STRETCHABLE AND TRANSFORMABLE PLANAR HEAT PIPE FOR APPAREL AND FOOTWEAR, AND PRODUCTION METHOD THEREOF

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Appl. No.: 11/307,359
Filed: Feb. 2, 2006

Related U.S. Application Data
Continuation-in-part of application No. 11/306,529, filed on Dec. 30, 2005.
Continuation-in-part of application No. 11/306,530, filed on Dec. 30, 2005.
Continuation-in-part of application No. 11/307,051, filed on Jan. 20, 2006.
Continuation-in-part of application No. 11/307,125, filed on Jan. 24, 2006.

Publication Classification
Int. Cl. A43B 7/02 (2006.01)
A43B 7/06 (2006.01)
U.S. Cl. 36/3 R; 36/2.6

ABSTRACT
Transformable and stretchable essentially planar heat pipe disposed as element of thermal management in apparel or footwear articles.
Figure 5

- Pressure (atm)
- Temperature (°C)

- vapor
- liquid
- liquid and vapor
STRETCHABLE AND TRANSFORMABLE PLANAR HEAT PIPE FOR APPAREL AND FOOTWEAR, AND PRODUCTION METHOD THEREOF

RELATED APPLICATIONS

[0001] This application is a continuation-in-part of each of:


FIELD OF THE INVENTION

[0007] The present invention relates to an article of apparel or footwear having passive heat conditioning structure incorporated therein.

BACKGROUND OF THE INVENTION

[0008] Methods for comforting footwear articles have been under development for a long time. Plurality of techniques was proposed for such task including forced air cooling, forced liquid cooling, active refrigeration systems, and heat pipes.

[0009] This invention utilizes completely passive design that most closely relates to subject disclosed in international application PCT/FR96/01270 filed by Denis Clodic. Cited invention is illustrated on FIG. 1. It employs heat pipe 13 that fixed in anti-intrusion sole 11. The pipe extends along the length of the shoe and bends to form segments 13a and 13b. Air circulating channel 21 supplies forced air flow underneath the heat pipe.

[0010] Technology of this invention inherits drawbacks of heat pipe technologies. One of such disadvantages is metal shell that gives footwear significant usability limitations. Article of cited invention will be registered by metal detector at security checkpoint which adds inconvenient to wearer. Additional weight and lack of flexibility makes cited article impractical in sport related applications where the maximum comfort is a must to have paradigm.

[0011] Forced air circulation of cited invention creates complexity in shoe design and provides little or no relieve to stationary wearer. Surface area of foot sole in several times exceeds combined area of toe and heal, which makes passive heat loss very inefficient.

SUMMARY OF THE INVENTION

[0012] Subject of present invention uses technology disclosed in co-pending U.S. patent application Ser. No. 11/306,529. This technology enables flexible perforates polymeric film to be used as a heat pipe. This pipe can be seamlessly integrated into design of a shoe providing no discomfort or weight. Its perforation allows for free air circulation that prevents moisture buildup caused by impermeable continuous surfaces. Flexible film design allows for the pipe to be wrapped around all areas of the foot on front, sides, and its back.

[0013] Resulting shoe provides thermal comfort in both stationary and mobile state of its wearer. In stationary state excessive surface area of the film noticeably exceeds area of the sole providing efficient heat exchange with passively circulating air. In mobile state perforated mesh like topology of the film allows for incoming air to circulate through the voids which boosts heat transfer rate.

[0014] Durability of polymer structure significantly exceeds one of metal in applications where continuous stretches and deformations take place. It is particularly important in sports apparel and footwear.

DETAILED DESCRIPTION OF THE INVENTION

[0015] The following description discloses an article of footwear in accordance with present invention. On FIG. 2 footwear is depicted as having a configuration that is suitable for athletic activities. The concept disclosed with respect to the footwear may be applied to footwear styles that are specifically designed for wide range of other non-athletic activities. Accordingly, one skilled in the relevant art will recognize that the concepts disclosed herein may be applied to a wide range of footwear and apparel styles and are not limited to embodiments discussed below and shown in the figures.

[0016] The footwear is depicted in FIG. 2 and includes an upper 2 and a sole structure 1. Upper 2 is formed from various material elements that are stitched or adhesively bonded together to form an interior void that comfortably receives a foot and secure the position of the foot relative to sole structure 1. Sole structure 1 is secured to lower portion of upper 2 and provides durable, wear-resistant component for attenuating ground reaction forces, adsorbing energy (i.e. providing cushioning), and stopping heat (i.e. reduce heat exchange between ground and the foot) as footwear impacts the ground.

[0017] Upper 2 and sole structure 1 have structure that cooperatively articulate, flex, stretch, or otherwise move to provide a wearer with comfortable sensation. That is upper 2 and sole structures 1 are configured to complement the natural motion of the foot during activities. In contrast with traditional footwear, however, sole structure 1 controls nanoclimate around the foot. It adsorbs excessive heat and disposes it through upper 2 reducing overall heat stress of a wearer.

[0018] The various material elements forming upper 2 combine to provide a structure having a lateral side, an opposite medial side, a tongue (omitted on FIG. 2), and a lasting sock. A variety of materials are suitable for upper 2, including the materials that are conventionally utilized in
footwear uppers. Essential layer of perforated nonmetallic heat pipe film 4 is disposed through the structure of upper 2. This film is blended with other elements of upper 2 and protected from direct exposure to outer surface. FIG. 2 depicts this film directly adjacent to inner void of the shoe. Instead an additional interior layer may be disposed to provide additional comforting sensation.

Upper 2 includes plurality of incisions 6 that expose underlying elements of its construction. By exposing interior layers 4, the stretch properties of upper 2 are selectively modified. In areas where incisions 6 are present, air circulation increases heat disposal from heat pipe film 4. In areas with no incisions 6, heat exchange occurs through the surface of upper 2 only, and layer structure exterior and layers contributes to stretch resistance. In areas where incisions 6 are present they permit layers of the upper 2 to stretch to a greater degree. In addition, incisions 6 may be utilized as art to contribute overall appearance of the footwear.

Heat pipe film 4 includes plurality of incisions 7 that provide stretch and flexibility to the film 4. Incisions 7 pattern not necessarily overlay pattern of incisions 6. Overall dimensions of pattern of incisions 7 are smaller than ones for incisions 6. This aids adhesive penetration and heat exchange with air. In places where incisions 6 overlap pattern of incisions 7 portions of film 4 are directly exposed to ambient air flow. In places with no incisions 6 adhesive or stitching bonds provide reliable thermal connection between film 4 and outer layer of upper 2.

Incisions 7 forms hermetically sealed seams between opposing layers that form film 4 which described in co-pending patent applications 11/306,529, 11/307,051, and 11/307,292. FIG. 2 depicts incisions 6 and 7 in dramatically increased size that does not represent their actual dimensions and patterns.

Sole structure 1 includes heat pipe film 3 and all customary elements such as an insole, a midsole, and an outsole. Film 3 has composition similar or identical to film 4. Both films are thermally connected to each other via overlapping regions. In preferred embodiment depicted on FIG. 2, film 3 and film 4 are adjacent areas of the same continuous film that wrapped in shape of inner void of the footwear article. However, it is possible for these films to be separate elements that assembled in a way that overlap their edges across full or partial perimeter of sole structure 1. Top surface of film 3 may be covered by lasting sock for added wear protection.

Sole film 3 includes plurality of incisions 5 that are nearly identical to incisions 7. Pattern of incisions 5 designed to maximum stretching and flexibility of the insole surface of sole structure 1. Incisions 5 are used for durable stitched or adhesive connection of film 3 and the sole 1. However, it is possible to mold layer of film 3 as a top surface of midsole. Sole structure 1 may include top sole cushion layer 9 underneath film 3 to improve comfort of the article. Insole layer or lasting sock may be added on top of film 3 for improved durability and comfort.

Refrigerant fluid disposed in volume 8 of film 3 includes single chemical or chemical mix. Plurality of well known liquids and gases can be utilized as refrigerant fluid herein. However, preferred embodiment emphasizes on creating maximum wearer comfort. In cold temperatures it is not advisable to divert heat from wearer foot. Boiling point of decahalorobutane fluid can be easily controlled by slight changes in pressure. FIG. 5 depicts graphical dependency between boiling point temperature and pressure. Because volume 8 is formed by elastic material it is not difficult to adjust pressure within. Part of wearer weight distributes directly onto surface of film 3, the rest of it applies to midsole through incisions 5. Sole designer can select optimal boiling point most suitable for specific article. It is also possible for wearer to adjust comfort temperature by tuning said pressure pneumatically, hydraulically or mechanically. When temperature of foot sole drops below comfort settings heat pipe 3 ceases heat transfer allowing wearer foot to warm up. When temperature increases to comfort point fluid inside film 3 begin to boil transferring heat to upper 2. It is obvious that other refrigerant fluids can be used in similar fashion and invention is not limited by this particular selection.

Material of insole 10 should provide comfort sensation and moderate thermal conductivity. Many materials traditionally used to make insoles can provide these properties. However, best results can be achieved when insole 10 is produced as perforated heat pipe made with soft polymer or rubber. FIG. 3 depicts insole 10 that includes heat pipe layer 11 and liner layer 12. Liner layer 12 provides high wear and abrasion resistance. Common materials for liner layer 12 are fabrics or laminates.

Heat pipe 11 consists of flexible and elastic shell film 15 made of polymer or rubber. In preferred embodiment this material in nylon reinforced butyl rubber film. The shell incases open cell neoprene foam 14. The foam has mesh pattern. Upper and lower walls of shell film 15 are fused through all mesh openings forming incisions 13. Volume 16 around incisions forms vapor channels, while partially compressed neoprene foam 14 performs wick functions. Refrigerant liquid of this embodiment is perfluorobutane. However, use of other refrigerants and their mixes is possible as well. Refrigerant supplies supporting pressure about 3.6 atmospheres that provides comfortable cushioning sensation and simultaneously sinks heat toward sole structure 1. Accordingly, one skilled in the relevant art will recognize that the concepts disclosed herein may be applied to using a wide range of materials, refrigerants and styles and are not limited to embodiments discussed herein.

Heat pipe film 3 and heat pipe film 4 may or may not have wick structure imbedded within. Because of dominant vertical disposition of these elements and primary heat source presented by foot sole locates at lowest point it is possible to utilize gravity type heat pipe with no wick. Method of making cited heat pipe film is disclosed below. Other methods can be utilized as well as it is obvious to one experiences in relevant art plurality of traditional techniques may produce identical products. The method disclosed herein only illustrates the concept and disclosed in great details in co-pending patent application.

FIG. 4 depicts schematic of disclosed method. Layers of top and bottom walls of the heat pipe and optional layers of wick and spacer materials are engaged as continuous rolls. Perforation pattern is created (if necessary) on wick and spacer layers. Position of perforation pattern is synchronized with pattern of fuser unit. Fuser unit bonds top
and bottom walls through perforation incisions leaving side edges of all layer unsealed. Fusion process may utilize any known method of bonding planar sheets (i.e. soldering, sintering, molding, stitching, vulcanizing, welding, copolymerization, adhesive application, etc.). The shape of incisions may be used to provide necessary stretching, flexibility or any other benefits including artistic impression.

Continuous assembled tape of cited layers reoriented if necessary to take vertical or inclined orientation. Strictly horizontal arrangement is not preferred and should be avoided. Yet even small tilt (i.e. several degrees) is sufficient. Non horizontal tape is locked in sealed volume of press where temperature and pressure combination setup in a way that maintain refrigerant fluid in liquid phase. Refrigerant fluid disposed in the same volume through bottom inlet. Refrigerant fluid is degassed and contains minimal amount of dissolved gases. Fluid gradually fills sealed volume of the press disposing residual gases through top outlet. Upon completion of filling step press is engaged to seal perimeter or plurality of closed profiles disposed within volume perimeter. The surface of the press may contain special forms planar and three dimensional that allow to shape the tape to any form necessary. The profiles are sealed at the same time by fusion of opposite walls. Processing steps continue to next unsealed area of the tape.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1. Prior Art.

FIG. 2. Shoe design with heat pipe mesh integrated throughout the upper and the midsole. View A shows complete enclosure of a feet by the heat pipes. Separate heat pipe sheets are pressed against each other to form thermal interface between the sole and the upper (top center). Perforated structure of heat pipe enables humidity control and passive heat exchange (top right). Heat pipe film surrounds feet from sides as well (bottom right).

FIG. 3. Insole with perforated heat pipe film. Enlarged view of the film structure (right). Insole appearance (bottom right).


FIG. 5 depicts graphical dependency between boiling point temperature and pressure.

What is claimed is:

1. A heat pipe device that has a shape topologically equivalent to closed planar profile, wherein overall shape and area of said device could be changed by means of external force without disrupting its functionality.

2. A method of producing heat pipe devices of claim 1 wherein said heat pipe has at least one of its dimensions ten times smaller than any other, and wherein opposing walls separated by said dimension contain plurality of incisions that connect outer surfaces of said walls together and each incision has shape of closed profile.

3. A method of claim 2 wherein some of said closed profiles have preferred direction and their dimension along that direction significantly differs from their size in orthogonal direction.

4. A device of claim 1 where material of shell of said heat pipe is partly permeable to abundant atmospheric gases and is impermeable to vapors of refrigerant fluid disposed within.

5. A heat pipe device of claim 1 formed as element of apparel or footwear structures.

6. An apparel or footwear article utilizing heat pipe devices of claim 1 that disposed in overlapping manner such that there is area of surface of one of said heat pipe in direct thermal contact with surface of another heat pipe.

7. An article of footwear comprising heat pipe device of claim 1 disposed in direct thermal contact with foot sole and mostly exposed to thermal contact or heat exchange with air circulating around and through the upper surfaces of said article.

8. An article of footwear according to claim 6 wherein at least one of said heat pipes is disposed under foot sole.

9. An article of claim 6 wherein at least one of said heat pipes contains refrigerant fluid at such volume and pressure conditions that suppress its evaporation at temperature below certain, and said certain temperature is within range from +15 degree Centigrade to +37 degree Centigrade.

10. An article of apparel or footwear incorporating a device of claim 1 wherein said device has low heat transfer at temperatures below certain point and high heat transfer at temperature above certain point.

11. An article of claim 10 wherein wearer can adjust said certain temperature point.

12. An insole article wherein device of claim 1 is disposed within.