BLAST PROTECTIVE FOOTWEAR
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This invention relates to protective footwear which will reduce the damage to a human foot that would otherwise result from exposure to the blast effects of an anti-personnel land mine and, more particularly, to protective footwear having a deflector in the boot which will reduce the gross impulse and peak transmitted stresses applied to a human foot by an underwater explosion.

Small, blast-type, anti-personnel, land mines are used extensively in areas of military conflict to produce non-lethal, incapacitating injuries. Such mines are normally triggered by the pressure of a foot stepping on the mine and the blast effect is exerted primarily on the foot and lower portion of the leg. While any injury to the foot or lower leg is serious, destruction of the heel or arch of the foot or a serious shattering of the lower leg, the probable consequence of such an underwater explosion, is likely to require immediate amputation of at least a portion of the lower extremity. If the heel and arch portions of the foot and the lower portion of the leg can be protected from the blast of anti-personnel land mines, much of the devastating and permanent damage of these mines can be obviated. While protective devices have been used heretofore, especially by personnel clearing mine fields, such devices interfere with normal foot flexing movements and, consequently, greatly impede the mobility of the wearer. The protective footwear of the present invention provides protection against underwater explosions while not adversely affecting foot flexing properties. The protection afforded is not complete but is sufficient to reduce the degree of injury in the heel and arch portions of the foot and in the lower leg so that amputation of these parts will not normally be required.

Accordingly, an object of the present invention is to provide footwear which will protect the feet and legs of the wearer from the effects of an underwater explosion.

It is also an object of this invention to provide protection against the blast effect of an anti-personnel land mine exploding underwater by providing a protective component in conventional footwear which will not interfere with normal foot flexing movements.

These and other objects, advantages and capabilities of the invention will become apparent from the following description wherein reference is had to the accompanying drawing in which:

FIGURE 1 is a side elevational view of a boot according to the present invention with a blast-protective deflector shown in phantom;
FIGURE 2 is a bottom plan view of the sole of the boot of FIGURE 1, illustrating the outside configuration and showing the deflector in phantom;
FIGURE 3 is a vertical transverse sectional view of the blast-protective deflector illustrating the details of its construction;
FIGURE 4 is a vertical transverse sectional view of a modified deflector.
FIGURE 5 is a vertical transverse sectional view of still another deflector of the present invention.

Referring to FIGURES 1 and 2 of the drawings, there is shown an example of the protective footwear of the present invention in the form of a direct molded sole combat boot 10. This boot includes the usual leather upper section designated as an entirety by the number 12 which is generally similar to uppers of conventional boots and a lower section designated as an entirety by the number 14. The lower section comprises a heel portion 16, a shank portion 18 and a sole 20.

The lower section is made of vulcanizable rubber or rubber-like material of the type commonly used in making direct molded sole footwear so that upper section 12 may be directly molded to lower section 14 by fusing the two sections together along the welt line which is indicated more or less diagrammatically at 22. Protection against the blast of an underwater explosion is provided by an elongated wedge-shaped deflector 24 which is embedded in the lower section 14 so as to extend over the heel and shank portions thereof.

The deflector shown in FIGURES 1 and 2 of the drawing is dimensioned so as to extend over substantially all of the heel and shank areas of the boot. A three-inch wide by six-inch long deflector will, for example, provide coverage or protection to substantially all of the heel and shank portions of the most popular sizes of boots. The deflector, shown in detail in FIGURE 3, is a composite body, wedge-shaped when viewed in transverse section. When embedded in the boot, apex 26 of the deflector is directed downwardly toward the bottom surface of the lower section and the wall surface 28 of the deflector opposite the apex 26 is parallel with the bottom or top surfaces of the lower section. The outermost walls 30 forming the apex 26 of the deflector are formed of a single sheet of high tensile strength, non-shatterable material, e.g., stainless steel ¼" in thickness, which is bent along its longitudinal center line to form the desired apical angle, e.g., an included angle of 112°. The wall 28 opposite the apex 26 is formed of the same material as walls 30 and is a flat sheet resting on but not otherwise attached to the upper edges of walls 30. It is noted that wall 28 is dimensioned so as to extend laterally a distance beyond the upper edge of each of the walls 30. The walls 30 and 28 have a thickness of at least ¼" and preferably when constructed of stainless steel have a thickness of ⅛" or ⅛".

A wedge-shaped section of non-elastic, shock-absorbing material 32 occupies the triangular cavity defined by walls 30 and wall 28 and functions to spread the impulsive load over as long a time period as possible and to distribute the load over as large an area as is practicable. The shock-absorbing material used in the present invention should have a crushing strength (sustained stress during longitudinal cell compression) of from about 2500 p.s.i. to about 5000 p.s.i. Preferred materials, which combine high compressive strength with low weight, include aluminum hexagonal cell honeycombs having a cell size of ⅛-inch, e.g., an aluminum honeycomb constructed of foil having a thickness of .004-inch, a gross density of 15.3 pounds per cubic foot, and a crushing strength of 2550 p.s.i., or a honeycomb constructed of aluminum foil 0.060-inch in thickness, having a gross density of 23 pounds per cubic foot and a crushing strength of 4150 p.s.i. The cells of the honeycomb 32 within the triangular cavity are oriented so as to extend in the same direction as the apex and perpendicular to the wall surface 28.

An additional layer 34 of honeycomb, having a thickness of ⅛" to ¼", is included in the deflector design embodied in FIGURE 3 and is positioned above and flush with the wall surface 28 with its cells oriented so as to be perpendicular to said wall surface. This upper honeycomb layer 34 functions to distribute the transmitted load over as large an area as possible to cushion the impact of the residual velocity retained in the walls 28 and 30 after passage of the stress wave into the foot. A thin, e.g., .016-inch, aluminum plate 36 covers the top surface of layer 34. The height of the deflector taken from the
apex to the top surface thereof is from about 11° to 14°. The components of the deflector may be held together by any suitable mechanical means or adhesive to facilitate fabrication of the protective footwear. It is important to note, however, that the top wall 28 of the triangular wedge merely rests on the sidewalls 30 or at most is attached in a manner that will permit separation therefrom under shock load. This condition permits the sidewalls 30 to partially collapse and spread laterally so that the shock-absorbing material may be crushed.

The outer surfaces of the deflector 24 are coated with a rubber cement compatible with the rubber compound used to form the heel, shank and sole of the footwear so that the deflector will bond to this rubber compound and to the insole of the boot. When the deflector is fixed in position, the outside is molded in accordance with known direct molding processes for footwear. The deflector thus is embedded or built into the footwear as shown in FIGURES 1 and 2.

In FIGURE 4 there is shown a deflector 40 of modified construction. The sidewalls 42 forming the apex 44 are constructed of an integral sheet of high tensile strength, non-shatterable material, said sheet being thickest at the apex and tapering toward the upper edges thereof. The increased thickness in the apex region provides greater strength and resistance to deformation in this area. A wedge-shaped honeycomb 46, similar in construction to the honeycomb 32 in FIGURE 3 occupies the triangular cavity defined by the sidewalls 42 and the upper wall 48. Upper wall 48 is not integral with or permanently attached to the upper edges of the sidewalls 42 but merely rests thereon so that the sidewalls may more easily deform under the transmitted load of an underfoot explosion. An additional thin layer of honeycomb 47 is placed above the upper wall 48 and is covered with a thin sheet 49 of non-shatterable material. The included angle of the apex 44, as measured from the outside surfaces of sidewalls 42 is 112°.

FIGURE 5 of the drawing illustrates another blast deflector of this invention designated generally as 50 which is also wedge-shaped in transverse section. The downwardly directed apex 54 of the wedge is formed by bending a flat sheet of high tensile strength, non-shatterable material along its center line until the included angle at the apex is approximately 112°. The integral sidewalls forming the apex are identified as 52. Placed across the top edges of the walls 52 is a flat sheet 56 of the same material used to form the sidewalls. Sheet 56 which rests on and is not affixed to the top edges of the walls 52 extends laterally a short distance beyond each sidewall. The interior of the wedge-shaped deflector is filled with shock-absorbing material 58, e.g., an aluminum honeycomb having a crushing strength of 2550 p.s.i. and having the longitudinal axis of the cells thereof oriented in the same direction as the apex 54.

The gross impulse of the underfoot explosion transmitted to the protective footwear of this invention can be reduced by minimizing the ground contact area of the boot. Field studies have demonstrated that the greatest reduction in gross impulse without adverse effect on stability and wearing qualities of the boot results when the area of the outside material in contact with a land mine, e.g., a 3-inch diameter, blast-type, land mine, is reduced to a one-inch long wedge or ridge of outsole material. The outsole configuration shown in FIGURES 1 and 2 starting at the rear edge of the heel has an approximately 1-inch long ridge of material extending across the heel that makes contact with the ground, followed by an approximately one-inch depression in the heel, followed by another one-inch ridge of material that contacts the ground. Proceeding along the bottom of the boot the next area thereof that makes contact with the ground will be the sole in a vicininity of the ball of the foot.

The protective footwear of this invention provides a high level of protection against the impulse load (blast effect) generated by a land mine while not affecting the normal functional qualities of such footwear. The design of the outsole so as to minimize the area thereof coming into contact with a mine, reduces the gross impulse delivered to the boot without substantially affecting stability or wearing qualities of the boot. By employing a wedge-shaped deflector in the lower section of the boot, the shock absorber is subjected to a maximum reflected pressure, with an oblique plane surface which permits the oblique reflection of particles and allows an escape path for the gases of combustion thereby further reducing the gross impulse. The peak transmitted pressure of a few microseconds duration is reduced by a layered system of impedance mismatched materials. The honeycomb wedge serves to spread the impulsive load over as long a time period as possible and to distribute the load over an large area as is practical.

Damage to a human foot resulting from an underfoot explosion is related to the peak pressure and impulse associated with the impulsive load. The protective footwear of our invention provides effective protection against the blast effects of an underfoot explosion by reducing both the total impulse transmitted to the foot and by reducing the peak pressure transmitted to the foot. This invention provides the maximum degree of protection possible without significantly affecting the functional qualities of the boot.

The foregoing description is illustrative only, and it will be understood that various changes in the details, materials, and arrangements of parts which have been herein described and illustrated, may be made by those skilled in the art within the principle and scope of the invention as expressed in the appended claims.

We claim:

1. Protective footwear to attenuate the force of a blast from an underfoot explosion of an anti-personnel land mine on the heel and arch of the foot of the wearer thereof comprising an upper section and a lower section to form the heel, shank and sole portions of said footwear, said lower section embodying an elongated blast-resistant deflector, wedge-shaped in transverse section, extending over substantially all of the heel and shank portions thereof, said deflector comprising sidewalls of high tensile strength, non-shatterable material, said deflector having an apex thereof oriented downwardly, a sheet of high tensile strength, non-shatterable material extending across and covering the top of said deflector and forming the top wall thereof, and the interior of said deflector being filled with non-elastic, shock-absorbing material.

2. Protective footwear according to claim 1 wherein the included angle in said downwardly directed apex is in the range of about 60 degrees to about 140 degrees.

3. Protective footwear according to claim 2 wherein said non-elastic, shock-absorbing material is of honeycomb construction, having the longitudinal axis of the cells thereof oriented in the same direction as the apex of said deflector, and having a crushing strength of at least 2500 p.s.i.

4. Protective footwear according to claim 3 wherein the included angle of said downwardly directed apex is about 112 degrees.

5. Protective footwear according to claim 4 wherein said lower section has an outsole configuration beneath said deflector having alternate ridges and grooves which are perpendicular to the longitudinal axis of said lower section whereby the surface area of the outsole that comes into contact with the ground is reduced thereby reducing the gross impulse transmitted to the foot from an underfoot explosion.

6. Protective footwear according to claim 1 having a layer of non-elastic, shock-absorbing material of substantially uniform thickness extending over and covering said top wall, and a thin sheet of non-shatterable material covering said layer.
7. Protective footwear according to claim 6 wherein the included angle in said downwardly directed apex is in the range of about 60 degrees to about 140 degrees.

8. Protective footwear according to claim 7 wherein said non-elastic, shock-absorbing material is of honeycomb construction, having the longitudinal axis of the cells thereof oriented in the same direction as the apex of said deflector and having a crushing strength of at least 2500 p.s.i.

9. Protective footwear according to claim 8 wherein the included angle of said downwardly directed apex is about 112 degrees.

10. Protective footwear according to claim 9 wherein said sidewalls are formed of an integral sheet of high tensile strength, non-shatterable material.

11. Protective footwear according to claim 10 wherein said high tensile strength, non-shatterable material is steel having a thickness of from about \( \frac{3}{16} \)" to about \( \frac{1}{4} \)", wherein said honeycomb material has a crushing strength of from about 2500 p.s.i. to about 5000 p.s.i.

12. Protective footwear according to claim 9 wherein said lower section has an outsole configuration beneath said deflector having alternate ridges and grooves which are perpendicular to the longitudinal axis of said lower section whereby the surface area of the outsole that comes into contact with the ground is reduced thereby reducing the gross impulse transmitted to the foot from an underfoot explosion.

13. Protective footwear according to claim 12 wherein said sidewalls are formed of an integral sheet of high tensile strength, non-shatterable material, wherein said high tensile strength, non-shatterable material is stainless steel having a thickness of from about \( \frac{3}{16} \)" to about \( \frac{1}{4} \)", and wherein said non-elastic shock-absorbing material is an aluminum honeycomb having a crushing strength of from about 2500 p.s.i. to about 5000 p.s.i.

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