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(54) **INSOLE FOR REDUCING PEAK PRESSURES UNDER A FOOT**

EINLEGESOHLE ZUR VERRINGERUNG VON DRUCKSPITZEN UNTER EINEM FUSS

SEMELLE INTÉRIEURE POUR RÉDUIRE LES PRESSIONS DE PIC SOUS UN PIED

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Description

[0001] The invention relates to an insole for reducing peak pressures under a foot.

[0002] In the present context it is noted that the term "insole", as used throughout the present document, may refer to a removable or fixed inner sole of a boot or shoe.

[0003] Reducing peak pressures under feet of various people may be desirable for various reasons. It is, for example, particularly desirable for people with diabetes. The reason is that high peak pressures under the feet of people with diabetes can result in diabetic foot ulcers. These ulcers may eventually lead to (partial) amputation of the affected lower limb. Keeping peak pressures below 200 KPa prevents ulcerations.

[0004] Custom made insoles are commonly used. In the best situation these are based on a one time pressure measurement. Production processes like 3D printing and CAD have helped with decreasing production costs of these insoles. However, over time pressure spots change due to changes in the foot structure and the insole does not adapt to these changes.

[0005] US2017348181A1 discloses an insole, which actually does adapt to changes in the foot structure over time. In fact, the insole known from US2017348181A1 even effectively adapts to changes in pressure spots, dynamically when the patient walks. This known insole is capable of changing along when pressure spots change during walking. However, this known insole is very complex, as well as very expensive. The reason is that this known insole has a layer of many modules, wherein each module has many co-operating parts and aspects, such as a deformable cushion with a cavity, a valve, a tank, a pressure sensor, and a feedback loop.

[0006] It is further noted that WO 2018/115874 A1 discloses a deformable support structure for a human or animal body. The support structure has a network of resilient upstanding partitions or walls. The upstanding partitions are formed such that the partitions resist an applied load in two modes. A first mode involves resilient compression of the upstanding partitions up to a first loading threshold. A second mode involves reversible collapse of the upstanding partitions beyond the first load threshold, for example by buckling or crushing of the partitions.

[0007] It is further noted that KR 101 869 660 B1 discloses an insole according to the pre-characterizing portion of appended independent claim 1 of the present disclosure.

[0008] It is an object of the present invention to provide at least an alternative insole for reducing peak pressures under a foot, wherein the insole is effective to adapt to changes in pressure spots, dynamically when the patient walks, and wherein the insole is less complex and less expensive than the insole known from the above-mentioned US2017348181A1.

[0009] For that purpose, the invention provides an insole according to the appended independent claim 1. Preferable embodiments of the invention are provided by the appended dependent claims 2-7.

[0010] Hence, the invention provides an insole for reducing peak pressures under a foot, wherein the insole has an insole surface in accordance with a width direction and a length direction of the insole, and wherein the insole comprises a plurality of resilient supporting elements, which are distributed over the insole surface for resiliently supporting a foot in a supporting direction, which is transverse to the insole surface, and wherein, for each supporting element of said plurality of supporting elements, the supporting element has an undeformed condition, from which the supporting element is resiliently deformable under influence of an external compressive force, which is exerted on the supporting element in the supporting direction, the supporting element having a supporting surface for receiving said external compressive force, and wherein the supporting element returns into said undeformed condition in reaction to a condition in which said external compressive force vanishes, and wherein the supporting element comprises a resiliently collapsable buckling part designed to have a buckling behaviour such that:

- the buckling part resiliently collapses in the supporting direction in reaction to a condition in which said external compressive force exceeds a first force threshold, and,
- if thus being collapsed, the buckling part resiliently expands in the supporting direction in reaction to a condition in which said external compressive force falls below a second force threshold, which is lower than the first force threshold,

wherein, as seen in said undeformed condition of the supporting element, the buckling part of the supporting element is formed by an elastically deformable circumferential or perimetric buckling wall, which is extending circumferentially or perimetrically around a central axis of the supporting element, said central axis of the supporting element being parallel to the supporting direction, and
wherein,
as seen in said undeformed condition of the supporting element, and as seen in at least one cross-sectional plane containing said central axis of the supporting element:

- the supporting element further comprises a main supporting portion, wherein said supporting surface is an outer surface of the main supporting portion,

- the main supporting portion in at least a sub-range along said central axis has a narrowing outer shape, such as for example a frusto-conically or frusto-pyramidally narrowing outermost shape, as seen in a direction away from said supporting surface,
- the circumferential or perimetric buckling wall is on a side of the main supporting portion facing away from said supporting surface, and
- the circumferential or perimetric buckling wall in at least a sub-range along said central axis is widening, such as for example conically or pyramidally widening, as seen in a direction away from said supporting surface.

[0011] It is noted that the terms "resilient" and "resiliently", as used throughout the present document in relation to the above-mentioned supporting element, generally refer to the ability of the supporting element to automatically spring back into shape after being compressed in the above-mentioned supporting direction. Said springing back is occurring towards the above-mentioned undeformed condition of the supporting element and is based on spring force provided by the supporting element itself.

[0012] It is further noted that the term "buckling", as used throughout the present document in relation to the above-mentioned supporting element, more particularly as used in relation to the above-mentioned resiliently collapsable "buckling" part having the above-mentioned "buckling" behaviour, is to be understood to mean: angularly bending as a result of a locally abruptly lower bending stiffness of the supporting element.

[0013] The foot of the user will exert pressure on the insole, the pressure being distributed over the total number of supporting elements that are present. The resulting pressure distributed over the surface of an individual supporting element results in a compressive force proportional to the pressure and surface area of the supporting element. This compressive force causes the supporting element to buckle.

[0014] As will be readily appreciated from the more detailed example of the drawing figures discussed further below, the resiliently collapsable buckling part with its buckling behaviour can be noncomplex, easy to produce, durable and reliable.

[0015] The key features of the insole according to the invention are:

- the plurality of the above-mentioned supporting elements distributed over the insole surface, in combination with
- the fact that each supporting element has the above-mentioned resiliently collapsable buckling part having the above-mentioned collapsing and expanding buckling behaviours in dependence of how the external compressive force behaves relative to the above-mentioned first and second force thresholds, and in combination with
- the above-mentioned narrowing outer shape of the main supporting portion and the above-mentioned widening circumferential or perimetric buckling wall.

[0016] Thanks to these key features local peak pressures are effectively prevented, since one or more of the collapsable buckling parts of one or more of the supporting elements will immediately collapse in case the external compressive force exceeds the first force threshold. Thanks to the collapsing of the buckling part(s) concerned high pressures are automatically prevented at the supporting element(s) concerned. At the same time a larger number of neighbouring supporting elements in unison will take over the load from the supporting element(s) concerned. Hence, the insole according to the invention automatically and dynamically prevents local peak pressures by redistributing the pressures over a larger number of neighbouring supporting elements. In other words, the insole according to the invention provides a highly effective dynamically self-adjusting pressure distribution for reducing peak pressures under a foot. Thanks to the above-mentioned narrowing outer shape of the main supporting portion and the above-mentioned widening circumferential or perimetric buckling wall, the major feature of the invention, i.e. the supporting element as a whole, is realized in a compact, noncomplex, nonexpensive and reliable manner.

[0017] In a preferable embodiment of the invention, said plurality of resilient supporting elements is an integrally manufactured one-piece structure. Such an integrally manufactured one-piece structure further contributes to the noncomplex and/or nonexpensive character of the insole. The one-piece structure may for example be made by a 3D printer. However, many various other manufacturing techniques are available as well, for example various 3D layerwise manufacturing technologies, injection moulding technologies, etc.

[0018] In further preferable embodiments of the invention,

- an external pressure exerted on the supporting surface of the supporting element and a first pressure threshold for said external pressure are defined as to proportionally correspond, in terms of uniform pressure distribution over the supporting surface, to the external compressive force exerted on the supporting element and the first force threshold, respectively, and
- said first pressure threshold is higher than 100 kPa and lower than 300 kPa; more preferably higher than 140 kPa and lower than 250 kPa; and yet more preferably higher than 180 kPa and lower than 200 kPa. Depending on the

circumstances, these values of the first pressure threshold may reduce peak pressures under a foot to effective levels for preventing various foot problems, such as for example diabetic foot ulcers.

[0019] In further preferable embodiments of the invention, the second force threshold is higher than 10% of the first force threshold and lower than 95% of the first force threshold; more preferably higher than 20% of the first force threshold and lower than 85% of the first force threshold; and yet more preferably higher than 30% of the first force threshold and lower than 75% of the first force threshold.

[0020] Making designs choices so as to obtain values of the second pressure threshold within the above-mentioned ranges, may, depending on the circumstances, contribute to obtaining a favorably even pressure distribution under a foot as seen dynamically when the patient walks. The closer the second pressure threshold is to the first pressure threshold, the sooner the supporting elements will tend to expand again after being collapsed.

[0021] In another preferable embodiment of the invention the circumferential buckling wall in collapsed condition of the buckling part is received against the narrowing outer shape of the main supporting portion.

[0022] This further contributes to obtaining a compactly collapsing buckling part of the supporting element.

[0023] In another preferable embodiment of the invention the main supporting portion is a solid portion of the supporting element in the sense of not being hollow and not containing spaces or gaps.

[0024] Such a solid portion further contributes to a favourable deformation behaviour of the supporting element, and it also contributes to a stable supporting behaviour as provided by the supporting element.

[0025] In another preferable embodiment of the invention:

- transverse outermost boundary contours of the supporting element are defined as outermost boundary contours of the supporting element, respectively, as seen at least in said undeformed condition of the supporting element, and as seen in cross-sectional planes, which at different positions along said central axis, respectively, are transverse to said central axis, and
- wherein at least one of said outermost boundary contours, and preferably all of said outermost boundary contours, of the supporting element has/have an hexagonal shape.

[0026] The hexagonal shape provides the following advantages for providing predictable and reproducible buckling behavior of the supporting elements. The hexagonal shape allows for a maximum of six neighboring elements for each supporting element as opposed to for example a square shape where only a maximum of four neighboring elements may be achieved. In this manner the hexagonal shape advantageously maximizes the amount of neighboring elements that can take over the load from a supporting element, the hexagonal shape thus optimally redistributes the pressure over said neighboring supporting elements.

[0027] The hexagonal shape also allows for an even distance between the outermost boundary contours of adjacent supporting surfaces thus providing a more uniform surface for more effectively redistributing the pressure, as opposed to for example a round shape which would leave more space in-between adjacent supporting elements.

[0028] Furthermore, the hexagonal shape advantageously allows for the largest number of supporting elements distributed over the insole surface, thus maximizing the amount of supporting elements on the insole

[0029] The above-mentioned aspects and other aspects of the invention will be apparent from and elucidated with reference to the embodiments described hereinafter by way of non-limiting examples only and with reference to the schematic figures in the enclosed drawing.

Fig. 1 shows, in a perspective view, an example of an embodiment of an insole according to the invention, wherein the supporting elements of the insole are in their undeformed conditions.

Fig. 2 separately shows, in a perspective view, one of the plurality of resilient supporting elements of the insole of Fig. 1, wherein the shown supporting element is in its undeformed condition.

Fig. 3A shows the supporting element of Fig. 2 in its undeformed condition, however this time in a cross-sectional plane which contains the central axis of the supporting element.

Fig. 3B shows the situation of Fig. 3A again, however this time in a deformation condition of the supporting element in which an external compressive force is exerted on the supporting element in the supporting direction, wherein the external compressive force is lower than the above-mentioned first force threshold, so that the buckling part of the supporting element has not yet collapsed in the supporting direction.

Fig. 3C shows the situation of Fig. 3B again, however this time in a condition in which said external compressive force exerted on the supporting element has exceeded said first force threshold, so that the buckling part of the supporting element has collapsed in the supporting direction.

Fig. 4 separately shows three mutually adjacent ones of the plurality of resilient supporting elements of the insole of Fig. 1, in a cross-sectional plane which contains the central axes of the three supporting elements, wherein the leftmost and rightmost of the three supporting elements are in the deformation condition of Fig. 3B, while the middle one of the three supporting elements is in the deformation condition of Fig. 3C.

Fig. 5 shows a qualitative force/displacement graph, which is typical for a supporting element, such as the specific supporting element of Fig. 2, wherein the graph depicts, for each considered standstill displacement of the supporting element, the resilient reaction force provided by the supporting element when balanced by an oppositely directed equal external compressive force exerted on the supporting element at each considered standstill displacement, respectively.

Fig. 6 shows a full-line graph and a broken-line graph, both as a function of time, wherein the full-line graph is an example of a qualitative force/time graph during a gait cycle performed by a person, the full-line graph qualitatively indicating an imposed external compressive force exerted on a supporting element, such as the specific supporting element of Fig. 2, as a function of time, and wherein the broken-line graph qualitatively indicates the correspondingly resulting displacement of the supporting surface of the supporting element as a function of time during said gait cycle.

[0030] The reference signs used in Figs. 1-6 are referring to the above-mentioned parts and aspects of the invention, as well as to related parts and aspects, in the following manner.

1	insole
2	width direction
3	length direction
4	supporting direction
5, 5A, 5B, 5C	supporting element
6	supporting surface
7	collapsable buckling part
8	perimetric buckling wall
9	main supporting portion
10	central axis
F_1	first force threshold
F_2	second force threshold
D_{max}	maximum displacement of the supporting surface (as seen relative to the undeformed condition of the supporting element).

[0031] Based on the above introductory description, including the brief description of the drawing figures, and based on the above-explained reference signs used in the drawing, the shown examples of Figs. 1-6 are for the greatest part readily self-explanatory. The following extra explanations are given.

[0032] The insole 1 illustrated by Figs. 1-6 is an insole according to each of the appended independent claims 1-7.

[0033] As seen in Fig. 1, the insole 1 has a large plurality of mutually identical supporting elements, generally indicated by the reference numeral 5. Three mutually adjacent ones of these identical supporting elements 5 have more specifically been indicated by the reference numerals 5A, 5B, 5C, respectively. These are the three supporting elements 5A, 5B, 5C which are also shown in the cross-sectional plane of Fig. 4. In Fig. 1 it is further seen that the insole 1 of Fig. 1 further has a number of supporting elements, which are different from said mutually identical supporting elements 5. These different supporting elements are located along the outer circumferential boundary edge of the insole 1. In fact these different supporting elements are truncated versions of the supporting elements 5.

[0034] In the shown example all supporting elements of the insole 1 are interconnected with one another via the perimetric buckling walls 8 of their collapsable buckling parts 7 in a manner as shown in Fig. 4, thereby forming the insole 1 as an integrally manufactured one-piece structure. In fact, the integrally manufactured one-piece insole 1 has been manufactured by means of a 3D-printer.

[0035] Figs. 2-4 show the above-mentioned narrowing outer shape of the main supporting portion 9 of the supporting element 5, as seen in a direction away from the supporting surface 6. More specifically it is seen that, in the shown example, said narrowing outer shape is a frusto-pyramidally narrowing outermost shape.

[0036] Figs. 2-4 further show that the circumferential buckling wall 8 is widening in a manner as mentioned above. More specifically it is seen that, in the shown example, the perimetric buckling wall 8 is pyramidally widening, as seen in a direction away from the supporting surface 6.

[0037] As seen in Figs. 3-4, the pyramidally widening perimetric buckling wall 8, at least in the undeformed condition of the supporting element 5, is defining a recess of the supporting element 5. The main supporting portion 9, on the other hand, is a solid portion of the supporting element 5 in the shown example.

[0038] Furthermore, Figs. 1-2 show the above-mentioned hexagonal shapes of the above-mentioned outermost boundary contours of the supporting element 5. More specifically, in the shown example said hexagonal shapes of the outermost boundary contours are occurring along the entire extension range of the supporting element 5 along the central axis 10.

[0039] Figs. 3A-3C are illustrating the deformation behaviour of the supporting element 5, including the buckling behaviour of the collapsable buckling part 7, under influence of external compressive forces exerted on the supporting surface 6 of the supporting element in the supporting direction. The undeformed condition of the supporting element 5 as shown in Fig. 3A corresponds to a situation in which the external compressive force is absent.

[0040] The condition of the supporting element 5 as shown in Fig. 3B corresponds to a situation in which the external compressive force is present, but does not exceed the first force threshold F_1, so that the buckling part 7 of the supporting element has only been deformed slightly, but has not yet collapsed. Accordingly, in Fig. 3B it is seen that the supporting surface 6 has been only slightly displaced relative to its position (indicated by a broken line) that would correspond to the undeformed condition of the supporting element 5.

[0041] The condition of the supporting element 5 as shown in Fig. 3C corresponds to a situation in which the external compressive force is present, and has exceeded the first force threshold F_1, so that the buckling part 7 of the supporting element has fully collapsed. That is, in Fig. 3B it is seen that the supporting surface 6 has been displaced over the maximum displacement D_{max} relative to its position (indicated by a broken line) that would correspond to the undeformed condition of the supporting element 5.

[0042] If, starting-off from the collapsed situation shown in Fig. 3C, the external compressive force would fall below the second force threshold F_2 (which is lower than the first force threshold F_1), the buckling part 7 would resiliently expand in such manner that the supporting element 5 would attain a deformation condition similar to that shown in Fig. 3B, or, if the external compressive force would fully vanish, the undeformed condition of Fig. 3A.

[0043] Reference is now made to Fig. 5 in order to further explain the deformation behaviour of the supporting element 5, including the buckling behaviour of the collapsable buckling part 7, under influence of external compressive forces exerted on the supporting surface 6 of the supporting element in the supporting direction.

[0044] As already mentioned in the introduction, the resilient supporting element 5 has the ability to automatically spring back into shape after being compressed in the supporting direction. Said springing back is based on spring force provided by the supporting element itself. In that sense, the supporting element 5 is for example comparable with a compression spring. A compression spring has a "spring constant", which defines a linear relationship between external compressive force and displacement. The resilient supporting element of the insole of the present invention, on the other hand, has a totally different relationship between external compressive force and displacement. This is illustrated by Fig. 5, wherein the horizontal axis depicts the displacement of the supporting surface 6 of the supporting element 5, between 0 millimeter and D_{max}, and wherein the vertical axis depicts the involved external compressive force, between 0 Newton and F_1.

[0045] Fig. 5 shows that at the start of deforming the supporting element 5, there is a more or less linear relationship between external compressive force and displacement. Next, when the external compressive force reaches the first force threshold F_1, the collapsable buckling part 7 starts to collapse, meaning that the resilient reaction force of the supporting element 5 drastically decreases in combination with a drastically increased displacement, eventually upto the maximum displacement D_{max}. To maintain the maximum displacement D_{max}, it suffices that the external compressive force is higher than or equal to the second force threshold F_2.

[0046] It is noted that, in the shown example, the first and second force thresholds F_1 and F_2 are dependent on various design choices of the supporting element 5. For example, in the shown example it has appeared that these first and second force thresholds F_1 and F_2 are highly influenceable by the wall thickness of the perimetric buckling wall 8, as well as by the angle between the perimetric buckling wall 8 and the central axis 10 as important design parameters.

[0047] Reference is now made to Fig. 6 in combination with Fig. 4. In Fig. 6 the full-line graph could for example indicate an imposed external compressive force exerted on the supporting element 5B of Fig. 4 during a gait cycle performed by a person, wherein the broken-line graph of Fig. 6 indicates the correspondingly resulting displacement of the supporting surface 6 during said gait cycle. From Fig. 6 it is seen that the supporting element 5B of Fig. 4 is in fully collapsed condition during a major part of the gait cycle. Fig. 4 illustrates that, when the supporting element 5B is collapsed, the neighbouring supporting elements, such as the elements 5A and 5C of Fig. 4, in unison will take over the load from the supporting element 5B. Accordingly, Figs. 4 and 6 make clear that local peak pressures under a foot are effectively prevented thanks to the insole 1, since one or more of the collapsable buckling parts of one or more of the supporting elements of the insole 1 will immediately collapse in case the external compressive force exceeds the first force threshold. Thanks to the collapsing of the buckling part(s) concerned high pressures are automatically prevented at the supporting element(s) concerned. At the same time a larger number of neighbouring supporting elements in unison will take over the load from the supporting element(s) concerned. Hence, the insole according to the invention automatically and dynamically prevents local peak pressures by redistributing the pressures over a larger number of neighbouring supporting elements. In other words, the insole according to the invention provides a highly effective dynamically self-adjusting pressure distribution for reducing peak pressures under a foot.

[0048] Prototypes of the invention were manufactured by Fused Deposition Modelling 3D printers using thermoplastic polyurethane filament. Each supporting element 5 was manufactured with a height of 9 mm, a supporting surface 6 area of 1.46 cm2, a D_{max} of 3.5 mm. Again, specific pressures over the supporting surface 6 will result in proportional values for the force thresholds. Different values for the main design parameters, said design parameters being wall thickness of the circumferential buckling wall 8, the angle between the circumferential buckling wall 8 and the central axis 10, were manufactured and these resulted in the following example first force thresholds (F_1) and example second force thresholds (F_2) during quasi-static measurements that provided good functionality:

Wall Thickness	Angle	F_1	F_2
0.90 mm	40°	14.9 N / 102 kPa	10.8 N / 74 kPa
1.05 mm	40°	19.3 N / 132 kPa	13.7 N / 94 kPa
1.20 mm	40°	28.9 N / 198 kPa	19.6 N / 134 kPa
0.90 mm	45°	11.4 N / 78 kPa	8.1 N / 55 kPa
1.05 mm	45°	15.4 N / 105 kPa	10.5 N / 72 kPa
1.20 mm	45°	20.9 N / 143 kPa	15.0 N / 103 kPa

[0049] The values shown for F_1 and F_2 are the compressive force measured on the supporting surface, and the corresponding local pressure on the supporting surface at buckling (F_1) and springing back (F_2). It is noted that these example values were identified by the inventors under laboratory conditions as providing good functionality, but other values for the wall thickness of the circumferential buckling wall 8, the angle between the circumferential buckling wall 8 and the central axis 10 may be identified with further development that also provide equal or better functionality.

[0050] It is noted that in Fig. 1 the width direction 2 and the length direction 3 of the insole are both depicted as straight linear directions. Generally, however, both the width direction 2 and the length direction 3 may also be curved directions, so that also the insole surface of the insole may generally be a two-dimensionally curved surface. In fact the insole 1 of Fig. 1 is a deformable structure in both said directions.

[0051] While the invention has been described and illustrated in detail in the foregoing description and in the drawing figures, such description and illustration are to be considered exemplary and/or illustrative and not restrictive; the invention is not limited to the disclosed embodiments.

[0052] For example, in the shown example, the outermost boundary contours of the supporting element 5 have hexagonal shapes. Instead, many various other shapes of such outermost boundary contours are also possible according to the invention, such as circular, oval, or otherwise rounded shapes, or triangular, square, or otherwise piecewise linear shapes, etc.

[0053] As a further example it is mentioned that one insole according to the invention may comprise different kinds of the supporting elements, having different shapes, collapsing properties, etc., instead of all the same supporting elements. For example, the different kinds of supporting elements may be located in different zones along the support surface of the insole, respectively. In fact, an insole according to the invention may be designed both as a custom design and as an off-the-shelf design.

[0054] It is further noted that an insole according to the invention may not only be beneficial for people with diabetes. It may also be beneficially applied to many various other boots or shoes, such as for example to many various sports shoes.

Claims

1. An insole for reducing peak pressures under a foot, wherein the insole (1) has an insole surface in accordance with a width direction (2) and a length direction (3) of the insole, and wherein the insole comprises a plurality of resilient supporting elements (5, 5A, 5B, 5C), which are distributed over the insole surface for resiliently supporting a foot in a supporting direction (4), which is transverse to the insole surface, and wherein, for each supporting element of said plurality of supporting elements, the supporting element has an undeformed condition, from which the supporting element is resiliently deformable under influence of an external compressive force, which is exerted on the supporting element in the supporting direction, the supporting element having a supporting surface (6) for receiving said external compressive force, and wherein the supporting element (5) returns into said undeformed condition in reaction to a condition in which said external compressive force vanishes, and wherein the supporting element (5) comprises a resiliently collapsable buckling part (7) designed to have a buckling behaviour such that:

   - the buckling part (7) resiliently collapses in the supporting direction in reaction to a condition in which said external compressive force exceeds a first force threshold (F1), and,
   - if thus being collapsed, the buckling part (7) resiliently expands in the supporting direction in reaction to a condition in which said external compressive force falls below a second force threshold (F2), which is lower

than the first force threshold (F1),
wherein, as seen in said undeformed condition of the supporting element (5), the buckling part (7) of the supporting element is formed by an elastically deformable circumferential or perimetric buckling wall (8), which is extending circumferentially or perimetrically around a central axis (10) of the supporting element, said central axis of the supporting element being parallel to the supporting direction (4), and
wherein,
as seen in said undeformed condition of the supporting element (5), and as seen in at least one cross-sectional plane containing said central axis (10) of the supporting element:

- the supporting element further comprises a main supporting portion (9), wherein said supporting surface (6) is an outer surface of the main supporting portion,
- the circumferential or perimetrical buckling wall (8) is on a side of the main supporting portion (9) facing away from said supporting surface (6), and
- the circumferential or perimetrical buckling wall (8) in at least a sub-range along said central axis (10) is widening, such as for example conically or pyramidally widening, as seen in a direction away from said supporting surface (6),

characterized in that,
as seen in said undeformed condition of the supporting element (5), and as seen in at least one cross-sectional plane containing said central axis (10) of the supporting element:

- the main supporting portion (9) in at least a sub-range along said central axis (10) has a narrowing outer shape, such as for example a frusto-conically or frusto-pyramidally narrowing outermost shape, as seen in a direction away from said supporting surface (6).

2. An insole according to claim 1, wherein said plurality of resilient supporting elements (5) is an integrally manufactured one-piece structure.

3. An insole according to claim 1 or 2, wherein:

- an external pressure exerted on the supporting surface (6) of the supporting element (2) and a first pressure threshold for said external pressure are defined as to proportionally correspond, in terms of uniform pressure distribution over the supporting surface, to the external compressive force exerted on the supporting element and the first force threshold (F1), respectively, and
- said first pressure threshold is higher than 100 kPa and lower than 300 kPa; preferably higher than 140 kPa and lower than 250 kPa; and more preferably higher than 180 kPa and lower than 200 kPa.

4. An insole according to any one of the preceding claims, wherein the second force threshold (F2) is higher than 10% of the first force threshold (F1) and lower than 95% of the first force threshold (F1); preferably higher than 20% of the first force threshold (F1) and lower than 85% of the first force threshold (F1); and more preferably higher than 30% of the first force threshold (F1) and lower than 75% of the first force threshold (F1).

5. An insole according to any one of the preceding claims, wherein the circumferential or perimetrical buckling wall (8) in collapsed condition of the buckling part (7) is received against the narrowing outer shape of the main supporting portion (9).

6. An insole according to any one of the preceding claims, wherein the main supporting portion (9) is a solid portion of the supporting element (5) in the sense of not being hollow and not containing spaces or gaps.

7. An insole according to any one of the preceding claims, wherein:

- transverse outermost boundary contours of the supporting element (5) are defined as outermost boundary contours of the supporting element, respectively, as seen at least in said undeformed condition of the supporting element, and as seen in cross-sectional planes, which at different positions along said central axis (10), respectively, are transverse to said central axis, and
- wherein at least one of said outermost boundary contours, and preferably all of said outermost boundary contours, of the supporting element (5) has/have an hexagonal shape.

Patentansprüche

1. Einlegesohle zum Verringern von Druckspitzen unter einem Fuß, wobei die Einlegesohle (1) eine Einlegesohlenoberfläche in Übereinstimmung mit einer Breitenrichtung (2) und einer Längsrichtung (3) der Einlegesohle aufweist, und wobei die Einlegesohle mehrere elastische Stützelemente (5, 5A, 5B, 5C) umfasst, die über die Einlegesohlenoberfläche verteilt sind, um einen Fuß in einer Stützrichtung (4), die quer zur Einlegesohlenoberfläche verläuft, elastisch zu stützen, und wobei bei jedem Stützelement der mehreren Stützelemente das Stützelement einen unverformten Zustand aufweist, aus dem das Stützelement unter dem Einfluss einer äußeren Druckkraft, die auf das Stützelement in der Stützrichtung ausgeübt wird, elastisch verformbar ist, wobei das Stützelement eine Stützfläche (6) zur Aufnahme der äußeren Druckkraft aufweist, und wobei das Stützelement (5) als Reaktion auf einen Zustand, in dem die äußere Druckkraft verschwindet, in den unverformten Zustand zurückkehrt, und wobei das Stützelement (5) ein elastisch zusammenklappbares Knickteil (7) umfasst, das so ausgelegt ist, dass es ein Knickverhalten aufweist, bei dem:

- das Knickteil (7) als Reaktion auf einen Zustand, in dem die äußere Druckkraft einen ersten Kraftschwellenwert (F1) überschreitet, elastisch in der Stützrichtung zusammenklappt, und
- das Knickteil (7), wenn es so zusammengeklappt wird, sich als Reaktion auf einen Zustand, in dem die äußere Druckkraft unter einen zweiten Kraftschwellenwert (F2) fällt, der niedriger als der erste Kraftschwellenwert (F1) ist, in der Stützrichtung elastisch ausdehnt,

wobei, gesehen im unverformten Zustand des Stützelements (5), das Knickteil (7) des Stützelements durch eine elastisch verformbare umlaufende oder perimetrische Knickwand (8) gebildet wird, die sich umlaufend oder perimetrisch um eine zentrale Achse (10) des Stützelements erstreckt, wobei die zentrale Achse des Stützelements parallel zur Stützrichtung (4) ist, und
wobei,
im unverformten Zustand des Stützelements (5) und in wenigstens einer Querschnittsebene, die die zentrale Achse (10) des Stützelements enthält, gesehen:

- das Stützelement ferner einen Hauptstützabschnitt (9) umfasst, wobei die Stützfläche (6) eine Außenfläche des Hauptstützabschnitts ist,
- die umlaufende oder perimetrische Knickwand (8) sich auf einer von der Stützfläche (6) abgewandten Seite des Hauptstützabschnitts (9) befindet, und
- die umlaufende oder perimetrische Knickwand (8) in wenigstens einem Teilbereich sich entlang der zentralen Achse (10) in einer von der Stützfläche (6) wegweisenden Richtung verbreitert, wie zum Beispiel sich konisch oder pyramidenförmig verbreitert,

<u>**dadurch gekennzeichnet, dass,**</u>
im unverformten Zustand des Stützelements (5) und in wenigstens einer Querschnittsebene, die die zentrale Achse (10) des Stützelements enthält, gesehen:

- der Hauptstützabschnitt (9) in wenigstens einem Teilbereich entlang der zentralen Achse (10) eine sich verjüngende äußere Form, wie zum Beispiel eine kegelstumpfförmige oder kegelstumpfförmig verjüngende äußerste Form, gesehen in einer Richtung weg von der Stützfläche (6), aufweist.

2. Einlegesohle nach Anspruch 1, wobei die Vielzahl von elastischen Stützelementen (5) eine ganzheitlich hergestellte einteilige Struktur ist.

3. Einlegesohle nach Anspruch 1 oder 2, wobei:

- ein auf die Stützfläche (6) des Stützelements (2) ausgeübter äußerer Druck und ein erster Druckschwellenwert für den äußeren Druck so definiert sind, dass sie bei gleichmäßiger Druckverteilung über die Stützfläche proportional jeweils der auf das Stützelement ausgeübten äußeren Druckkraft und dem ersten Kraftschwellenwert (F1) entsprechen, und
- der erste Druckschwellenwert höher als 100 kPa und niedriger als 300 kPa ist; vorzugsweise höher als 140 kPa und niedriger als 250 kPa; und bevorzugter höher als 180 kPa und niedriger als 200 kPa.

4. Einlegesohle nach einem der vorhergehenden Ansprüche, wobei der zweite Kraftschwellenwert (F2) höher als 10 % des ersten Kraftschwellenwerts (F1) und niedriger als 95 % des ersten Kraftschwellenwerts (F1); vorzugsweise höher als 20 % des ersten Kraftschwellenwerts (F1) und niedriger als 85 % des ersten Kraftschwellenwerts (F1);

und bevorzugter höher als 30 % des ersten Kraftschwellenwerts (F1) und niedriger als 75 % des ersten Kraftschwellenwerts (F1) ist.

5. Einlegesohle nach einem der vorhergehenden Ansprüche, wobei die umlaufende oder perimetrische Knickwand (8) im zusammengeklappten Zustand des Knickteils (7) gegen die sich verjüngende äußere Form des Hauptstützabschnitts (9) aufgenommen wird.

6. Einlegesohle nach einem der vorhergehenden Ansprüche, wobei der Hauptstützabschnitt (9) ein fester Abschnitt des Stützelements (5) in dem Sinne ist, dass er nicht hohl ist und keine Zwischenräume oder Lücken enthält.

7. Einlegesohle nach einem der vorhergehenden Ansprüche, wobei:

- quer verlaufende äußerste Begrenzungskonturen des Stützelements (5) als äußerste Begrenzungskonturen des Stützelements definiert sind, wie sie wenigstens in dem unverformten Zustand des Stützelements gesehen werden, und wie sie in Querschnittsebenen gesehen werden, die an verschiedenen Positionen entlang der zentralen Achse (10) jeweils quer zu der zentralen Achse verlaufen, und
- wobei wenigstens eine der äußersten Begrenzungskonturen und vorzugsweise alle der äußersten Begrenzungskonturen des Stützelements (5) eine hexagonale Form hat/haben.

Revendications

1. Semelle intérieure pour réduire les pressions maximales sous un pied, dans laquelle la semelle intérieure (1) a une surface de semelle intérieure selon une direction de la largeur (2) et une direction de la longueur (3) de la semelle intérieure, et dans laquelle la semelle intérieure comprend une pluralité d'éléments de support élastiques (5, 5A, 5B, 5C), qui sont répartis sur la surface de la semelle intérieure pour supporter de manière élastique un pied dans une direction de support (4), qui est transversale à la surface de la semelle intérieure, et dans laquelle, pour chaque élément de support de ladite pluralité d'éléments de support, l'élément de support a un état non déformé, à partir duquel l'élément de support est déformable de manière élastique sous l'influence d'une force de compression extérieure, qui est exercée sur l'élément de support dans la direction de support, l'élément de support ayant une surface de support (6) pour recevoir ladite force de compression extérieure, et dans laquelle l'élément de support (5) revient dans ledit état non déformé en réaction à un état dans lequel ladite force de compression extérieure disparaît, et dans laquelle l'élément de support (5) comprend une pièce de gauchissement qui peut fléchir de manière élastique (7) conçue pour présenter un comportement de gauchissement de telle sorte que :

- la pièce de gauchissement (7) fléchit de manière élastique dans la direction de support en réaction à un état dans lequel ladite force de compression extérieure dépasse un premier seuil de force (F1), et,
- si elle est ainsi fléchie, la partie de gauchissement (7) se déploie de manière élastique dans la direction de support en réaction à un état dans lequel ladite force de compression extérieure chute au-dessous d'un second seuil de force (F2), qui est inférieur au premier seuil de force (F1),

dans laquelle, comme vu dans ledit état non déformé de l'élément de support (5), la partie de gauchissement (7) de l'élément de support est constituée par une paroi de gauchissement circonférentielle ou périmétrique déformable de manière élastique (8), qui s'étend de manière circonférentielle ou périmétrique autour d'un axe central (10) de l'élément de support, ledit axe central de l'élément de support étant parallèle à la direction de support (4), et

dans laquelle, comme vu dans ledit état non déformé de l'élément de support (5), et comme vu dans au moins un plan en coupe transversale qui contient ledit axe central (10) de l'élément de support :

- l'élément de support comprend en outre une partie de support principale (9), dans lequel ladite surface de support (6) est une surface extérieure de la partie de support principale,
- la paroi de gauchissement circonférentielle ou périmétrique (8) se situe sur un côté de la partie de support principale (9) qui fait face en s'éloignant de ladite surface de support (6), et
- la paroi de gauchissement circonférentielle ou périmétrique (8) dans au moins une plage secondaire le long dudit axe central (10) s'élargit, par exemple de manière conique ou pyramidale, comme vu dans une direction en s'éloignant de ladite surface de support (6),

caractérisée en ce que, comme vu dans ledit état non déformé de l'élément de support (5), et comme vu dans au moins un plan en coupe transversale contenant ledit axe central (10) de l'élément de support :

- la partie de support principale (9) dans au moins une plage secondaire le long dudit axe central (10) a une forme extérieure rétrécissante, par exemple la forme la plus extérieure rétrécissante en forme tronconique ou tronpyramidale, comme vu dans une direction s'éloignant de ladite surface de support (6).

2. Semelle intérieure selon la revendication 1, dans laquelle ladite pluralité d'éléments de support élastiques (5) est une structure fabriquée d'une seule pièce.

3. Semelle intérieure selon la revendication 1 ou 2, dans laquelle :

- une pression extérieure exercée sur la surface de support (6) de l'élément de support (2) et un premier seuil de pression de ladite pression extérieure sont définis afin de correspondre proportionnellement, en termes de distribution de pression uniforme sur la surface de support, à la force de compression extérieure exercée sur l'élément de support et au premier seuil de force (F1), respectivement, et
- ledit premier seuil de pression est supérieur à 100 kPa et inférieur à 300 kPa ; de préférence supérieur à 140 kPa et inférieur à 250 kPa ; et encore mieux, supérieur à 180 kPa et inférieur à 200 kPa.

4. Semelle intérieure selon l'une quelconque des revendications précédentes, dans laquelle le second seuil de force (F2) est supérieur à 10 % du premier seuil de force (F1) et inférieur à 95 % du premier seuil de force (F1) ; de préférence supérieur à 20 % du premier seuil de force (F1) et inférieur à 85 % du premier seuil de force (F1) ; et encore mieux, supérieur à 30 % du premier seuil de force (F1) et inférieur à 75 % du premier seuil de force (F1).

5. Semelle intérieure selon l'une quelconque des revendications précédentes, dans laquelle la paroi de gauchissement circonférentielle ou périmétrique (8) dans l'état fléchi de la partie de gauchissement (7) est reçue contre la forme extérieure rétrécissante de la partie de support principale (9).

6. Semelle intérieure selon l'une quelconque des revendications précédentes, dans laquelle la partie de support principale (9) est une partie solide de l'élément de support (5) dans le sens où elle n'est pas creuse et ne contient ni espaces ni intervalles.

7. Semelle intérieure selon l'une quelconque des revendications précédentes :

- dans laquelle les contours limites les plus extérieurs transversaux de l'élément de support (5) sont définis en tant que contours limites les plus extérieurs de l'élément de support, respectivement, comme vu au moins dans ledit état non déformé de l'élément de support, et comme vu dans des plans en coupe, qui à différentes positions le long dudit axe central (10), respectivement, sont transversaux audit axe central, et
- dans laquelle l'un au moins desdits contours limites les plus extérieurs, et de préférence tous lesdits contours limites les plus extérieurs, de l'élément de support (5) ont une forme hexagonale.

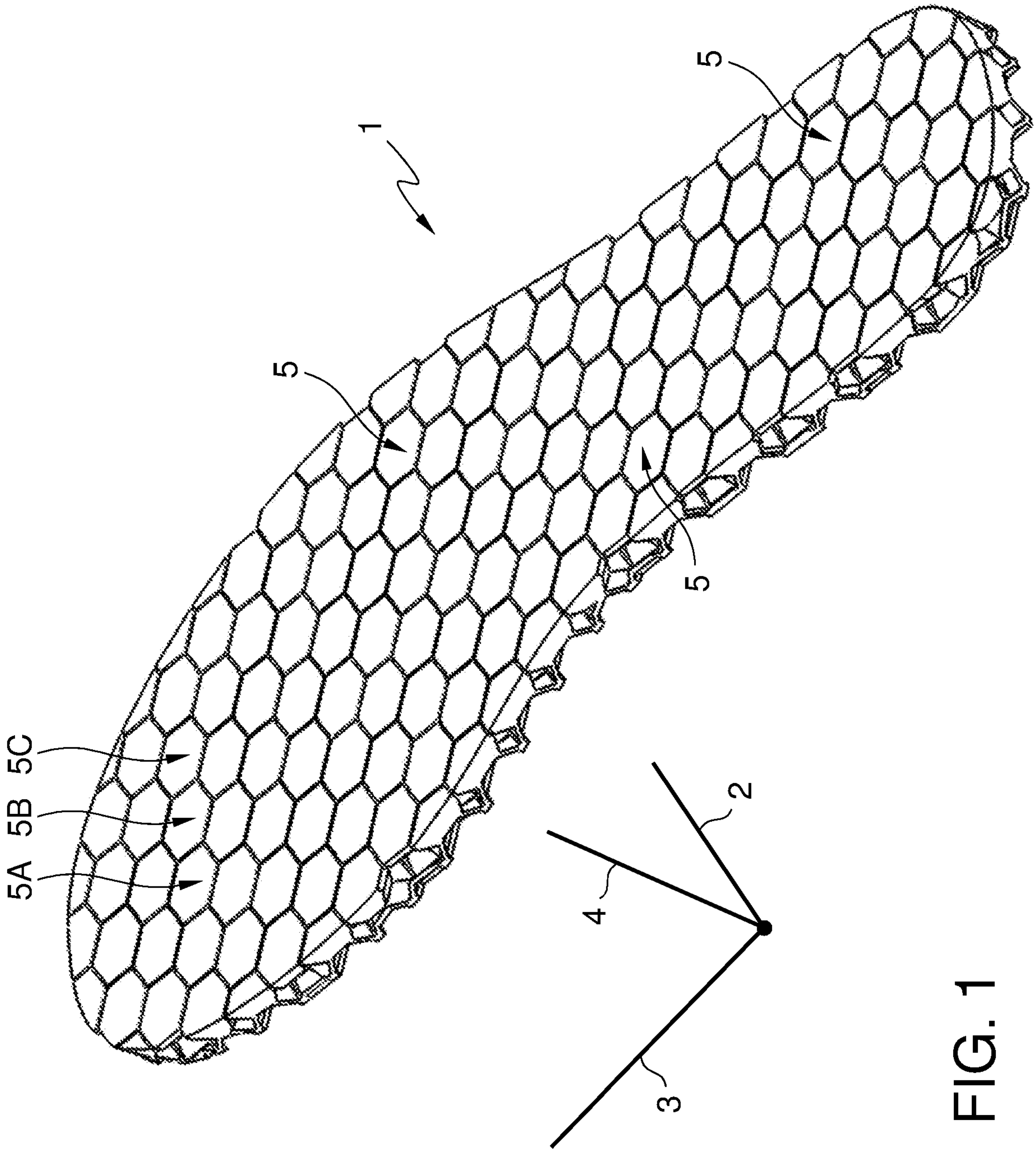

FIG. 1

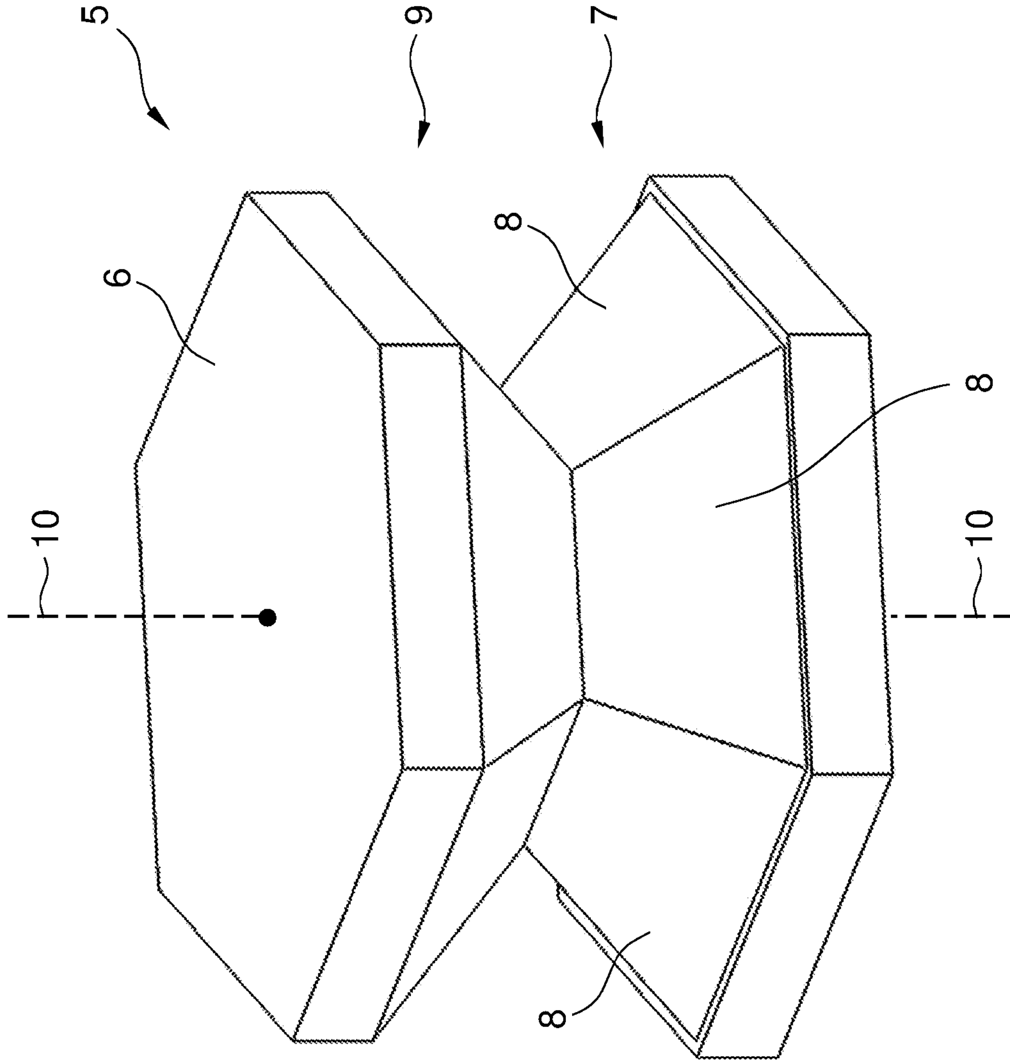

FIG. 2

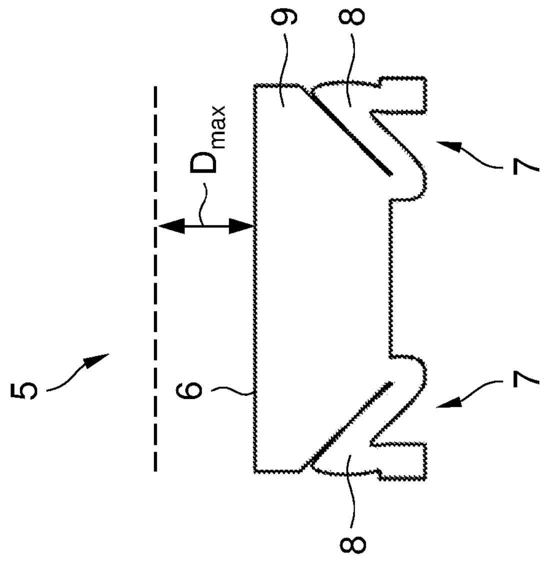

FIG. 3C

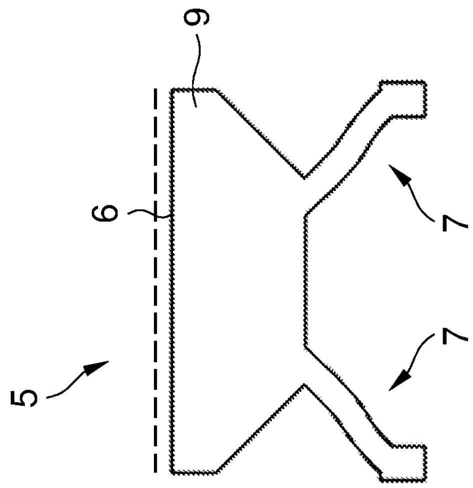

FIG. 3B

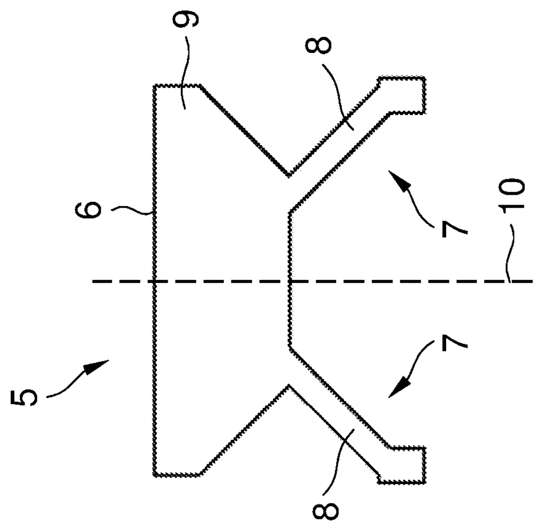

FIG. 3A

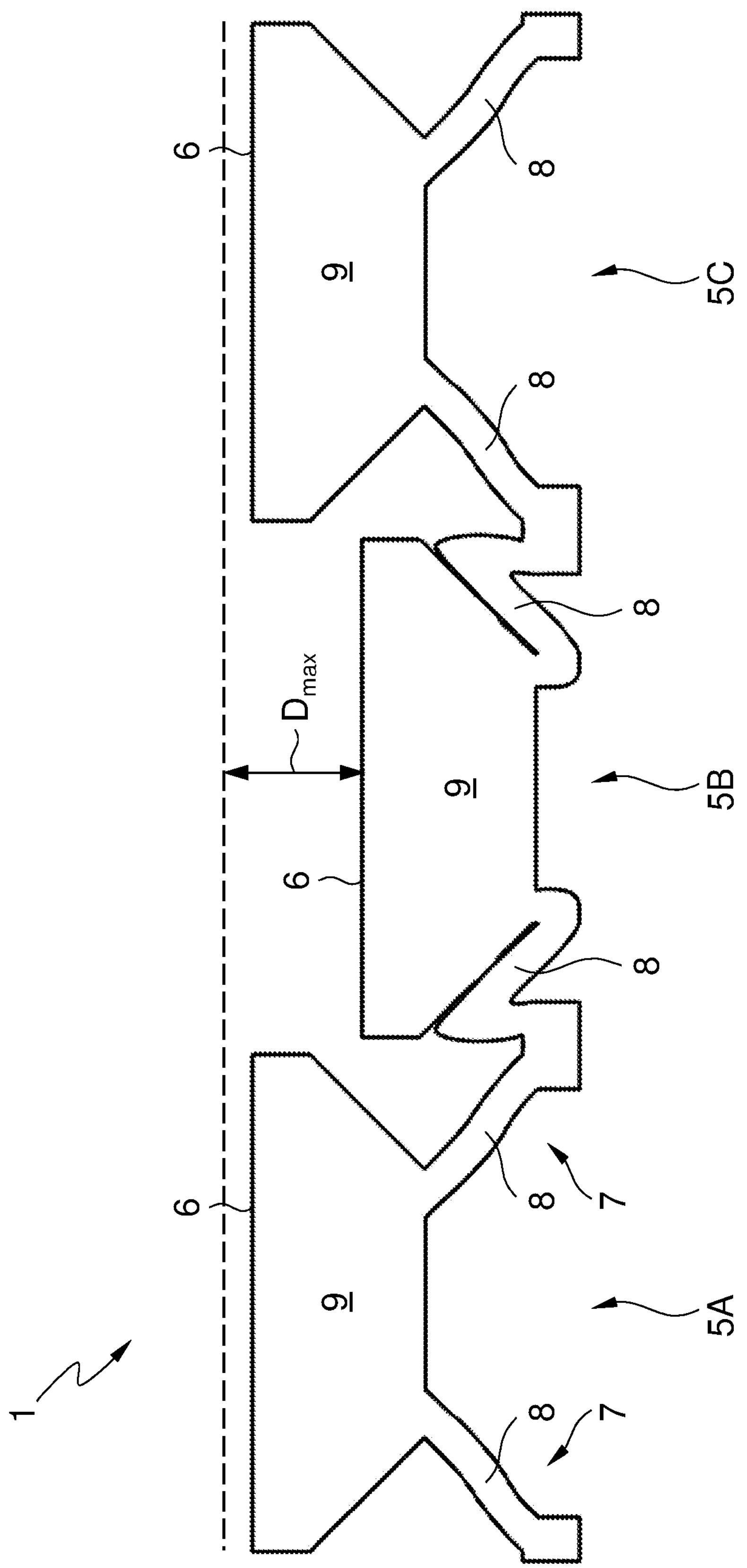

FIG. 4

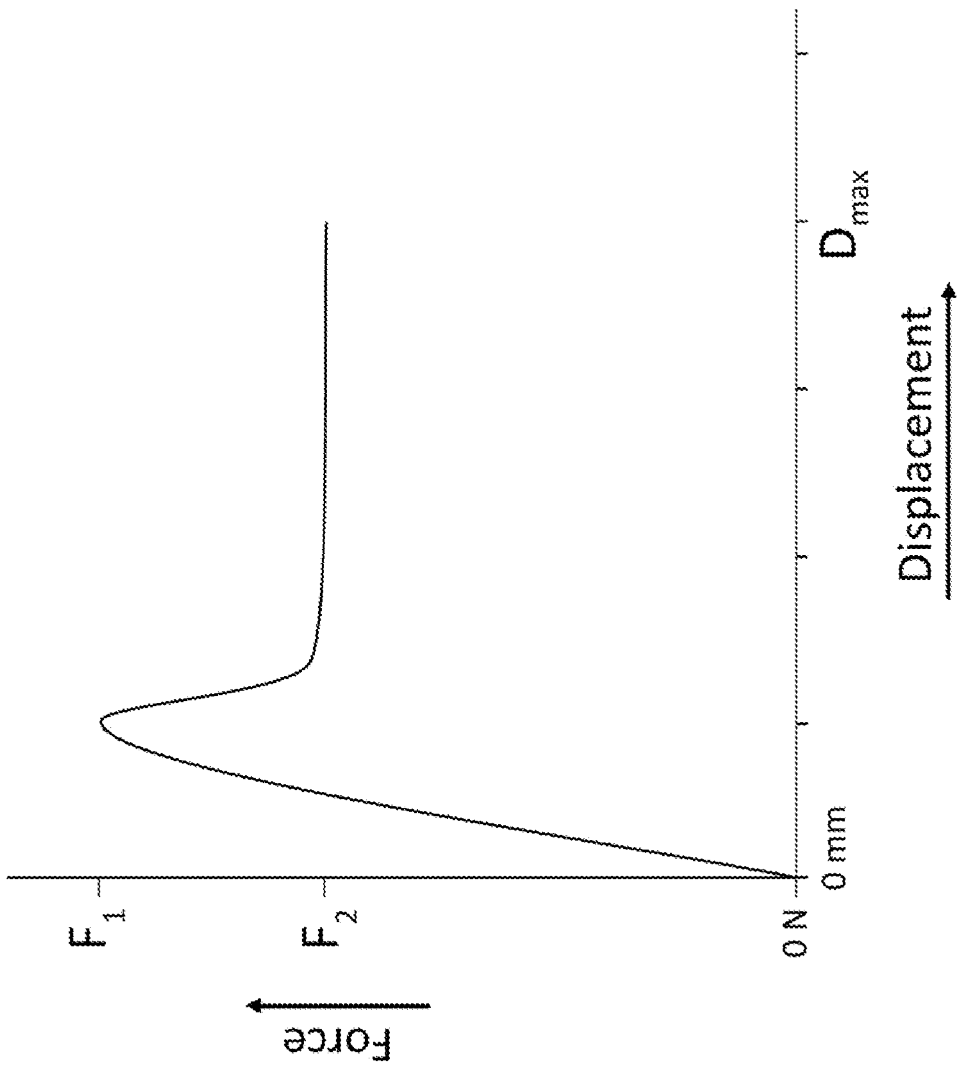

FIG. 5

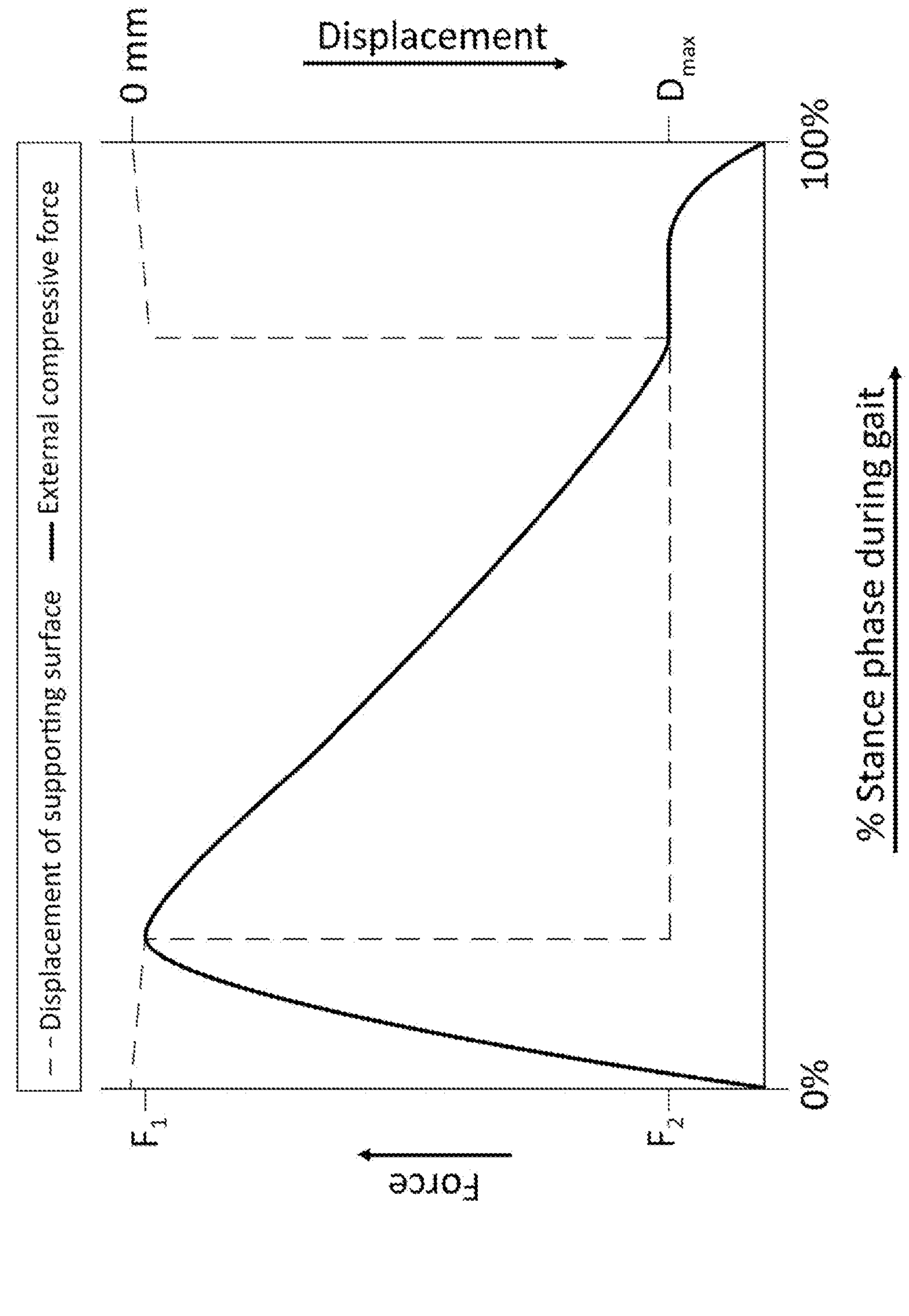
Displacement of supporting surface
External compressive force
Displacement
0 mm
D_{max}
Force
F_1
F_2
0%
100%
% Stance phase during gait

FIG. 6

REFERENCES CITED IN THE DESCRIPTION

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