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(54) **Tubular cushioning system for shoes.**

(57) The present invention utilizes an upper (22) and a midsole (14) which is disposed in a conventional manner below the upper (22). The midsole includes an elastomeric material and has a number of spaced-apart horizontal tubes (28, 30) extending the width of the midsole (14) which are encapsulated in the elastomeric material. The tubes (28, 30) are hollow and lay side by side in a direction either perpendicular to the longitudinal axis of the shoe (10), parallel to the axis, or in any other direction functional for foot and shoe mechanics. The elastomeric material has a hardness less than the tubes (28, 30) and fills the space between the tubes (28, 30).

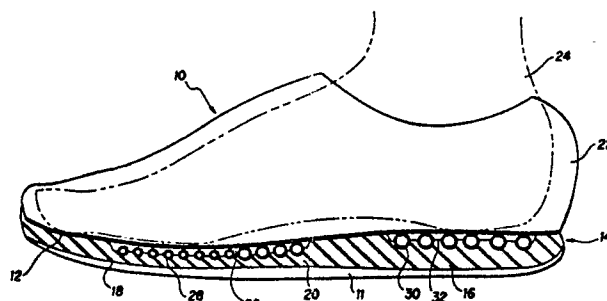


FIG.1

TUBULAR CUSHIONING SYSTEM FOR SHOES

This invention relates generally to athletic shoes, and more particularly to systems for cushioning the midsoles of athletic shoes.

In recent years, there have been a number of attempts to incorporate additional cushioning into the midsole of an athletic shoe. The midsole of a shoe is the portion of the shoe which lies between the outsole and the inner sole and it is the development of the midsole which has led to shoes which take into account human foot physiology. It is the midsole of the shoe, usually made of a polyurethane or ethylene vinyl acetate (EVA) material, which is primarily designed to manage pronation problems and to absorb shock.

One category of developments which attempt to cushion the foot of a user is those which incorporate a pneumatic device within the midsole. This concept is shown in U.S. Patent No. 545,705, issued to MacDonald. In this patent, an elastic air-filled cushioning device is incorporated into the heel of a shoe to provide cushioning. A similar device is taught in U.S. Patent No. 1,498,838 issued to Harrison, Jr., which utilizes a number of tubes which lie within the midsole of a shoe. These tubes are inflated by a valve to maintain a pressure above ambient pressure. The tubes in Harrison, Jr., are made of a flexible material which is inelastic. Another patent in this same category is U.S. Patent No. 4,219,945, issued to Rudy, which discloses a pneumatically inflated insert which is encapsulated in a foam midsole. In the shoe taught by this patent, the insert is filled with a mixture of large-molecule gases which attempts to prevent diffusion outwardly from the chambered insert.

The disadvantages of encapsulating gas within the midsole of a shoe are numerous. It is exceedingly difficult and costly to encapsulate gas in a material which also has desirable mechanical properties. It is much easier, for example, to cut a piece of EVA to desired specifications than to make a container which retains pressurized air or other gas. Many easily molded plastics will allow encapsulated air to diffuse out of its container. Therefore, large molecule gases must be used as the encapsulated gas thereby increasing the expense of manufacturing such a shoe. Material puncture is also a problem with pressurized gas midsoles.

Another serious drawback with shoes utilizing a pressurized encapsulated midsole is that the pressure of the gas within the encapsulating container is temperature dependent. As a shoe warms up, it has a different stiffness. Similarly, the shoe may respond differently in warm or cold temperature. The response of these types of midsoles may also be altitude dependent.

Yet another serious drawback in the encapsulated gas midsoles of the prior art is that these shoes do not have adequate rearfoot control and stability. In simple terms, encapsulated gas midsoles are often times too mushy to give proper support.

In addition to the three patents discussed above, there are a number of other patents which attempt to cushion the midsole of a shoe by using a pneumatic insert. Many of these devices have the same disadvantages, e.g., requiring that the tubes maintain their inflated pressure, diffusion through the tubes, and manufacturing difficulties.

Another category of development which attempts to provide extra cushioning to the midsole of a shoe is disclosed in U.S. Patent No. 4,322,892 issued to Inohara, which teaches a shoe having a wedge portion which forms the heel of the shoe. This wedge portion has incorporated therein a number of hexagon-shaped apertures which traverse the width of the shoe. This patent also discloses the possibility of using circular cylinders rather than hexagonal apertures. Because the apertures are merely voids formed directly in the midsole, the shoe taught by this patent does not achieve rebound and cushioning to the extent possible. U.S. Patent No. 4,235,026, issued to Plagenhoef, shows a midsole of a shoe which utilizes triangular openings. These openings extend from the lateral side of a shoe but do not extend completely through the shoe. This allows greater cushioning at the portion of the foot which first impacts the ground and less cushioning at the medial side of the shoe. This shoe seeks to account for the fact that the lateral side of a shoe strikes the ground first and the foot rolls in the direction of the medial side of the shoe. U.S. Patent No. 4,445,284, issued to Sakutori, shows a shoe which has bores which traverse the shoe in a direction perpendicular to the longitudinal axis of the shoe. These bores have at each end thereof a check valve which allows air to flow into the longitudinal bores but not out of the longitudinal bores. Also communicating with each bore is a narrow slot which enables air to flow out of the bore upon compression of the bore. Another patent which uses air at ambient pressure within circular bores is U.S. Patent No. 4,593,482, issued to Mayer, which shows a sandal having a plurality of interconnecting modular elements. These modular elements form the sole of a shoe and are closely packed. U.S. Patent No. 4,656,760, issued to Tonkel *et al.*, is a cellular insert for a midsole of a shoe. While in one embodiment of this invention the cells formed by a polymeric woven material form hollow cells, these cells are formed from a

single strand of material and therefore cannot act independently of each.

U.S. Patent No. 4,430,810, issued to Bente, discloses a shoe which utilizes at least one replaceable insert in the sole of a shoe. The tubes in this shoe are made to frictionally engage a bore in the midsole of the shoe, thereby causing localized pressure differentials and gradients in the surrounding material. The Bente patent is directed to a device for controlling the stiffness of a shoe and is therefore able to use solid rod inserts.

U.S. Patent No. 4,536,974, issued to Cohen, is a shoe with a deflective and compressible midsole. This shoe utilizes a plurality of ribs which, when a force is applied to the midsole, deflect and come into contact thereby restricting further deflection. There are two separate and distinct compression stages in the Cohen midsole. Initially, the ribs in Cohen do not easily deflect. As the midsole compresses, it becomes increasingly less difficult to compress the midsole. Therefore, in the first stage of compression there is a negative pressure gradient, that is, the greater the deflection, the less force needed to deflect. In the second compression stage of Cohen, the ribs come into contact with each other. When the ribs are in contact, the only way for the midsole to compress is for the ribs to compress. Therefore, in the second stage of compression there is a positive pressure gradient; the more the midsole is compressed the greater force is needed to compress. In the Cohen device there may also be secondary buckling of the ribs because the forces are not angled along the rib.

It is clear from the developments discussed above that there are many disadvantages in the art related to the present invention. The disadvantages of encapsulated gas soles include high construction costs, lack of stability, puncture problems, temperature dependence, and diffusion of gas out of the gas container. For other soles having various apertures, the disadvantages include abrupt changes in the pressure needed to deflect the midsoles. Other shoes simply have not recognized the need to provide a sole having good rebound as well as cushioning.

SUMMARY OF THE INVENTION

In accordance with the purposes of the present invention as embodied and broadly described herein, the athletic shoe of the present invention utilizes an upper and a midsole which is disposed in a conventional manner below the upper. The midsole includes an elastomeric material and has a number of spaced-apart horizontal tubes extending the width of the midsole which are encapsulated in the

elastomeric material. The tubes are hollow and lay side by side in a direction either perpendicular to the longitudinal axis of the shoe, parallel to the axis, or in any other direction functional for foot and shoe mechanics. The elastomeric material has a hardness less than the tubes and fills the space between the tubes. The tubes preferably have a Shore D Durometer hardness of between 55 and 72 and are spaced at a distance which causes the material between the tubes to compress when a force is applied perpendicular to the midsole. The material between the tubes is compressed because of the deformation of the tubes and causes the tubes to resist further compression.

In another aspect of the invention, the elastomeric material used to form the midsole preferably has an Asker C Durometer hardness of between 35 and 65. The elastomeric material may be made of either polyurethane (PU) or ethylene vinyl acetate (EVA).

In yet another aspect of the invention, the tubes may be placed in either the heel portion of the midsole or in the forefoot portion of the midsole or both. The tubes used in the athletic shoe preferably have a circular cross-section and have an outside diameter of between 4 and 18 millimeters and have a wall thickness of between 0.4 and 1.0 millimeters. The spacing between adjacent tubes is preferably between 0.5 and 9.0 millimeters.

In yet a further aspect of the invention, the tubes used within the midsole are preferably made of Hytrel (TM), manufactured by E.I. DuPont de Nemours and Company, Inc.

In yet another aspect of the invention, the tubes, when placed in the forefoot part of the midsole, are preferably disposed at a 13° angle from perpendicular to the longitudinal axis of the shoe and are substantially parallel to a line formed by the metatarsals of the foot.

One advantage of the invention is that maximum rebound effect can be obtained by using a particular spacing of tubes in a midsole. Another advantage of the invention is that the midsole of the present invention is easily manufactured and utilizes easily available materials.

Another advantage of the invention is realized when using Hytrel, which has good rebound characteristics, is lightweight, and provides superior cushioning effects. Hytrel is also a sturdy material and is easily bonded to the surrounding elastomeric midsole.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and form a part of the specification, illustrate the embodiments of the present invention and, together with the description, serve to explain the principles of the invention. In the drawing:

Figure 1 is a longitudinal, sectional side view of an athletic shoe midsole incorporating a preferred embodiment of the present invention;

Figure 2a is a schematic showing adjacent tubes of the present invention without force being applied;

Figure 2b is a schematic showing adjacent tubes of the present invention with a force applied;

Figure 3 is a perspective view of one embodiment of the invention utilizing tubes in the forefoot of a shoe;

Figure 4 is a perspective view of an embodiment of the present invention utilizing tubes in the heel portion of a midsole;

Figure 5 is a perspective, partially cutaway, exploded view showing one possible construction of the invention; and

Figure 6 is a perspective, exploded view of another possible construction of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to the accompanying drawings, Figure 1 is a side elevation view of an athletic shoe incorporating the shock absorbing midsole of the present invention. The shoe, designated generally as 10, has an inner sole 12 which is positioned above the midsole 14. The inner sole is attached to the other components of the shoe in any conventional manner such as by gluing or stitching. As with most shoes, an outsole 11 is attached to midsole 14 as shown in Figure 1.

The midsole 14 of the present invention has a heel portion 16, a forefoot portion 18, and a midfoot or arch portion 20. There are not specific boundaries which define these three sections of the midsole, however it should be generally understood that these three portions of the midsole, together, extend the entire length of the midsole. A conventional upper 22 may be attached to the midsole in any conventional manner. In the preferred embodiment of the invention, the upper is cemented to the midsole in any of a number of well known ways.

One purpose of the invention is to give cushioning to a foot 24, shown in dashed lines, and to provide a rebounding effect when the foot is not

applying pressure to the midsole.

In one embodiment of the invention, sections 26 and 32 are cut from the upper surface 15 of midsole 14 in the forefoot and heel and have semi-circular seats which provide a stable physical structure for seating forefoot tubes 28 or heel tubes 30 or both. The tubes may either be seated as shown in Figure 1 or completely encapsulated as shown in Figures 5 and 6. In the embodiment shown in the figures, the tubes have a circular cross section. By using tubes having this geometry, the tubes take up a maximum volume with the least amount of material. Because weight is an important parameter when designing a shoe, this allows the shoe to have a minimum weight.

The midsole material may be made of any conventional elastomeric material. In the preferred embodiment of the invention either polyurethane or EVA is used to form the midsole. The tubes 28 and 30 are formed from a material having a hardness of between 55-72 Shore D Durometer. An ideal material for the tubes is Hytrel (TM), manufactured by E.I. DuPont de Nemours and Company, Inc. Hytrel is semi-crystalline and a full polymerized, high molecular weight, chemically stable, thermoplastic polyester elastomer composed of alternate amorphous and crystalline chains. This material is ideal for utilization in the tubes of the present invention because it has exceptional memory characteristics. In other words, Hytrel tubes tend to return to their original shape after being deformed. This enables the Hytrel tubes to be used for both cushioning and rebound in the present invention. In operation, energy is stored when the tubes are compressed and returns in the form of rebound energy when the user is lifted. The Hytrel also has good strength characteristics and can withstand many compression cycles.

Referring now to Figure 2, two schematics are shown which help to describe the interaction of tubes in the present invention. Figure 2a shows a schematic of the tubes 34a and 34b in an unstressed state. The tubes shown in this figure are seated in the semi-circular seats 36 which are formed in an elastomeric material 38. On top of the tubes rests inner sole 12. It can however be appreciated that the tubes may be completely encapsulated by the polyurethane material and in fact in a preferred embodiment of the invention the tubes are completely encapsulated, including encapsulation of the ends of the tubes. By encapsulating the ends of the tubes, the ends do not easily collapse as with open ended tubes. If a polyurethane or other elastomeric material is used to completely encapsulate the tubes 34 the inner sole 12 may be attached directly to the elastomeric material. In such a case there may be a space between the tubes 34a and 34b and the inner sole 12 which is

filled with the elastomeric material.

Figure 2b of the accompanying drawings is a schematic of the tubes of the present invention under compression. The large arrows represent the force of a foot pressing on the midsole and the corresponding pressure from the ground. When these forces are placed in the midsole the tubes are compressed and are therefore no longer circular in cross-section. Because the tubes have a major axis which is parallel to the ground, the material between the tube is compressed. In other words, the smallest distance between the tubes is decreased thereby causing the elastomeric material between the tubes to compress. This compression in turn helps to resist further compression of the midsole. In short, the more the midsole is compressed the more difficult it is to compress the midsole further. One aspect of the invention is that the tubes 34a and 34b never come into contact with each other. This avoids abrupt changes in the cushioning effect and creates a constant pressure gradient through the thickness of the midsole.

After the forces shown in Figure 2b are removed, the midsole returns to the configuration shown in Figure 2a. The Hytrel used to practice the invention has good memory characteristics and therefore readily returns to the original configuration. Because the material between the tubes 32 has been compressed, a force is generated in the compressed material to help the tubes return to their original shape. Also, the pressure created by adjacent tube members generates a quicker response in returning the tubes to their original shape.

Because the invention seeks to form a midsole which has superior cushioning and rebound characteristics, the spacing of the tubes as well as the material used to make the tubes and the encapsulating midsole must be carefully chosen. The outside diameter of the tubes should be between 4 millimeters and 18 millimeters and must preferably allow for at least one millimeter of polyurethane encapsulation at the bottom of the tubes. If the entire tube is encapsulated there should be at least one millimeter of encapsulation at the top and bottom of the tubes. The wall thickness of the tubes should be between 0.4 millimeter and 1.0 millimeters and the spacing between the tubes should be between 0.5 millimeter and 9.0 millimeters. The above spacing is measured at the closest point between tubes and is measured in an unstressed configuration. In other words, when a tube having a circular cross-section is used the closest distance between the tubes shown in Figure 2a should be between 0.5 millimeter and 9.0 millimeters. The distance between the tubes is chosen as a function of the desired amount of tube collapse desired before the effects of the compression be-

tween the tubes has a significant effect. Because there is material between tubes 34a and 34b, the tubes are never in contact with each other. The tubes are harder than the surrounding material and preferably have a Shore D Durometer hardness of between 55 and 72. The surrounding elastomeric material may have a Asker C Durometer hardness of between 35 and 65 in the preferred embodiment of the invention.

Figure 3 shows one embodiment of the invention in which tubes 28 are placed in the forefoot portion 18 of a midsole 14. In this embodiment of the invention the tubes are placed in the forefoot portion 18 only and a solid polyurethane, EVA, or other elastomeric material is used to form the heel portion of the shoe. In this embodiment any conventional method may be used to form the heel while the present invention is used in the forefoot section.

Similarly, Figure 4 shows an embodiment of the invention wherein tubes 30 are placed only in the heel portion of midsole 14. In this embodiment of the invention a conventional forefoot section is used in combination with the invention.

Figures 5 and 6 show two possible methods of making the invention. The tubes of Hytrel and the polyurethane can be molded into the shape of a midsole as shown in Figure 5 or a die cutout may be formed into pieces and incorporated into another midsole component. It should be noted that the cutaway views of Figure 5 are for illustration only. In actuality, the midsole is a single unitary piece which has had Hytrel or other hollow tubes encapsulated thereby. In the embodiment of the invention shown in Figure 6, heel tubes 30 are encapsulated into a heel die cutout material formed of either polyurethane or ethylene vinyl acetate (EVA). The entire die cutout section 41 which includes the tubes 30 and the heel die cut material 40 is incorporated into heel 16 of the midsole 14. The die cutout section 41 is placed within cutout 46 and attached in any conventional manner. For example the die cutout section 41 may be glued in place using any conventional bonding material. The heel die cut material 40 may be a different material than the material used to form the main part of the midsole 14. For example, the heel die cutout material 40 may be formed of polyurethane while the remaining portion of midsole 14 may be formed with a material such as ethylene vinyl acetate.

Similarly, the forefoot portion of the midsole 18 may be formed by using a forefoot die cutout section which includes a forefoot die cutout material 43 and forefoot tubes 28. As with the heel section of the shoe, the die cutout section of the forefoot 42 may be inserted into opening 48 in the forefoot of the midsole. This is done in the same manner as with the heel as described above.

Grooves 44 may be included in the forefoot section for the purposes of flexibility.

Although the forefoot tubes 28 in Figure 6 are shown to extend perpendicular to the longitudinal axis of the midsole, in the preferred embodiment of the invention the forefoot tubes 28 are angled to run parallel with the metatarsal portion of the foot. Typically the tubes are angled approximately 13° from perpendicular to the longitudinal axis of the midsole such that the tubes are furthest away from the heel on the medial side of the shoe.

The foregoing description of the preferred embodiment of the invention has been presented for purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form disclosed, and obviously many modifications and variations are possible in light of the above teachings. The embodiments were chosen and described in order to best explain the principles of the invention and its practical applications to thereby enable others skilled in the art to best utilize the invention in various embodiments and with various modifications as are suited to the particular use contemplated. For example it is possible that the tubes used to practice the invention may have a noncircular cross-section. It is possible for instance to have a cross-section which acts in a similar manner as the circular cross section described above. Although the drawings show tubes which are disposed perpendicular to the longitudinal axis of the shoe, it is possible to include tubes at other orientations. It is intended that the scope of the invention be defined by the claims appended hereto.

Claims

1. A midsole for an athletic shoe, comprising: elastomeric material and a plurality of spaced-apart, juxtaposed, hollow, horizontal tubes extending the width of said midsole, and encapsulated by said elastomeric material; said elastomeric material having a hardness less than said tubes and filling the space between said tubes, said tubes being spaced at a distance effective to compress said elastomeric material between said tubes when force is applied substantially perpendicular to said midsole due to deformation of said tubes, thereby inhibiting said tubes from further compressing said elastomeric material between said tubes which in turn inhibits further compression of said tubes.

2. The midsole of claim 1, wherein said tubes have a Shore D Durometer hardness of between 55 and 72.

3. The midsole of claims 1 or 2, wherein said elastomeric material has an Asker C Durometer hardness of between 35 and 65.

4. The midsole of any of claims 1 to 3, wherein said elastomeric material is polyurethane.

5. The midsole of any of claims 1 to 3, wherein said elastomeric material is ethylene vinyl acetate.

6. The midsole of any of claims 1 to 5, wherein said tubes are disposed in the heel and/or in the forefoot part of said midsole.

7. The midsole of any of claims 1 to 6, wherein said tubes are circular in cross-section and have an outside diameter of between 4 mm and 18 mm and a wall thickness of between 0.4 mm and 1.0 mm.

8. The midsole of claim 7, wherein the spacing between said tubes is between 0.5 mm and 9.0 mm.

9. The midsole of any one of claims 1 to 8, wherein said tubes comprise Hytrel.

10. The midsole of any of claims 6 to 9, wherein said tubes disposed in the forefoot part of said midsole are disposed at an angle, substantially parallel to the line formed by the metatarsal joints of the foot.

11. An athletic shoe, comprising:

(a) an upper;

(b) a midsole according to any of claims 1 to 10 and being disposed below said upper.

12. An athletic shoe, comprising:

(a) an upper;

(b) a midsole disposed below said upper, said midsole comprising an elastomeric material having a plurality of semicircular half-cylinder, spaced-apart seating grooves and a plurality of hollow tubes seated within the seating grooves.

13. The athletic shoe of claim 12, wherein said tubes are spaced at a distance effective to compress elastomeric material between said tubes when force is applied substantially perpendicular to said midsole due to deformation of said tubes, thereby inhibiting said tubes from further compressing said elastomeric material between said tubes which in turn inhibits further compression of said tubes.

14. The athletic shoe of claims 12 or 13, wherein the midsole of the athletic shoe further comprises the features of any of claims 2 to 10, either alone or in combination.

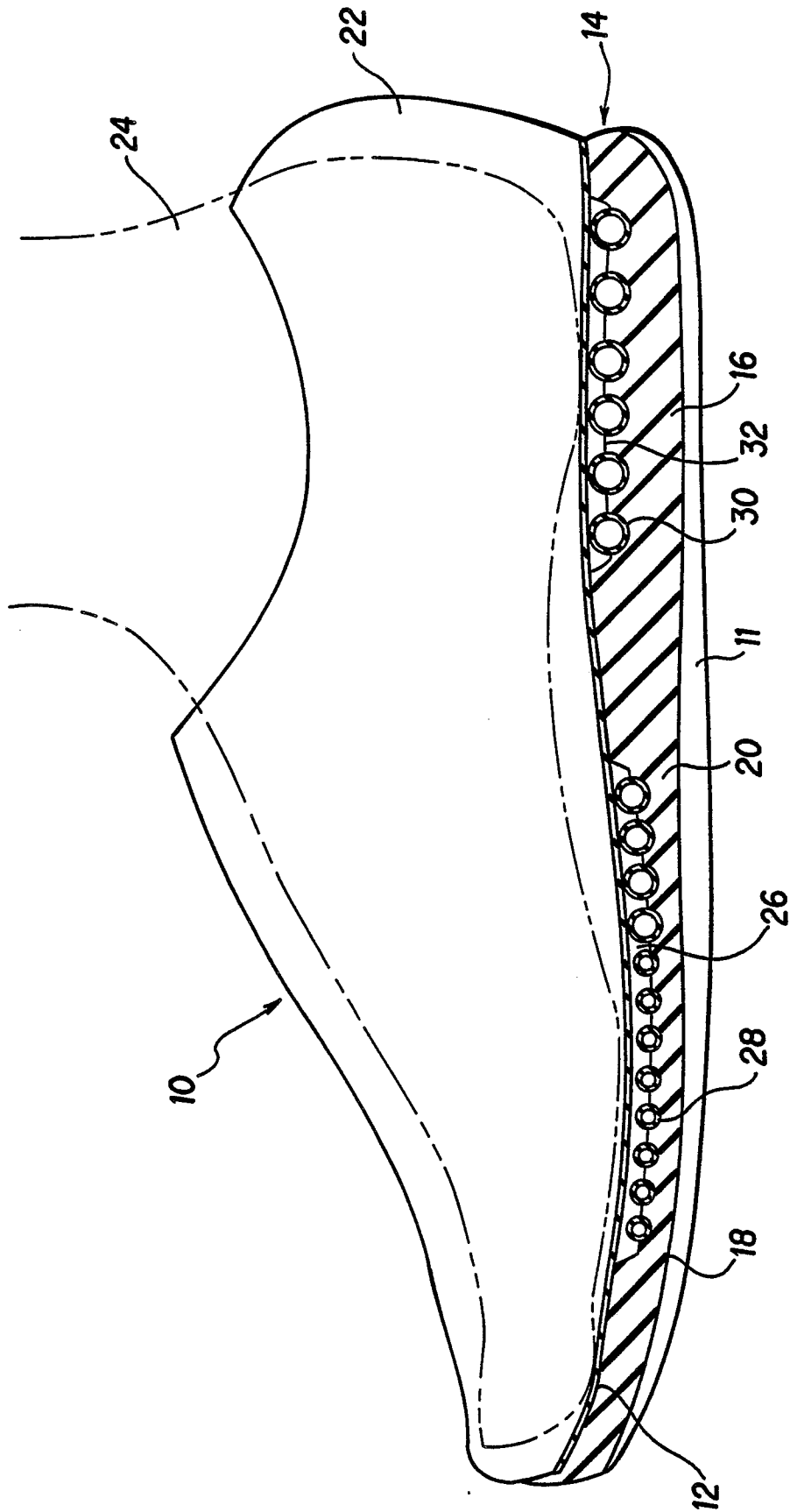


FIG. 1

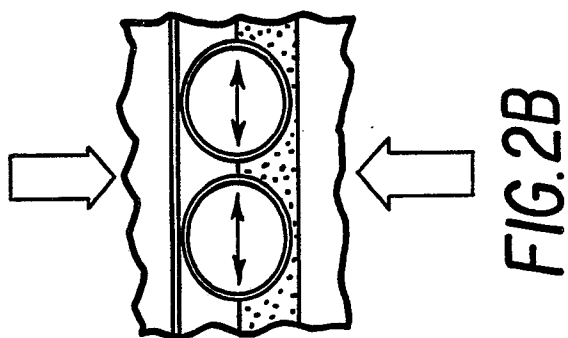
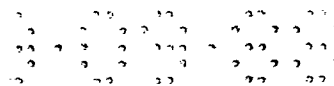


FIG. 2B

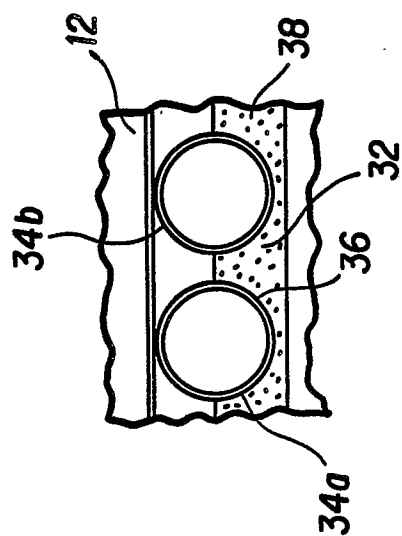


FIG. 2A

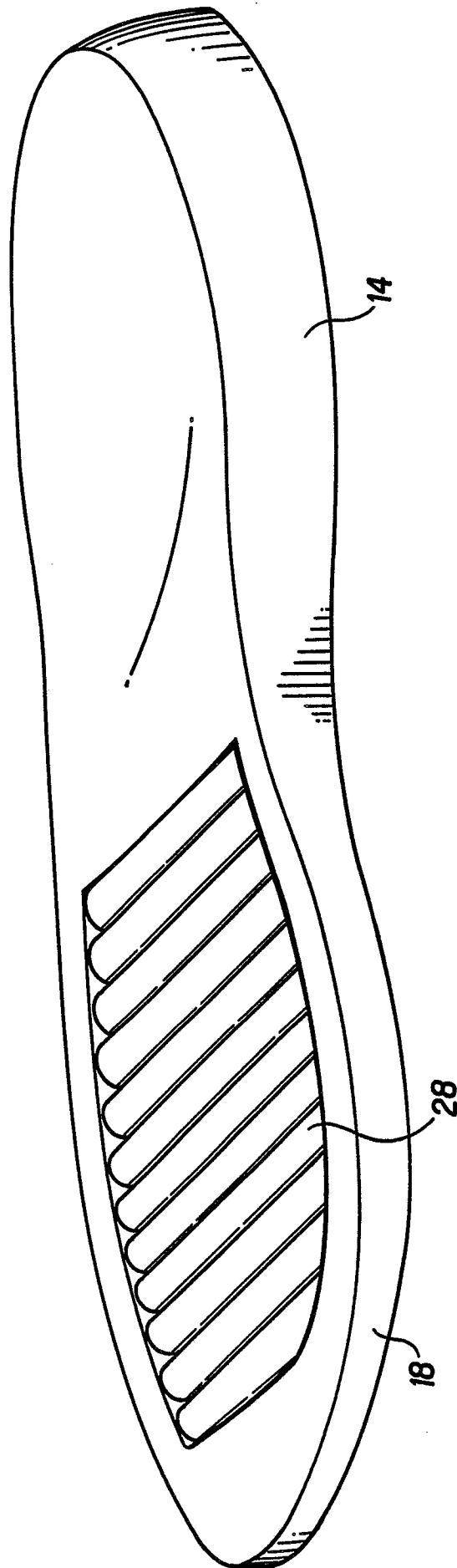
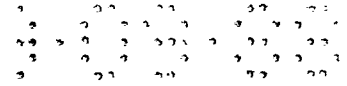


FIG. 3

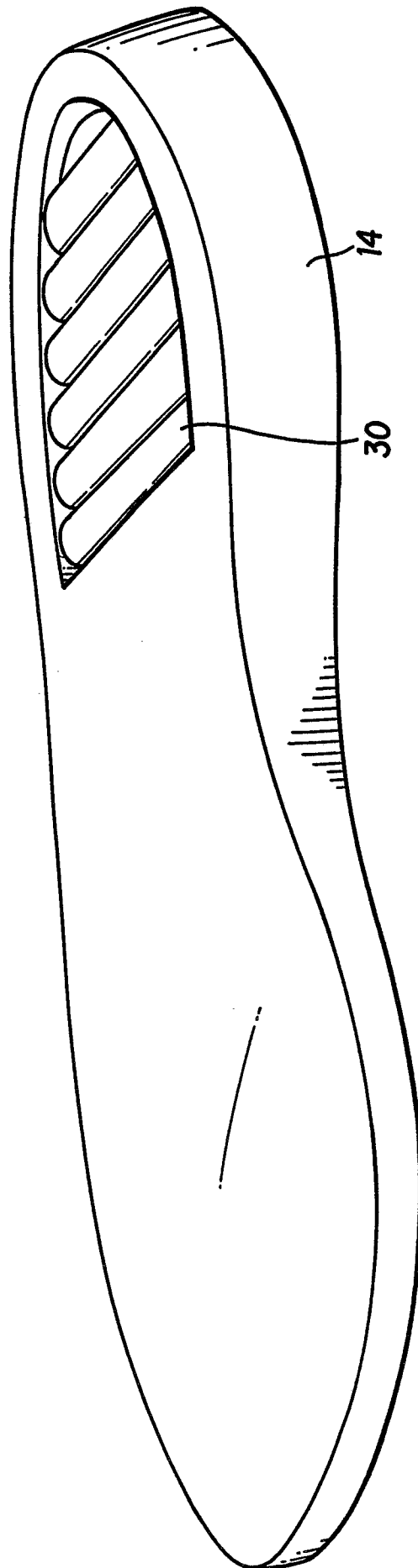


FIG. 4

