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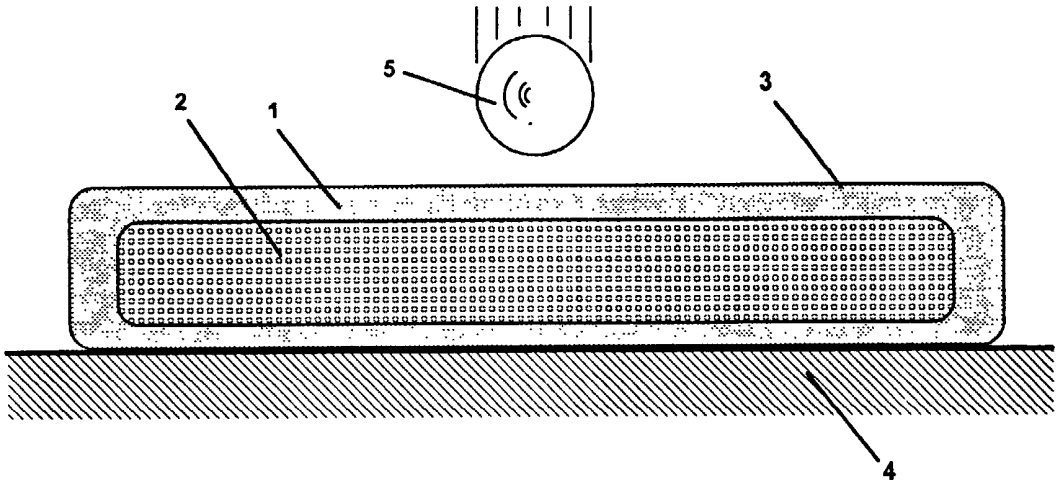
(54) Title: FLUID FILLED IMPACT ABSORBER



(57) Abstract: An impact absorbing device, consisting of a block of cellular elastomeric solid material, which totally enclodes one or more cavities or tunnels, which are filled with an elastic fluid, comprising a liquid, grease or jelly blended with a plurality of elastomeric capsules, characterised by the fluid being driven through the cavity or tunnels, away from the impact zone, during an impact on part of one face of the block, with the displaced fluid compressing elastomeric material, adjacent to the impact zone. The device will be useful for cushioning the front ends of vehicles, to satisfy pending European legislation, relating to pedestrian friendly vehicles. Blast mitigating versions of the invention, taking the form of building blocks will be useful for constructing blast resisting structures. Depicts a block of elastomeric cellular matrix material, (1) which includes a large cavity (2) filled with elastic fluid. The matrix block is preferably, but not essentially, covered with a stout, snug fitting, flexible cover (3) which does not stretch significantly during the impact. The device rests on a flat rigid surface, (4). When a body (5) falls onto the device, the front face of the device deforms and elastic fluid is driven to the sides of the impact zone.

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Fluid Filled Impact Absorber

Technical Field

This invention relates to improvements in devices used as energy absorbers, to mitigate the undesirable effects of sudden blows, blasts or vibrations on bodies or machines.

According to the present invention, there is provided, an impact absorbing device, consisting of a block of cellular elastomeric solid material, which totally encloses one or more cavities or tunnels, which are filled with an elastic fluid, comprising a liquid, grease or jelly blended with a plurality of elastomeric capsules, characterised by the fluid being driven through the cavity or tunnels, away from the impact zone, during an impact on part of one face of the block, with the displaced fluid compressing elastomeric material, adjacent to the impact zone.

Background Art

Fluid filled impact absorbing devices have been described in patents GB 2324352 and GB2335447 and patent application PCT/GB98/03594 (Courtney), filed by the present inventor. The present invention is intended to compliment these prior inventions, not to replace them. Patent GB 2324352 described impact absorbers consisting of stout, flexible packages filled with large numbers of small, resilient capsules and a matrix liquid. These packages combine the elastomeric properties of a closed cell foam with the viscous damping and hydraulic pressure equalisation properties of a liquid. Patent application PCT/GB98/03594 described impact or vibration absorbing devices consisting of a deformable container or flexible package, filled with a mixture of a liquid, grease or jelly fluid and a plurality of resilient capsules, with the device including one or more permeable barriers, characterised by the provision of viscous damping when some of the fluid is forced through small holes in the barrier(s) during violent impacts. Patent application PCT/GB98/03594 also described fluid filled impact absorbers which have flexible front faces but are mounted on cellular foam pallets. Patent GB2335447 describes impact absorbing building structures.

Brief description of the drawings

Figure 1 depicts a block of elastomeric cellular matrix material which includes a large cavity filled with elastic fluid.

Figure 2 depicts an impact absorber comprising five overlapping devices, each constructed in a similar manner to that depicted in Figure 1.

Figure 3 depicts a foot-bed for a shoe, according to the invention.

Definitions

In what follows, the term "*matrix fluid*" will be used when referring to any liquid, grease or jelly which occupies the void space between an assembly of small resilient capsules in the interior of the impact absorber. For impact absorbing purposes, as illustrated in the present patent application, the matrix fluid can be considered as an incompressible state of matter.

The term "*elastic fluid*" will be used when referring to any blend of small resilient capsules and matrix fluid, which, en-masse acts like a compressible fluid.

The term "*elastomeric matrix block*" will be used to describe a block of elastomeric cellular material, which includes one or more cavities or tunnels, which, according to the present invention, are filled with the elastic fluid. The cellular material may have a honeycomb, open or closed cell foam structure.

The term "*small capsules*" will be used as a relative term and will imply that, at their largest, the capsules just fit inside the cavities or tunnels. In most working examples of the invention the relative size of the capsules will be considerably smaller than this.

Disclosure of the invention

The inventive step described in this patent application is a method for absorbing the energy of impacts, blasts or vibrations, using cushioning blocks, which allow elastomeric material, to the sides of the impact zone, to participate in the energy absorbing process. It differs from the earlier intellectual property described by the present inventor in patents GB 2324352 and GB2335447 and patent application PCT/GB98/03594 (Courtney) in that the elastic fluid is totally enclosed in a cellular solid matrix material. The present invention has different impact absorbing and handling characteristics, making it more appropriate for certain applications. These applications will be illustrated by way of examples in what follows.

The essential principles of operation of the new device will be explained with the aid of Figure 1. **Figure 1** depicts a block of elastomeric cellular matrix material, **1** which includes a large cavity **2** filled with elastic fluid, as defined above and described in further detail by the present inventor in patent number GB 2324352. If the elastomeric matrix block is made from permeable material, for example open cell foam, then the walls of the cavity may be sealed or the elastic fluid may be retained inside an elastic flexible bag. The matrix block is preferably, but not essentially, covered with a stout, snug fitting, flexible cover **3** which does not stretch significantly during the impact. The cover is preferably but not essentially made from woven fabric, in a similar manner to the covers described by the present inventor in patent application PCT/GB98/03594 (Courtney). In the present example, the device rests on a flat rigid surface, **4**. When a body, **5** falls onto the device, the front face of the device deforms and elastic fluid is driven to the sides of the impact zone. The hydraulic pressure within the

matrix fluid exerts compressive stresses upon (i) the resilient capsules within the fluid, causing them to shrink in volume and (ii) exerts stresses on the walls of the cavity, compressing the cellular matrix material. If the cover **3** is omitted, impact energy is also absorbed as the parts of the block to the sides of the impact zone bulge out.

Figure 2 depicts an impact absorber comprising five devices, **1-5**, similar to those described with reference to Figure 1. Each of the devices is individually covered with strong low stretch sheet material, to discourage bulging during impacts. The devices are overlapped, such that a body impacting at any point of the upper surface, except for the extreme ends, always overlies one or two cavities filled with elastomeric fluid. In this example it will be assumed that the elastomeric cellular matrix material has a lower stiffness than the elastic fluid. It will also be assumed that the individual devices are bonded to the underlying surface **6** or are linked together by an outer cover or are otherwise bonded together, so that they do not move apart during an impact. Two types of impacts will be considered, the first involving a small mass **7**, then a larger mass **8**. For both impacts, it will be assumed that the desired function of the impact absorber is to minimise the peak retarding forces acting on the impacting masses as they come to rest. This means that for both impacts the masses must come to rest just before the impact absorber becomes highly compressed under the impact zone and the impact absorbing material bottoms out. In the case of the small mass **7**, the elastic fluid is shifted sideways during the impact, compressing the relatively soft matrix block material to the sides of the impact zone, but the elastic fluid itself is only slightly compressed. In contrast, when the larger mass **8** hits the impact absorber, the soft matrix block material bottoms out at an early stage of the impact, throughout the interior of the device, and the stiffer elastic fluid takes over as the dominant energy absorbing material during the remainder of the impact event. The net effect is that the larger mass reacts against an impact absorber which exhibits a greater mean uniaxial stiffness than for a small mass impact.

It is an intention of this version of the invention, to provide a variable uniaxial stiffness impact absorber, which allows the impact absorber to optimise its impact absorbing ability to protect both small, low mass impacting bodies and also larger, higher mass impacting bodies. The impact absorber described in this application could be used, for example, as the basis for a vehicle front bumper, which provided good levels of cushioning for pedestrian lower leg impacts and also, for low speed bumper-to-bumper impacts.

The version of the invention depicted in Figure 2 comprises a plurality of slightly overlapping devices in order to ensure that the comparatively stiff elastomeric fluid contributes a useful degree of impact energy absorbing compression, for larger body impacts. A similar enhanced elastic fluid contribution can be achieved using a single, longer impact absorber, similar to that depicted in Figure 1, by including an elastic fluid which offers a very high degree of viscous damping, so that the compression impulse, which travels through the elastic fluid to the sides of the impact zone, dies away rapidly. Methods of enhancing the viscous damping to achieve this effect include: (i) employing a highly viscous matrix fluid, (ii) using non-spherical elastomeric capsules which disrupt the flow of matrix fluid, relative to the elastomeric capsules during impact, e.g. capsules having pillow shapes, ridges or edges, (iii) bulking out the matrix fluid using polymeric microspheres, (v) replacing the single interior cavity with a plurality of narrow tunnels which extend throughout the elastomeric matrix block, at right angles to the direction of impact.

If the cavity takes the form of a plurality of tunnels, it is not essential for the tunnels to have a uniform diameter along their length, to be parallel or straight. The shape and orientation of the tunnels depends on the specific application for the device. The only essential requirement, for effective functioning, is that the tunnels are positioned, such that they can channel fluid away from the impact zone.

The tunnels may take any labyrinth form, including being the voids in elastomeric open cell foams. For elastic fluid filled, open cell foam versions of the invention, this inner foam is physically isolated by a seal or barrier, from the surrounding block of dry matrix solid.

The present invention offers the following advantages over the earlier elastic fluid based impact absorbers described by Courtney:

1. It has the potential to provide a greater difference in uniaxial stiffness for small and large body impacts.
2. The mean weight of the impact absorber is reduced because the matrix block is constructed from lower density material than the enclosed elastic fluid.
3. It offers a higher level of leak protection against accidental or malicious puncturing of the outer cover.
4. It has superior shape retention properties, allowing large impact absorbers to be constructed which do not sag noticeably over long periods of time, under the pull of gravity or other static forces.
5. Large solid faced blocks of material are easier to handle than flexible bags of elastic fluid, of a similar size.

If the elastomeric matrix block, according to the invention, forms all, or part of the foot-bed of a shoe, then the tunnels can be positioned such that a heel impact pumps fluid into the sole, pre-stiffening the elastomeric material under the ball of the foot and so enhancing the spring, when the walker or runner moves forward, with the ball of the foot striking the ground after the heel. Shoe foot-beds, according to the present invention will solve foot and lower leg problems in a number of markets, from osteoarthritis sufferers to cricket players, who need footwear fitted with studs, which is comfortable during long periods of standing still, while fielding, but also need to be able to move fast to retrieve balls. For footwear applications in particular, but not exclusively, some at least of the tunnels may be constructed from transparent, high stiffness elastomeric material, exposed to view at the sides of the shoe. The elastomeric beads can have a different surface colour to the surrounding matrix liquid, allowing the movements of the elastomeric beads, during a foot impact, to be clearly seen. The heel and ball of foot bed pads could of course be made from separate elastomeric matrix blocks with both blocks being linked via common fluid transmission tunnels. **Figure 3** shows a possible design, with item **1** being the heel, constructed from solid or cellular elastomeric material and item **2** the sole of the foot-bed constructed from elastomeric cellular material. Item **3** is a fluid filled cavity, totally enclosed within the heel, item **4** is a fluid filled cavity, totally enclosed within the sole and items **5** and **6** are fluid filled tubes which pass between the sole and the heel. Items **7** and **8** are optional variable diameter, elastic iris valves, which dilate, to allow the fluid to move quickly from the heel to the sole, during heel strike, but contract in diameter, to slow down the return flow, so that an excess of fluid is retained inside the sole, for a short period, until the ball of the foot hits the ground.

Explosives tests show that packaged blends of elastic fluid as described in patent GB 2324352 have the ability to mitigate blast waves. According to the present invention, blast mitigating building blocks may be manufactured using a suitable matrix block material for example, Airex® high density polyurethane foam. A robust outer cover made from, for example, a plurality of layers of Kevlar, would enhance the ability of such blocks provide protection against shrapnel and fast flying debris. Those skilled in the arts of temporary and prefabricated civil engineering product design will be able to design interlocking building block versions of the invention using existing reversible bonding techniques, including tongues and grooves, dovetailing, elastic cords and toggles, straps, touch and close material, clamps and poles which pass through holes in the blocks. The blocks may be pre-printed or painted on their outer faces with suitable textures and patterns, to fit in with the visual environment in which they are expected to be used.

The matrix and/or elastic fluid may be pumped into or out of the device on the site where the device is to be used. This feature will be of particular interest to engineers building temporary blast proof structures using building blocks, having blast absorbing properties according to the invention. To facilitate this feature, two valve and feed pipe systems may be added to each block. The first pipe to allow the injection of fluid and the second to allow the release of trapped air. These roles may be reversed, for pumping out the fluid, during dismantling, after use. The feed pipe systems may include filters, to prevent the elastomeric capsules being flushed out of the blocks during the filling or emptying processes. Skilled engineers will be able to design a range of fill-on-site versions of the invention, using existing technology, to satisfy a range of end user needs. For example, the feed pipes to adjacent blocks may lock together, allowing a single source of fluid to pump fluid into all of the connected blocks simultaneously or in sequence. Any visible connecting pipes may have transparent walls, allowing the progress of the fluid through the assembly of blocks to be checked during filling. The matrix fluid may be water, allowing the blocks to simultaneously serve as water storage tanks. Water sweetening chemicals may be added to the dry mix of elastomeric capsules, at the device manufacturing stage. A separate bladder or tank filled with water may be used as or mounted on the roof of a structure of such blocks, with the roof tank being plumbed into the feed pipe system. If this version of the invention is used, for example to build a small field hospital or barracks in a desert war zone, the water may be used as a heat reservoir, with chilled water from the roof tank being pumped into the wall blocks at dawn and warm water from the roof tank being pumped into the wall blocks at dusk. These thermal benefits can be enhanced, if the block consists of two parts, on opposite sides of the enclosed elastic fluid. The first block part being a good thermal insulator and the second block part being a good thermal conductor.

The novel improvements described in this patent application are capable of being applied to a wide range of designs of impact and vibration absorbers. The scope of the present invention is extended to include at least:

i) Versions of the invention in which at least some of the elastomeric material in the elastic fluid, consists of hollow resilient capsules.

ii) Versions of the invention in which at least some of the elastomeric material in the elastic fluid, consists of solid resilient capsules.

iii) Versions of the invention in which at least some of the elastomeric material in the elastic fluid, consists of

gas capsules, having at least one open end, with the gas trapped inside being retained at the boundary with the surrounding liquid by capillary action.

iv) Versions of the invention with the beads or capsules in the fluid, having at least two different sizes, with smaller beads or capsules fitting into the void spaces between the larger size beads or capsules.

v) Versions of the invention including one or more weak impermeable barriers, which partition the cavity or tunnels into short lengths during gentle impacts, but break down, to allow the fluid to travel further along the tunnels, during violent impacts.

vi) Versions of the invention, in which at least some, of any gas filled capsules are bonded to the inner walls of the cavity or tunnels.

vii) Versions of the invention, in which, at least some, of any gas filled capsules, inside the cavity or tunnels, are linked together on internal sheets, on open mesh grids of flexible material or on long stands of fibre.

viii) Versions of the invention, in which, at least some, of any gas filled capsules can have their internal pressure controlled by means of connections to external valves and compressed gas supplies, such as gas compression pumps.

ix) Versions of the invention having a nested structure, with larger elastomeric capsules including one or more smaller elastomeric capsules.

x) Versions of the invention, having a permeable outer cover, made for example, from tightly woven fabric, so that any fluid which leaks from the tunnels during an impact and comes to the surface of the block, is forced to do work, if it is driven through the fabric.

xi) Versions of the invention which include a partial outer cover or fascia made from a suitable flexible plastic or thin layer of malleable metal, for example an aluminium alloy.

xii) Versions of the invention which include an outer cover or plate that can shear, relative to the inner layers, during an impact.

xiii) Shearing versions of the invention, as above, with the shearing material also providing additional impact absorbing cushioning.

xiv) Versions of the invention which include a matrix block, made from material which varies in density, throughout its volume.

xv) Versions of the invention which include capsules and/or matrix block material made from aluminium foam or other good thermally conducting material, with the matrix fluid being a coolant, allowing the impact absorber to be plumbed into a heat source, for example a vehicle engine, with the impact absorber now also taking on the additional role of heat dissipating radiator.

xvi) Versions of the invention which include fluid inlet/outlet valves and are sufficiently robust that fluid can be pumped into their interior at high pressure, in order to re-shape the device.

xvii) Versions of the invention where the cells or honeycombs in the matrix block material are at least partially filled with a liquid or grease.

xviii) Versions of the invention which are modified or constructed, using known technology, to offer increased fire resistance.

xix) Versions of the invention which take the form of suspension or vibration energy absorbing systems.

xx) Versions of the invention, in which the liquid fraction is a liquid being stored or transported.

xxi) Versions of the invention, in which the fluid is an electrorheological or magnetorheological fluid, with the device being connected to suitable circuits, to activate the electrorheological or magnetorheological phenomenon in response to changing external conditions.

Fluid Filled Impact Absorber

Claims

1. An impact absorbing device, consisting of a block of cellular elastomeric solid material, which totally encloses one or more cavities or tunnels, which are filled with an elastic fluid, comprising a liquid, grease or jelly blended with a plurality of elastomeric capsules, characterised by the fluid being driven through the cavity or tunnels, away from the impact zone, during an impact on part of one face of the block, with the displaced fluid compressing elastomeric material, adjacent to the impact zone.

2. An impact absorbing device according to claim 1, with the block being enclosed in a snug fitting, flexible outer package, which reduces bulging of the block away from the impact zone, during an impact.

3. An impact absorbing device according to claims 1 or 2, with the cavity or tunnels being sealed with an elastic bladder or other form of fluid proof barrier which separates the elastic fluid from the surrounding matrix solid.

4. An impact absorbing device according to any of the above claims, with the tunnels taking the form of cavities in a block of open cell foam, with the block of open cell foam being separated by a flexible barrier from the surrounding cellular matrix solid.

5. An impact absorbing device according to any of the above claims, with the device including the means to add or remove at least some liquid, grease or jelly, during the working life of the device.

6. An impact absorbing device according to any of the above claims, with the mean compressive stiffness of the elastic fluid being greater than the compressive stiffness of the cellular elastomeric block material.

7. An impact absorbing device comprising a plurality of impact absorbing devices according to any of the above claims, with the individual devices being shaped and arranged, such that, except for the extreme edges of the total device, the impact zone of a body colliding with the device overlies at least one elastic fluid filled tunnel or chamber.

8. An impact absorbing device comprising a plurality of impact absorbing devices according to any of the above claims, with some at least of the cavities in each of the different devices being linked by robust walled, elastic fluid carrying tunnels, with do not bulge significantly during impacts.

9. An impact absorbing device according to the above claim, with the robust walled, linking tunnels including one or more valves which offer differential resistance to the flow of elastic fluid, depending on the direction of flow between the connected individual devices.

10. An impact absorbing device according to any of the above claims, with the block of cellular elastomeric solid including at least some cells which are filled with liquid.

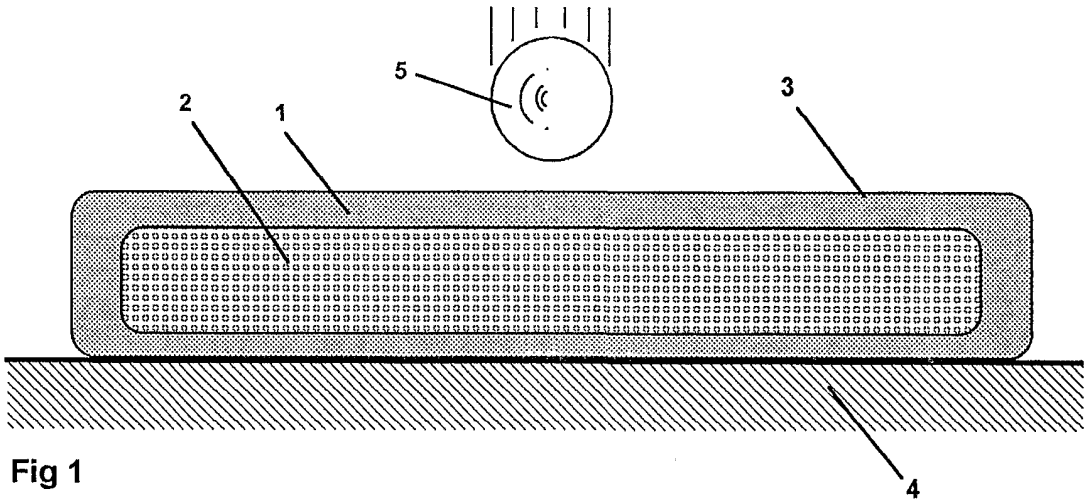

Fig 1

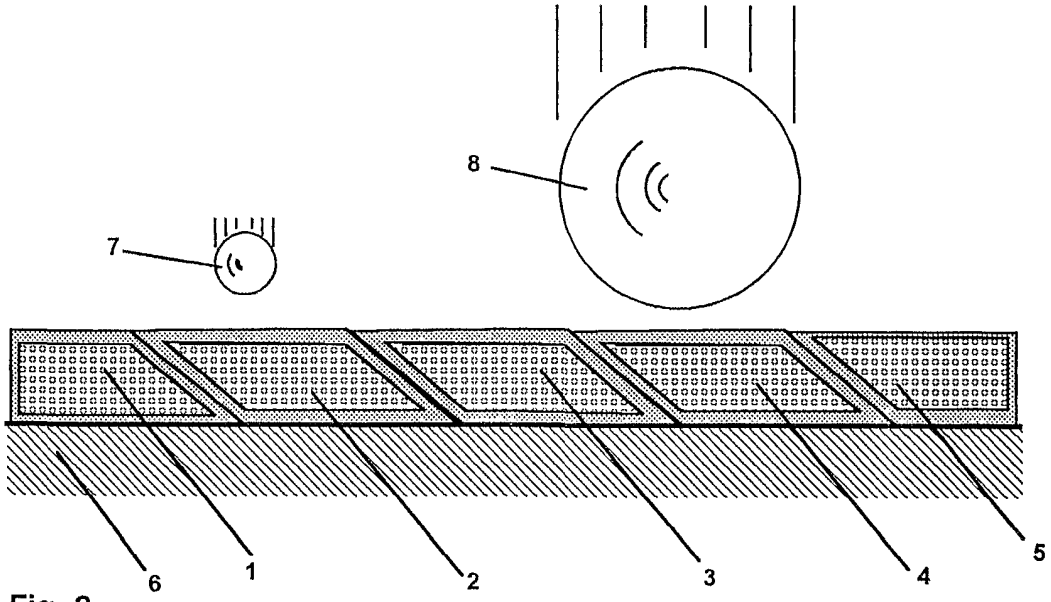

Fig 2

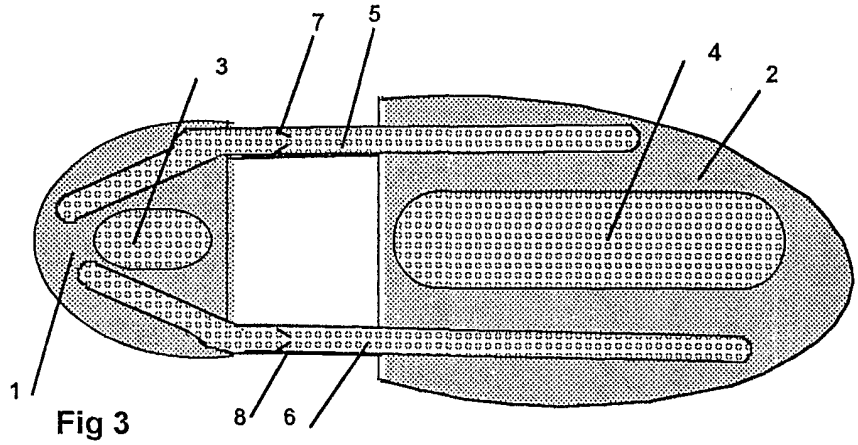

Fig 3

INTERNATIONAL SEARCH REPORT

In ional Application No
PCT/GB 01/03902

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 F16F5/00 F16F9/00 F16F9/30 A43B13/20

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 F16F A43B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

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Date of the actual completion of the international search	Date of mailing of the international search report
27 November 2001	04/12/2001

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Beaumont, A

INTERNATIONAL SEARCH REPORT

Ir tional Application No
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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A	US 5 996 250 A (MURRELL MARK D ET AL) 7 December 1999 (1999-12-07) figure 5 abstract	4
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