Summary and Conclusion

5. SUMMARY AND CONCLUSION

The summary and conclusion pertaining to the study entitled **"Development of nonwoven fabrics using *Sansevieria roxburghiana* and *Agave vera-cruz Mill* fibres for selected automobile acoustic applications"** are summarized here.

Technical textiles are the fastest growing area of textile consumption in the world. Nowadays nonwovens have emerged as an alternative to wovens in most of the technical applications due to the increased awareness about nonwoven fabrics. In recent times, consumers are very conscious about the environment to ensure safety to their health and life. Thus eco friendly products are gaining importance in the market remark Singha etal. (2011). Natural fibres being biodegradable, low cost, easily accessible, low density and with good acoustic property attract the manufacturers from diversified fields suggest Asdrubali (2006); Oladele etal. (2010). These natural fibres have great potential in automobile applications especially for light weight, ELV (End of Life Vehicle) and NVH (Noise, Vibration and Harshness) products.

The investigator considered all the above factors in mind and has selected the present work to extract fibres from natural plants using eco friendly method. The extracted fibres were converted into nonwoven structures and were analyzed for its application in automobiles as acoustic materials.

The objectives of the study are to

- Elicit information from the consumers and markets through survey about the existing and needed textiles for automobiles.
- Extract fibres from *Sansevieria roxburghiana* and *Agave vera-cruz Mill* leaves using various fibre extraction methods and to study its physio chemical characterization.
- Blend the extracted fibres with coir and PET for needle punching and analyzing its properties.
- Surface modify the extracted fibres using alkali treatment.
- Make composites using both the extracted and surface modified fibres with polypropylene fibre as matrix and analyze its various mechanical properties.

- Find out the suitability of needle punched and composite samples as acoustic materials in automobiles.

Methodology

The methodology of this study consisted of three phases with the following aspects.

Phase - 1

Survey

A survey was conducted in 25 auto care shops and 25 consumers regarding the type of fabric used, cost, durability, comfort, care and other factors considered to collect information about the existing and proposed textiles in the automotive sector in and around Coimbatore district.

Pilot Study

A pilot study was conducted with five different plant parts namely *Sansevieria roxburghiana* (leaves)*, Agave vera-cruz Mill* (leaves)*, Hibiscus rosa-sinensis* (Stems)*, Curcuma longa* (Stems) *and Saccharum officinarum* (Stems) to find out the best varieties of plant for fibre extraction. Finally two plants namely *Sansevieria roxburghiana* and *Agave vera-cruz Mill leaves* were selected for fibre extraction.

Collection of Leaves

Sansevieria roxburghiana leaves were collected from the farms in and around Salem district and *Agave vera-cruz Mill* leaves were collected from Burgur forest in Krishnagiri district, Tamilnadu.

Fibre Extraction Methods

To find out the best method of fibre extraction, common methods such as decortication, stagnant water retting and running water retting were carried out in this study. After analyzing the various parameters of fibre extraction like quality using visual inspection, quantity, duration of fibre extraction and eco friendliness decortication method was selected for this study.

Combing

The extracted fibers were hand combed using hackles to remove the impurities and short fibres present in it thus arranging the remaining fibres parallel.

Fibre Testing

The physio chemical characterization of both the extracted fibres were analyzed using various fibre tests namely chemical composition, fibre strength and elongation, length, diameter, density, moisture properties, fineness, SEM study, spectroscopic Study, XRD and DSC.

Phase - 2

Selection of Fibres

Fibres namely PET fibre of 64mm cut length with 3denier, polypropylene fibre of 40mm cut length with 2.5denier and coir fibre of 60mm cut length were used for this study. PET fibres were procured from Nowatex Fabs, Coimbatore, polypropylene fibres were procured from Zenith Fibres, Baroda and coir fibres from coir market in Suramangalam, Salem.

Cutting of Fibres

The *Sansevieria roxburghiana* and *Agave vera-cruz Mill* fibres were cut into small pieces with the help of knife manually for easy blending with other fibres. The cut lengths of the fibres were 100mm - 150mm approximately.

Blending of Fibres

The raw *Sansevieria roxburghiana* and *Agave vera-cruz Mill* fibres were blended with coir and PET for needle punching process in 12 different ratios.

Steps involved in web formation

The initial step in the preparation of nonwoven fabrics is web formation which involves the following steps.

Pre-opening

The blended fibres were mixed manually according to their desired combination and were fed to the pre-opening machine. Rieter MBO type of machine was used for pre-opening which produces smaller tuft of fibres, thus creating a large surface area for easy and efficient removal of trash particles during the fine opening process.

Mixing

The fibres after pre-opening were intermixed by passing the fibres into series of mixing zones by suction method before they enter into the fine opener. Thus mixing ensures proper opening and blending of the fibres.

Fine Opening

The mixed fibres were passed through an Erko fine opener which opens and cleans the fibres and thus improves the intimacy of the blend. This helps to achieve good web qualities.

Carding

The opened fibres were pneumatically fed to card feeders. The nonwoven carding machine has two main cylinders, worker/stripper rollers, doffers and take up rollers. The machine direction:cross direction was 1:1 for this carding machine hence the web formed was a condensed web.

Crosslapping or Layering

Single layers of carded web were too light and diffuse to make into a fabric. So a number of layers are laid on top of one another (crosslapping) to get the necessary web thickness.

Needle Punching Technique

The web was then provided integrity and strength by bonding through mechanical interlocking method known as needle punching process.

Pre-needling

The crosslapped web was fed to a pair of compression rolls, followed by a pre-needler. In the pre-needling process downward punching of the web takes place using Fehrer pre-needle punching loom. It also squeezes the web, allowing easier movement through the needle loom bed plate and stripper plate gap. This machine has 1500 needles per 1m working width with 40mm stroke height. The width of the needle was 2.2m-9.0m with 500strokes/min. The delivery speed was 0.6m/min.

Main Needling

In the main needle punching process the pre-needled batt is made to pass through a number of needles with barbs, mounted on a board which reciprocates at high speed. For the needle punching process German based Dilo machine was used.

Fabric Testing

The needle punched fabrics were assessed for their visual inspection. Standard test procedures were used to measure the physical properties of nonwoven fabrics such as ASTM D5035 – 06 for tensile properties namely breaking strength & elongation, ASTM D 5729 – 97 for fabric thickness, ASTM D

6242 – 98 for aerial density, ASTM D 5732 – 95 for fabric stiffness, ASTM D 737 – 75 for air permeability, ASTM E 1050 for impedance test and thermal conductivity by Lee's disc method.

Phase - 3

Surface Modification of Fibres

Sansevieria roxburghiana and *Agave vera-cruz Mill* fibres were given alkali treatment with 6 per cent NaOH at 80°C in water bath for 1 hour with constant stirring. Then the fibres were removed from the NaOH bath and rinsed thoroughly for neutralizing.

Blending of Fibres

Composites were prepared by blending original and surface modified fibres of *Sansevieria roxburghiana* with polypropylene in 6 different ratios. The same procedure was followed for *Agave vera-cruz Mill* fibre.

Web Formation for Composites

Sansevieria roxburghiana and *Agave vera-cruz Mill* fibres were used as reinforcement fibre with Polypropylene fibre as matrix. The sample size for composites is small hence to minimize the fibre waste the web was prepared using mini carding machine. For even distribution of fibres in the composites, web formation was done twice by both hand and machine methods.

Preparation of Mould

The web has been cut according to the template size of 20cm X 20cm. In order to get the desired thickness of the composite samples ten layers of webs were combined together to form a bed. Then the prepared sample was placed on the mould and it was covered over another mould.

Composite Preparation

The prepared mould was placed in the Uni polymer composite machine over the fixed iron plate (lower jaw) at a temperature of 190°C. The movable iron plate (upper jaw) was tightened to transfer the temperature between plates and to exert pressure of 20bar over the samples which was noted in the pressure guage. This temperature was maintained for 10min then the mould was allowed to cool. Then the prepared composite samples were removed from the mould.

Testing Methods for Composites

Composite samples were assesed by visual inspection and for mechanical properties using American Standard Testing Methods (ASTM). The three tests performed for mechanical properties includes tensile test (ASTM D3039), flexural test (ASTM D4812-99) and impact test (ASTM D790). For surface morphological study, Scanning Electron Microscope (SEM) was used. Thermal conductivity of the samples was tested by Lee's disc method and ASTM E 1050 for impedance test.

Analysis of Results

The test results of needle punched and composite samples were analyzed statistically using Multivariance Analysis. Similarly fibre properties were analyzed using mean, standard deviation and coefficient of variation.

Findings of the Study

Survey

Information gathered from the market survey revealed that automobile sector mostly consumes nonwoven fabrics made up of synthetic fibres which are non degradable, high cost with medium weight. The consumer survey indicates that majority of the people were not satisfied with the maintenance of fabric, cost, quality and comfort property of the automotive textile material. It also indicates that there was a great demand for light weight automobile parts which are recyclable or bio degradable. Hence this study was undertaken to satisfy the demands of the consumers and auto care shops.

Evaluation of Fibre Extraction Methods

Among the various fibre extraction methods decortication was found to be the best method for commercial extraction of both S and A fibre. The quality of sample SA and AA was found to be the best in terms of general appearance, colour, lustre and texture. Moreover this eco friendly method yields more quantity of fibre in short duration of time.

Evaluation of Fibres

Chemical composition

The chemical composition of sample S reveals the presence of cellulose (92.85%), lignin (3.29%), wax (0.58%) and ash content (1.93%). Similarly sample A has cellulose (77.43%), lignin (3.55%), wax (0.26%) and ash content (1.71%). Hence these fibres were suitable for textile applications.

Mechanical Properties

The **tensile strength** of sample S and A was found to be 257.81gf and 1129.41gf respectively. Similarly the **elongation** value of sample S and A was identified as 1.60% and 2.27% correspondingly.

Physical properties

Sample S has **length** and **diameter** of 1.03m and 0.261mm whereas sample A has length and diameter value of 1.721m and 0.278mm respectively. The **moisture content** of sample S and A was estimated as 9.53% and 8.03%. Similarly the **moisture regain** of sample S and A was calculated as 8.24% and 8.73% respectively. Sample S has **fineness** value of 6.8tex and sample A has fineness of 36tex. The **density** value of both sample S and A was noted as 1.1g/cc.

Characterization Studies

SEM Analysis

The SEM images of sample S and A shows the presence of hemicellulose and lignin coating over the cellulosic fibres. The fibres are arranged as a set of fibrils along longitudinal direction. The cross sectional view shows the presence of voids in both the fibres. The samples ST and AT had reduced in their thickness when compared to the original S and A samples due to the removal of surface impurities during alkali treatment.

IR Spectroscopy

The infrared spectra of the samples confirmed the presence of cellulose, hemicelluloses, lignin, pectin and water molecules in its structure. This indicates that both S and A samples were ligno cellulosic fibres. The ST and AT samples indicates the presence of sodium hydroxide which was checked by N – H and C = C bond.

XRD Study

The original sample S and A has crystalline index of 52.86% and 35.4% respectively. The degree of crystallinity of alkali treated ST and AT samples was 42.4% and 31.8% respectively.

DSC Measurements

The glass transition (T_g) of sample S begins approximately in the range of 50°C but in the case of sample A the peak starts at 73°C. Both the natural fibres withstand temperature upto 300°C without fibre decomposition. Hence these fibres can be used for preparing composites using compression moulding technique.

Evaluation of Needle Punched Fabrics

Visual Inspection

Overall the sample S3 has good general appearance, colour and evenness with medium texture and low lustre in visual inspection.

Mechanical Properties

As for mechanical properties of **dry** needle punched samples in machine direction, sample S3 seems to have high **breaking strength** of 38.8Kg and sample S10 has low elongation of 4.1inches. Along cross direction sample S1 has high breaking strength of 14.6Kg and sample S7 has minimum **elongation** of 5.38inches. Statistically it was proved that it exist one per cent significant level among the samples for breaking strength and elongation.

The **breaking strength** of **wet** needle punched samples across machine direction was high for sample S1 (30.80Kg) whereas elongation was low for sample S12 (4.02inches). Similarly breaking strength in cross direction was maximum in sample S3 (16.40Kg) and sample S12 has minimum **elongation** of (2.62inches) when compared to other needle punched samples. Statistically also it was confirmed that there exists one per cent level of significant difference among the samples

Physical Properties

As far fabric stiffness was considered sample S6 seems to be the best with high **stiffness** value along both machine and cross direction. Hence it suits best for automobile upholstery. Statistical interpretation reveals that fibre proportion has one per cent level of significant difference on fabric stiffness.

It was concluded that fabric S3 has maximum **thickness** (5.36mm), **aerial density** (304.60g/m^2) and low **air permeability** (195c.c/cm.sq./sec.). Due to its low air permeability sample S3 can suitably be used as upholstery in automobiles. The statistical data proved that it was significant at one per cent level among all the samples.

Sample S1 with low **moisture content** and **moisture regain** can be used effectively as upholstery in automobiles. Sample S2 with low **wicking length** of 0.4mm and high **sinking time** of 45min can also be used in automobiles. The fabric properties like wicking, sinking and moisture properties have one per cent level of significance between all the samples.

Thermal Conductivity

The results of thermal conductivity of needle punched samples revealed that sample S3 has minimum thermal conductivity of 0.0186w/m/k. Statistically it was proved that the samples have one per cent level of significance. It was found that sample S3 seems to have good thermal insulation property due to its high fabric thickness. Hence it can be used as thermal insulator when compared to other samples.

Impedance Test

Among all the fabrics, sample S2 and S3 have high sound absorption of 79% and 78% at the frequency of 1600Hz. Sample S2 and S3 also have good sound absorption at various frequency ranges from 200 – 2000Hz. Hence this can be used effectively as sound insulation pads in automobiles.

Evaluation of Composites

Visual Inspection

As far as visual inspection was concerned, sample SC1 of S composite and sample AC3 of A composite sample ranked good for general appearance, colour, texture, lustre and evenness.

Mechanical Properties

Tensile Properties

Overall sample SC3 of S composite and sample AC4 of A composite ranks good in tensile strength when compared to all the composites. Sample SC3 has high tensile strength of 29.33MPa and high tensile modulus of 7.28MPa. Similarly sample AC4 has high tensile strength and modulus of 28.20MPa and 10.11MPa respectively. Statistically it was proved that it has one percent level of significance. Hence these can be used effectively for structural applications.

Flexural and Impact Properties

The flexural strength was high for sample SC1 (21.96N/mm^2) and AC1 (23.51N/mm^2) when compared to other S and A composite samples. Among the entire S and A fibre composites the impact strength was higher for sample SC2 (2.02Joules) and AC6 (2.40Joules). Hence these composites can be used effectively for structural applications. The statistical results confirmed that both flexural and impact strength of composites has one per cent level of significance.

Morphological Analysis

The SEM images of untreated fibre composites shows the presence of holes which was created during fibre pull-out in tensile strength analysis. The holes occured due to poor fibre matrix compatibility. Whereas the composites made of treated fibre samples indicates uniform matrix coating over the fibres.

Thermal Conductivity

Overall it was identified that in S composites, sample SC1 seem to have lower thermal conductivity of 0.0320W/m/K. Hence composite SC1 can be used as thermal insulator. Among all the A composites, sample AC4 seem to have minimum thermal conductivity value of 0.023w/m/k thus can act as a good thermal insulator. Statistically it was shown that there exists one per cent level of significant difference among the samples.

Impedance Test

It was concluded that among all the sample S composites, sample SC1 had maximum sound absorption of 86% in the frequency of 1800Hz. Overall it was observed that sound absorption coefficient of this sample was higher for various frequencies (200 – 2000Hz). Among the entire A composites, sample AC6 had good sound absorption coefficient in all the frequency ranges. The maximum sound absorption of 82% was noticed in sample AC6 at a frequency of 800Hz. Hence these two samples can be effectively used in automobile interiors as sound insulators.

Conclusion

Sansevieria roxburghiana and *Agave vera-cruz Mill* plants were considered as wild plants and were available in plenty in farms and forest areas. Fibres were extracted from the leaves of these two plants by eco friendly decortication method. The chemical constituent of both the extracted fibres has high cellulose, low lignin and wax content. The extracted fibres have good strength, low elongation, low density and high length to width ratio, which makes it suitable for textile applications. Hence these fibres were blended easily with coir and PET fibres in twelve different ratios and were converted into needle punched fabrics. Among all the needle punched fabrics, sample S3 has good general appearance, high strength, high stiffness, high aerial density, maximum thickness, maximum sound absorption coefficient, low air permeability and low thermal conductivity.

The extracted fibres were given alkali treatment with sodium hydroxide to modify the fibre surface. Both the untreated and treated *Sansevieria roxburghiana* and *Agave vera-cruz Mill* fibres were blended with polypropylene fibres and converted into web in six different ratios each. Composites were prepared using these webs by compression moulding technique. The results of the composites reveal that sample SC1 has good general appearance, high flexural strength, high impact strength, good thermal insulation and good acoustic property. Similarly sample AC6 has high flexural strength, high impact strength, good thermal insulation and good acoustic property. Hence both the needle punched and composite fabrics can be used effectively as acoustic materials in automobiles.

Recommendations for further study

- Instead of changing the fibre proportion the needle punching parameters namely punch density, web thickness, etc can be varied by keeping fibre combination as constant.
- The needle punched fabrics can also be evaluated for their applications in various fields of technical textiles.
- Composites can be made even using needle punched fabrics.
- Composites can be tried out using various resins and different moulding techniques.
- In composites the natural fibres can be given various surface modification treatments and it can be evaluated.
- Several types of natural dyes can be tried out in these fibres.
- The fibres can be converted into woven structures which can also be used for composite preparations.