International Journal of Modern Science and Technology, 2018;3(3):47-52.
ISSN: 2456-0235.
www.ijmst.co

Research Article

Development of Non-woven Composite Materials made from Reclaimed Cotton/Polyester and Polypropylene Fiber

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Abstract

Reclaimed fibers are generally used in dissimilar applications and one of the most important applications is to develop and advance technology for new automobile products. Reclaimed fiber non-woven composites, currently, are in greater demands in industries because of their advantages such as low cost, biodegradability, acceptable mechanical & physical properties and so on. Reclaimed fiber has been identified as a recyclable source for industrial wastes. Renewable and eco-friendly nonwoven composites have been developed using reclaimed cotton, polyester and polypropylene fibers. The present research was focused to investigate on optimizing the manufacturing techniques and testing of both air-laid non-woven, and melt-blended reclaimed composite materials. To form the composites, two methods of bonding were used such as air-laid non-woven and melt-blend technology. Each series of experimentation was to be combined with specific amount of copolymer chemical agent, the recycled post-industrial polypropylene powder, and reclaimed fiber. The reclaimed fiber non-woven composites are characterized for their physical properties such as dimensional stability performance and the mechanical properties, like internal bond, static bonding and tensile stress can be tested in accordance with ASTM standard. The results revealed that physical properties can be determined for both conditions like 24 hrs soak and 2 hrs boil. The physical properties like thickness, water absorption and linear expansion can be analyzing separately the air laid materials have more properties than the melt extrusion. The air- laid and melt- bond has deviation likewise coupling agent can change the properties.

Keywords: Reclaimed fiber; Composites; coupling agent; Melt-blend; Air-laid non-woven composites.

Introduction

The use of reclaimed fibres has the compensation of consuming less water and chemical products; it provides economic profit to developing countries which have been critically damaged in recent years due to extreme mass production of cotton. The production costs are lower than fully certified organic cotton. One of the shortcomings of non-woven mat composite is that poor attractions and low interfacial bonding between the hydrophilic cotton and hydrophobic polyester limit the reinforcement imparted [1].

The environmental concerns, a very large numbers of companies are currently developing manufacturing process using alternative materials for their products and seeking new markets. With the significant production of waste fibrous materials, different companies are looking for applications where waste materials may represent an added-value material [2]. The fibers are initially held together by mechanical interlacing. The web can then be fused or thermoformed into panels with a variety of shapes. Alternatively, a thermosetting resin can be incorporated in the web to provide additional bonding of the fibers [3]. Hence, the amount of compressive load and fiber orientation in the fabric are very much important for its tensile behavior during crack or void generation [4].

The mechanical properties of textile material characterize the response of the material to applied forces and deformations [5]. During the bonding conditions below the peak, fabric failure occurs by bond disintegration because of insufficient fiber fusion or "under-bonding" [6]. Non-woven fabric properties are determined by the characteristics of bond points and in particular by the stress-strain relationship of the bridging fibers [7]. Composite is a material that

Received: 23.01.2018; Received after Revision: 20.03.2018; Accepted: 20.03.2018; Published: 25.03.2018

consists of more than one component, in which at least one of the components remains in solid state during its manufacture. The light weight and superior mechanical properties of polymer composites [8]. Several applications of reclaimed fiber composites can be found in construction, packaging, furniture and automotive fields [9]. This more environment friendly composite that can be compression molded into a wide range of parts has a greater bending stiffness, is more resistant to fire, less expensive and without the odor problems that accompany many recycled fibers [10]. Formation of composites by using reclaimed polyester fibers and biodegradable melt blown (PVA, PLA and PEA) Polymers as main components [11].

To produce the rolls, the fibers are per-cut to 5-7 cm lengths, blended, randomly laid down in layers, compression rolled to a desired density and consolidated using needle punching [12,13]. Non-woven from recycled fibers that can be applied in buildings as a filling and facing insulation materials. Structural and insulation materials made of synthetic raw materials (e.g. polyester and polypropylene) ensure full and active “breathing” of the whole structure element giving users a real feeling of building comfort [14].

Materials and methods

Materials

Reclaimed Polyester fibers were about 3.5denier, 35mm long and crimped for non-woven web forming with reclaimed fibers. To make the melt-bond extrusion materials using reclaimed fibers, recycled polypropylene (RPP) was used. The RPP is Fortilene HB 3907, an injection molding grade homopolymer with a melt flow index of 40g/10 min. A version polypropylene powder (VPP) and recycled polyester (Rpet) fibers were also obtained.

Methods of web formation

There are two main forming technologies used to produce air laid webs. With one system the reclaimed fiber is shifted through a coarse screen and deposited with vacuum assistance on to the forming wire below. The second system uses drum formers; in this instance the fibers pass through a series of holes or slot in a large cylinder that spans on the wide of the forming wire. These both systems are used to make a reclaimed fiber web formation.

Methods of bonding

To form the materials, two methods of bonding were used.

Air laid non-woven bonding

The reclaimed fiber sprayed to give a 5 percent (dry-weight basis) resin content based on the oven-dry weight of reclaimed fibre. Four percent of RPP coupling agent was introduced into fibers when it was needed in some investigational composites. The forming machine produces a 350 mm wide continuous web. Following the web forming process is a needler which consolidates the bond, improves the bond integrity. For material production, the multiple bonds were required to be stacked together to attain a certain basis weight. A multi-layered mattress bond which was cut into 350 mm by 350 mm single mat was hot-pressed into composite materials at a thickness of 6.5 mm and an average specific gravity of 1.

Five types of composites were made from air-laid mats using a non-woven forming machine. They were:

(i) 100% reclaimed fiber (KB)/5% PF resin;

(ii) 90% reclaimed bark fiber/5% PF resin/10% virgin polypropylene fiber (VPP)

(iii) 90% reclaimed bark fiber/5% PF resin/10% recycled polyester fiber (Rpet);

(iv) 50% reclaimed bark fiber/50% RPP/0% coupling agent (MAPP); and

(v) 50% reclaimed bark fiber/50% RPP/3% coupling agent.

Melt-blended process

The melt bellowing is an industrial method for the rapid production of non-woven fabrics. In melt bellowing a polymer is melted and extruded through a capillary while heated air is blown through an air nozzle. Segregated reclaimed fiber from the cutting wastes and recycled polypropylene powder (RPP) were compounded using a Davis Standard 32 mm twin screw extruder. The compounded materials were then extruded in long strips to form a desired web dimension of 350 mm x 350 mm. The webs were hot-pressed to 6.5 mm thick in a steam heated platen press at a pressure of about 5 Mpa at 177°C.

Three types of composite materials were extruded using melt-blend process:
(i) 50% reclaimed fibre /50% RPP/0% MAPP coupling agent
(ii) 50% reclaimed fibre /50% RPP/3% MAPP coupling agent
(iii) 50% reclaimed fibre /50% RPP /3% coupling agent

Methods of testing

Six replicate layers were prepared for each type of reclaimed composites at constant factors of thickness at 6.5 mm and a specific gravity at 1.00, resulting in a total of forty-eight layers. All experimental layers were tested for mechanical and physical properties according to the ASTM standard. Prior to the test, all specimens were conditioned at 65% relative humidity (RH) and 20°C. Three-point static bending modules of rupture (MOR) and modules of elasticity (MOE), and tensile parallel to face-stress (T) and tensile perpendicular to face or internal bond (IB) were mechanically tested using a universal testing machine. For physical properties evaluation, specimens were tested for 24-hour water soak 2-hour water boil, and exposure to 90% relative humidity (RH) from 50% RH condition. Values of thickness swell, water absorption and linear expansion were calculated to determine the dimensional stability of composite specimens made from different combinations of reclaimed fibers and coupling agent. All tests were conducted in accordance with methods described in American Society for Testing and Materials (ASTM) D-1037. The Canadian 0188.0-M78 Standard was followed to conduct the 2-hour water boil test.

Results and discussion

Table 1 shows the analysis of results on the mechanical property of the reclaimed non-woven composites. The mechanical properties like internal bond, static bonding and tensile stress can be tested in accordance with ASTM standard. The graphic representation shows the difference in the readings for the diversity of combinations.

Static bonding of reclaimed non-woven composite materials

The figure 1 shows the static bonding of non-woven composites was strongly influenced by air laid nonwoven composites. The values significantly increased for all air laid non-woven composite materials in comparison of melt bellowing non-woven composites. The results revealed that the high modulus of elasticity of the air laid non-woven composites, by their thickness and all so their location of the nonwoven composites.

Tensile stress of reclaimed non-woven composite materials

The tensile stress of reclaimed non-woven composites materials, the figure 2 shows that the tensile stress between airs laid nonwoven composites and melt bellowing non-woven composites. The results revealed that the average tensile strength values also appear in the table 1 the air laid non-woven composite materials presented higher tensile stress values than melt bellowing non-woven composites. The bonding strength between airs laid and melts bellowing non-woven composite materials could be improved.

Table 1. Mechanical properties of reclaimed nonwoven composites

Layer formulation	Static bonding		Tensile stress	Internal bond
	MOR (Mpa)	MOE(Gpa)	(Mpa)	(Kpa)
Air –laid web				
R100-RPP0-R5	32.5	5.02	22.5	88
R90-VPP10-R5	21.5	3.5	20.6	54
R90-RPP10-R5	11.2	1.79	4.9	43
R50-RPP50-CA0	57.9	4.56	31.6	1324
R50-RPP50-CA3	65.9	5.67	38.7	2265
Melt –bond extrusion				
R50-RPP50-CA0	24.5	2.5	10.5	1938
R50-RPP50-CA3	40.5	2.95	15.4	1678
R50-RPP50-CA3	36.5	2.90	13.4	2075
F_0 value	0.000118	0.0001123	0.0000345	0.124847

Air laid and melt bellowing non-woven composites using adhesives is necessary to achieve higher bonding strength, and the tests specimen was overlaid with polypropylene fibers.

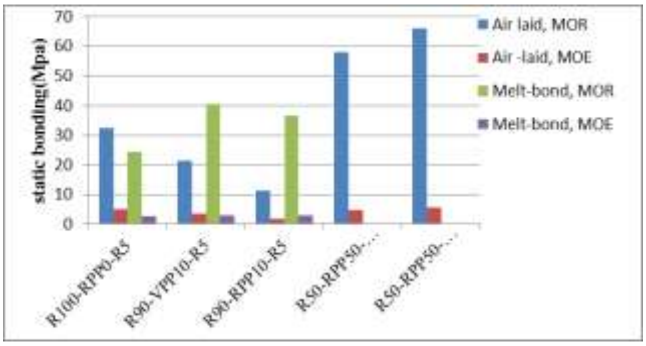

Figure 1. Static bonding of the reclaimed nonwoven composites

Tensile stress of reclaimed non-woven composite materials

The tensile stress of reclaimed non-woven composites materials, the figure 2 shows that the tensile stress between airs laid nonwoven composites and melt bellowing non-woven composites. The results revealed that the average tensile strength values also appear in the table 1 the air laid non-woven composite materials presented higher tensile stress values than melt bellowing non-woven composites. The bonding strength between airs laid and melts bellowing non-woven composite materials could be improved. Air laid and melt bellowing non-woven composites using adhesives is necessary to achieve higher bonding strength, and the tests specimen was overlaid with polypropylene fibers.

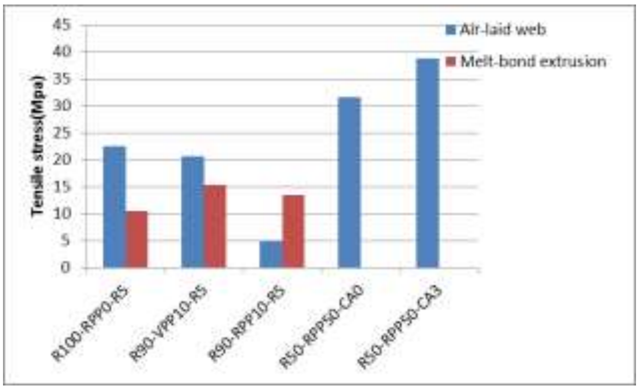

Figure 2. Tensile stress of the reclaimed nonwoven composites

Internal bond of reclaimed non-woven composite materials

The figure 3 shows that the internal bond (IB) of non-woven composites weakest binding strength with in air laid non-woven composite normally in the lower density core layer. According to the result obtained, the IB, strength was not affected by the air laid non-woven composites. There was no significant difference in IB/strength between airs laid and melts bellow non-woven composite materials. The mechanical properties of air laid non-woven composite materials have more difference than the melt extrusion the variations due to the content of virgin polypropylene and reclaimed polypropylene the resin content can also change the properties.

Table 2 gives the details of physical properties of reclaimed non-woven composite materials. According to the figures for physical properties of reclaimed non-woven composites melt extrusion has more properties than the air lay.

Table 2. Physical properties of reclaimed non-woven composites

Layer formulation	24- Hour soak		2- Hour boil		Linear expansion
	Thickness swell (%)	Water absorption (%)	Thickness swell (%)	Water absorption (%)	50%-90% RH (%)
Air –laid web					
R100-RPP0-R5	174	171	189	174	0.42
R90-VPP10-R5	152	167	187	166	0.53
R90-RPP10-R5	234	265	254	227	0.33
R50-RPP50-CA0	6.5	4.5	9.5	4	0.09
R50-RPP50-CA3	3.5	3.5	6.6	3.3	0.15
Melt –bond extrusion					
R50-RPP50-CA0	2.5	2.5	3.3	3.3	0.23
R50-RPP50-CA3	1.2	1.1	1.2	2.4	0.29
R50-RPP50-CA3	2.2	2.4	3.4	3.4	0.89
F_0 value	0.028004	0.032144	0.036114	0.028738	0.00075

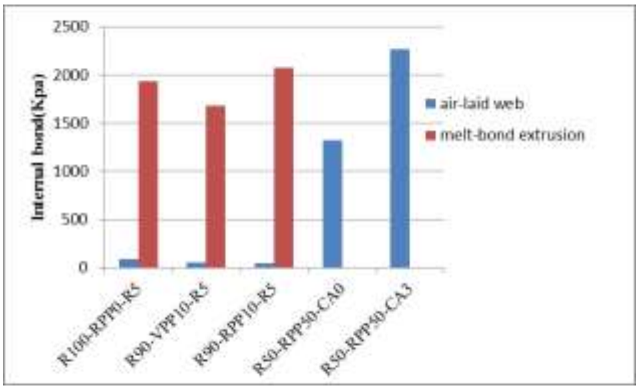

Figure 3. Internal bond of the reclaimed nonwoven composites

Thickness swelling of reclaimed non-woven composite materials

Figure 4 shows that the thickness swelling (TS) as expected for reclaimed non-woven composites without lamination, the dimensional stability after 24 hrs water soaking of melt bellowing composite materials was higher compared with air laid non-woven composites. The TS values of melt bellowing non-woven composites decreased with lamination of the non-woven composites, this decrease in TS value was mainly caused by the reduced water penetration in to the melt bellowing non-woven composites.

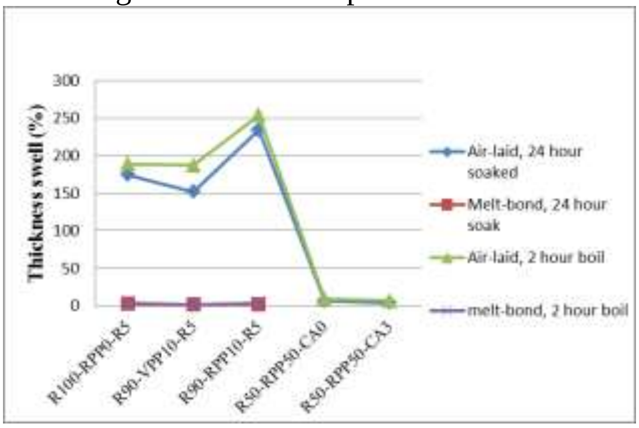

Figure 4. Thickness swell of the reclaimed nonwoven composites

Linear expansion of reclaimed non-woven composite materials

Figure 5 shows that the linear expansion of melt bellows non-woven composites were improved by lamination with air laid non-woven composites the melt bellows non-woven composites as a barrier to improve the entry of water vapor in to the core in the case of air laid lamination non-woven composite, specimens caused a decrease in the measure of length of the specimen.

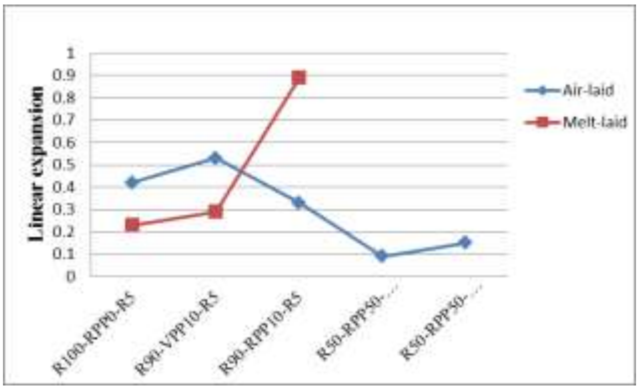

Figure 5. linear expansion of the reclaimed nonwoven composites

Water absorption of reclaimed non-woven composites

The figure 6 proved that in the case of melt bellows non-woven composites water absorption values presented lowest water absorption compared with air laid non-woven composites with or without lamination for 24 hrs water soaking. The melt bellows non-woven composites values were three times lower than that of air laid non-woven composites. The results revealed that the fracture of non-woven composites which were observed in the melts bellowing non-woven composites was observed in 24hrs water soaking, which suggests strong bonding.

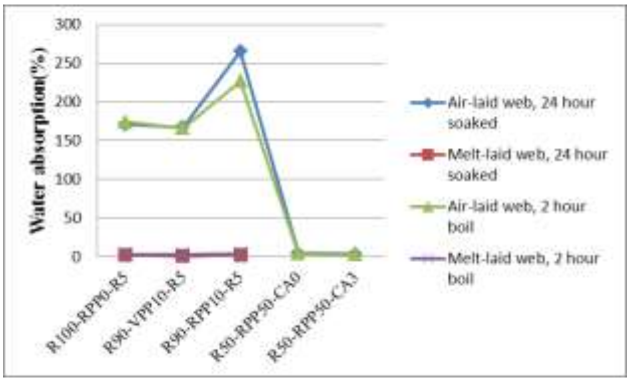

Figure 6. Water absorption of the reclaimed nonwoven composites

Conclusions

The air laid reclaimed non-woven composite materials showed excellent mechanical properties of tensile stress, internal bond and static bonding of the materials. The thickness swelling and water absorption values were clearly reduced as a result of the barrier to water penetration provided by melt bellowing non-woven composites. Where the lamination process potentially induced fracture at core where water could penetrate. The leaner expansion of air laid and melts bellowing non-woven composites materials were all so reduced as a result of lamination with melt bellowing non-woven composites. The air laid non-woven composite materials exhibited significantly greater tensile stress values in comparison with melt bellowing non-woven composites. The absence of internal bond failure at the air laid and melts bellowing interface demonstrated proper poly propylene adhesive bonding, a result that was confirmed by the tensile stress tests perpendicular to the surface. However, the air laid non-woven composites materials presented a decrease in internal bonding values of fracture in the core layer during the lamination process, one possible solution would be to apply less pressure during lamination, but enough to ensure good bonding strength. In this research work it can be concluded that the physical and mechanical properties of air laid and melt bellowing non-woven composite materials were greatly improved by lamination with opportunity to access the new range of application.

Conflicts of Interest

The authors hereby declare that they have no conflict of interest.

References

[1] Zent Z, Long JT. Automotive sound absorbing material survey results. SAE Technical Paper, 2007. https://doi.org/10.4271/2007-01-2186.

[2] Arbelaiz A, Fernandez B, Cantero G, Llano-Ponte R, Valea A, Mondragon I. Mechanical properties of flax fibre/polypropylene composites. Influence of fibre/matrix modification and glass fibre hybridization. Applied Science and Manufacturing. 2005;36:1637-1644.

[3] Carvalho R, Rana S, Fangueiro R, Soutinho F. Noise reduction performance of thermobonded nonwovens, 12th World Textile Conference, Carotia: 2012.

[4] Govardhan G, Rao RN. Effect of fibre content and alkali treatment on mechanical properties of *Roystonea regia*-reinforced epoxy partially Biodegradable composites. Bulletin of Materials Science. 2011;34:1575-1581.

[5] Ioan C, Mariana DS, Camelia C, Vasile O. Assessment of acoustic properties of biodegradable composite material with textile inserts. Material Plastic. 2012;49:68-72.

[6] Koizumi T, Tsujiuchi N, Adachi A. The development of sound Absorbing materials using natural bamboo fibers. High performance structure and composites. WIT Press, Southampton; UK: 2002.

[7] Kozłowski R, Mieleniak B, Muzyczek M, Mańkowski J. Development of Insulation Composite Based on FR Bast Fibers and Wool. International Conference on Flax and Other Bast Plants, Austria: 2008.

[8] Stanciu MD, Curtu I, Cosereanu C, Lica C, Nastac S. Research regarding Acoustical properties of recycled composites. 8th International DAAAM Baltic Conference. Tallinn, Estonia: 2012.

[9] Stanton Greer D, Walter L, Bradley, Danny N, Ryan JV. More sustainable Non-woven fabric composites for automotive using coir (coconut) fibers. International conference of Sydney. 2010.

[10] Chand S, Bhat GS, Spruiell JE, Malkan S. Structure and properties of polypropylene fibers during thermal bonding. Indian Textile Journal. 2000;9:52-59.

[11] Sengupta S. Sound reduction by needle-punched nonwoven fabrics. Indian journal of Fiber and Textile Research. 2010;35:237-242.

[12] Teli MD, Pal A, Roy D. Efficacy of nonwoven materials as sound insulator. Indian Journal of Fiber and Textile Research. 2007;32:2020-206.

[13] Yang TL, Chiang DM, Chen R. Development of a novel porous laminated composite material for high sound absorption. J Vib Contr. 2001;7(5):675-678.

[14] Lee Y, Joo C. Sound absorption properties of recycled polyester fibrous assembly absorbers. Autex Research Journal. 2003;3(2):78-84.

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