



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
25.04.2018 Bulletin 2018/17

(51) Int Cl.:
A41D 13/00 (2006.01)

(21) Application number: **17275164.6**

(22) Date of filing: **17.10.2017**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
MA MD

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(30) Priority: **18.10.2016 GB 201617636**

(54) **LOW DRAG GARMENT**

(57) A low drag garment comprises a textured fabric in at least one side region of the garment, wherein the textured fabric has a substantially uniform texture height in the range 0.2-0.8mm.

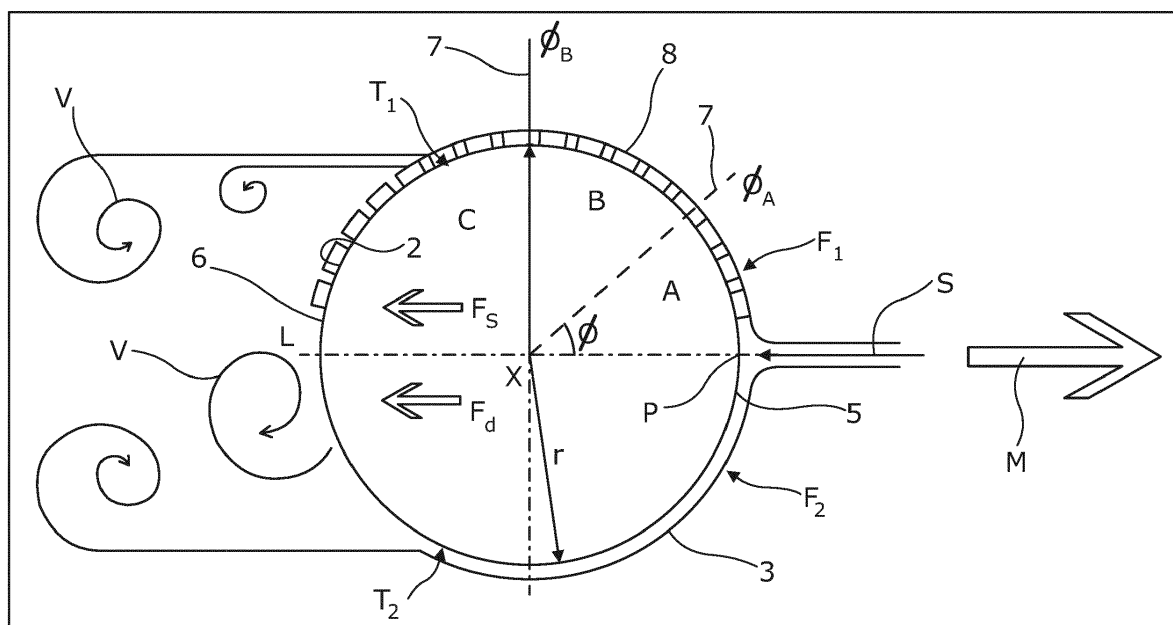


Fig. 1

Description

[0001] The present invention relates to a garment with low aerodynamic drag. In particular, but not exclusively, the invention relates to a garment comprising an article of sports clothing for use in sports where the athlete typically travels at a speed in the range 5-20m/s, for example cycling, sprint running, skiing and speed skating, where aerodynamic drag on an athlete can have a significant effect on the athlete's performance.

[0002] When airflow passes over a body there are two fundamental mechanisms that produce a drag force. These forces come from surface drag, caused by friction as the air passes over the surface, and pressure drag caused primarily by the separation of vortices from the boundary layer. The ratio of surface drag to pressure drag is highly dependent on the shape of the object. Where objects are specifically shaped for optimum aerodynamic efficiency, the aspect ratio (length: width) will generally be at least 3:1. With an increased length to width ratio it is possible to have a wing-like shape with a narrow trailing edge. The advantage of this is that the flow can remain attached to the surface of the object so that the streamlines follow the shape of the profile. Although the surface area of the object and the resulting surface friction are increased, the flow is able to "recover" beyond the widest point of the object, resulting in a small net pressure drag. Generally, the reduction in pressure drag far outweighs the increase in surface drag.

[0003] The human body tends to have a much lower aspect ratio, particularly when upright, which may typically be nearer to 1:1 for the arms and legs, and 1:2 for the torso. As a result, the human body approximates to a "bluff body", and pressure drag tends to be by far the larger contributory factor to the overall aerodynamic drag experienced by an athlete.

[0004] Where it is not practical to modify the shape of the body and the aspect ratio is lower than about 3:1 in the flow direction, a high level of pressure drag can be caused by flow separation soon after the flow has passed the widest point of the body. In such situations in engineering and nature, it is known to adjust the surface texture of the body to help delay the separation point and thereby reduce the net pressure force that retards motion of the object.

[0005] A number of techniques are known to reduce the net drag force on bluff bodies, including the use of trip edges and textured surfaces. Although these techniques may give rise to an increase in surface drag, it is generally possible to find a solution whereby the reduction in pressure drag outweighs the increase in surface drag. This allows the total drag to be reduced in various applications.

[0006] In the case of the human body, these techniques can be applied by designing a garment that provides the required trip edges and textured surfaces. However, current technologies have the following limitations:

- Trip edges can be very effective in ideal circumstances, but in practice they are extremely sensitive to position. If the trip edges are not placed precisely in the correct locations they can have a detrimental effect, increasing the overall drag. This means that trip edges, or multiple trip edges, are not appropriate for commercial clothing applications, where the exact shape of the body is unknown.
- Environmental conditions can affect the onset of turbulent flow within the system in which the subject is positioned, and are variable and unpredictable. For example, the flow direction experienced by a cyclist can vary by 10° or more from the direction of travel owing to crosswind effects. Experience has shown that it is not possible to have a trip edge that works effectively for all conditions.
- Textured surfaces work to an extent, but the types of textured surfaces available are limited and they are often designed for purposes that are not specific to delaying flow separation. The effectiveness of the textured surface also depends on the speed of the athlete through the air, and garments that work well at one speed might not be so effective at a different speed.
- Fabrics with different textures are sometimes used in sports clothing and in certain circumstances this can reduce drag. However, changes in fabric texture often require the presence of seams, which can have a detrimental effect on the overall drag. Also, fabrics tend to be provided with uniform repeating texture patterns, which are not optimised to control flow separation.

[0007] US 5887280 describes a garment that includes an array of vortex generators designed to reduce pressure drag ("form drag"). The vortex generators are arranged in rows transverse to the direction of air flow and are relatively large, for example having a height of 2.5mm or 6mm, leading to a significant increase in surface drag ("skin friction").

[0008] In European patent application EP16165668.1 (EP3085259) there is described a low drag garment that is made from a texture fabric, wherein the texture height increases substantially continuously from the front to the rear of the garment. Such a garment potentially provides a very low level of drag within a specific range of speeds. However, in practice providing a texture height that increases substantially continuously can be technically difficult and the resulting garment can therefore be very expensive.

[0009] In European patent application 16165662.4 (EP3085258) there is described a low drag garment having a plurality of textured zones, including a first zone with a mean texture height in the range 0-200µm, and a second zone with a mean texture height that is greater

than the mean texture height of the first zone and preferably in the range of 100-500 μ m. Such a garment is slightly simpler and cheaper to manufacture than the garment described in EP16165668.1, and provides a very low level of drag within a specific range of speeds, but it is still expensive compared to many "off the shelf" cycling garments. Also, we have found that the garment must be fitted very well (both in manufacturing and when putting the garment on) to ensure that the zones are located in the correct positions for optimum performance.

[0010] We have realised that a very low level of drag can also be achieved by providing a garment with a substantially uniform texture height that extends over at least part of the surface of the garment, providing that the texture height is optimised according to the expected speed range of an athlete during a specific event or competition.

[0011] The competition may for example be a cycle race. Within the world of sport cycling, competitors in different events or competitions may travel at very different speeds: for example, in track cycling competitors may travel at speeds of up to 20m/s. In road cycling instantaneous speeds may vary between about 6m/s (when hill climbing) and 20m/s or more (when descending or sprinting), while the average speed for a top cyclist on level ground may be about 12m/s. In other events such as road time trials and triathlon events, average speeds for top competitors may typically be in the range 10-15m/s. The recognition that different sports have different speed profiles opens up the possibility of designing garments that are optimised for particular sports, competitions or events.

[0012] In a sport such as road cycling, the speed range 5-20m/s is crucial as the aerodynamic drag is very significant and competitors tend to spend the majority of the race travelling at speeds in this range. Some garments designed for cycling have textures that produce low drag at the upper end of this range, but not at the lower end. Other cycling garments produce low drag at the lower end of the speed range but not at the upper end. Ideally, a garment designed for use while road cycling should produce low drag across the whole of the 5-20 m/s speed range.

[0013] The speed range 5-20m/s is also crucial as well as a number of other sports, for example running (typical speed 5-10m/s), speed skating (up to 15m/s), horse riding (up to 15m/s) and downhill skiing (average speed about 15-20m/s).

[0014] It is an objective of the present invention to provide a garment with low aerodynamic drag, which mitigates one or more of the problems set out above. Particular preferred objectives of the invention are to provide a garment that reduces aerodynamic drag on the body of an athlete, by providing surface textures that minimise pressure drag in the speed range 5-20 m/s, where laminar flow is still significant (as opposed to higher speed applications such as aerospace and automotive applications where the laminar flow region is negligible and turbulent flow dominates), and preferably without signifi-

cantly increasing friction drag. In particular, it is an objective of the invention to provide low drag garments for use in applications where the input power is limited, for example athletic sports, in which drag reduction can significantly improve performance.

[0015] According to one aspect of the present invention there is provided a low drag garment comprising a textured fabric in at least one side region of the garment, wherein the textured fabric has a texture pattern with a substantially uniform texture height in the range 0.2-0.8mm.

[0016] The terms "side region", "front region" and "rear region" as used herein are defined in relation to the direction of movement of an athlete wearing the garment while taking part in a particular sport, and are therefore related to the direction of airflow over the garment during normal use. The term "front region" relates to the part or parts of the garment that face forward in the direction of movement during use: i.e. into the airflow, and the term "rear region" relates to the part or parts of the garment that face backward opposite to the direction of movement: i.e. away from the airflow. The term "side region" relates generally to those parts of the garment that connect the front and rear regions of the garment and face substantially perpendicular to the direction of movement and the direction of airflow. It should be noted that in a sport such as rowing where the athlete normally faces backwards, the front region of the garment will be positioned on the athlete's back and the rear region on their front.

[0017] Preferably, the textured fabric has a texture pattern with a substantially uniform texture height in the range 0.3-0.7mm, more preferably 0.4-0.6mm.

[0018] The textured surface of the fabric is designed to minimise pressure drag while not significantly increasing surface drag, thereby increasing the athletic performance of the person wearing the garment. The textured fabric is provided in at least one side region of the garment, where the flow is essentially laminar and the boundary layer is growing. The textured fabric helps to turbulate the flow of air over the surface, thereby delaying flow separation at the transition point. We have also found that a garment with a substantially uniform texture height is less sensitive to position on the body, so that the fit of the garment is slightly less critical.

[0019] In an embodiment, the garment includes a body portion and the textured fabric is provided in at least one side region of the body portion, and wherein the textured fabric in the side region of the body portion has a texture pattern with a substantially uniform texture height in the range 0.2-0.4mm.

[0020] In an embodiment, the garment includes a sleeve portion and the textured fabric is provided in at least one side region of the sleeve portion, and wherein the textured fabric in the side region of the sleeve portion has a texture pattern with a substantially uniform texture height in the range 0.3-0.8mm, preferably 0.4-0.6mm.

[0021] In an embodiment, the garment includes a leg

portion and the textured fabric is provided in at least one side region of the leg portion, and wherein the textured fabric in the side region of the leg portion has a texture pattern with a substantially uniform texture height in the range 0.2-0.4mm.

[0022] In an embodiment, the garment includes a body portion and either or both of (a) a sleeve portion and (b) a leg portion, wherein the textured fabric provided in at least one side region of the body portion has a texture pattern with a substantially uniform texture height in the range 0.2-0.4mm, if the garment includes a sleeve portion the textured fabric provided in the side region of the sleeve portion has a texture pattern with a substantially uniform texture height in the range 0.3-0.8mm, and if the garment includes a leg portion the textured fabric provided in the side region of the leg portion has a texture pattern with a substantially uniform texture height in the range 0.2-0.4mm.

[0023] It is not generally necessary for the garment to be made entirely of the textured fabric. For example, in one or more inner front regions of the garment where the flow is essentially laminar the fabric may have a relatively smooth surface to minimise surface drag. In an embodiment, the low drag garment comprises a relatively smooth fabric in at least one front region of the garment, wherein the relatively smooth fabric has a texture height of less than 0.2mm, preferably less than 0.1mm.

[0024] In one or more rear regions of the garment where the flow separation has taken place, the fabric may have an increased texture height to further reduce pressure drag. In an embodiment the low drag garment comprises a textured fabric in at least one rear region of the garment, wherein the textured fabric in the rear region of the garment has a texture height of at least 0.4mm, preferably at least 0.5mm. Alternatively, in the rear region the textured region may have a reduced texture height. In some applications the flow of air in the third region may separate from the surface of the fabric and may become erratic: in this case the texture height in the third region may have relatively little impact on the overall aerodynamic performance of the garment.

[0025] In an embodiment, the side region comprises a region of the garment in which the surface angle has a minimum value θ_1 in the range 5° to 45° , preferably 10° to 25° , and a maximum value θ_2 in the range 95° - 160° , preferably 105° - 140° . Alternatively, where the garment is designed it fit a part of the body having a radius of curvature similar to that of a cylinder with a diameter in the range 80mm to 130mm, the width of the side region may lie in the range 30-170mm, preferably 50-140mm.

[0026] The term "surface angle" as used herein is defined as the angle subtended between the direction of forward movement in use, and a line that is perpendicular to the surface of the fabric. In the case of a garment worn by a person, the surface angle is the angle subtended between the direction of forward movement of the person and a line that is perpendicular to the surface of the fabric forming the garment when worn by the person in an

adopted body.

[0027] The term "adopted body shape" as used herein in the description and in the claims refers to the adopted shape either of the whole body or any part thereof (for example, the legs, arms or torso, or parts thereof such as the upper arm, lower arm and so on), when the individual person has adopted a preferred posture for participating in a selected activity (e.g. cycling, running, speed skating etc).

[0028] In an embodiment, the textured region has a texture pattern that comprises a plurality of isolated texture formations separated by regions with substantially no surface texture. In an embodiment the texture formations are arranged in rows that extend transverse to the direction of airflow over the texture pattern. The rows may have a mean spacing D in the direction of airflow in the range 1mm to 10mm, preferably 2mm to 8mm. The texture formations forming the rows may have a mean spacing G in a direction perpendicular to the direction of airflow in the range 1mm to 10mm, preferably 2mm to 8mm. We have found that isolated texture formations, which are separated from one another by areas of fabric with substantially no surface texture, provide reduced surface drag as compared to fabrics with continuous texture formations, as well as reduced pressure drag.

[0029] In an embodiment, the fabric has a texture pattern that is provided by jacquard knitting of the fabric, or by printing a 3D pattern on the outer surface of the fabric, or by the application of a solid material, for example silicone, to the outer surface of the fabric.

[0030] In an embodiment, the garment is an article of sports clothing. The garment may be an article of sports clothing for use in sports where the athlete typically moves with a speed in the range 5-20 m/s, and preferably 10-20m/s, including for example cycling, running, skiing, horse racing or speed skating.

[0031] Optionally, the garment is a shirt, trousers, leggings shorts, bibshorts, shoes, overshoes, arm covers, calf guards, gloves, socks or a bodysuit. Other articles of clothing are of course possible. Preferably the garment is close-fitting to the body so that it follows the contours of the body and does not flap significantly as the air flows over the surface of the garment.

[0032] Embodiments of the present invention will now be described by way of example with reference to the accompanying drawings, wherein:

Figure 1 illustrates schematically the flow of air around a cylindrical object;

Figure 2a illustrates graphically the results of a set of tests investigating the variation of drag coefficient (Cd) with air speed for various textured fabrics on an 80mm radius cylindrical body;

Figure 2b illustrates graphically the results of a set of tests investigating the variation of drag coefficient (Cd) with air speed for various textured fabrics on a

130mm radius cylindrical body;

Figure 3 is a plan view of an exemplary texture pattern according to an embodiment of the invention;

Figure 4 is a sectional view of the exemplary texture pattern on line A-A of figure 3;

Figure 5 is a sectional view of the exemplary texture pattern on line B-B of figure 3;

Figure 6 is a front view of a cyclist wearing a bodysuit for cycling; and

Figure 7 is a side view of the cyclist wearing the bodysuit shown in Figure 6.

[0033] For the majority of the applications in which use of the invention is envisaged, the Reynolds number will have a value of up to 10^6 , such that the flow of air will be in the laminar/turbulent transition zone. We have used wind tunnel testing to understand and derive optimum textures for use in the invention, and in particular on garments that are worn in applications where they are exposed to an airflow with a speed in the range 5-20m/s, preferably 10-20m/s.

[0034] In order to simplify experimentation, much of our research is based on optimising the drag around cylindrical objects with radii of 80mm and 130mm. This has enabled us to identify the surface requirements for a wide range of applications. Testing is conducted at a range of speeds and consideration is also given to wind direction. Within the sizes of cylinder used it is possible to approximate a range of curvatures that the airflow will encounter on a human body in a range of applications. For example, for an adult, the upper arm typically has an average radius (based on circumference) of about 50mm, the thigh typically has an average radius of about 80mm, and the chest typically has an average radius of about 160mm. It is of course recognised that the human body is not a perfect cylinder and in regions such as the chest it is closer to an elliptical shape. However, a cylinder provides a good first approximation to an irregular curved body in which the radius of curvature is similar to that of the cylinder.

[0035] Figure 1 illustrates a typical airflow around a cylindrical body 2, wherein the longitudinal axis X of the cylindrical body is perpendicular to the direction of airflow relative to the cylindrical body. It will be understood that the movement of a body through stationary air may be modelled in a wind tunnel by creating a moving airstream that flows over a stationary body, as depicted in the drawings. In this example the direction of airflow as indicated by arrow S is perpendicular to the surface of the cylindrical body at point P, which is called the "stagnation point". This is equivalent to forward relative movement of the body 2 through the air in the direction of arrow M.

[0036] On either side of the stagnation point P the air-

flow splits into two streams F1, F2 that pass around opposite sides of the cylindrical body 2. Up to approximately the widest point of the cylindrical body relative to the flow direction, the airflow is substantially laminar, allowing a boundary layer to build up against the surface of the cylindrical body 2.

[0037] After passing the widest point of the cylindrical body 2 relative to the direction of flow, the flow streams F1, F2 tend to separate from the surface of the cylindrical body forming vortices V in the region behind the cylindrical body. This creates a low pressure zone L behind the cylindrical body 2 and the resulting pressure difference between the front and the rear faces 5, 6 of the cylindrical body creates a pressure drag force F_d that opposes movement of the cylindrical body relative to the air. The movement of air over the surface of the cylindrical body also creates a surface friction force F_s , which is usually much smaller than the drag force F_d at relative speeds in the range 6-40m/sec.

[0038] The points where the boundary layer separates from the surface of the cylindrical body 2 are called the transition points T_1 , T_2 . The pressure drag force F_d experienced by the cylindrical body 2 depends in part on the area of the cylindrical body located within the low pressure zone L between the transition points T_1 , T_2 . If the transition points T_1 , T_2 can be moved rearwards, this will reduce the size of the area affected by the low pressure zone L, thereby reducing the pressure drag F_d acting on the cylindrical body 2.

[0039] It is known that the transition points T_1 , T_2 can be shifted rearwards by providing a suitable texture 8 on the surface of the cylindrical body 2. It should be understood that the texture pattern 8 shown on the upper part of the cylindrical body 2 may also be repeated on the lower side of the body. In the present invention we have sought to design a fabric with a substantially uniform surface texture, which maximises the reduction in pressure drag F_d without significantly increasing surface friction drag F_s .

[0040] As illustrated in Figure 1 we have discovered that the pressure drag force F_d can be reduced substantially, without significantly increasing the surface friction drag force F_s by covering the cylindrical body 2 with a fabric 3 having a texture pattern 8 comprising a plurality of texture formations 8a on at least the side regions of its outer surface, between the front face 5 and the rear face 6 of the cylindrical body 2. The size of the side region can be expressed in terms of the surface angle θ , which is the angle subtended between the direction of forward movement M and a line 7 that is perpendicular to the surface of the cylindrical body.

[0041] Our research has identified the optimum height and spacing of the surface texture formations for a range of curvatures, speeds, and onset flow angles. This has allowed us to derive a simple texture pattern that can be utilised to give an optimum level of airflow perturbation without being sensitive to flow direction changes, whilst minimising the surface friction drag through effective

spacing of the texture formations 8a that form the three-dimensional texture pattern 8.

[0042] Much research has been done into the change in the drag on a cylindrical body through a range of speeds. It is well known that the drag coefficient falls and then increases again as the speed of the airflow increases for a given cylinder size. This is due to vortex formation and periodic shedding, which affects the laminar transition points behind the cylindrical body.

[0043] Our research has enabled us to modify this flow behaviour through the use of variable surface textures and thus minimise the pressure drag for the speed range in question (5-20m/s). We have conducted a series of wind tunnel tests to determine how different textured fabrics affect the drag coefficient for 80mm and 130mm radius cylinders at air speeds ranging from 3m/s to 25m/s. The results are illustrated in Figs. 2a and 2b.

[0044] In Fig. 2a the wind tunnel test results are illustrated for a plain 80mm radius cylinder and for six different fabrics on an 80mm radius cylinder, the fabrics being as follows:

- Sample A - a prior art textured fabric that performs best at high speeds;
- Sample B - a prior art textured fabric that performs best at low speeds;
- Sample C - a new fabric comprising an embodiment of the invention, having a silicone chevron texture pattern with a spacing of 7mm and a constant texture height of 0.4mm;
- Sample D - a new fabric comprising an embodiment of the invention, having a silicone chevron texture pattern with a spacing of 7mm and a constant texture height of 0.5mm;
- Sample E - a new fabric comprising an embodiment of the invention, having a silicone chevron texture pattern with a spacing of 7mm and a constant texture height of 0.6mm;
- Sample F - a new fabric of the type described in EP16165668.1, which does not comprise an embodiment of the invention, having a silicone chevron texture pattern with a spacing of 7mm and a texture height that increases gradually from 0.5mm to 5.0mm (the portion with the smallest texture height being positioned on the front part of the cylinder).

[0045] The fabrics were all wrapped around the circumference of the cylinder for the test.

[0046] As can be seen in Fig. 2a, the prior art Sample A fabric performed well at speeds above 17m/s, having a drag coefficient Cd of less than 0.72 at air speeds between 17m/s and 23m/s, but less well at lower speeds, the drag coefficient rising rapidly at air speeds of less than 17m/s to a value in excess of 1.00 at air speeds less than 14m/s.

[0047] The Sample B fabric performed well at low speeds, having a drag coefficient Cd of less than 0.80 at air speeds between 6m/s and 8m/s, but less well at higher

speeds, the drag coefficient exceeding 1.00 at air speeds of more than 16m/s.

[0048] The new Sample F fabric with a gradually varying texture height performed well across a wide range of speeds, having a drag coefficient Cd of less than 1.00 at speeds above 8m/s and a drag coefficient Cd of less than 0.80 at speeds between 10m/s and 25m/s.

[0049] The new Sample C, Sample D and Sample E fabrics were all comparable with the Sample F fabric and performed well across a wide range of speeds, particularly in the crucial 5-20m/s speed range. All three had a drag coefficient Cd of less than 1.00 at speeds above 8.5m/s and a drag coefficient Cd of less than 0.82 at speeds between 10m/s and 25m/s, the Sample E fabric performing slightly better than the Sample c and Sample D fabrics at speeds below 9m/s, and not quite so well at speeds above 11m/s.

[0050] Therefore, neither of the prior art Sample A and Sample B fabrics provided a low drag coefficient across the entire 5 m/s to 20 m/s speed range, the Sample A fabric providing low drag only at high speeds between 16m/s and 25m/s, and the Sample B fabric providing low drag only at relatively slow speeds between 6 m/s and 10 m/s.

[0051] By comparison the three new constant height fabrics (Samples C, D and E) provided a much wider range of low drag performance, all providing a drag coefficient of less than 1.00 at air speeds above 9m/s, and less than 0.82 at air speeds between 11m/s and 25m/s.

[0052] In Fig. 2b the wind tunnel test results are illustrated for a plain 130mm radius cylinder and for four different fabrics on a 130mm radius cylinder, the fabrics being as follows:

- Sample A - a prior art textured fabric that performs best at high speeds;
- Sample B - a prior art textured fabric that performs best at low speeds;
- Sample C - a new fabric comprising an embodiment of the invention, having a silicone chevron texture pattern with a spacing of 7mm and a constant texture height of 0.4mm;
- Sample D - a new fabric of the type described in EP16165668.1, which does not comprise an embodiment of the invention, having a silicone chevron texture pattern with a spacing of 7mm and a texture height that increases gradually from 0.5mm to 5.0mm (the portion with the smallest texture height being positioned on the front part of the cylinder).

[0053] The fabrics were each wrapped around the circumference of the 130mm radius cylinder for the test.

[0054] As can be seen in Fig. 2b, the prior art Sample A fabric again performed well at high speeds, having a drag coefficient of less than 0.60 at air speeds between about 14m/s and 20m/s, but less well at lower speeds, the drag coefficient rising rapidly to a value in excess of 1.00 at air speeds less than about 12m/s.

[0055] The Sample B fabric performed well at low speeds, having a drag coefficient of less than 0.80 at an air speed of about 5m/s, but less well at higher speeds, the drag coefficient exceeding 0.88 at air speeds of more than 10m/s.

[0056] The Sample D fabric with a gradually varying texture height performed well across a wide range of speeds, having a drag coefficient of less than 1.00 at speeds above 6m/s and a drag coefficient of less than 0.80 at speeds between 8m/s and 25m/s.

[0057] However, the Sample C fabric performed even better than the Sample D fabric across the entire 5-20m/s speed range, having a drag coefficient of less than 1.00 at speeds above 5.5m/s and a drag coefficient of less than 0.80 at speeds between 7m/s and 25m/s.

[0058] As a result of these and other tests we have identified the following advantageous characteristics in relation to a low drag garment that is designed to provide a low drag coefficient across a range of relative speeds including in particular the range 5-20 m/s:

- the garment comprises a textured fabric in at least a side region of the garment, wherein the textured fabric has a texture pattern with a substantially uniform texture height in the range 0.2-0.8mm, preferably 0.3-0.7mm, more preferably 0.4-0.6mm.
- the garment includes a body portion, and the textured fabric is provided in at least one side region of the body portion, wherein the textured fabric in the side region of the body portion has a texture pattern with a substantially uniform texture height in the range 0.2-0.4mm.
- the garment includes a sleeve portion and the textured fabric is provided in at least one side region of the sleeve portion, wherein the textured fabric in the side region of the sleeve portion has a texture pattern with a substantially uniform texture height in the range 0.3-0.8mm, preferably 0.4-0.6mm.
- the garment includes a leg portion and the textured fabric is provided in at least one side region of the leg portion, and wherein the textured fabric in the side region of the leg portion has a texture pattern with a substantially uniform texture height in the range 0.2-0.4mm.
- the garment additionally comprises a relatively smooth fabric in at least one front region of the garment, wherein the relatively smooth fabric has a texture height of less than 0.2mm, preferably less than 0.1mm.
- the garment additionally comprises a textured fabric in at least one rear region of the garment, wherein the textured fabric in the rear region of the garment has a texture height of at least 0.4mm, preferably at least 0.5mm.
- the side region of the garment comprises a region of the garment in which the surface angle has a minimum value θ_1 in the range 5° to 45° , preferably 10° to 25° , and a maximum value θ_2 in the range 95° -

160° , preferably 105° - 140° .

- the texture pattern 8 comprises a plurality of isolated texture formations 8a separated by regions with substantially no surface texture.
- the texture formations 8a are arranged in rows 10 that extend transverse to the direction of air flow, preferably with a mean spacing between the rows in the range 1mm to 10mm, more preferably 2mm to 8mm.

[0059] The garment may include any one or a combination of the preferred characteristics set out above.

[0060] We have found that in certain embodiments the textured fabric 3 covering the surface of a cylindrical body 2 can be divided into a number of zones including a front zone A, a side zone B and a rear zone C, which are defined in relation to the direction of forward movement M, as shown in Figure 1. The first zone A is located generally in an inner front region of the cylindrical body 2, the side zone B is located generally in an outer region of the cylindrical body 2, and the rear zone C is located generally in a rear region of the cylindrical body 2.

[0061] In the front zone A the fabric may be relatively smooth, having a texture height H_A of less 0.2mm, to minimise friction drag.

[0062] In the side zone B the texture pattern preferably has a height H_B in the range 0.2-0.8mm, more preferably 0.2-0.4mm in a body portion of the garment, 0.4-0.8mm in a sleeve portion and 0.2-0.4mm in a leg portion.

[0063] In the rear zone C the texture pattern preferably has a height H_C that is at least as great as that in the side zone B, and may be greater to further reduce pressure drag.

[0064] The side zone B may be defined as comprising the region of the textured fabric in which the surface angle θ has a minimum value θ_1 in the range 5° to 45° , preferably 10° to 25° , and a maximum value θ_2 in the range 95° - 160° , preferably 105° - 140° . The front zone A and the rear zone C comprise the remaining portions of the textured fabric.

[0065] The texture pattern 8 can take various different forms, an example being illustrated in Figures 3-5. The texture pattern illustrated in Figures 3-5 comprises a staggered array of chevron-shaped texture formations 8a, which are arranged in transverse rows 10 with a mean separation D between the rows in the direction of air flow typically in the range 1mm to 10mm, preferably 2mm to 8mm. The mean separation G between the texture formations 8a that form each row 10 in a direction perpendicular to the direction of air flow is typically in the range 1mm to 6mm, preferably 2mm to 4mm. The height of the texture pattern corresponds to the height H of the formations 8a. The chevron-shaped texture formations 8a are preferably arranged to point in the expected direction of airflow over the surface.

[0066] In this embodiment the texture pattern 8 comprises a plurality of isolated texture formations 8a, which are separated by regions with substantially no surface

texture. We have found that isolated texture formations, separated by areas of fabric with substantially no surface texture, provide reduced surface drag as compared to fabrics with continuous texture formations, as well as reduced pressure drag.

[0067] It should be noted that the exemplary texture pattern illustrated in Figures 3-5 is only one example of the many different patterns that may be used.

[0068] In the case of a garment made from a textured fabric, the texture pattern 8 may for example be provided by using a jacquard knitted fabric. Alternatively, the texture pattern can be printed onto the fabric or it can be created by applying a suitable solid material, for example silicone, to the surface of the fabric. The silicone may for example be applied to the surface of the fabric using a 3D printer.

[0069] The garment is preferably an article of sports clothing, which may be used for any sport where the reduction of drag is important. This applies particularly to sports where the input power is limited (for example being supplied by the athlete or the force of gravity) and where the athlete travels at a speed typically in the range 5-20m/sec, for example cycling, running, speed skating or skiing. The article of clothing may for example consist of a shirt, trousers, leggings, shorts, bibshorts, shoes, overshoes, arm covers, calf guards, gloves, socks or a one-piece bodysuit. The article of clothing may also be an item of headwear, for example a hat or helmet, or a fabric covering for a helmet.

[0070] An example of a garment intended for use while cycling is illustrated in Figures 6 and 7. The garment in this case is a one-piece bodysuit 11 comprising a body portion 12 that covers the athlete's trunk, with short sleeves 14 and legs 16 that cover the upper portions of the athlete's arms and legs. The garment has a plurality of zones that are defined in relation to the direction of forward travel M of the athlete, and which take account of the athlete's posture. The zones include a first zone A located generally in an inner front region of the garment, a second zone B located in a side region of the garment and a third zone C that is located in a rear region of the garment. The outer surface of the garment has a texture that varies across the three zones, the fabric being essentially smooth in the first zone A (e.g. having a height less than 0.2mm), have a height of 0.2-0.8mm in the second zone B, and a height in third zone C that is either equal to or greater than that in the side region B.

[0071] In this example, the first zone A is located primarily on the chest and shoulder regions of the trunk 12 and on the forward facing portions of the sleeves 14 and the legs 16. The second zone B is located primarily on the side and back regions of the body 12 and on the side regions of the sleeves 14 and the legs 16. The third zone C is located primarily on the lower back portion of the body 12 and the rear portions of the sleeves 14 and the legs 16. This arrangement of texture patterns has been found to be particularly advantageous for cyclists adopting the classic crouched posture illustrated in Figure 6 &

7. It will be appreciated that in other sports where the athletes adopt different postures, the arrangement of the texture patterns will be adapted as required to provide a low level of pressure drag.

Claims

1. A low drag garment comprising a textured fabric in at least one side region of the garment, wherein the textured fabric has a texture pattern with a substantially uniform texture height in the range 0.2-0.8mm.
2. A low drag garment according to claim 1, wherein the textured fabric has a texture pattern with a substantially uniform texture height in the range 0.3-0.7mm, preferably 0.4-0.6mm.
3. A low drag garment according to claim 1 or claim 2, wherein the garment includes a body portion and the textured fabric is provided in at least one side region of the body portion, and wherein the textured fabric in the side region of the body portion has a texture pattern with a substantially uniform texture height in the range 0.2-0.4mm.
4. A low drag garment according to claim 3, wherein the garment includes a sleeve portion and the textured fabric is provided in at least one side region of the sleeve portion, and wherein the textured fabric in the side region of the sleeve portion has a texture pattern with a substantially uniform texture height in the range 0.3-0.8mm, preferably 0.4-0.6mm.
5. A low drag garment according to claim 3 or claim 4, wherein the garment includes a leg portion and the textured fabric is provided in at least one side region of the leg portion, and wherein the textured fabric in the side region of the leg portion has a texture pattern with a substantially uniform texture height in the range 0.2-0.4mm.
6. A low drag garment according to any one of the preceding claims, comprising a relatively smooth fabric in at least one front region of the garment, wherein the relatively smooth fabric has a texture height of less than 0.2mm, preferably less than 0.1mm.
7. A low drag garment according to any one of the preceding claims, comprising a textured fabric in at least one rear region of the garment, wherein the textured fabric in the rear region of the garment has a texture height of at least 0.4mm, preferably at least 0.5mm.
8. A low drag garment according to any one of the preceding claims, wherein the side region of the garment comprises a region of the garment in which the surface angle has a minimum value θ_1 in the range

5° to 45°, preferably 10° to 25°, and a maximum value θ_2 in the range 95°-160°, preferably 105°-140°.

9. A low drag garment according to any one of the preceding claims, wherein the side region of the garment comprises a region of the garment having a width in the range 30-170mm, preferably 50-140mm. 5
10. A low drag garment according to any one of the preceding claims, wherein the textured region has a texture pattern that comprises a plurality of isolated texture formations separated by regions with substantially no surface texture. 10
11. A low drag garment according to claim 10, wherein the texture formations are arranged in rows that extend transverse to the direction of airflow, wherein the rows have a mean spacing D in a direction of airflow in the range 1mm to 10mm, preferably 2mm to 8mm. 15
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12. A low drag garment according to claim 11, wherein the texture formations forming the rows have a mean spacing G in a direction perpendicular to a direction of airflow in the range 1mm to 10mm, preferably 2mm to 8mm. 25
13. A low drag garment according to any one of the preceding claims, wherein the fabric has a texture pattern that is provided by jacquard knitting of the fabric, or by printing a 3D pattern on the outer surface of the fabric, or by the application of a solid material, for example silicone, to the outer surface of the fabric. 30
14. A low drag garment according to any one of the preceding claims, wherein the garment is an article of sports clothing, and optionally wherein the garment is a shirt, trousers, leggings, shorts, bibshorts, shoes, overshoes, arm covers, calf guards, gloves, socks or a bodysuit. 35
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15. A low drag garment according to claim 14, wherein the garment is an article of sports clothing for use in cycling, running, skiing, horse racing or speed skating, or a sport where an athlete typically travels at a speed in the range 5-20m/s, preferably 10-20m/s. 45

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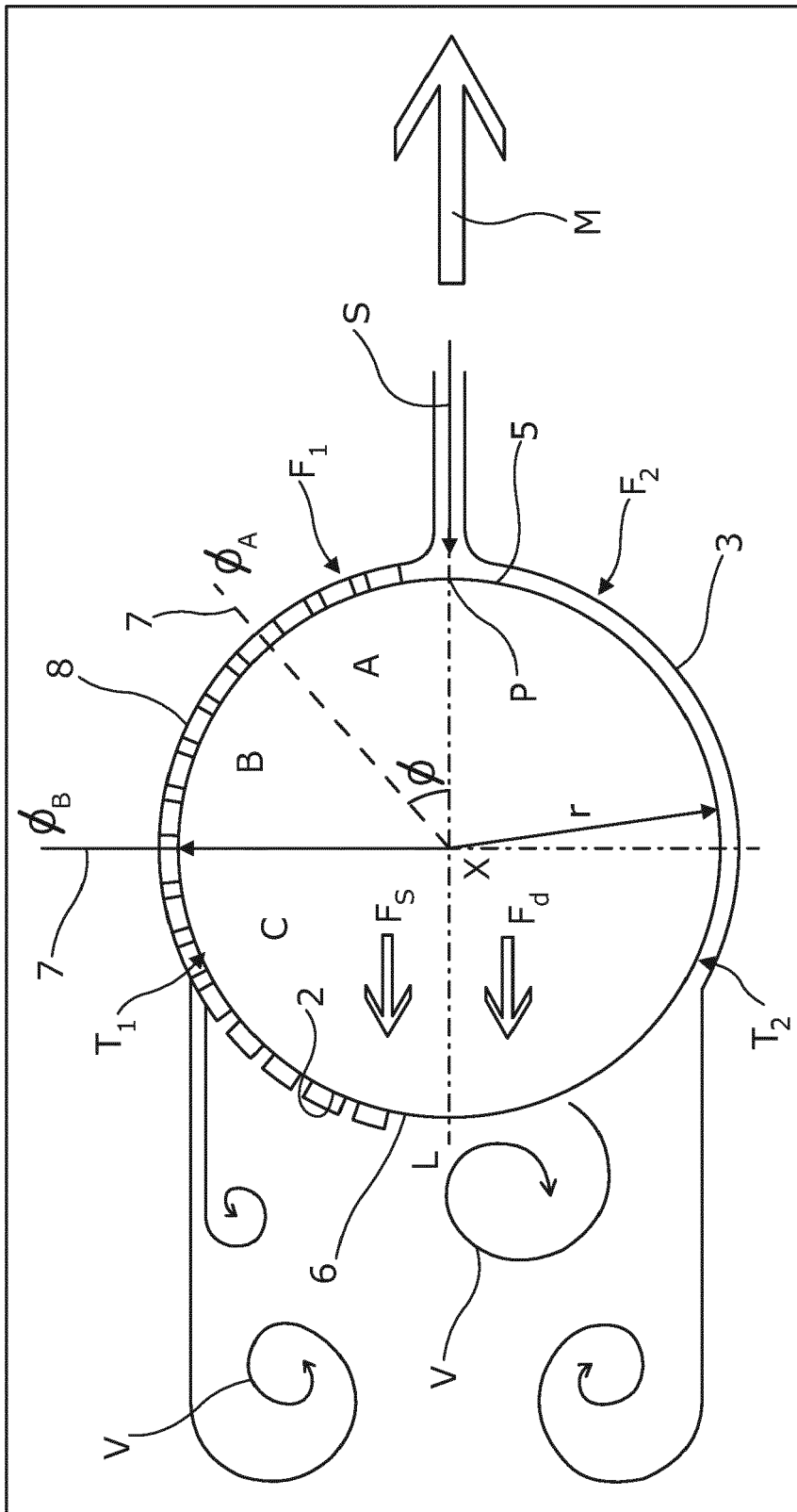


Fig. 1

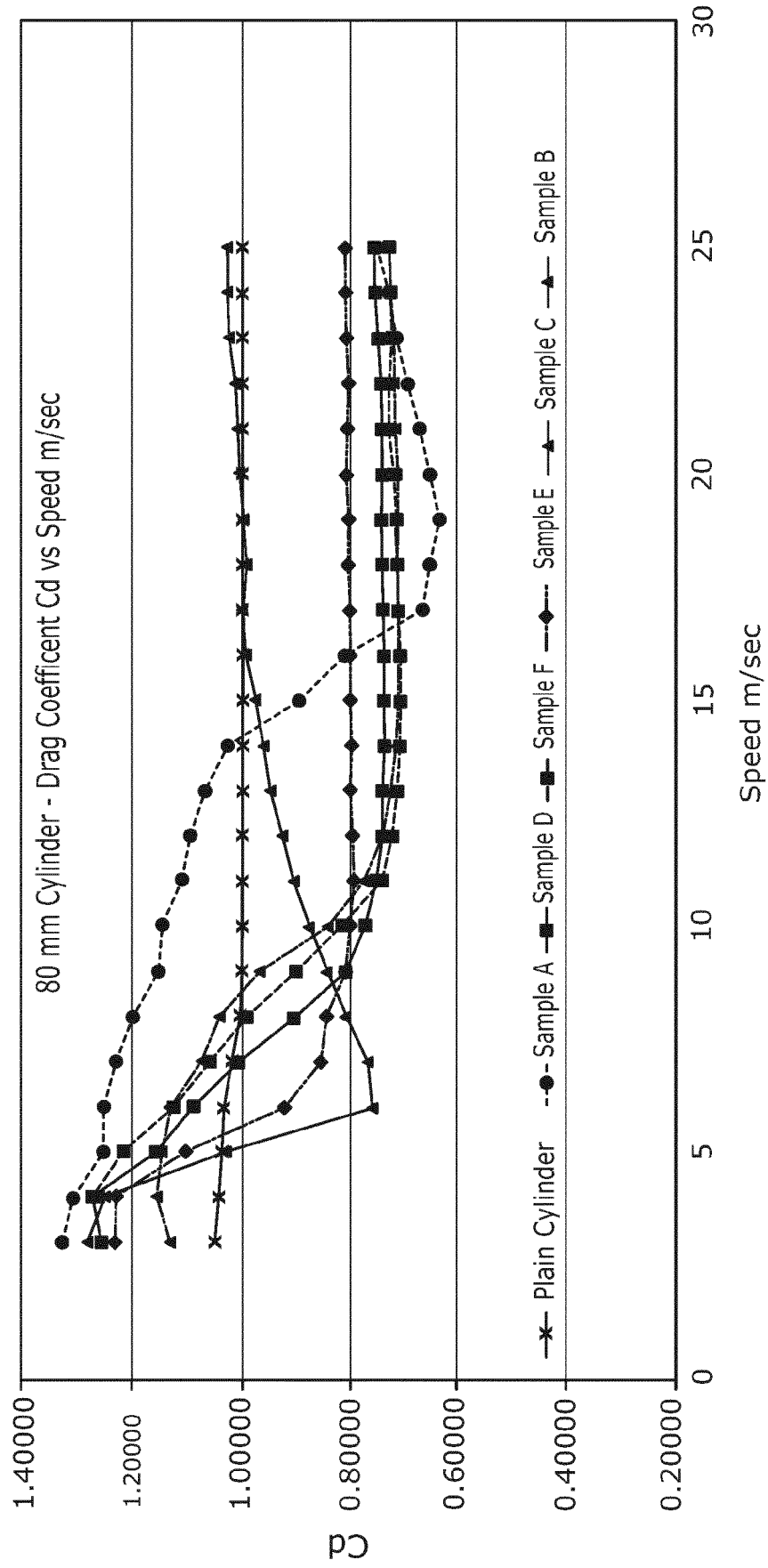


Fig. 2a

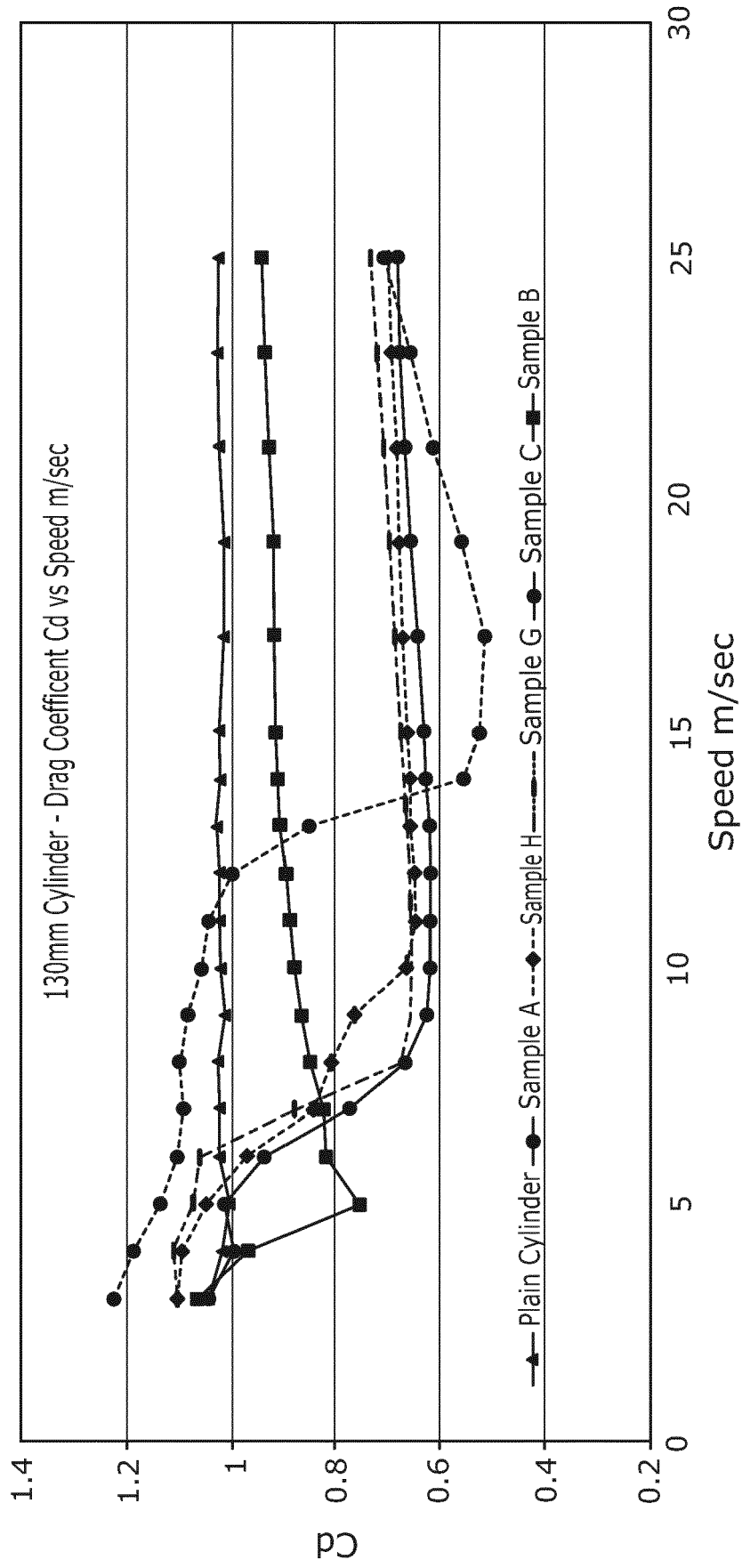


Fig. 2b

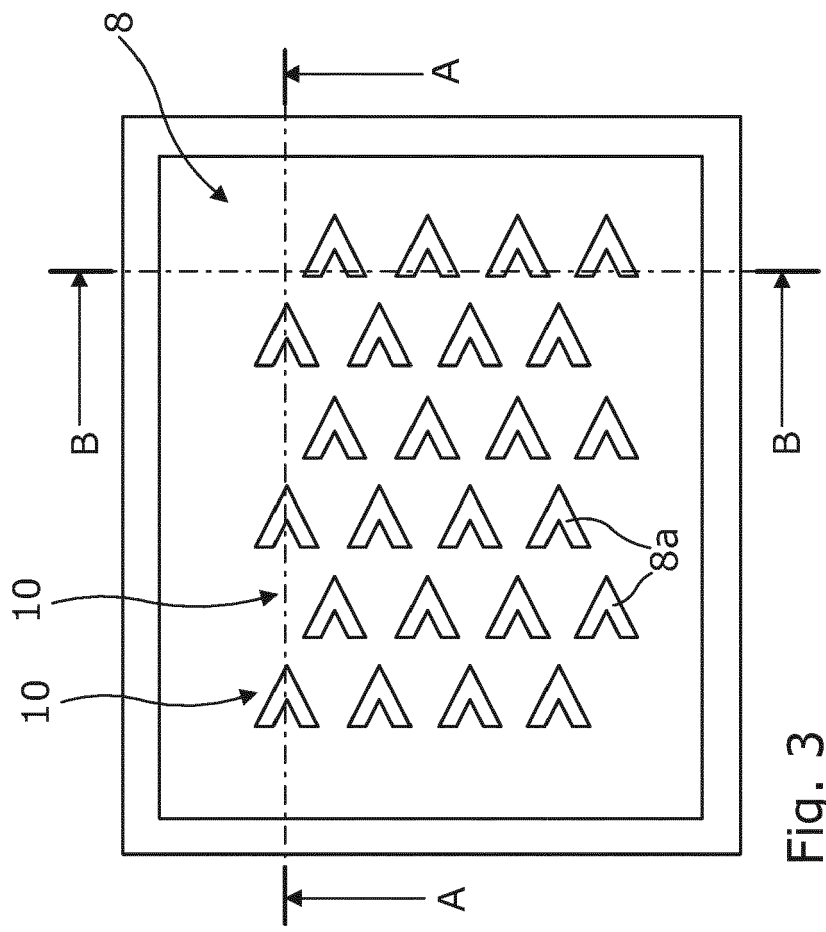


Fig. 3

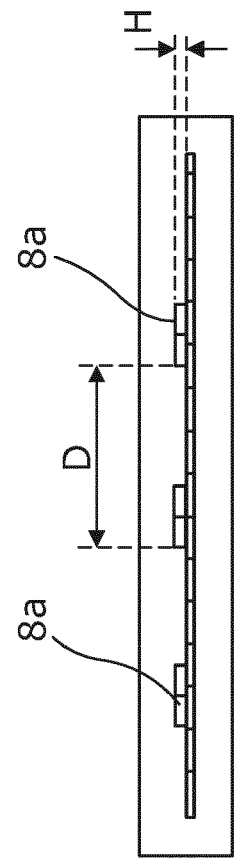
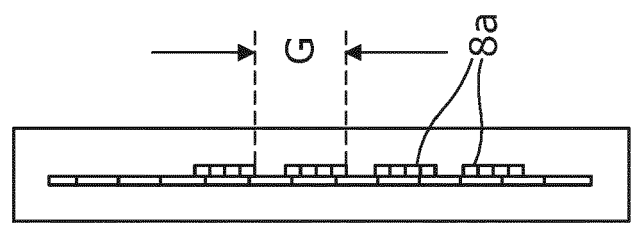


Fig. 4 SECTION A-A



SECTION B-B
Fig. 5

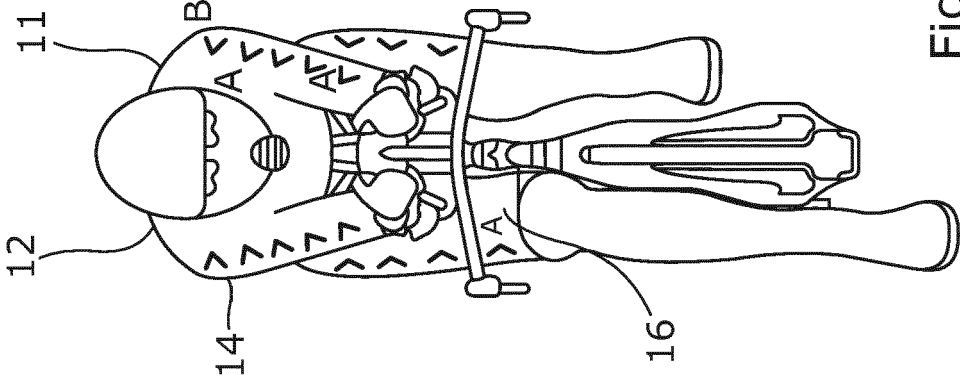


Fig. 6

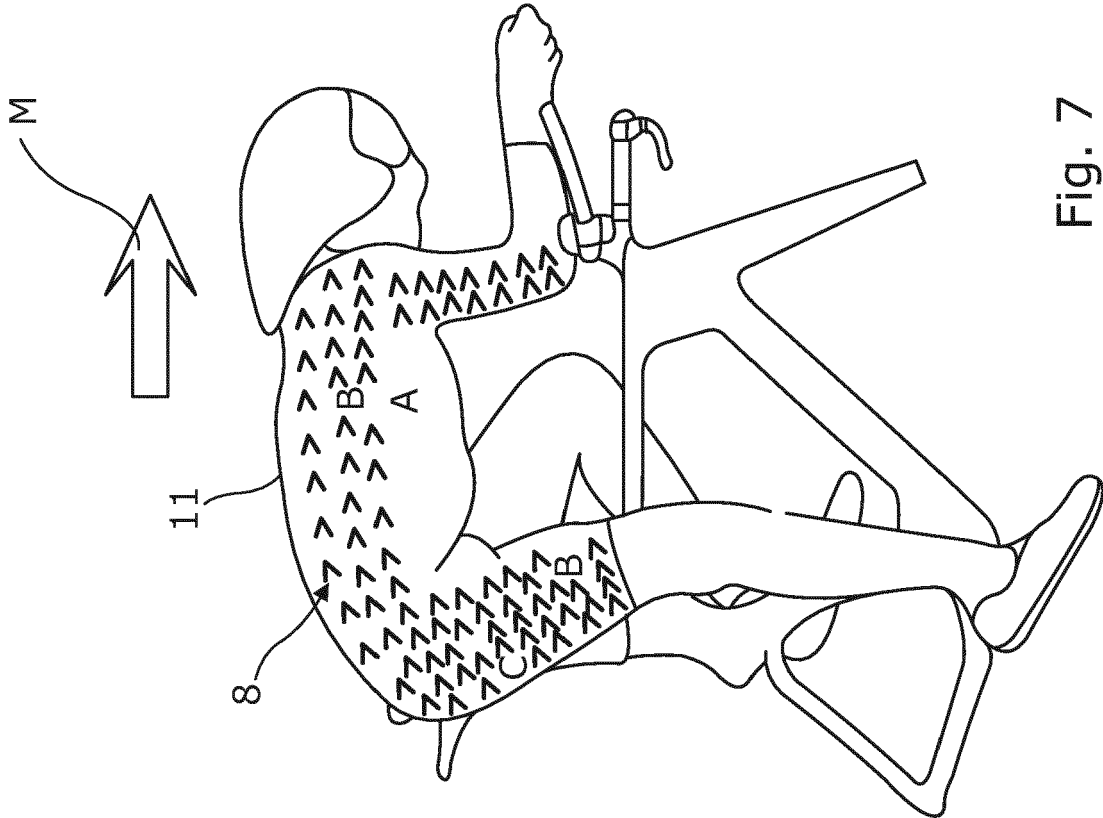


Fig. 7



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Application Number
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The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 26 January 2018	Examiner van Voorst, Frank
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