pre-existing textile
structures such as mechanically bonded (needle punched) nonwoven fabric is impregnated in different types of polymer and copolymer latices to fabricate the polymer reinforced nonwoven fabric composites by maintaining the polymer composition above 60%.

It is clear from the literature survey that, although, much work has been done in the area of chemically bonded nonwoven fabric with varieties of polymer latices for disposable applications, the literature lacks the information and many data with respect to nonwoven fabric composites containing high amount of polymer matrix embedded in nonwoven textile structure. Hence, there is an ample scope to establish the properties of composites for various applications. The following steps are incorporated in the envisaged research work:

- Fabrication of a series of composites by impregnating the needle punched polyester nonwoven fabric in different polymer latices such as; (a) poly (styrene-co-butyl acrylate), (b) acrylonitrile-butadine (NBR) copolymer, (c) polyvinyl acetate (PVAc)/melamine formaldehyde (MF) blend, (d) reactive composition containing castor oil and diisocyanates, (e) Synergistic flame retardant (antimony trioxide-brominated additive) filled PVAc/MF blend and (f) polyaniline filled PVAc.
- Characterisation of molded composites as per SATRA standard
- Thermal stability assessment through TGA and heat ageing studies.
- Fabrication and biodegradation studies on natural polymer/natural fibre incorporated nonwoven fabric composites.
- To evaluate the applicability of sorption isotherm models for biopolymer filled nonwoven fabric composites
- Molecular transport phenomenon of polymer reinforced-polyester nonwoven fabric composites
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