ISSN: 2319-8753

International Journal of Innovative Research in Science, Engineering and Technology
Vol. 2, Issue 4, April 2013

Application of Chicken Feathers inTechnical Textiles

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Abstract: The nonwoven is manufactured by using chicken feathers which are available at very low cost, so the end product too. The advantage is that there is a wide range of application of chicken feathers in textile field. The nonwoven which is prepared by chicken feather has very versatile and a wide application in the field of technical textiles.

Keywords: Chicken Feathers; Chemical Bonding;nonwoven; Thermal Bonding

I. INTRODUCTION

An estimated 15 million tons of chicken feathers are available globally each year as a by-product of meat manufacture. The raw material is tough and chemically resistant. Currently the feathers are disposed of in landfill, burned or processed to make a low-grade animal feedstock. These methods are environmentally unsound and are restricted. More expensive disposal method is to use as a low quality protein feed. However demand is less.Feathers are made from protein keratin there are two forms of microcrystalline keratin in the feathers. These are: the fiber and the quill. Thermal energy required to perturb the quill is less than that required by fibers .Therefore the feather fiber can withstand both thermal and mechanical stress. Feathers are chemically keratin just as WOOL, but the surface area is much larger because the diameter of the fiber is much smaller. So the fiber can absorb more water than the wool or cellulose fibers.The spinnability is limited due to smaller length. Based on these efforts have been made to utilize them and to produce a nonwoven web.Walter Schmidt and other researchers at the United States Department of Agriculture (USDA) have patented a method of removing the stiff quill from the fibers which make up the feather.

II.STRUCTURE

The feathers consist of three basic sections, as depicted in Figure1: the quill, the pennaceous fibers, which are located on theupper portion of the quill, and the plumulaceous fibers, which extend from the lower part of the quill . The plumulaceous fibers usually consist of a stem with two to three branches attached, and are soft and flexible. The pennaceous fibers are generally straighter, stiffer, and larger in diameter than the plumulaceous fibers.

Chicken feathers have a unique structure and properties not found in any natural or synthetic fibers. Although feathers as such cannot be processed as the proteinfibers wool and silk due to the complex structure of the feathers, the secondary structures of feathers i.e. the barbs have the structure and properties that make them suitable for use as natural protein fibers. The low density, excellent compressibility and resiliency, ability to dampen sound, warmth retention and distinctive morphological structure of feather barbs make them uniquefibers. For example, the density chicken feathers are about 0.8 g/cm^3 compared to about 1.5 g/cm^3 for cellulose fibers and about 1.3 g/cm^3 for wool. None of the natural or synthetic fibers commercially available today have a density as low as that of chicken feathers. Such unique properties make barbs preferable for many applications such as textiles and composites used for automotive applications. In addition to the unique structure and properties, barbs are cheap, abundantly available and a renewable source for protein fibers. Poultry feathers contain about 90% protein and are cheap and renewable source for protein fibers.

A feather is mainly composed of three distinct units as shown in Figure 1. The central shaft of the feather is called the rachis to which are attached the secondary structures, the barbs. The tertiary structures of the feathers, the barbules are attached to the barbs in a manner similar to the barbs being attached to the rachis. A rachis runs the entire length of the feather and could be up to 7 inches in length. The barbs have lengths anywhere from 1 to 4.5 cm depending on their location along the length of the rachis. Barbs at the base of the rachis are longer than those at the tip.

ISSN: 2319-8753

International Journal of Innovative Research in Science, Engineering and Technology
Vol. 2, Issue 4, April 2013

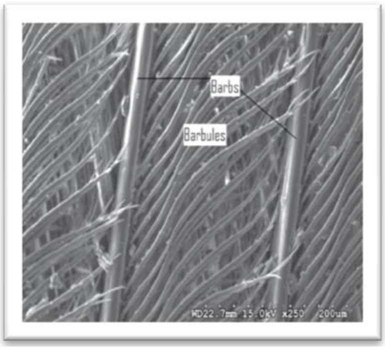

Fig.1 Morphological structure of chicken feather

Recently, several attempts on using the barbs as “feather fibers” for composites and nonwovens have been reported.These feather fibers have been recently characterized for their micro structural properties . However, commercially available feather fibers are the barbs in a pulverized form with lengths of about 0.3–1.3 cm . Feather fibers do not have the lengths required to be processable on textile machines and are therefore not suitable for making spun yarns and wovenfabrics in100% form or as blends with other natural and synthetic fibers. Being able to produce yarns and fabrics from barbs is important because of the potentialfor the higher value addition and the largest textile market. About 50% of the weight of the feathers are barbs and the other 50% is rachis. Even assuming that 20% of the barbs have lengths greater than 1 inch required for textile applications, about 400 million pounds of barbs will be available as natural protein fibers every year. This means an availability of 8% of the protein fibers consumed in the world every year. Feathers consist of about 91% keratin, 1.3% fat, and 7.9% water. Keratin is a hard protein that is also found in hair, skin, hooves and nails.

III. PHYSICAL PROPERTIES OF CHICKEN FEATHER

In keratin protein there are both hydrophilic and hydrophobic amino acids, but 39 of the 95 amino acids are hydrophilic . Serine is the most abundant amino acid and the-OH group in each serine residue helps chicken feathers to absorb moisture from the air. Feather fiber is, therefore, hygroscopic. Chicken feather fibers and quill have a similarcontent of moisture, around 7%. Fiber diameter is approximately 5-50 μm [9]. Fiber length through differentprocessing can be different, but it can be expected to be 3-13 mm. Therefore, the fiberaspect ratio (length/diameter) can be in the range of 400-2600.Because the chicken feather fiber is not completely solid, the fiber’s volume alwaysincludes both solid matter (the walls of fiber) and air (the hollow inside the fiber). Thedensity of chicken feather fibers is always interpreted as apparent density. It is reportedthat the density of chicken fibers is 0.89 g/cm3 and measured by displacing a knownvolume and weight of ethanol with an equivalent amount of fiber.Since the chicken feather fiber is mainly made up of the structural protein keratin, itschemical durability is primarily determined by keratin. Because keratin has extensivecross-linking and strong covalent bonding within its structure, the feather fiber showsgood durability and resistance to degradation.

IV.CHEMICAL PROPERTIES OF CHICKEN FEATHER

The action of acids, alkalis and solvents on feather fibers were found by a solubility test. The visible change in fibers due to chemical action was observed.

A. Effect of Acids

The feathers have good chemical resistance to mild acids, but have poor resistance to strong acids, so they get dissolved.

B. Effect of Alkalies

The feathers have good chemical resistance to mild acids, but have poor resistance to strong acids, so they get dissolved.The chicken feather fibers degrade rapidly in alkali environments,butsignificantly less in near-neutral and slightly acidic conditions.

V. MECHANICAL PROPERTY OF CHICKEN FEATHER

The functions of a bird's feathers are highly related to their mechanical propertiesand their mechanical properties are related to the keratin structure. Keratin has a structurewhich transports forces through negligible distortion. It is reported that elasticity moduliof feather keratin ranges from 0.045 GPa to 10 GPa. The Young's modulus ofchicken feather fibers was found to bechicken feather fibers was found to be in the range of 3 - 50 GPa and the tensilestrength of oven-dried chicken feather fibers in the range of 41-130 MPa.

VI. MANUFACTURING OF NONWOVEN:

A.Collection of chicken feathers
B.Washing

To remove the impurities washing is carried out in following order:

a) Chlorine hot wash
b) Cold wash
c) Acetone wash
d) Drying

C. Extraction of fibers from feathers
The quill has been separated from the feathers by two methods

a) Grinding
b) Cutting

In mixer grinding only 40% efficiency in fiber extraction from feathers has been achieved. The ground feather was found to be fluffy in nature. Then the quills were removed manually from the feather fiber by hand picking method. Cutting takes a lot of time but efficiency is greater than grinding method.

VII. PREPARATION FOR NONWOVENS

While starting with the preparations first and foremost the raw-materials to be acquired and the methods to be followed in the nonwoven manufacturing should be assessed first.
Nonwoven is produced by

1. Spray Bonding Technique
2. Chemical bonding
3. Thermal bonding

A. Spray bonding
In spray bonding, binders are sprayed onto moving webs. Spray bonding is used for fabric applications that which require the maintenance of highloft or bulk, such as fiberfill and air-laid pulp wipes. The binder is atomized by air pressure, hydraulic pressure, or centrifugal force and is applied to the upper surfaces of the web in fine droplet form through a system of nozzles.

Lower-web-surface binder addition is accomplished by reversing web direction on a second conveyor and passing the web under a second spray station. After each spraying, the web passes through a heating zone to remove water, and the binder is cured (set/cross-linked) in a third heating zone.For uniform binder distribution, spray nozzles are carefully engineered. Typical spray bonding is illustrated in fig.

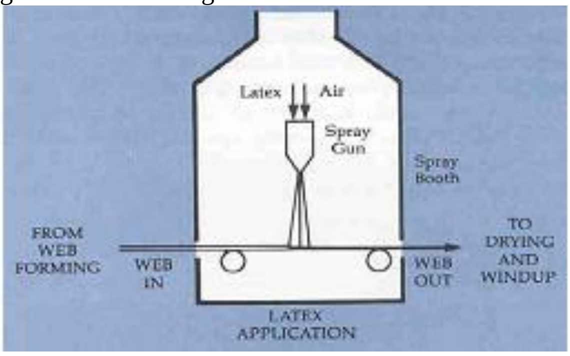

Fig.2. Schematic of spray bonding process

Fig.3. Industrial spray bonding process

The above said combinations of two bonding techniques are employed while manufacturing a Nonwoven out of a Chicken Feather. Namely, Spray bonding and Chemical bonding respectively.

B. Chemical bonding

For more than four decades, almost all nonwovens required a chemical binder in order to provide any measure of structural integrity. In addition, the binder was called upon to contribute and convey numerous properties that were necessary for the effective performance of the fabric.During this extended period, binders were essentially the weak element in developing fully acceptable nonwoven fabrics. The fibers that were available to the nonwoven industry where the same fibers that were available to the textile and other fiber-based industries; hence, the fibers were fully acceptable. Generally, the binder limited the performance of the nonwoven fabric. The deficiencies cited against nonwovens generally were deficiencies attributable to an inadequate binder.
Deficiencies are as follows:

1. The fabric doesn't have enough strength.
2. The fabric is too stiff.
3. The fabric has inadequate absorbency.
4. The fabric shows poor laundering ability.
5. The fabric has inadequate dry cleaning ability.
6. The fabric simply doesn't feel like a textile.

Consequently, a great deal of effort has been put into the development and continuous improvement of chemical binders. The steady improvements in nonwovens performance that occurred over a period of many years were, in no small measure, due to improvements in the performance and utility of the binder.

In the very early stages of nonwovens development, different types of natural resins and glues were used to bond nonwovens. While they conveyed some integrity and strength to these webs, they also had many glaring deficiencies. Consequently, synthetic binders were developed to meet the structural and performance requirements of nonwoven fabrics.

Polyvinyl acetate was the first successful synthetic binder used in substantial volume. This material had distinctly superior adhesive properties, strength, and performance compared to the early natural adhesives. This binder is flexible and it can be applied to fiber webs by many ways including print bonding.

The industry was faced with the inevitable compromise in fabric properties of nonwovens bonded with synthetic materials. In order to build strength in the fabric, increasing amounts of resin must be applied, which results in more stiffness. If softness is necessary, it can be achieved, but primarily by sacrificing strength.

A substantial improvement in this trade-off of strength and softness was achieved with the introduction of acrylic-based latex binders in the 1950s and 1960s. By proper selection of co-monomers, it is possible to build improved softness

ISSN: 2319-8753

International Journal of Innovative Research in Science, Engineering and Technology
Vol. 2, Issue 4, April 2013

properties with adequate strength. Consequently, these binders became widely used by most of the nonwoven industry, despite the somewhat higher cost.

As polymer technology for manufacturers of synthetic binder systems improved, a greater variety of chemical building blocks became available with much greater flexibility in terms of binder strength, durability, and other properties.

The construction of a nonwoven with suitable binders is to achieve improved characteristics such as strength, softness, adhesion, firmness, durability, stiffness, fire retardence, hydrophilicity, hydrophobicity, anti-microbial properties, organic compatibility, reduced surface tension, improved dimensional stability and solvent, wash and acid resistance. The following list illustrates some general considerations required for an ideal binder. The required properties can be varied depending on the end-uses.

Strength: The strength of a nonwoven fabric is more closely related to the strength of the applied binder.

Adhesion to Fibers: Even though the mechanism of adhesion is not completely understood, the adhesion strength of the binder-to-fiber bond has to be considered.

Flexibility/handle: The some movements of fibers should be allowed, especially when a soft hand is desired.

Elastic Recovery: To avoid the permanent deformation of fabric, good elastic recovery is required under strain.

Resistance to washing/ Drying cleaning: Some nonwoven products need durability in cleaning processes according to their end-uses.

Resistance to aging: The binder should be stable and not be degraded in the fabric during storage and use.

Good color and color retention: Diverse ranges of colors are required, and the colorfastness and yellowing problems should be considered.

Economical: Minimizing the cost is an ongoing requirement.

Other special requirements: Such as Flame resistance, resistance to chemicals, air, oxygen, light, heat, etc.

C.Thermal bonding

Thermal bonding is one of the most widely used bonding technologies in the nonwoven industry. From its definition, bonded nonwoven fabric is prepared from a combination of fibers and a bonding agent which works as 'glue' to firmly bind the mat together to form the nonwoven fabric.The bonding agent has a significant effect on the properties of the fabric. There are many kinds of the binding agent, for example, dispersion foam, paste, powder and so on. In this research, binding fibers were used so the bonding of the mat was called Fiber Bonding (Thermofusion). In this method, the mat is heated to the temperature at which part or whole bonding fibers melt. The molten mass binds the\matrix fibers which do not melt at their intersection points.In Fiber Bonding method, low energy is needed during the process; the producednonwoven fabric is high-bulking, but still fairly strong. The mat is not affected bypressure during heat treatment; and the produced nonwovens have high air permeability.Thermal bonding can be taken in many ways such as through-air bonding, infrared bonding, ultrasonic bonding, and thermal point bonding, hot calendering , belt calendaring and so on. In this research, we used thermal plate bonding, that is, hot pressing, in which two hot plates were used and the requiredequipment are very simple and easy to control. A uniform fabric requires uniform pressure, uniform temperature,besides uniform input mat, all of which the heated plate can supply because smooth plates provide uniform pressure and heat from hot plates makes thin mat uniformly hot.

In this thermal plate bonding, after the mat is formed, it is placed in between theplates. Between the plates, thermal bonding proceeds through three stages: firstcompressing and heating the mat, second bonding the mat, and third cooling the bonded mat.During compression, minimal pressure is demanded at the nip to produce fiber-to fiber contact. Sufficient pressure is required to compress the mat and decrease its thickness. In this way, efficient heat transfer through conduction can happen. Over the range of pressures commercially applied, higher nip pressures do not necessarily produce higher performance. At the same time of compression, both of the plates are heated. Since heating the mat begins when the mat first touches the hot plate and continues until it leaves the plate, the time spent in the nip is also the time available for heating the mat. The heating occurs primarily through conduction, the fibers placed between two plates get heated very quickly. To form a bond, the binding fibers in the middle of the nip must reach a certain temperature. The plate temperature must stay below the melting points of fibers; otherwise the web will fuse to the plates. If the time in the nip is greater than the time to reach the temperature, the bond is strong. However, longer heating time cannot guarantee strong bond because long time heating maybe produces over-bonding and this makes bond spot fiber lose their orientation, then some strength would be lost. The effect of heating time on the strength of nonwovens was tested.In the thermobonding process parameters were fixed at required pointssuch as sufficient pressure, time and temperature. The thermobonded nonwovens were tested for their filtration and mechanical properties. The solution of chemicals was sprayed as tiny droplets and the web was cured at a temperature of 170 at a delivery speed of 0.5m/min in stenter.

VIII. POSSIBLE APPLICATIONS OF FEATHER FIBERS

Environmental concerns always encourage study to replace synthetic materialswith a variety of natural materials. Natural fibers have recently attracted scientists'attention because of their advantages from the environmental standpoint, but almost all the research has been focused on cellulose from vegetable sources. Currently, the keratin fiber from chicken feathers is recognized as an almost infinite source of high performance materials, but it needs further studies to demonstrate a basis for innovative technologies and useful raw materials.

To obtain and use the feather fiber, barbs need to be stripped from the quill. InFebruary 1998, Agricultural Research Service chemist Walter Schmidt and his colleagues (George Gassner, Mike Line, Rolland Waters and Clayton Thomas) received a patent for a process for cleaning, chopping, and separating feather fibers from the quill of chicken feathers . From it, two pounds of feathers yields about one pound of the fiber fraction and one pound of the quill fraction. This patent involves the following basic steps collecting raw feathers, washing feather in a polar water-soluble organic solvent, repeating the washing step, drying the feathers, removing the fibers from feather shafts using mechanical shredding or shearing or a high speed constant flow centrifugal grinder andseparating the light fibers from the heavier quills through a turbulent airflow by apparent density difference. The unique shape, a center fiber with many branching fibers, makes feather fibers ideal for random orientation processes such as injection molding, dry mat formation, or wet lay. Maybe these materials derived from chicken feathers could be used to improve the properties of existing composite materials, to replace non-renewable constituents, orto develop entirely new biocomposite materials with novel applications. There have been a few reports about useful products manufactured from feathers.
Walter Schmidt invented a technique to mix chicken feather fibers with paper andstrong, less dense plastic composites to produce products such as car dashboards and boat exteriors. A fiber that can be used in lightweight, sound-deadening composite materials maybe find use in office cubicles, cars and sleeping compartments of tractor trailers.

The Environmental Quality Laboratory scientist also found feather fiber can takeplace of some of the wood pulp to make such paper products as air filters and decorative paper. Because of the super fine size and shape of feather fibers, filtration may be the first commercial value for processed chicken feathers. Many filters are made from wood pulp, but feather fiber has an advantage--it is finer than wood pulp. Wood pulp fibers have a width of 10-20 microns, but feather fibers' thickness is only 5 μm. Therefore, filters produced from feather fiber will have smaller holes, causing more spores, more dust and dander to be taken away from the air and entrapped in the filter. Homes and office buildings maybe obtain the benefit of using this kind of air filter for their fine filtration, resulting in lessening allergies and sick building syndrome. Another possible use may be in vacuum filters, decreasing the amount of spores and dust that can injure asthmatic lungs. A process of making air filter paper using chicken feather fiber has been patented in China. The process includes using feather fiber as major material, mixing with plant fiber at a given ratio, and making specific paper with multiple applications. Compared with existing paper-making process, this process has the advantages of better air permeability and filterability, full utilization of waste, lesspollution to the environment, reduced consumption of wood pulp, reduced cost, and high application value. Furthermore, the composite paper is able to contain only 49 % wood pulp and 51% feather fiber . In one word, the chicken feather paper meets the requirement for environmental protection.Feather fibers might be used in water filters. This application might not onlyhelp solve the waste-feather problem, but it might also produce better water filters thanpresent common filters, such as those made of activated carbon. Before the fiber wasplaced in a filter, it was "activated" with ultrasound to produce additional microscopicpores in the fiber's structure. The prototype of feather-fiber water filters was produced bypacking the fibers into plastic columns. Tests indicated that the feather filters tookcontaminants away from home drinking water or industrial waste. In the laboratoryexperiments, it had also found that feather fiber filters filtrated nuclear byproducts suchas radioactive strontium and cesium and the microstructure of feather fibers trapped thesehard-to-remove contaminants.

Dweib et al.used vacuum-assisted resintransfer molding to infuse feather mats along with sheets of recycled paper with soybeanoil-based resin. These materials were combined with structural foam to constructa sandwich beams. The beam of recycled paper and chicken feathers had a global modulusof 950 MPa and a failure load of 24.2 kN while the woven E-glass beam had a globalmodulus of 1580 MPa and a failure load of 39.3 kN during testing in 4-point bends. Theflexural rigidity and strength of the feather/recycled paper beam were comparable tovalues for cedar wood.

The studies of chicken feather fibers reinforced LDPE polymer matrix shows some interactionbetween the fiber and polymer without the need for coupling agents or chemical treatment of the fibers. The feather fibers could be directly incorporated into the polymerusing standard thermomechanical mixing techniques. The density of the composite uponintroduction of keratin feather fiber is not increased, but reduced by 2%.Hamoush and El-Hawary tried to improve concrete properties such as strengthand durability by adding chicken feather fibers to the concrete. The feathers werewashed, screened, and dried. Three volume fractions of chicken feathers (1, 2, and 3%) were tested. Their study showed that the feather fiber reinforced concrete was lighter in weight and stronger in flexure than ordinary Portland cement plain concrete and smaller in compressive and tensile strengths than those of plain concrete, which indicates that feathers help produces cheaper lightweight concrete. The concrete with 1% feathers had higher flexural strength after 14, 28 and 56 days and so was that with 2% feather fibers after 56 days, which provides a possibility for the concrete used under impact loading. One disadvantage was that the flexural strength decreased when the feather content wasover 2%. It was found that the pore solution in cement-based materials are stronglyalkaline, with a pH of 12.5-13.5. Alkaline environments accelerate feather fiberdecay. The alkaline testing conditions caused low compressive and tensile strengthmeasurement value. Two methods (treating feathers by a water-repellent agent andimpregnating feathers with a blocking agent followed by a water-repellent agent) are usedto reduce the alkalinity of the matrix to prevent both short- and long-term decay, bothcompressive and tensile strength. The compressive, tensile and flexural strengths ofconcrete with treated feather were improved compared to untreated-feather-reinforcedconcrete.

Using chicken feather fiber was studied to separate heavy metals from water. Itwas found that the chicken feather fiber has very good adsorbent properties and removedeffectively heavy metals such as copper, lead, chromium, mercury and uranium fromsolutions. The solution with pH 2-8 adsorbed heavy metals best and alkaline ultrasonictreatment improved the metal uptake of the keratin fiber many times. Washing featherfibers with dilute hydrochloric acid at a pH of 1.2 could desorb 99% of adsorbed copperions. All of the testing results showed that it is possible that the stability of feather fibersallows them usable as anabsorbent for a number of cycles after being washed withhydrochloric acid.

IX. USES

1. Automotive textile: usage of Nonwoven made out of Chicken feathers are used in seats and cushioning ,Interior Linings etc.,
2. Packing material : while transporting delicate articles from one place to another, the cartons lined with nonwovens made out of chicken feathers are placed inside as the interlining which makes sure that the articles are tightly impact at the same place , and would be transported without any damages.
3. Filter property : Nonwovens made out of chicken feathers as obvious it has a very good porosity and is lighter in weight, it has a promising future in Chemical industries as it has a good resistance to milder acids and alkalies.
4. Insulation: To conduct any kind of electricity one must have a conducting element like water content (or moisture). But the chicken feathers lack such elements , so they hence a very good insulating property hence they can be act as insulating materials
5. Household product: for the Nonwovens made out of Chicken feathers are very versatile in their property they are used as a decorating materials in the households.
6. Soil control: The nonwovens made out of Chicken feathers are very stiff and rigid where in which when placed on the soil it will restrict the eroding of the top layered soil, thereby controlling soil erosion respectively.
7. Winter jackets: The nonwovens made out of Chicken feathers are used in the jackects as the interlining where in which it keeps the body very warm.

X. CONCLUSION

Production of erosion control fabrics consisting of chicken feather fibers can be performed utilizing air laid web formation and latex bonding. However, greater control of the latex. Application is required to obtain increased product consistency. The chicken fiber fabrics, in comparison to the commercial erosion control fabrics evaluated, performed better than expected.

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