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(54) **TUNABLE ACOUSTICAL ABSORBING COMPOSITE BATT**

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(57) **ABSTRACT**

A composite batt structure that forms an effective low frequency sound absorber for use in buildings, appliances, automotive vehicles, and the like. The composite structure uses a facer covering a batt comprised of carded and crosslapped mixture of fibers. The general acoustic behavior of the composite batt structure has a low frequency absorption maximum by varying the number of crosslaps or the proportions of the fiber mixture. This allows for the composite batt structure to be tunable or layered with different laps.

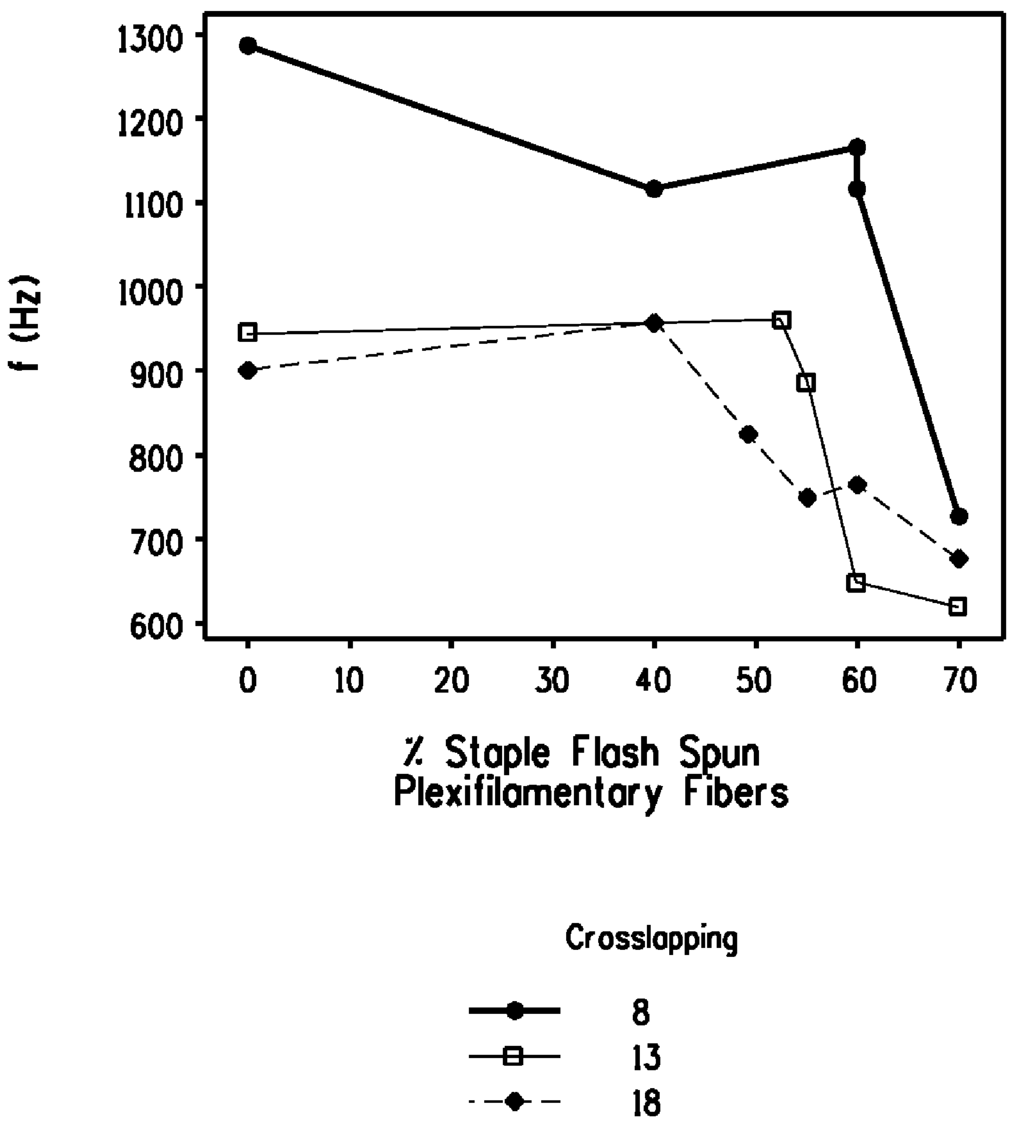
f (Hz)
1300
1200
1100
1000
900
800
700
600
0
10
20
30
40
50
60
70
% Staple Flash Spun Plexifilamentary Fibers
Crosslapping
8
13
18

FIG. 1

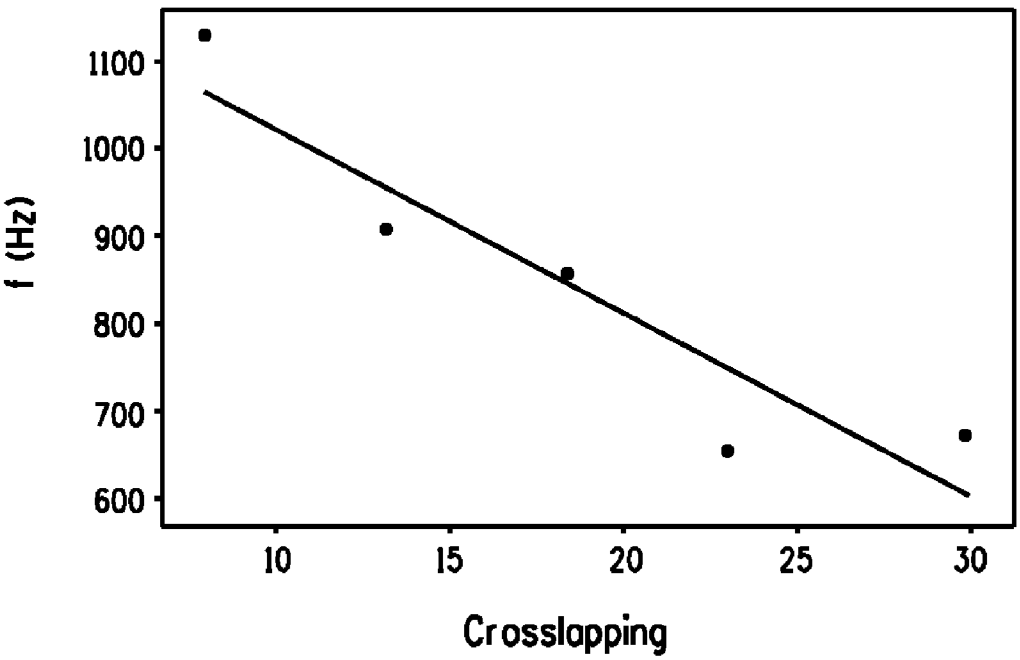


FIG. 2

# TUNABLE ACOUSTICAL ABSORBING COMPOSITE BATT

## BACKGROUND OF THE INVENTION

**[0001]** 1. Field of Invention

**[0002]** The invention relates generally to an acoustic absorber for use any place where low frequency sound needs to be minimized, that is essentially sound transparent in the voice frequency range, and a method for tuning the acoustical absorbance.

**[0003]** 2. Description of the Related Art

**[0004]** An acoustic absorber is known that comprises a batt and facer structure. For instance, United States Patent Application Publication 2009/0173569 to Levit et al discloses an acoustic absorber with a core of acoustically absorbing material having two major surfaces, and a facing for covering the core on at least one major surface. However, there is no disclosure to means to tune the acoustic absorber.

**[0005]** It is desirable to have an acoustic absorber that is tunable to absorb various acoustic frequencies.

## SUMMARY OF THE INVENTION

**[0006]** An embodiment of the invention is a tunable acoustically absorbing article comprising a batt of acoustically absorbing material comprised of 10 to 70% by weight staple flash spun plexifilamentary fibers or staple melt spun fibrillated fibers, 10 to 70% by weight staple fibers, 5 to 30% by weight binding agent, which are carded and crosslapped; and a facer adhered to the batt on at least one major surface.

**[0007]** Another embodiment of the present invention is changing the number of crosslaps in the batt of acoustically absorbing material to tune the frequency at which the acoustically absorbing article attenuates sound to a desired frequency.

### Definitions

**[0008]** The term "batt" as used herein means single or multiple sheets of fibers used in the production of a nonwoven.

**[0009]** The term "nonwoven" or "web" as used herein means a structure of individual fibers or threads that are positioned in a random manner to form a planar material without an identifiable pattern, as in a knitted fabric.

**[0010]** The term "plexifilamentary fibers" as used herein means a three-dimensional integral network or web of a multitude of thin, ribbon-like, film-fibril elements of random length and with a mean film thickness of less than about 4 microns and a median fibril width of less than about 25 microns. The average film-fibril cross sectional area if mathematically converted to a circular area would yield an effective diameter between about 1 micron and 25 microns. In plexifilamentary structures, the film-fibril elements intermittently unite and separate at irregular intervals in various places throughout the length, width and thickness of the structure to form a continuous three-dimensional network.

**[0011]** The term "polymer" as used herein, generally includes but is not limited to, homopolymers, copolymers (such as for example, block, graft, random and alternating copolymers), terpolymers, etc., and blends and modifications thereof. Furthermore, unless otherwise specifically limited, the term "polymer" shall include all possible geometrical configurations of the material. These configurations include, but are not limited to isotactic, syndiotactic, and random symmetries.

**[0012]** The term "polyolefin" as used herein, is intended to mean any of a series of largely saturated polymeric hydrocarbons composed only of carbon and hydrogen. Typical polyolefins include, but are not limited to, polyethylene, polypropylene, polymethylpentene, and various combinations of the monomers ethylene, propylene, and methylpentene.

**[0013]** The term "polyethylene" as used herein is intended to encompass not only homopolymers of ethylene, but also copolymers wherein at least 85% of the recurring units are ethylene units such as copolymers of ethylene and alpha-olefins. Preferred polyethylenes include low-density polyethylene, linear low-density polyethylene, and linear high-density polyethylene. A preferred linear high-density polyethylene has an upper limit melting range of about 130° C. to 140° C., a density in the range of about 0.941 to 0.980 gram per cubic centimeter, and a melt index (as defined by ASTM D-1238-57T Condition E) of between 0.1 and 100, and preferably less than 4.

**[0014]** The term "polypropylene" as used herein is intended to embrace not only homopolymers of propylene but also copolymers where at least 85% of the recurring units are propylene units. Preferred polypropylene polymers include isotactic polypropylene and syndiotactic polypropylene.

**[0015]** The term "facer" as used herein means any solid film, such as polyethylene, or any nonwoven fabric that is adhered to the face of a batt.

## DESCRIPTION OF THE DRAWINGS

**[0016]** FIG. **1** is a graph depicting the acoustic absorption vs. % by weight of staple flash spun plexifilamentary fibers for various crosslappings.

**[0017]** FIG. **2** is a graph depicting the acoustic absorption vs. crosslappings.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

**[0018]** The present invention is directed to a tunable acoustically absorbing article comprising a batt of acoustically absorbing material having 10 to 70% by weight of staple flash spun plexifilamentary fibers or staple melt spun fibrillated fibers, and 10 to 70% by weight of staple fibers, and 5 to 30% by weight binding agent; which are carded and crosslapped; and subsequently faced with a facer on at least one surface. Preferably, the present invention is directed to a tunable acoustically absorbing article comprising a batt of acoustically absorbing material 25 to 60% by weight of staple flash spun plexifilamentary fibers or staple melt spun fibrillated fibers, and 25 to 60% by weight of staple fibers, and 5 to 30% by weight binding agent; which are carded and crosslapped; and subsequently faced with a facer on at least one surface.

**[0019]** The tunable acoustically absorbing article comprises two elements. The first element is a batt of acoustically absorbing material which comprises a carded and crosslapped structure made from staple flash spun plexifilamentary fibers or staple melt spun fibrillated fibers, staple fibers, and binding agent.

**[0020]** The staple flash spun plexifilamentary fibers of the tunable acoustically absorbing article can be made according to the flash spinning process described in U.S. Pat. No. 7,744, 989 to Marin et al., which is hereby incorporated by reference. The flash spinning process produces a flash spun web of plexifilamentary fibers. The plexifilamentary fibers can be unbonded or lightly bonded. The flash spun web of plexifilamentary fibers can then be cut to a length of at least about 2.5 cm to make the staple flash spun plexifilamentary fibers. The staple flash spun plexifilamentary fibers preferably have a surface area of at most 10 m2/g, or a crush value of at least 1 mm/g, and more preferably a surface area of at most 5 m2/g, or a crush value of at least 1.5 mm/g. The staple flash spun plexifilamentary fibers can be made of polyolefin polymer, preferably polyethylene.

**[0021]** The staple melt spun fibrillated fibers can be made according to any general process known to those skilled in the art. For example, melt spun fibrillated fibers can be made by melt spinning bicomponent polymer fibers with fiber cross sections such as round pie shape with pie wedges of alternating polymers or islands in the sea with the islands made from one polymer and the sea made from another polymer. The melt spun bicomponent polymer fibers can then be cut to a length of at least about 2.5 cm to make staple melt spun unfibrillated fibers. The staple melt spun unfibrillated fibers are later converted into staple melt spun fibrillated fibers via a carding process. The staple melt spun fibrillated fibers can be made of polyolefin polymer, polyester polymer, polyamide polymer or mixtures thereof.

**[0022]** It has been found that the frequency at which the acoustic absorber of the present invention attenuates sound can be tuned by the proportion of staple melt spun fibrillated fibers in the batt. As shown in FIG. **1**, higher proportion of staple melt spun fibrillated fibers absorb lower frequencies of sound. One embodiment of the present invention is changing the proportion of staple melt spun fibrillated fibers in the batt to tune the frequency at which the acoustic absorber attenuates sound to a desired frequency of sound.

**[0023]** The staple fibers can be made according to any general process known to those skilled in the art. The staple fibers preferably are stiff to provide some support and loft to the batt. The staple fibers can be made of polyester polymer, preferably polyethylene terephthalate, polyolefin polymer, polyamide polymer or viscose rayon.

**[0024]** The binding agent comprises at least one polymeric component with a melting point below the melting point of the staple flash spun plexifilamentary fiber melting point and the staple fiber melting point. The binding agent can take the form of staple binder fibers or small particles. The staple binder fibers can comprise multiple polymeric components with (a) at least one polymeric component with a melting point below the melting point of the staple flash spun plexifilamentary fiber melting point or the staple melt spun fibrillated fiber melting point and the staple fiber melting point and occupying at least a portion of a surface of the staple binder fibers and (b) at least one polymeric component with a melting point above that of the melting point of the at least one polymeric component with a melting point below the melting point of the staple flash spun plexifilamentary fiber melting point or the staple melt spun fibrillated fiber melting point and the staple fiber melting point. A common example of this type of staple binder fiber is a bicomponent fiber wherein a low melting point polymer on at least a portion of the surface of the fiber melts and adheres to another fiber while a high melting point polymer does not melt keeping a portion of the fiber intact. The staple flash spun plexifilamentary fibers or staple melt spun unfibrillated fibers, staple fibers and a binding agent are mixed and fed to a carding machine to form a carded web. The carding process splits the larger diameter staple flash spun plexifilamentary fibers into microfibers or splits the staple melt spun unfibrillated fibers into staple melt spun fibrillated fibers by breaking the fibers apart along the interfacial boundary between the different polymers.

**[0025]** The carded web is fed, for example, onto a conveyor belt or apron to a crosslapper, where lapper aprons crosslap the carded web by traversing a carrier means such as an intermediate apron in a reciprocating motion, to produce a batt of fibers that are oriented primarily in the transverse direction. The number of laps used to form the batt depends upon variables such as the desired weight of the base layer, and the final weight of the batt. The batt is then, optionally, fed into an oven at a temperature that will activate the binding agent to adhere fibers together and impart strength to the batt.

**[0026]** The staple flash spun plexifilamentary fibers or staple melt spun unfibrillated fibers, staple fibers and a binding agent may optionally be mixed and pre-opened in a card opener (For example a Dell'orco Villani co/**1500** machine.) The blend may then be fed through a chute feeder (such as disclosed in U.S. Pat. No. 3,981,047), garnet (with crosslapping), or air-lay equipment to make a batt. The batt may then optionally be fed into an oven at a temperature that will activate the binding agent to adhere fibers together and impart strength to the batt.

**[0027]** It has been found that the frequency at which the acoustic absorber of the present invention attenuates sound can be tuned by the number of crosslaps in the batt. As shown in FIG. **2**, higher crosslaps will absorb lower frequencies of sound. Another embodiment of the present invention is changing the number of crosslaps in the batt to tune the frequency at which the acoustic absorber attenuates sound to a desired frequency of sound.

**[0028]** The second element is a facer. The facer element may be any solid film, such as polyethylene, or any nonwoven fabric. A preferred facer is a moisture vapor permeable, substantially liquid impermeable, substantially air impermeable nonwoven comprising flash spun plexifilamentary fibers. A suitable example is Tyvek® Homewrap™.

**[0029]** The tunable acoustically absorbing article is formed by covering one surface of the batt with the facer. The tunable acoustically absorbing article does not require the facer to be fastened or adhered to the batt. Optionally, the batt and facer may be fastened or adhered together for convenience of handling. For example, the batt and the facer can be adhered together by a spray-on adhesive. Any suitable adhesive that adheres the batt material to the facer material may be used.

Test Methods

**[0030]** In the non-limiting Examples that follow, the following test methods were employed to determine various reported characteristics and properties. ASTM refers to the American Society of Testing Materials.

**[0031]** Basis Weight was determined according to ASTM D-3776 and reported in g/m2. Thickness was obtained using a Gustin Bacon Measure-Matic™ thickness tester with a 130.7 g. weight. Bulk Density was calculated by dividing the basis weight by the sample thickness. The number is reported in g/m3.

**[0032]** The acoustical composite materials of the present invention were tested for absorption using a Model # 4206 impedance tube available from Bruel & Kjaer. The test procedures in accordance with ASTM E1050 and ISO 10534 were followed. The absorption coefficient was recorded and graphed. Surface Area of the plexifilamentary fiber was measured by the BET nitrogen absorption method of S. Brunauer, P. H. Emmett and E. Teller, J. Am. Chem. Soc., V. 60 p

309-319 (1938) and is reported as m2/g. Crush Value was determined using the following procedure. Three plexifilamentary fiber strands of different sizes were manually pulled from an unbonded plexifilamentary web. The three samples weighed about one, two and three grams. The reported crush values are the averages of the values measured on the three samples. Each sample plexifilamentary strand was formed into a ball shape with minimum application of pressure to avoid crushing and the sample was then weighed in grams. A crush tester comprised of an acrylic sample holder and crusher was used to measure the crush value of each sample. The sample holder comprised a cylindrical section having an inner diameter of 2.22 inches (5.64 cm) and an outer diameter of 2.72 inches (6.91 cm). The center of the cylinder was located at the geometric center of a square base measuring 6.00 inches by 6.00 inches (15.24 cm by 15.24 cm). The crusher comprised a cylindrical plunger rod (diameter =0.75 inches (1.91 cm)) having a first disk-shaped face (the disk having a thickness of 0.25 inches (0.64 cm) and a diameter of 2.20 inches (5.59 cm)) located at one end of the plunger rod and a second disk on the plunger rod spaced back 1.50 inches (3.81 cm) from the first disk.

**[0033]** The second disk also had a thickness of 0.25 inches (0.64 cm) and a diameter of 2.20 inches (5.59 cm). The disks were sized slightly smaller than the inner diameter of the cylindrical sample holder in order to allow air to escape from the sample during crushing. The plexifilamentary samples were placed, one at a time, in the sample holder and a thin piece of paper having a diameter of about 2.2 inches (5.59 cm) was placed on top of the plexifilamentary sample prior to crushing. The plunger rod was then inserted into the cylindrical sample holder such that the first disk-shaped face contacted the piece of paper. The second disk served to maintain the axis of the plunger rod in alignment with the axis of the cylindrical sample holder. Each plexifilamentary strand sample was crushed by placing a 2 lb (0.91 kg) weight on the plunger rod. The crush height (mm) was obtained by measuring the height of the sample from the bottom of the cylindrical sample holder to the bottom of the crusher. The plunger and weight were removed from the sample after approximately 2 minutes, leaving the piece of paper in place to facilitate measurement of the restored height of the sample. Each sample was allowed to recover approximately 2 minutes and the restored height (mm) of the sample was obtained by measuring the height of the paper from the center of each of the four sides of the sample holder and averaging the measurements. The crush value (mm/g) is calculated by subtracting the average crush height from the average restored height and dividing by the average of the weights of the samples. The crush value is a measure of how much the sample recovers its original size after being crushed, with higher values indicating greater recovery of original sample height.

**[0034]** The present invention will be described in more detail in the following examples.

## EXAMPLES

### Example 1

**[0035]** Example 1 represents an acoustically absorbing composite of the present invention. The staple flash spun plexifilamentary fibers of the acoustically absorbing composite were made by using the flash spinning technology as disclosed in U.S. Pat. No. 7,744,989 to Marin. Plexifilamentary fibers were flash spun at a temperature of 205° C. from a 20 weight percent concentration of high density polyethylene having a melt index of 0.7 g/10 min (measured according to ASTM D-1238 at 190° C. and 2.16 kg load) in a spin agent of 60 weight percent normal pentane and 40 weight percent cyclopentane. The plexifilamentary fibers were unbonded. The plexifilamentary fibers were cut to a length of about 2.5 cm to make the staple flash spun plexifilamentary fibers. The staple flash spun plexifilamentary fibers had a surface area of 8 m2/g and a crush value of 1 mm/g. A blend composed of 70% of the staple flash spun plexifilamentary fibers were then mixed with staple 15% polyester fibers with a cut length of about 2 cm and 15% of a low melting bicomponent sheath/core binder fiber of a polyester copolymer as the sheath and polyethylene terephthalate as the core. The staple mixture is fed to a carding machine. The carding process splits the larger diameter plexifilamentary fibers into microfibers and further produces a fibrous structure or carded web. The carded web is fed onto a conveyor belt or apron to a crosslapper, where lapper aprons crosslap the carded web **8** times by means of a traversing a carrier such as an intermediate apron in a reciprocating motion, to produce a acoustically absorbing batt of fibers that are oriented primarily in the transverse direction. A nonwoven facer, Tyvek® Homewrap™ (available from the DuPont Company, Wilmington, Del.) was then adhered to the acoustically absorbing batt by a spray on adhesive of **77** Multi-purpose (available from 3M, St. Paul, Minn.). The resulting acoustically absorbing composite had a basis weight of 322.92 g/m2, a thickness of 0.01905 m, a bulk density of 16951 g/m3 and an acoustic absorption maximum at 828 hz. This would be an effective low frequency sound absorber for buildings, appliances, interior passenger compartments and exterior components of automotive vehicles.

### Example 2

**[0036]** The acoustically absorbing batt of Example 2 is produced by the same process as Example 1 except the traversing carrier of the crosslapper placed 18 laps on the batt instead of 8. A nonwoven facer, Tyvek® Homewrap™ (available from the DuPont Company, Wilmington, Del.) was then adhered to the acoustically absorbing batt by a spray on adhesive of 77 Multi-purpose (available from 3M, St. Paul, Minn.). The resulting acoustically absorbing composite had a basis weight of 352.29 g/m2, a thickness of 0.0220 m, a bulk density of 16013 g/m3 and an acoustic absorption maximum at 654 hz. This would be an effective low frequency sound absorber for buildings, appliances, interior passenger compartments and exterior components of automotive vehicles.

### Example 3

**[0037]** Example 3 represents an acoustically absorbing composite of the present invention. The staple flash spun plexifilamentary fibers of the acoustically absorbing composite were made by using the flash spinning technology as disclosed in U.S. Pat. No. 7,744,989 to Marin. Plexifilamentary fibers were flash spun at a temperature of 205° C. from a 20 weight percent concentration of high density polyethylene having a melt index of 0.7 g/10 min (measured according to ASTM D-1238 at 190° C. and 2.16 kg load) in a spin agent of 60 weight percent normal pentane and 40 weight percent cyclopentane. The plexifilamentary fibers were unbonded. The plexifilamentary fibers were cut to a length of about 2.5 cm to make the staple flash spun plexifilamentary fibers. The staple flash spun plexifilamentary fibers had a surface area of

8 m2/g and a crush value of 1 mm/g. A blend composed of 40% of the staple flash spun plexifilamentary fibers were then mixed with staple 45% polyester fibers with a cut length of about 2 cm and 15% of a low melting bicomponent sheath/core binder fiber of a polyester copolymer as the sheath and polyethylene terephthalate as the core. The staple mixture is fed to a carding machine. The carding process splits the larger diameter plexifilamentary fibers into microfibers and further produces a fibrous structure or carded web. The carded web is fed onto a conveyor belt or apron to a crosslapper, where lapper aprons crosslap the carded web 8 times by means of a traversing a carrier such as an intermediate apron in a reciprocating motion, to produce a acoustically absorbing batt of fibers that are oriented primarily in the transverse direction. A nonwoven facer, Tyvek® Homewrap™ (available from the DuPont Company, Wilmington, Del.) was then adhered to the acoustically absorbing batt by a spray on adhesive of 77 Multi-purpose (available from 3M, St. Paul, Minn.). The resulting acoustically absorbing composite had a basis weight of 304.54 g/m2, a thickness of 0.0220 m, a bulk density of 15986 g/m3 and an acoustic absorption maximum at 1124 hz. This would be an effective low frequency sound absorber for buildings, appliances, interior passenger compartments and exterior components of automotive vehicles.

Example 4

**[0038]** The acoustically absorbing batt of Example 4 is produced by the same process as Example 3 except the traversing carrier of the crosslapper placed 18 laps on the batt instead of 8. A nonwoven facer, Tyvek® Homewrap™ (available from the DuPont Company, Wilmington, Del.) was then adhered to the acoustically absorbing batt by a spray on adhesive of 77 Multi-purpose (available from 3M, St. Paul, Minn.). The resulting acoustically absorbing composite had a basis weight of 342.94 g/m2, a thickness of 0.0220 m, a bulk density of 16013 g/m3 and an acoustic absorption maximum at 960 hz. This would be an effective low frequency sound absorber for buildings, appliances, interior passenger compartments and exterior components of automotive vehicles.

What is claimed is:

**1**. A tunable acoustically absorbing article comprising:

(a) a batt of acoustically absorbing material having two major surfaces comprising:

(i) 10 to 70% by weight staple flash spun plexifilamentary fibers or staple melt spun fibrillated fibers,

(ii) 10 to 70% by weight staple fibers,

(iii) 5 to 30% by weight binding agent,

(iv) carded and crosslapped; and

(b) a facer adhered said batt on at least one major surface.

**2**. The tunable acoustically absorbing article of claim **1** that is crosslapped at least 4 laps.

**3**. The tunable acoustically absorbing article of claim **1** that is crosslapped at least 8 laps.

**4**. The tunable acoustically absorbing article of claim **1** where the staple flash spun plexifilamentary fibers or staple melt spun fibers are at least 30% by weight.

**5**. The tunable acoustically absorbing article of claim **4** that is crosslapped at least 4 laps.

**6**. The tunable acoustically absorbing article of claim **4** that is crosslapped at least 8 laps.

**7**. The tunable acoustically absorbing article of claim **1** where the staple flash spun plexifilamentary fibers or staple melt spun fibers are at least 50% by weight.

**8**. The tunable acoustically absorbing article of claim **7** that is crosslapped at least 4 laps.

**9**. The tunable acoustically absorbing article of claim **7** that is crosslapped at least 8 laps.

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