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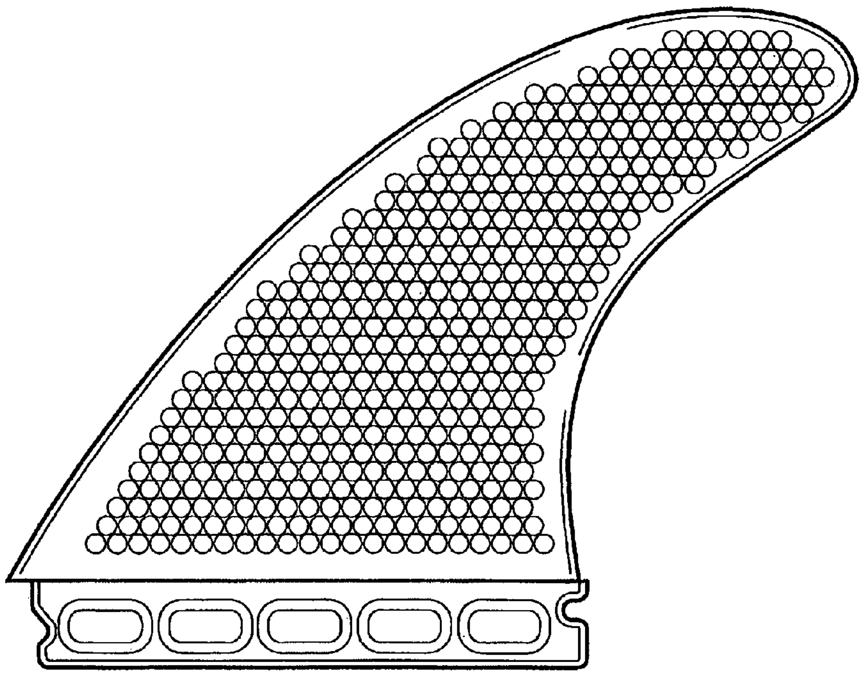

Fig 5

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(57) Abstract: In one aspect the present invention provides a watercraft fin including a first side surface and a second side surface wherein at least one of the first side surface or the second side surface includes a plurality of dimples.

WATERCRAFT FIN

FIELD OF THE INVENTION

The present invention relates to a fin for a watercraft and in particular a fin for a surfboard.

BACKGROUND TO THE INVENTION

A key part of a watercraft, and in particular a surfboard, is the fin or fins. The fin can act as a stabilizer which allows the user or rider greater control and enjoyment over the board or watercraft. Modern surfboards most commonly use the 3 and 4 fin arrangement. These 3 and 4 Fin designs known as the “Thruster” and “Quads” are able to maintain hold to the wave face and create propulsion. The propulsion is generated from the outward forces created by the side fins during turning.

The Side fins (left and right) work on similar principles to an aircraft wing. Fluid as it travels over the fin, moves faster over the curved foil face than it does on the flat inside foil face of the fin. This results in a high pressure on the flat side and a low pressure on the curved side. The high pressure is pushing the foil upwards. This creates lift for an airplane wing, or in the case of a surfboard fin the high pressure is pushing the foil/fin, outwards. The lift created outwards on the fin is the sensation surfer’s 'feel' when turning known as ‘drive’. The feel is based on the amount of control, speed and manoeuvrability a fin can produce. Drive is activated as the surfboard is turning and the angle of attack(flow) across the fin is such that it creates lift. If this outward force (lift) can be increased then this increases the amount of drive a fin has.

This increased lift has been, and remains a significant goal for fin designers whilst trying to minimize drag. An increase in speed while not sacrificing the control and manoeuvrability is desired. As an example, for surfboards, if the rider is lighter a smaller fin can be used as less lift is required for smaller surfers. Smaller fins provide less lift due to the reduction in surface area of the foil but also less drag. The shape of the foil can also be designed to trade off between lift and drag.

Over the years various attempts have been made to improve the designs of fins. Generally speaking these attempts have failed and only served to reinforce conventional design criteria which have largely been unchanged from original designs. Such failures have also led the industry to be extremely critical of any attempts to change the standard design.

While the design of the fin has been important, the actual construction of the fin is also critical. For example, it is understood that to minimize drag it is important to ensure that the surface of the fin is as smooth as possible so as to reduce the friction between the fin and water. It has been understood that friction needs to be reduced as much as possible to ensure that the fin is able to smoothly glide through the water.

Despite these efforts drag remains a problem for fin design, and hence the present invention in part seeks to reduce the drag caused by a fin.

SUMMARY OF THE INVENTION

In a broad form, there is provided a fin for a surfboard or other watercraft, wherein the surface of the fin includes a plurality of dimples which improve the performance of the fin. A dimple is like a small depression or indentation on the surface. In one aspect the present invention provides a watercraft fin including a first side surface and a second side surface wherein at least one of the first side surface or the second side surface includes a plurality of dimples. Reference to the two sides will be understood as referring to the two main faces of a fin. In conventional fins, for a side fin one side would be substantially flat and the other side would be curved. These sides can be compared to the top and bottom of an aircraft wing.

In the preferred arrangement the dimples will be substantially circular and have a diameter of between 2 mm and 4.5 mm, and a depth between 0.1 mm and 0.5 mm. Ideally the diameter will be between 3.8 mm and 4.3 mm, and the depth between 0.2 mm and 0.5 mm.

The spacing of the dimples is also important to the invention. It is expected that the midpoints between adjacent dimples will be between 3.7 mm and 4.5 mm apart, wherein the midpoint is considered the centre of the dimple and adjacent dimples refers to two dimples that are located proximate to each other and without any other dimples being located in between.

Ideally there will be some spacing between the dimples so as to not distort the shape of the foil or degrade the flex characteristics of the fin. The edges of adjacent dimples may be located between 0.2 mm and 0.5 mm apart. In preferred arrangements the distance between adjacent edges is between 0.3 mm and 0.4 mm.

The dimples may also be arranged in lines. In some embodiments these lines will be substantially parallel to the base of the fin, or plane of the watercraft. The base of the fin is that part of the fin that joins with or attaches to the watercraft, whereas the opposite end is the tip of the fin. In alternative embodiments these lines will run between 170 degrees and 190 degrees relative to the base of the fin, that is +/- 10 degrees from parallel.

In some embodiments substantially the whole side of the fin will be dimpled. In an alternative arrangement the dimples will be located from the widest point of the fin to the rear edge of the fin.

The dimples may also be located on both sides of the fin, or limited to one side only depending on the performance required.

It is expected that fins having only one dimpled side will be dimpled on the lift generating side.

Depending on the implementation, rather than being circular the dimples may be hexagonal, triangular, rectangular, oval or square in shape. Further some arrangements may elect to have varying dimple sizes, or the dimples increasing in size in a line starting from the leading edge of the fin extending to the trailing edge of the fin.

The present invention is a marked departure from conventional thinking employed in the design of current fins. The inclusion of dimples has led to marked improvements in the performance of fins, and thereby the watercraft to which they are attached.

BRIEF DESCRIPTION OF THE DRAWINGS

An illustrative embodiment of the present invention will now be described with reference to the accompanying figures. Further features and advantages of the invention will also be apparent from the accompanying description.

Figure 1a exemplifies the flow of water about a smooth surface.

Figure 1b exemplifies the flow of water about a dimpled surface.

Figure 2a demonstrates flow of water over the surface of a smooth foil.

Figure 2b demonstrates flow of water over the surface of a dimpled foil.

Figure 3a demonstrates the creation of vortices about the tip of a fin.

Figure 3b demonstrates the reduction of tip vortices through the use of dimples.

Figures 4a - c show the preferred location of dimples for different arrangements.

Figure 5 shows a foil of one embodiment of the present invention.

Figure 6 shows a representational cross sectional view of the foil of Figure 5. (ie the dimples are not to scale)

Figure 7 shows a foil of an alternative embodiment of the present invention.

Figure 8 shows possible shape variations for the dimples.

Figure 9 shows possible dimple arrangements on the curved outer face of a fin.

Figure 10 shows possible dimple arrangements on the ‘flat’ inner face of a fin.

Figures 11a - c show possible foil shapes.

Figure 12 shows a foil of an alternative embodiment of the present invention.

Figure 13 shows a foil of an alternative embodiment of the present invention.

Figure 14 shows a foil of an alternative embodiment of the present invention.

Figure 15 shows possible dimple arrangements on the applicants prior fin designs.

Figure 16 shows the arrangement of a preferred embodiment of the present invention.

Figure 17 shows the preferred depth and arrangement of one embodiment of the present invention.

Figure 18 a – d shows alternative embodiments of the present invention.

Figure 19 shows the number of dimples on the curved outer face of a small isometric fin in one embodiment of the present invention.

Figure 20 shows the number of dimples per side of a small symmetrical fin in one embodiment of the present invention.

Figure 21 shows the number of dimples on the curved outer face of a medium isometric fin in one embodiment of the present invention.

Figure 22 shows the number of dimples per side of a medium symmetrical fin in one embodiment of the present invention.

Figure 23 shows the number of dimples on the curved outer face of a large isometric fin in one embodiment of the present invention.

Figure 24 shows the number of dimples per side of a large symmetrical fin in one embodiment of the present invention.

Figure 25 illustrates the spacing of dimples from the edge of the fin in one embodiment of the present invention.

Figure 26 shows an alternative measuring to that of figure 25.

Figure 27 shows preferred setbacks of dimples for a particular fin of one embodiment of the present invention.

Figure 28a shows simulated flow streamlines over a conventional fin.

Figure 28b shows simulated flow streamlines over a dimpled fin.

Figure 29 is a graph and table comparing the lift force (N) of a dimpled fin to a conventional fin without dimples.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENT

The following description is presented to enable any person skilled in the art to make and use the invention, and is provided in the context of a particular application and its requirements. Various modifications to the disclosed embodiments will be readily apparent to those skilled in the art, and the general principles defined herein may be applied to other embodiments and applications without departing from the spirit and scope of the present invention. The present invention is not intended to be limited to the embodiments shown, but is to be construed at the widest scope consistent with the principles and features disclosed herein.

To obtain optimum control of watercraft such as a surfboard, it is desirable to ensure the flow of water maintains contact with the control surface such as a fin. Once the water flow detaches from the surface of the foil it begins to form a separation bubble. This usually occurs during high angles of attack or sharp turns and is undesirable as the Coanda effect (the tendency of flowing water to attach to a curved surface) no longer occurs, creating pressure drag, reducing lift and ultimately results in a stalling of the fin. In effect the watercraft reduces speed and controllability.

Referring to Fig 1a the laminar flow of water about a smooth object is shown. Laminar flow is also known as streamlined flow and is the flow of a fluid in parallel layers. The fluid will continue to flow in straight lines without mixing of the layers. When a smooth shaped object is introduced into the flow as shown in Fig 1a the parallel layers continue in the same general direction (left to right in the figure), however a large amount of separation between the layers is created.

In contrast, if a dimpled surface is introduced into the flow as shown in Fig 1b, the effect of the dimples is to reduce the separation. The dimples on the surface create a turbulent flow, which draws the flow back over the foil/fin and prevents back-flow also called flow separation from the high pressure region in the back. The turbulent boundary layer contains more energy, so will delay separation until a greater magnitude of negative pressure gradient is reached, effectively moving the separation point further aft on the foil and possibly eliminating separation completely.

This effect can also be seen in Fig 2 which exemplifies water flow over the surface of a fin. Similar to the smooth object in Fig 1a, the smooth surface of the fin in Fig 2a does not provide any attraction, and allows a large separation between the water and the surface of the fin. As a result the flow shears off the foil creating cavitation which results in a stalling of the fin during manoeuvres or high angles of attack. Fig 2b demonstrates the effect of the dimples on the surface of the fin. In this case turbulent flow created by the dimples draws the lamina flow back over the curved foil surface, allowing the foil to function at more extreme angles of attack.

Similarly, Fig 3a shows the known problem of vortices being created about the tip of the fin. These fin tip vortices are associated with induced drag, an unavoidable side-effect of the fin generating lift. Fin tip vortices form the major component of wake turbulence. A fin generates aerodynamic lift by creating a region of lower pressure in front of the fin as shown in Fig 3a. Fluids are forced to flow from high to low pressure, and the fluid behind the fin tends to migrate toward the top of the fin via the fin tips. The fluid does not escape around the leading edge of the fin due to velocity, but it can flow around the tip. As a consequence, fluid flows from behind the fin and out around the tip to the front of the fin in a circular fashion. This leakage will raise the pressure in front of the fin and reduce the lift that the fin can generate.

The problem of tip vortices can be lessened through the use of dimples about the tip of the fin. This is demonstrated in Fig 3b. In this case the dimples reduce the leakage of flow over the tip. By creating a turbulent flow along the tip it draws the escaping flow back to the tip surface.

All solid objects traveling through a fluid acquire a boundary layer of fluid around them where viscous forces occur in the layer of fluid close to the solid surface (being in this case the outer edge of the fin). Boundary layers can be either laminar or turbulent.

Fins to date by having a smooth surface resulted in a laminar flow of water over them. Achieving this laminar flow has been, and remains presently, the objective in the industry. However, in high angles of attack which a fin is subject to, the laminar flow actually increases drag and reduces the performance of a fin when contrasted with the present invention. The introduction of the dimples on the fin in the present invention results in a turbulent flow of water over the surface of the fin.

This reduces the separation of the water flowing over the fin by pulling the water molecules to the surface of the fin, thereby delaying energy sapping separation of the water flows.

This is due to reducing the laminar separation of the flowing water over the surface of the fin.

Flow separation occurs when the boundary layer travels far enough against an adverse pressure gradient that the speed of the boundary layer relative to the fin falls almost to zero. The fin becomes less efficient as the boundary layer separates resulting in less lift and speed and a stalling of the fin.

Boundary layer separation occurs when the portion of the boundary layer closest to the surface of the fin or leading edge reverses in flow direction. As a result, the overall boundary layer initially thickens suddenly and is then forced off the surface by the reversed flow at its bottom.

The fluid flow becomes detached from the surface of the smooth surface fin, and instead takes the forms of eddies and vortices (as shown in Fig 2a). In flow dynamics, flow separation results in increased drag.

When the laminar boundary layer around a fin surface separates so rapidly, it creates a very large wake with resulting cavitation of the fin.

The present invention creates a dimpled surface on a fin that thereby creates a turbulent flow of water over the fin surface.

The placement of dimples in areas of laminar separation of the flow over the fin delays flow separation and keeps the flow attached to the surface longer. This improves the performance of the fin at high angels of attack (such as critical manoeuvres of a surfboard).

The addition of dimples to the curved surface of the foil promotes the boundary layer to transition from laminar to turbulent sooner (compared to the standard design) along the foil's length. The turbulent boundary layer is able to remain attached to the surface of the foil much longer than a laminar boundary layer, reducing the overall pressure drag. A downside of this is the slightly increased viscous drag of a turbulent boundary layer compared to a laminar boundary layer. However, testing of dimpled fins has shown reduced pressure on the curved side of the fin resulting in an increased lift (9-12%) for angle of attacks between 7.5-15 degrees.

The placement of the dimples can be influenced by the intended use, or desired effect of the fin. Referring to Fig 4 there is shown the preferred location of dimples based on the expected angle of attack. Angle of attack is the direction of the water flow when it comes into contact with the fin. In Fig 4a if the fin is traveling in a straight line then the inclusion of dimples behind the widest point of the cross-section of the foil can create a clean transition without a lamina separation bubble forming. This clean transition reduces the pressure drag caused by the foil and thus improves performance. The transition is where the flow begins to change from lamina to turbulent. Due to the pressure changing from high to low, when this happens the flow detaches from the foil.

When fluid flows over the fin (foil), there is a layer of fluid called the boundary layer between the fins surface and where the fluid is undisturbed. Depending on the profile of the fin, the water will often flow smoothly in a thin boundary layer across much of the fin's surface. The boundary layer will be laminar near the leading edge and will become turbulent a certain distance from the leading edge (depending on surface roughness and Reynolds Number (speed)). However there comes a point, being the separation point, in which the boundary layer breaks away from the surface of the fin due to the magnitude of the positive pressure gradient. Beneath the separated layer, bubbles of stagnant water form, creating additional drag because of the lower pressure in the wake behind the separation point.

These bubbles can be reduced or even eliminated by adding dimples that trips the boundary layer into turbulence. The turbulent boundary layer contains more energy, so will delay separation until a greater magnitude of negative pressure gradient is reached, effectively moving the separation point further aft on the foil and possibly eliminating separation completely. A consequence of the turbulent boundary layer is increased skin friction relative to a laminar boundary layer, but this is very small compared to the increase in drag associated with separation.

When a board rider attempts a radical turn, the angle of attack can be considered extreme. This case is exemplified in Figs 4b and 4c. Surfboards turn in an arc or in s turns, usually being between 0-35 degrees and 0 – 360. Extreme angles of attack would be above 35 degrees to the straight path.

In some embodiments the dimples are located on one side of the fin only, as shown in Fig 4b. Generally this will be the lift generating side of the fin. However in other arrangements the dimples will be located on both sides of the fin as shown in Fig 4c. This will particularly be the case for asymmetrical fins.

This is to also reduce separation from the inside of the foil. Surfboards commonly have more than one fin and each side is in contact with the flow at different angles. It's desirable to reduce separation on both sides of the foil to maximize the foil performance. Separation occurs in different areas on a flat inside of a fin opposed to the curved outside of the fin.

The dimpled surface induces an early transition to a turbulent flow regime with the benefit of controlling the separation of the water from the surface.

Depending on the performance desired dimples may be placed to a lesser or greater extent over the surface of the fin, or portions of the fin. Referring to Fig

9 various embodiments are shown with the dimpled section of the fin in each case shaded.

Each different variation will provide a different feel and different performance. Surfing conditions also vary greatly and different dimple arrangements can be preferred in different conditions ie. More dimple coverage will result in a grippier feel and less feeling of the fins sliding out, this arrangement would be better in steeper waves and larger waves.

Generally speaking fins have an active curved side and a flat side. A common exception is the single fin and centre fin in a tri fin arrangement. In this case the centre fin is usually symmetrical with both sides being curved. These common foil shapes can be seen in Fig 11. Fig 11b shows a curved upper face and a flat inner face. Fig 11a shows a curved upper face, and a slightly curved inner face, which for simplicity we will consider flat like the foil of Fig 11b. Fig 11c shows the symmetrical foil shape with both the upper and inner faces being curved. This is the foil which is commonly used as a centre fin and single fin.

In the present invention the primary dimple arrangements are placed on the curved face of the fin. These arrangements have been explained above and exemplified in Fig 9. However, benefit is also gained from inclusion of dimples on the ‘flat’ side of the fin. Figure 10 shows the preferred location of dimples on the flat side of the fin. These are areas of expected separation.

In the preferred arrangement the dimples will be circular in shape. Circular is preferred as due to the combination of the wave and surfers manoeuvring, the flow is constantly changing and there is no steady flow from one direction. The circular dimples are uniform in the way they deal with the various flow angles. In modern day surfing the surfer may turn 360 degrees and ride the surfboard backwards. In these circumstances the round circular dimples can give a uniform result no matter which direction the surfers is traveling. However, a variety of different shapes can be used. Preferred shapes for the dimples are shown in Fig 8. The selection of dimple shape can depend on the intended use. Different performance may also be required for different craft. For example a wake board is towed behind a boat and generally goes in a straighter line and is not subject to as wide angles of attack as a surfboard is, therefore the wakeboard can benefit from dimples that are not circular, such as for example hexagon shaped dimples, although it will be understood that circular dimples will still improve performance.

In most embodiments the dimples will be of a common size and shape. However in some cases varying size dimples may be utilized. These variations of sized dimples could be smaller (0.1mm depth x 2mm width) at the tighter radius section of the leading edge, just forward of the widest point of the fin, leading to larger dimples in increments of about 1 mm until they reach a maximum size of size 0.325 mm depth x 4 mm width as they traverse the foils curved shape face, reducing in size to 0.1 mm depth x 2 mm width in increments of 1mm as they approach the trailing edge.

Current testing has shown that the preferred dimples have a diameter between 2 and 4.5 mm and a depth between 0.1 and 0.5 mm. It has been found that if the diameter is too small, for example less than 2 mm, that it increases drag, without reducing the pressure drag or increasing the lift to counter the increase, and similarly if the diameter is too large, for example greater than 5 mm then the surface area is increased too much and again drag is created.

In the preferred embodiment the dimples have a diameter of between 2.0 and 4.5 mm with the optimum diameter being between 3.8 and 4.3 mm. The depth of the dimples would also range from 0.2 mm to 0.5 mm, with an ideal range being between 0.28 mm and 0.325 mm.

In the preferred arrangement, as exemplified in figures 16 and 17, the dimples would have a diameter of 4.036 mm and a depth of 0.325 mm. Preferably the centre of each dimple would be located 4.378 mm apart providing a spacing of 0.367 mm between each dimple.

Alternative arrangements are exemplified in figure 18 which shows varying diameters, depth and spacing, of other preferred embodiments of the present invention.

Ideally the dimples will be arranged such that the distance between each dimple edge is between 0.2 mm and 5 mm. The ideal distance between the edges of each dimple is 0.3 mm to 0.4 mm.

In considering distances between the centre of each dimple the preferred range is between 3.70 mm and 4.5 mm. With the above arrangement it has been found that the number of dimples per side of the fin is preferably between 350 to

900. The range of dimples per side is dependant on the size of the fin. For example, small, medium and large sized fins may have the following dimensions and dimples:

a) Small sized left and right side fin, Isometric foil:

Base: 101.0 mm (3.98")

Depth: 105.0 mm

Area: 8964 mm2

As shown in Figure 19. Has 382 x 3.76 mm diameter dimples on curved outer face.

b) Small Centre fin symmetric foil:

Base: 100.0 mm (3.98")

Depth: 105.0 mm

Area: 8964 mm2

As shown in Figure 20. Has 764 x 3.76 mm diameter dimples on both curved outer faces.

c) Medium sized left and right side fin, isometric foil:

Base: 110.0 mm (4.37")

Depth: 115.0 mm (4.55")

Area: 9608 mm2

As shown in Figure 21. Has 418 x 4.15 mm diameter dimples on curved outer face.

d) Medium sized centre fin symmetric foil:

Base: 110.0 mm (4.37")

Depth: 115.0 mm (4.55")

Area: 9608 mm2

As shown in Figure 22. Has 836 x 4.15 mm diameter dimples on curved outer faces.

e) Large sized left and right side fin, isometric foil:

Base: 116.0 mm (4.55")

Depth: 115.0 mm

Area: 9608 mm2

As shown in figure 23. Has 456 x 4.036 mm diameter dimples on curved outer face.

f) Large sized centre fin symmetric foil:

Base: 116.0 mm (4.55")

Depth: 115.0 mm a

Area: 9608 mm2

As shown in Figure 24. Has 910 x 4.036 mm diameter dimples on both curved outer faces.

Figures 19 to 24 also show the preferred number of dimples on each "line". In the preferred arrangement each line of dimples will be substantially parallel to the surface of the surfboard or watercraft to which the fin is applied. This equates to each line of dimples being substantially parallel to the base of the fin which is then connected to the surfboard or watercraft. While the preferred arrangement will have the line of dimples being substantially parallel or 180 degrees, other embodiments may have the dimples arranged at between 170 degrees and 190 degrees. That is, whilst the preferred angle of rows of dimples is parallel to the base of the fin, variations of up to 10 degrees is acceptable.

Various embodiments of the fin with dimples may be provided. In one embodiment as shown in Fig 5 substantially the entire outer surface of the fin is dimpled, although the dimples are set back from the edge. Ideally the leading edge of the fin should be dimple free so as to maintain the curve of the foil, and thus not disturbing the coanda effect. Similarly in the preferred arrangements the trailing edge of the fin is dimple free so as to reduce vibration at the thinner section of the foil. Ideally the dimples would be no closer than 5mm to the trailing edge.

Figures 25 and 26 demonstrate the preferred set backs from the edge of the fin. From Figure 25 it can be seen that the set back from the edge of the fin in a line parallel with the line of dimples is between 5.0mm and 60.0mm. Alternatively with reference Figure 26 the centre of each dimple closest to the edge of the fin is located between 8.0 mm and 60.0mm perpendicularly from the edge of the fin.

The preferred setback relative to dimensions of one embodiment of the present invention is also shown in Figure 27.

In an alternative embodiment the fin has a dimpled surface located a set distance from the leading edge of the foil. This offset distance can be determined by reference to where the widest point of the foil is, and ensuring that the dimples begin behind this wide point. After the widest point of the foil is where the flow tends to separate, dimples placed after the widest point will reduce the separation by creating a turbulent layer drawing the flow back.

In another embodiment the dimples are located on the fin in areas where computational flow dynamics determine the greatest flow separation (and cavitation) occurs. However there comes a point, the separation point, in which the boundary layer breaks away from the surface of the fin due to the magnitude of the positive pressure gradient. Beneath the separated layer, bubbles of stagnant air form, creating additional drag because of the lower pressure in the wake behind the separation point.

These bubbles can be reduced or even eliminated by shaping the fin to move the separation point further along or by adding dimples that trips the boundary layer into turbulence. The turbulent boundary layer contains more energy, so will delay separation until a greater magnitude of negative pressure gradient is reached, effectively moving the separation point further aft on the foil and possibly eliminating separation completely. This separation point varies on different shaped fins, computer flow dynamics can determine the best area for dimples placement.

Fin designs to date have stipulated smooth surfaces. Contrary to conventional thinking the present invention improves the performance of watercraft fins, such as surfboard fins in modern surfing (which have dynamic manoeuvres with high angles of attack) by introducing the dimpled surface, to better control the surfboard. The conventional fin design with a smooth flat surface is unable to maintain its hold on the wave in extreme directional changes due to the cavitation caused by the separation of the flow over the foil surface of the fin.

The dimple design utilises turbulence to delay the flow separation, reducing cavitation and drag. The turbulent boundary layer helps the flow overcome an adverse pressure gradient and remain attached to the surface longer than it would otherwise.

A surfer who has 'caught a wave' and is in the process of propelling the board through the water feels the effects of the physics of fluid mechanics which dictate that the so called 'attached laminar fluid flow' around either side of each of the fins occurs following the Coanda effect during this linear motion.

The size, depth and distance apart of the dimples of the present invention are important and have a large effect on the overall performance of the fin and manufacture. If the dimples are too large in terms of depth and width, they create too much surface area resulting in an increase in the drag. Further the lift is reduced and therefore unable to offset the increased drag. Additionally with a larger, deeper dimple, the flex characteristics of the materials used to make the fin begin to change, making the material too thin in area's and also becoming too flexible or brittle thus reducing performance and making the fin difficult to manufacture. Conversely dimples that are too small or shallow do not provide the increased performance but rather increase the drag of the fin. The distance between the dimples also effect's the performance of the fin. If the dimples are too close together or even touching they have the effect of distorting the shape of the foil curve, thereby reducing the lift created by the fin and the coanda effect. dimples to close together will again also affect the flex characteristics of the materials used to make the fin, making the material to thin in area's and becoming too flexible, thus reducing performance and making the fin difficult to manufacture. Conversely dimples too far apart reduce the amount of lift created by the dimples and are therefore unable to offset the drag. The present invention thus provides parameters for dimples that produces improved performance that is contrary to conventional thinking within the industry.

It is expected that the fin of the present invention will be produced using known plastic injection moulding techniques. Injection moulding is a manufacturing process for producing parts from both thermoplastic and thermosetting plastic materials. Material is fed into a heated barrel, mixed, and forced into a mould cavity where it cools and hardens to the configuration of the cavity.

While injection moulding is likely to be the preferred option, other techniques such as CNC cut, vacuum moulding or casting may also be used. The choice of material will also depend on the construction technique used, and the desired effect. Suitable materials may include fibreglass, polyester, polycarbonate, polycarbonate with a glass fibre, nylon, nylon with a glass fibre, aluminium, epoxy, wood, rubber and other thermoplastics. For plastic injection the preferred materials that replicate the flex characteristics of fibre glass is Nylon with 30-50% Glass fibre, or alternatively Nylon with 30-50% Carbon fibre or Kevlar. It is not essential that the flex characteristics of fibre glass be maintained, however, existing surfers are comfortable with the feel of existing fibreglass fins and hence the preference to provide a similar flex characteristic.

Generally the nylon Kevlar is considered less abrasive on tooling but less commonly used material and more expensive.

Hydlar™ from Ensinger Industries Inc has been found to be a suitable material. An alternative is Nylon 6™ from IG Farben.

Nylon filled with Kevlar aramid fibres result in a material that is both stronger and has a greater wear resistance to nylon alone. Such a thermoplastic composite will generally outperform other reinforced plastics, and in particular increases the tensile and flexural strengths.

The advantage of this present invention can be seen Figure 29 which compares the lift force (N) of a dimpled fin of the present invention compared to a conventional fin without dimples.

The graph of Figure 29 shows the resultant lift provided by the respective fins at various flow angles (angles of attack). This graph illustrates two key points. Firstly, the dimpled design of the present invention has significantly more lift between 7.5 and 15 degrees. The increase in lift at this point is important as it increases the drive allowing a surfer to push the board harder and gain more speed through turns.

The second point is that the conventional fin design is unable to reduce the dramatic stalling effect after 25 degrees is reached. While the dimpled fin still stalls beyond the 25 degree point the stalling is not as dramatic as for a conventional fin, allowing the surfer to maintain the hold required to complete the turn.

This testing supports the applicants contention that the dimpled fin having parameters set out as in this specification increases the lift, reduces the pressure drag, and improves the fin performance of the fin as compared to a conventional fin.

The advantages of the present invention can also be seen in Figures 28a and 28b, which show the simulated flow streamlines as they approach and go over the fin. Fig 28a shows the flow over a standard or conventional fin, and Fig 28b shows the flow over the same fin design with the addition of dimples. Fig 28a in particular shows fin tip vortices.Fin tip vortices are circular patterns of rotating fluid left behind a fin as it generates lift. When a fin generates hydrodynamic lift the fluid on the top surface has lower pressure relative to the bottom surface. Fluid flows from below the fin and out around the tip to the top of the fin in a circular fashion. An emergent circulatory flow pattern named vortex is observed, featuring a low-pressure core.

In considering these tip vortices the simulated flow diagrams of Figures 28a and 28b again show two aspects of the present invention. Firstly, the tip of the standard fin has a spiralling turbulent flow in its wake. This is what is known as tip vortices, and create drag, stalling and reduced performance of the fin. The inclusion of dimples on the fin largely eliminate the tip vortices, resulting in reduced drag, less stalling and an improved overall performance compared to the conventional fin.

The other aspect that is seen is that the wake created by the standard fin is considerably larger than the wake created by the dimpled fin. This shows that the dimples are passing through the water more efficiently with less flow separation or cavitation occurring.

Prior to this application it was desired and common for fins to be of a smooth surface over the total area of the fins. Contrary to this, the present invention has disclosed a dimpled surface area on the fin surprisingly increasing the lift generated by the fin and reducing the effects of pressure drag and tip vorticies.

Contrary to conventional thinking the dimpled fin of the present invention provides greater drive and manoeuvrability, while maintaining hold and grip in the water, which is usually sacrificed when using a smooth fin in critical manoeuvres.

Prior to the present application the addition of dimples would have been seen as introducing imperfections that increased the surface area, drag of a fin, and thereby a degraded performance.

The addition of dimples on the surface of the fin as described herein utilizes the turbulent flow created, to maintain the connection of the water flow to the surface of the fin, longer during extreme changes of direction when subject to high angles of attack. This maintains the speed and holding ability of the fin during the manoeuvres, thereby increasing performance of the surfboard.

While the present invention has been explained in relation to a fin for a surfboard, it will be understood that the fin could be used on other watercraft. For example, a bodyboard, kiteboard, stand up paddleboard or wakeboard.

Reference throughout this specification to “one” or “an” embodiment means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment of the present invention. Thus, the appearances of the phrases “in one embodiment” or “in an embodiment” in various places throughout this specification are not necessarily all referring to the same embodiment.

Furthermore, the particular features, structures, or characteristics may be combined in a suitable manner in one or more combinations. It will be appreciated that persons skilled in the art could implement the present invention in different ways to the one described above, and variations may be reduced without departing from its spirit and scope.

Any discussion or documents, devices, acts or knowledge in this specification is included to explain the context of the invention. It should not be taken as an omission that any of the material forms part of the prior art base or the common general knowledge in the relevant art, in any country, on or before the filing date of the patent application to which the present specification pertains.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A watercraft fin including a first side surface and a second side surface wherein at least one of said first side surface or said second side surface includes a plurality of dimples.

2. A fin as claimed in claim 1 wherein said dimples are substantially circular and have a diameter of between 2.0 mm and 4.5 mm.

3. A fin as claimed in claim 2 wherein the dimples have a diameter of between 3.8 and 4.3 mm.

4. A fin as claimed in any preceding claim wherein said dimples have a depth of between 0.1 mm and 0.5 mm.

5. A fin as claimed in claim 4 wherein said dimples have a depth of between 0.2 mm and 0.5 mm.

6. A fin as claimed in any preceding claim wherein the diameter of said dimples is about 4.036 mm and the depth of said dimples is about 0.325 mm.

7. A fin as claimed in any preceding claim wherein midpoints between adjacent dimples are between 3.7 mm and 4.5 mm apart.

8. A fin as claimed in any preceding claim wherein edges of adjacent dimples are between 0.2 mm and 0.5 mm apart.

9. A fin as claimed in claim 8 wherein the edges of adjacent dimples are between 0.3 mm and 0.4 mm apart.

10. A fin as claimed in any preceding claim wherein at least one of said first side surface or said second side surface includes between 300 and 900 dimples.

11. A fin as claimed in any preceding claim wherein said fin includes a base which in use would join the fin to a watercraft, and wherein said dimples are arranged in lines, said lines running between 170 degrees and 190 degrees relative to said base.

12. A fin as claimed in claim 11 wherein said lines run substantially parallel to said base.

13. A fin as claimed in any preceding claim wherein said fin includes a leading edge and a trailing edge, and wherein said dimples increase in size from said leading edge to said trailing edge.

14. A fin as claimed in claim 13 wherein said dimples increase in size by increments of about 1 mm, and diameters range from about 2 mm adjacent said leading edge to about 4 mm adjacent said trailing edge.

15. A fin as claimed in any one of claims 1 to 12 wherein said fin includes a leading edge and a trailing edge, and wherein said dimples are located behind the widest point of the fin, said widest point being determined from a cross section of said fin between said leading edge and said trailing edge.

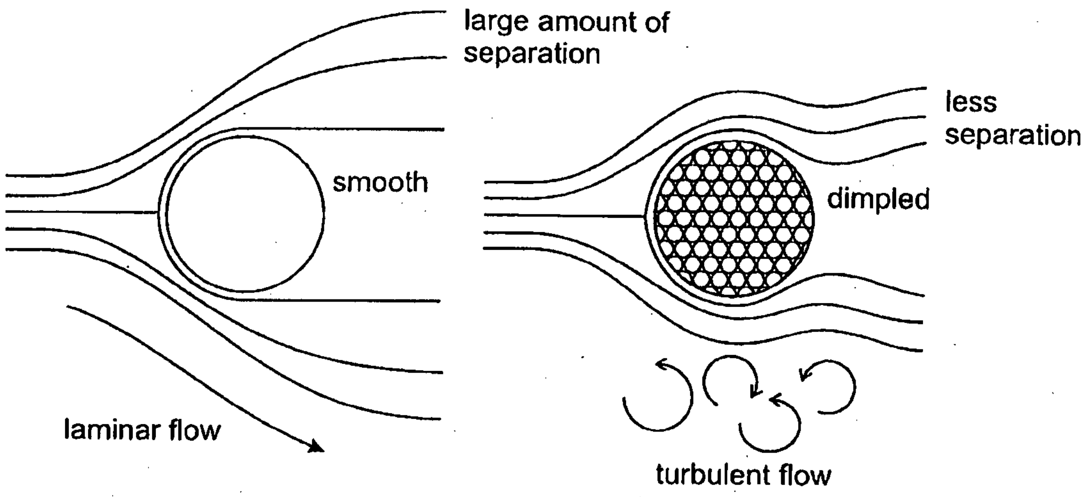
16. A fin as claimed in claim 1 wherein the dimples are hexagonal, triangular, rectangular, oval or square.

17. A fin as claimed in any preceding claim wherein said fin includes a tip and said dimples are located proximate to said tip.

18. A fin as claimed in any preceding claim wherein said dimples are located in areas where laminar separation of the water from the fin occurs.

19. A watercraft fin including a lift generating first side surface and a second side surface, wherein at least one of said first side surface or said second side surface includes a plurality of dimples, said dimples being substantially circular and having a diameter of between 3.8 and 4.3 mm, and a depth of between 0.2

mm and 0.5 mm, and wherein said dimples are arranged such that midpoints between adjacent dimples are between 3.7 mm and 4.5 mm apart, and/or edges of adjacent dimples are between 0.3 mm and 0.4 mm apart.



Dimple Effects

Fig 1a

Fig 1b

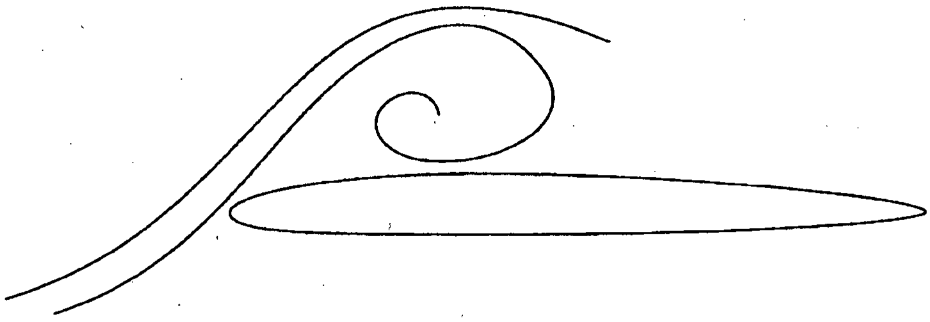


Fig 2a

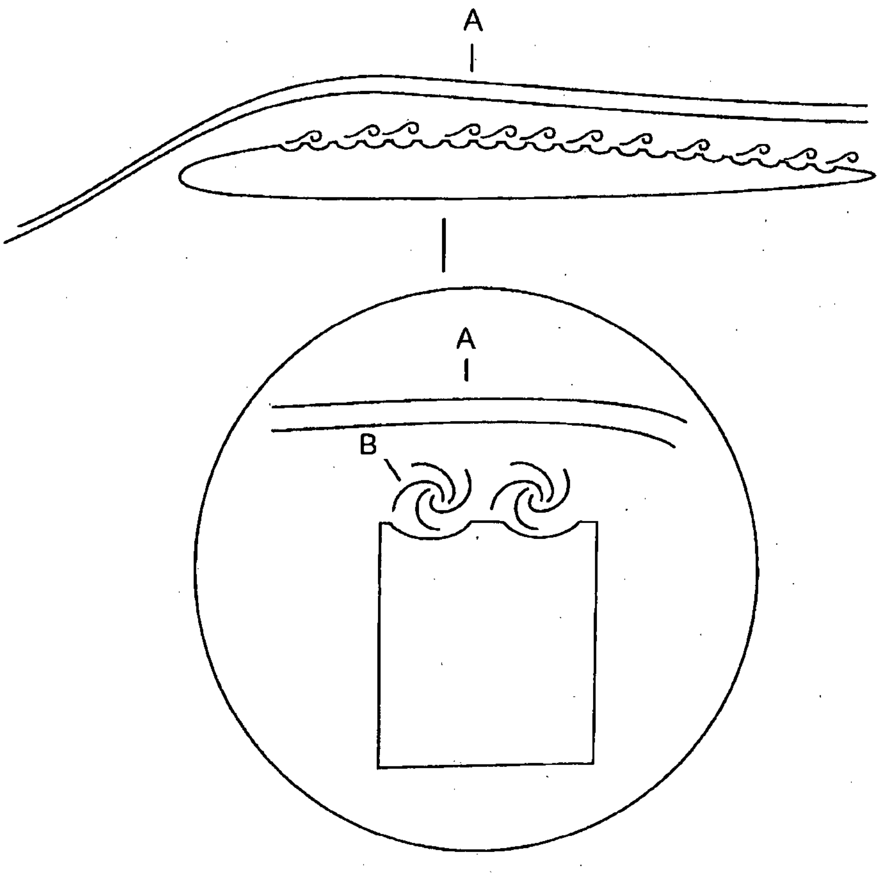


Fig 2b

Fig 3a

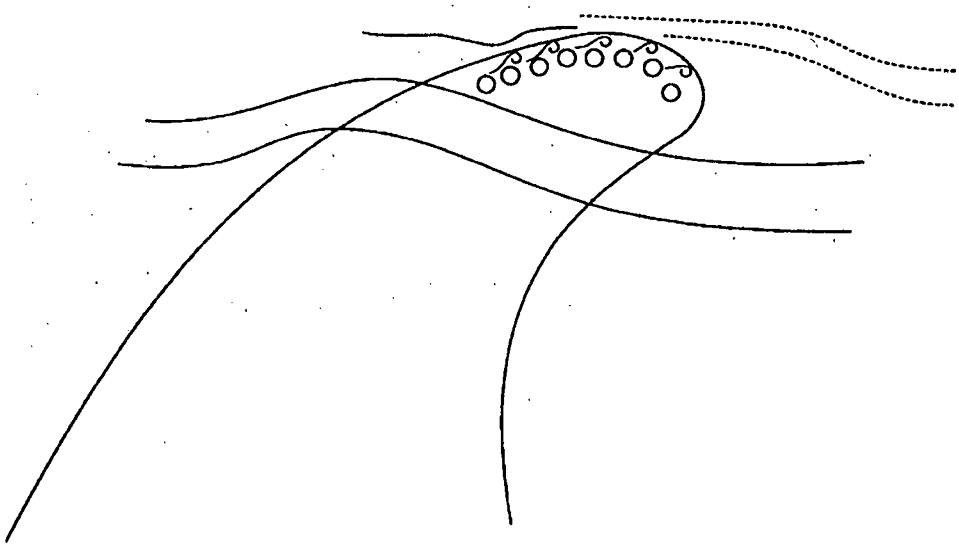


Fig 3b

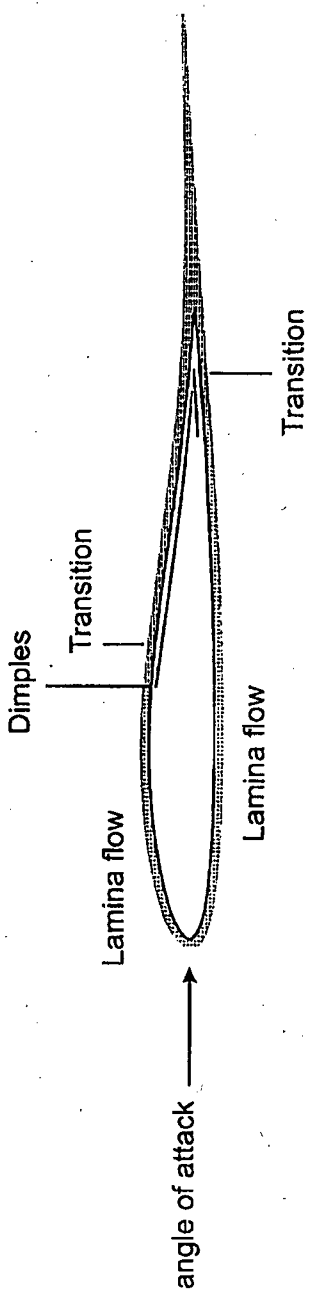


Fig 4a

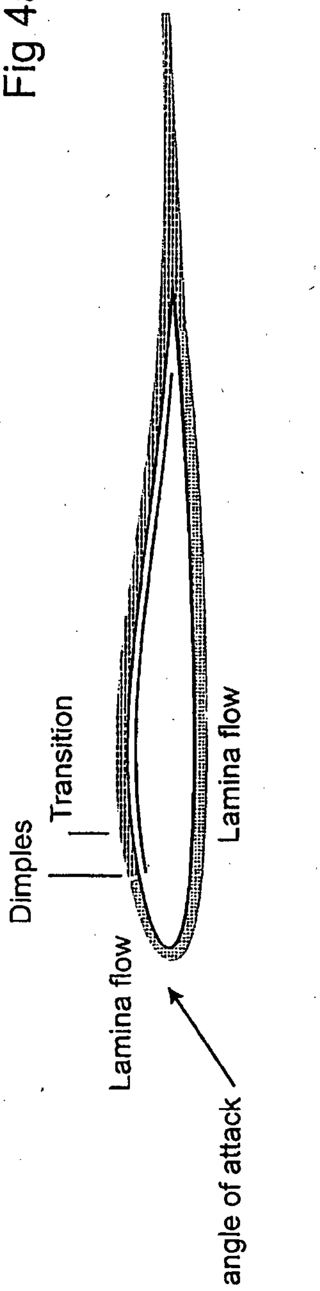


Fig 4b

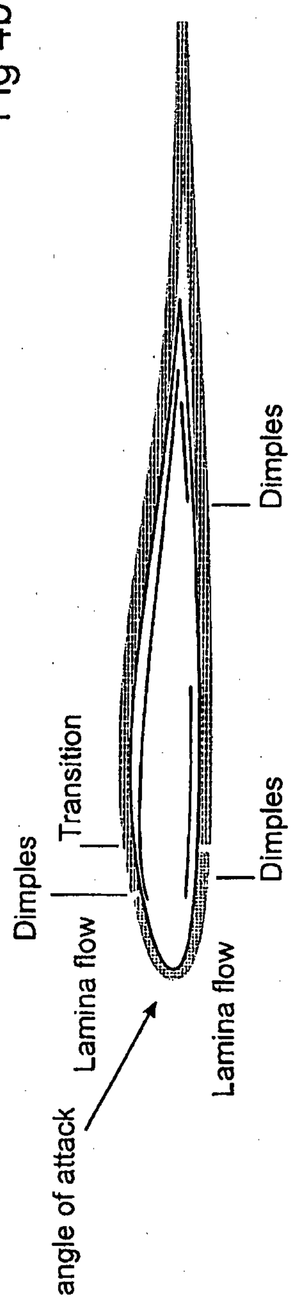


Fig 4c

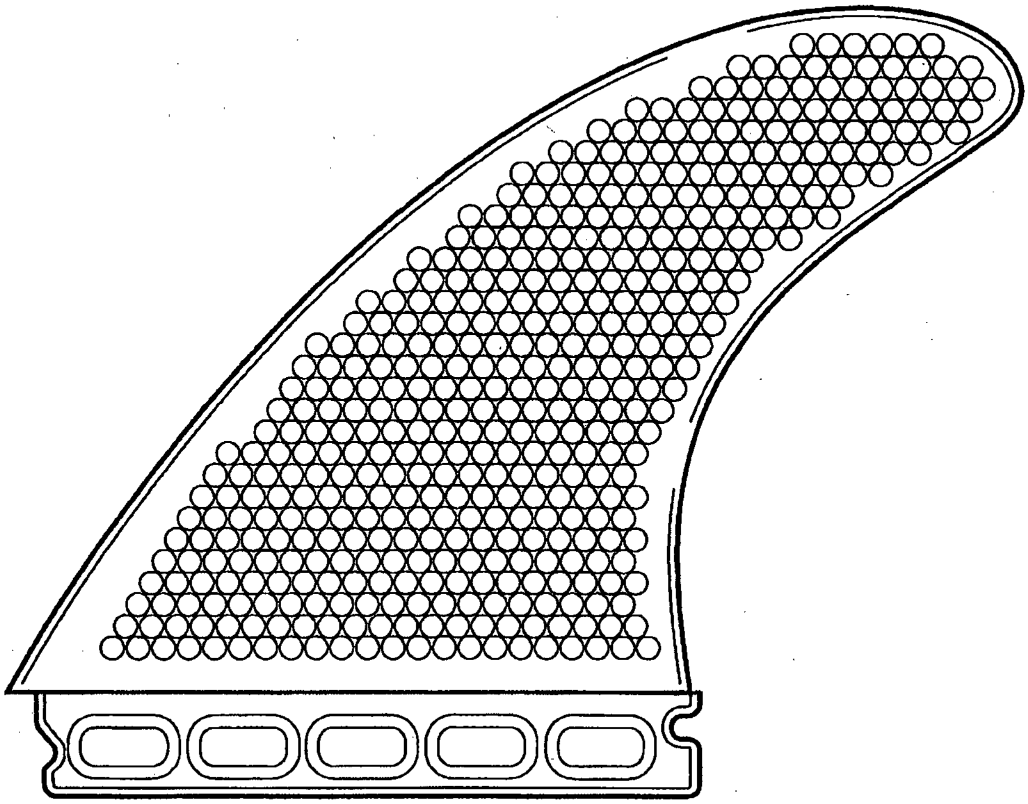


Fig 5

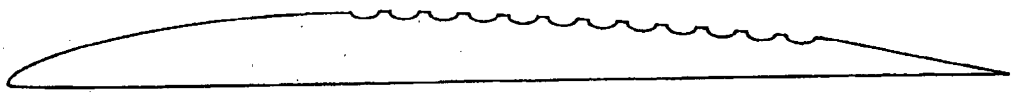


Fig 6

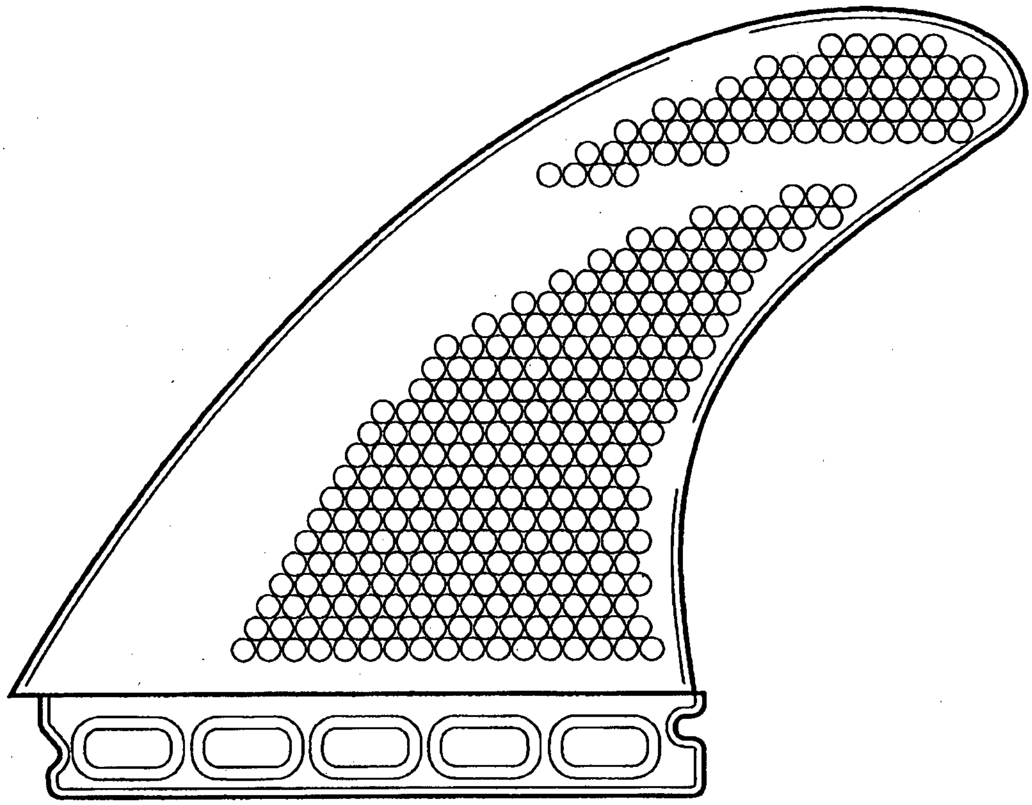


Fig 7

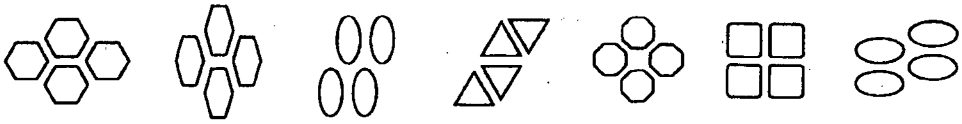


Fig 8

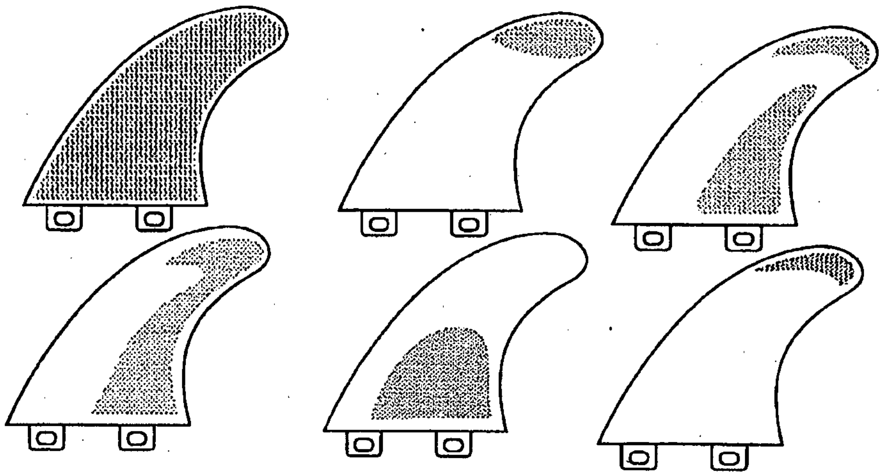


Fig 9

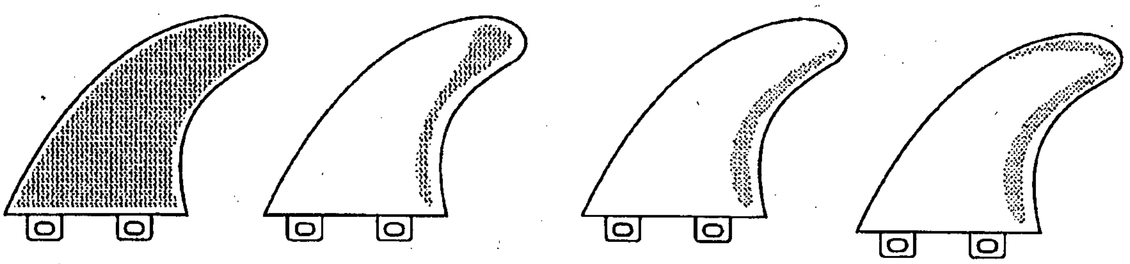


Fig 10

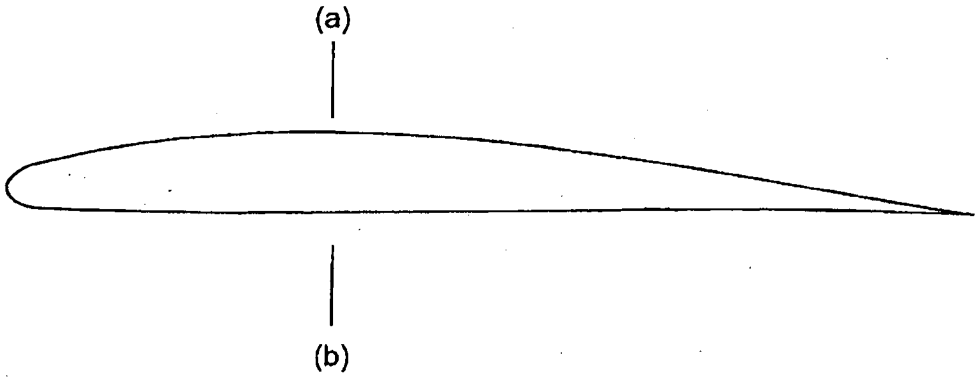


Fig 11a

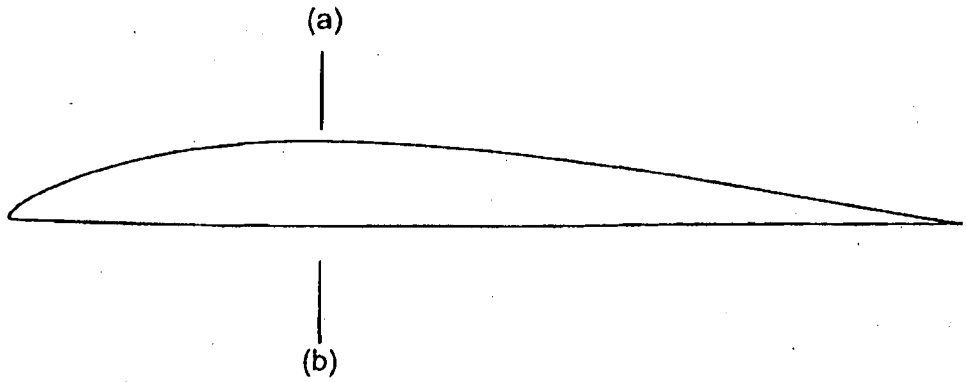


Fig 11b

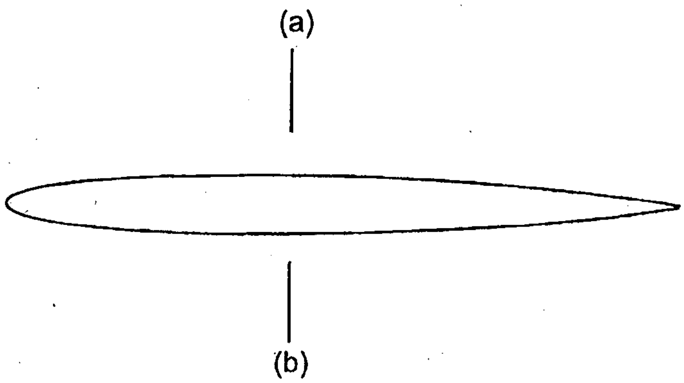


Fig 11c

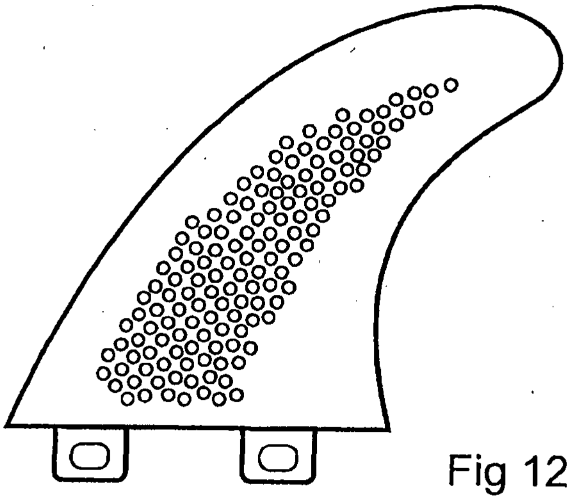


Fig 12

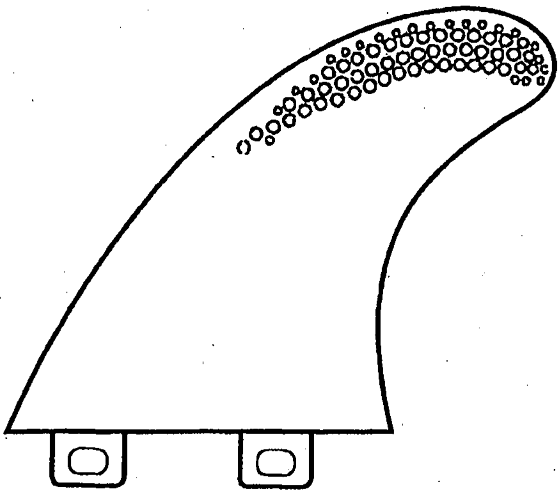


Fig 13

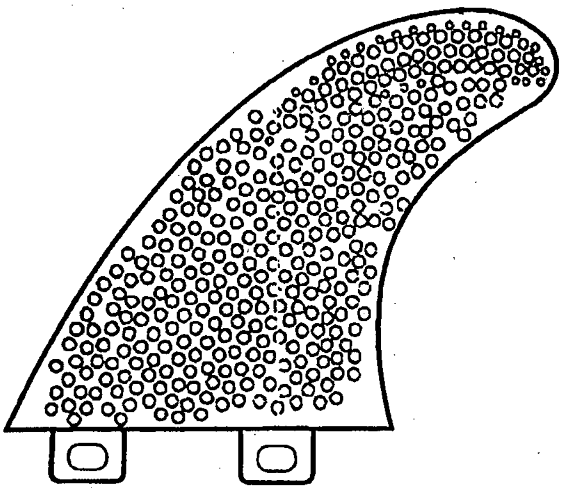


Fig 14

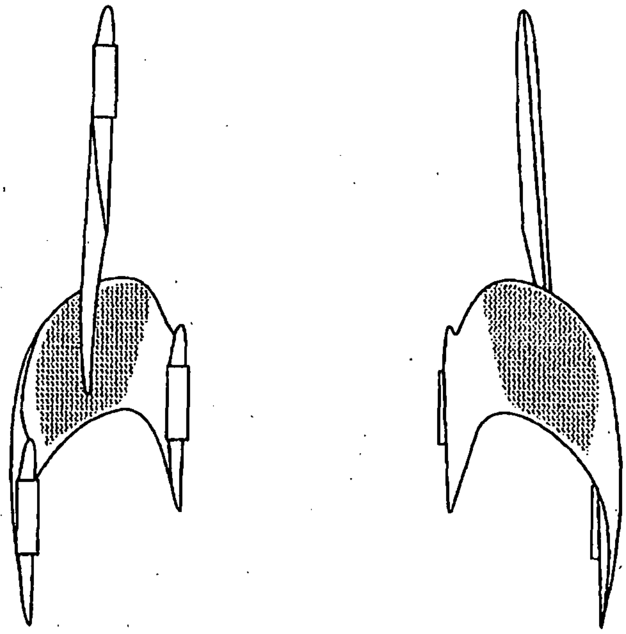


Fig 15a

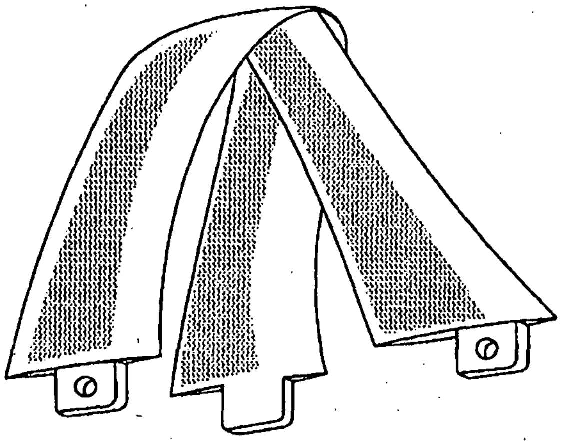


Fig 15b

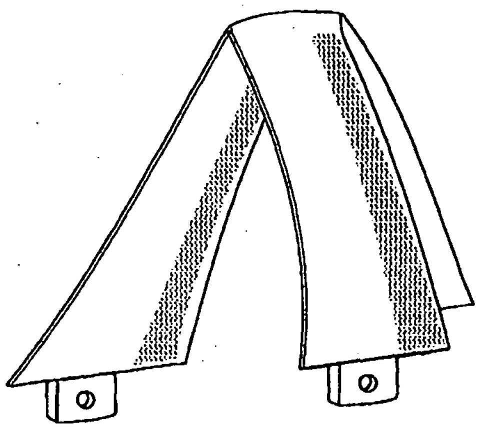


Fig 15c

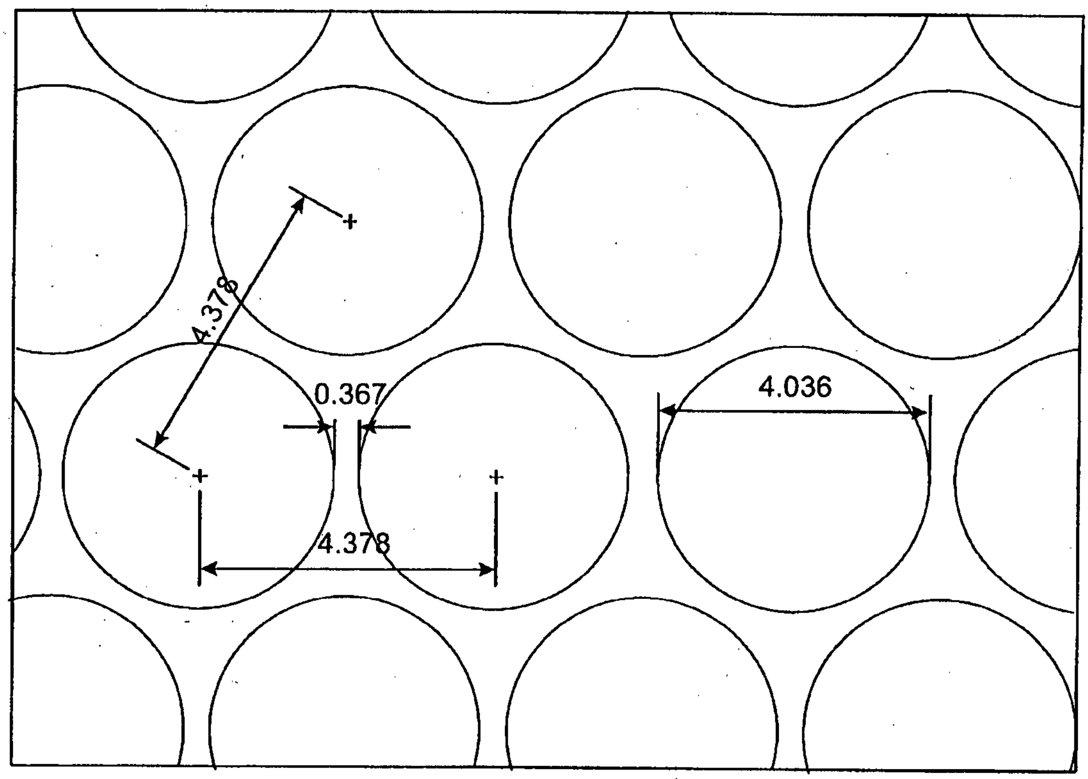


Fig 16

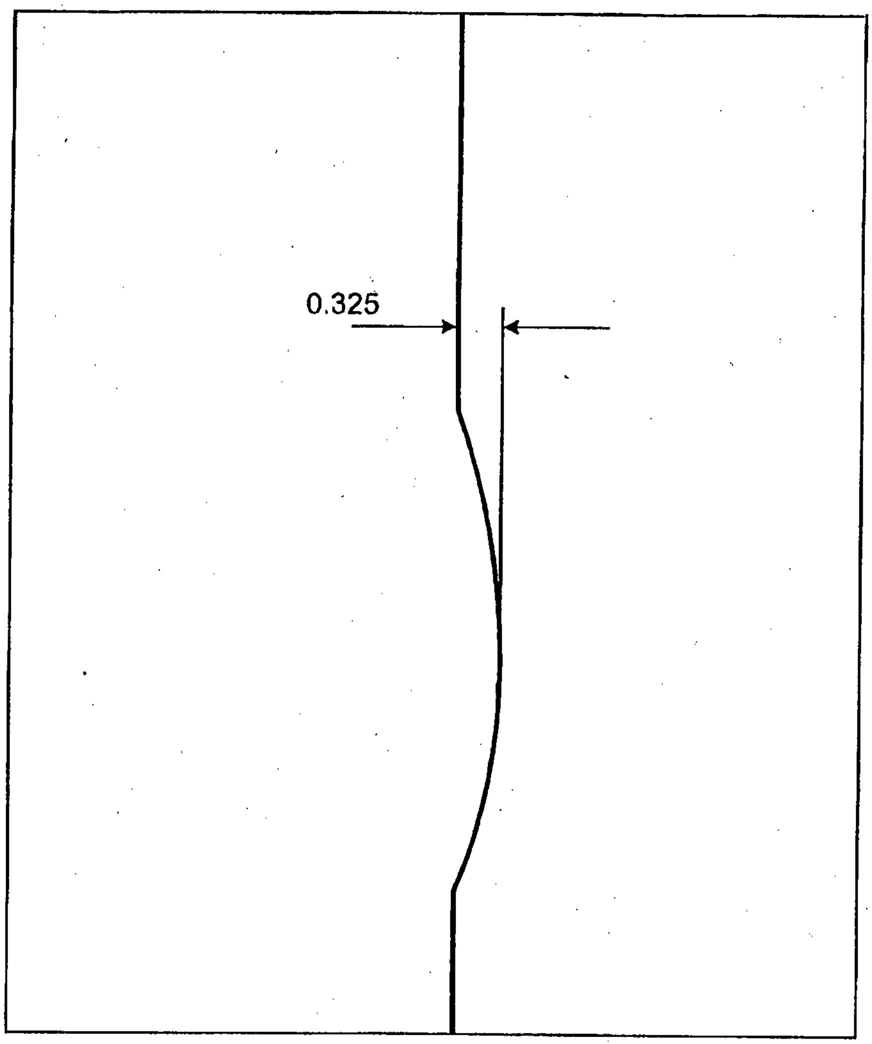


Fig 17

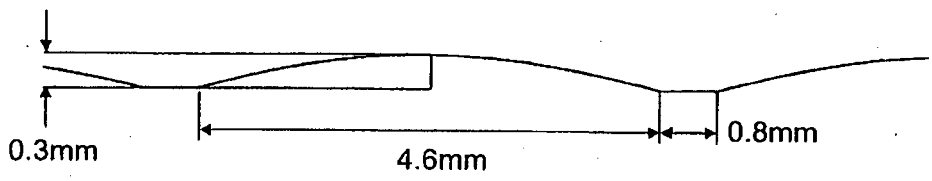


Fig 18a

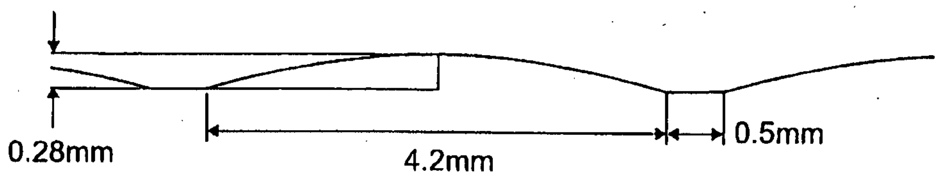


Fig 18b

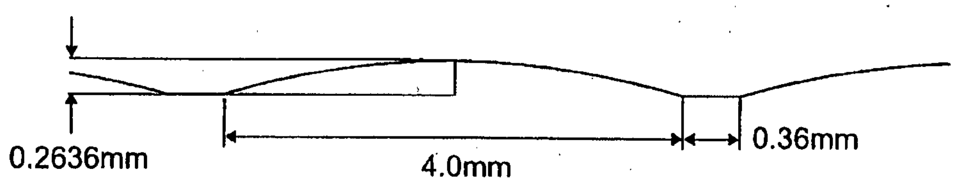


Fig 18c

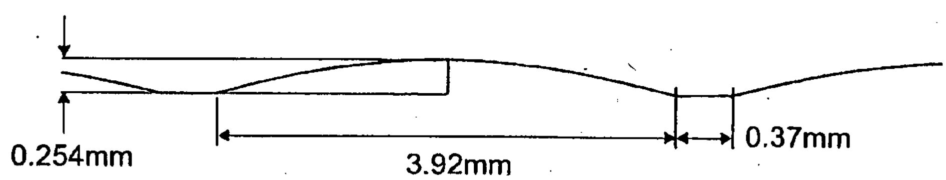
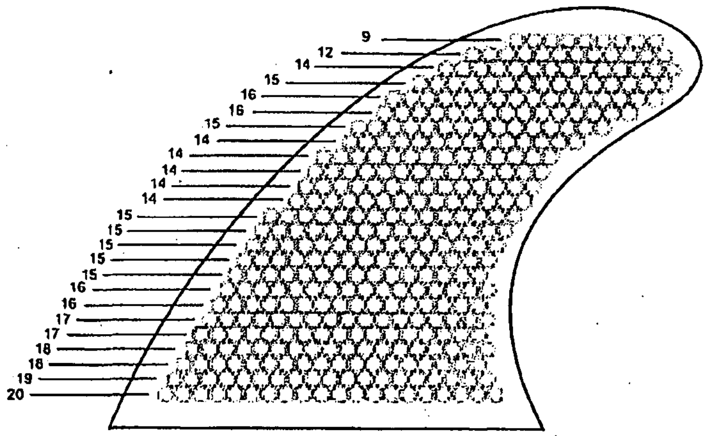
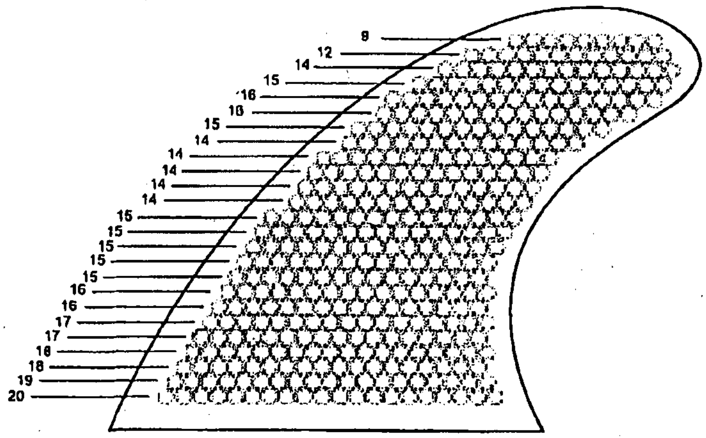


Fig 18d



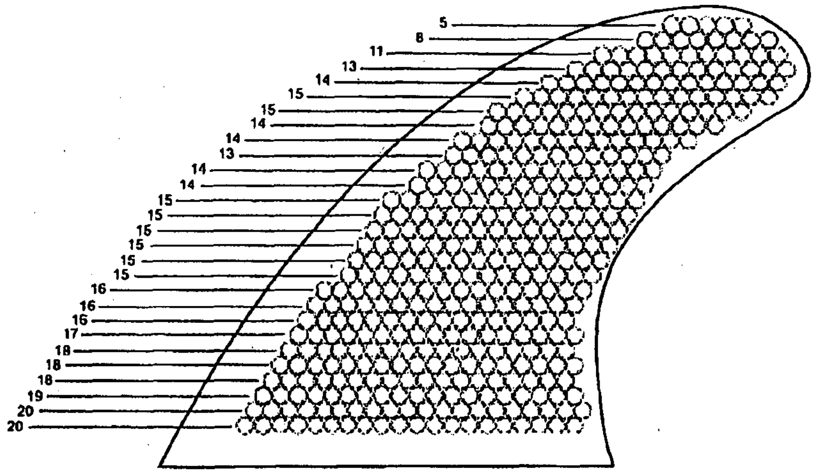
Small Left and Right side fins With isometric Foil = 382 Dimples on curved outface

Fig 19



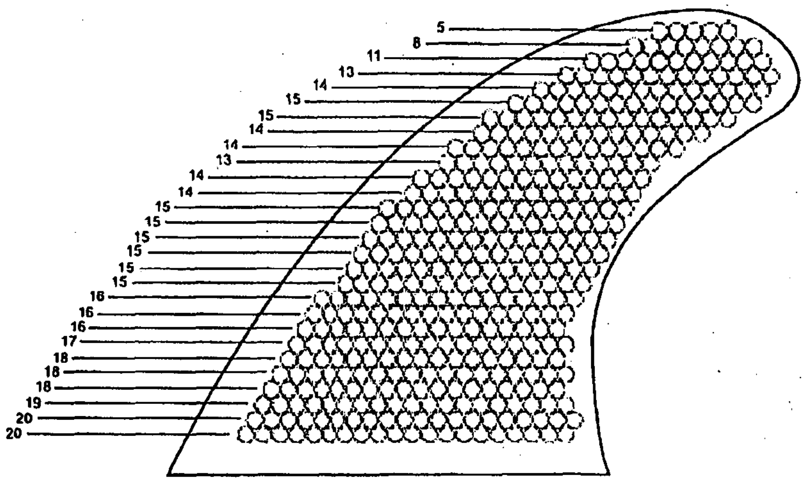
Small centre fin with symmetrical foil = 382 Dimples per side, Total Dimples = 764

Fig 20



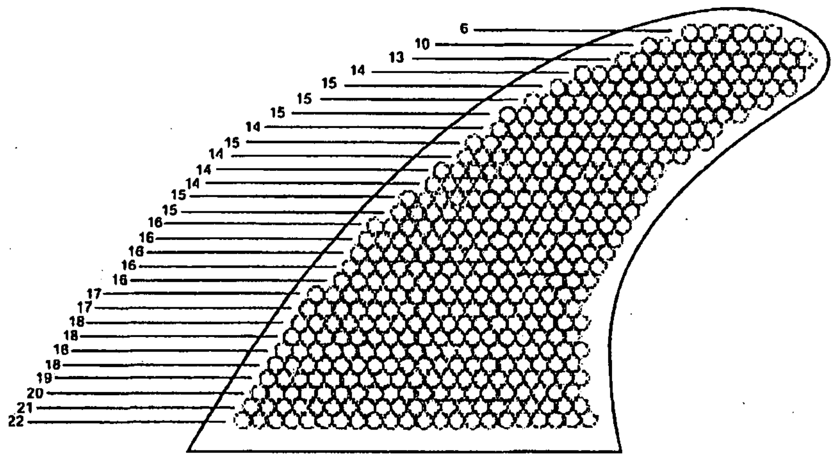
Medium Left and Right side fins with isometric Foil = 418 Dimples on curved outface

Fig 21



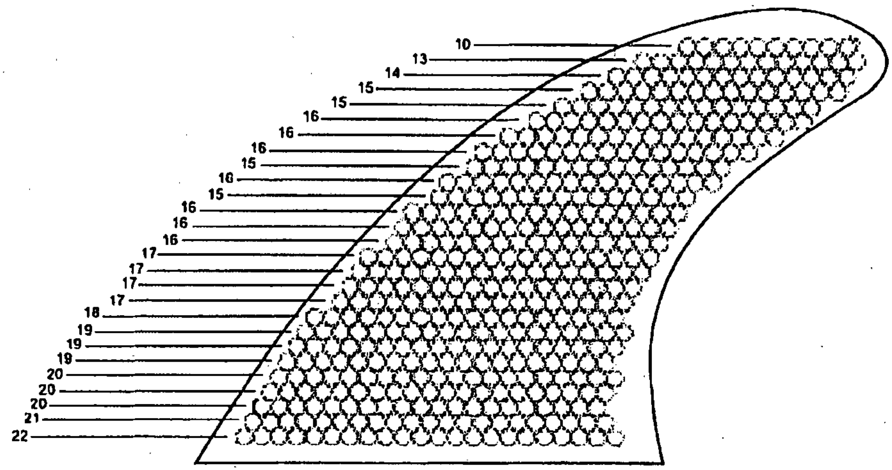
Medium Centre Fin with symmetrical Foil = 418 Dimples per side, Total Dimpes = 836

Fig 22



Large Left and Right with isometric Foil Curved outer face =456 Dimples

Fig 23



Large Centre Symmetrical Foil 455 per side, Total = 910 Dimples

Fig 24

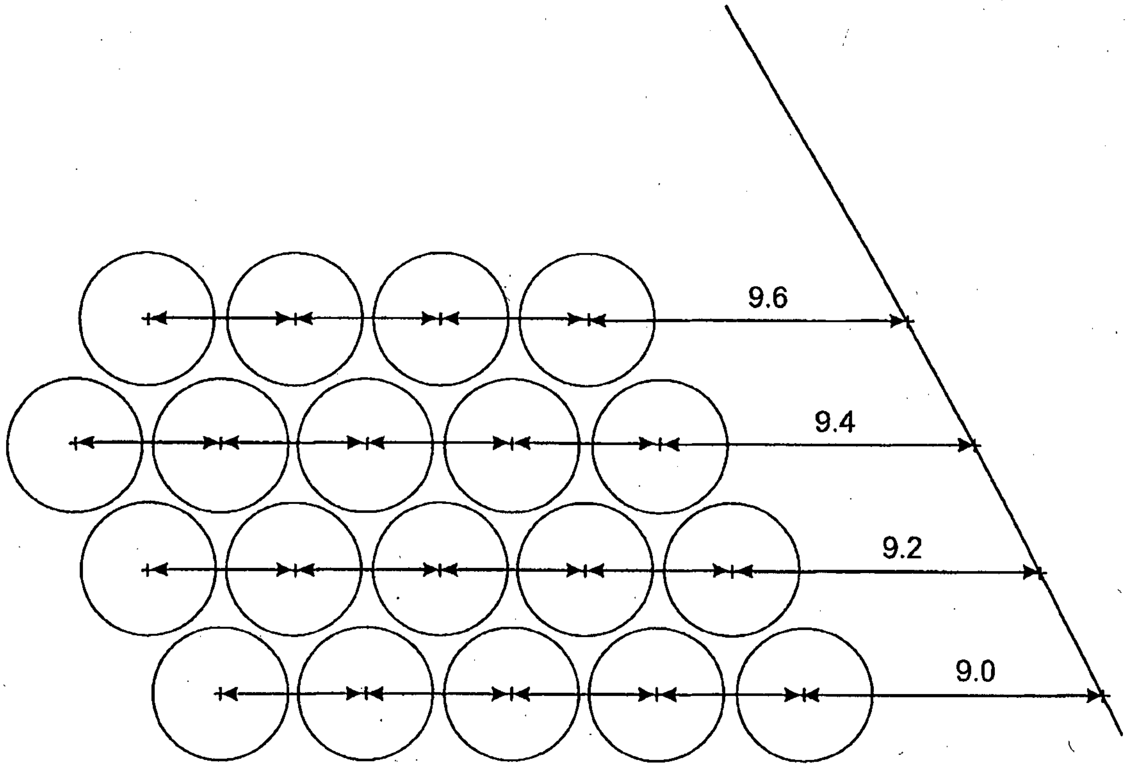


Fig 25

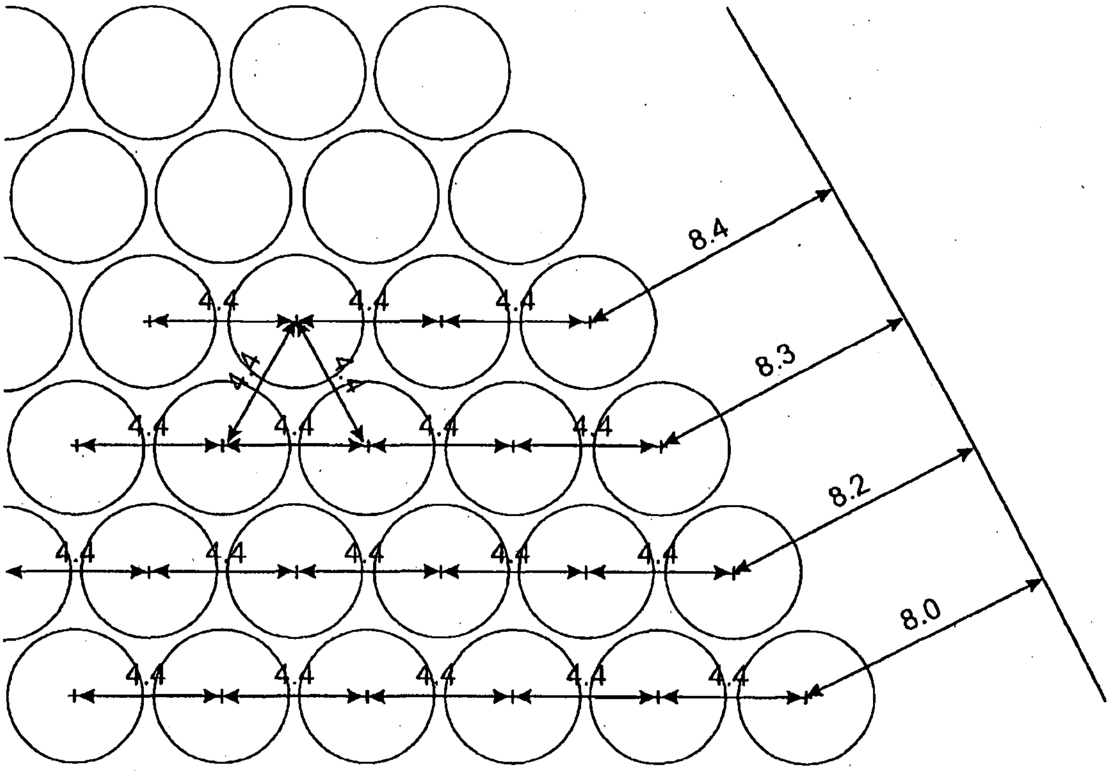


Fig 26

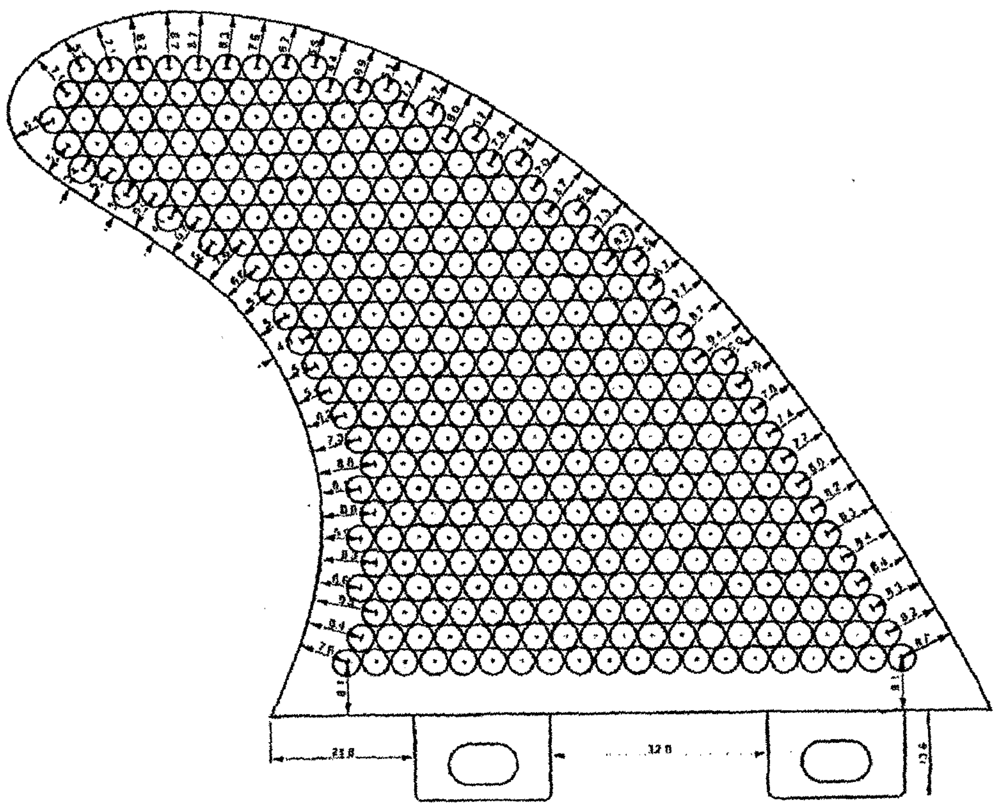


Fig 27

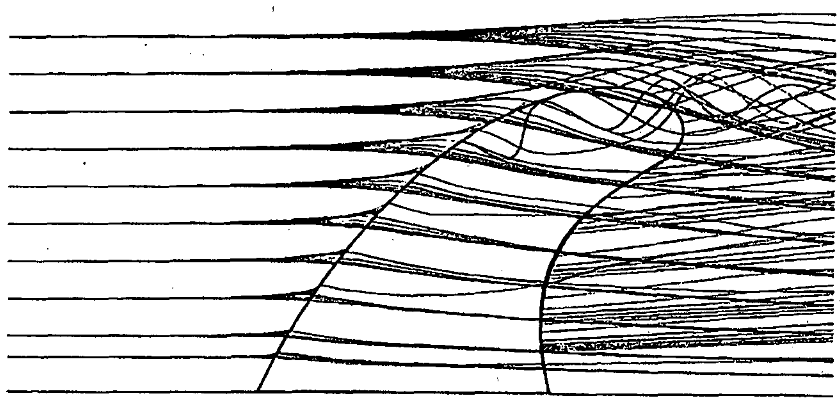


Fig 28a

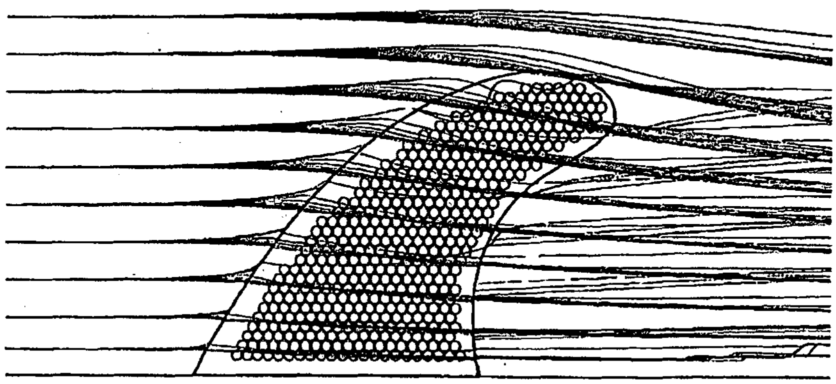
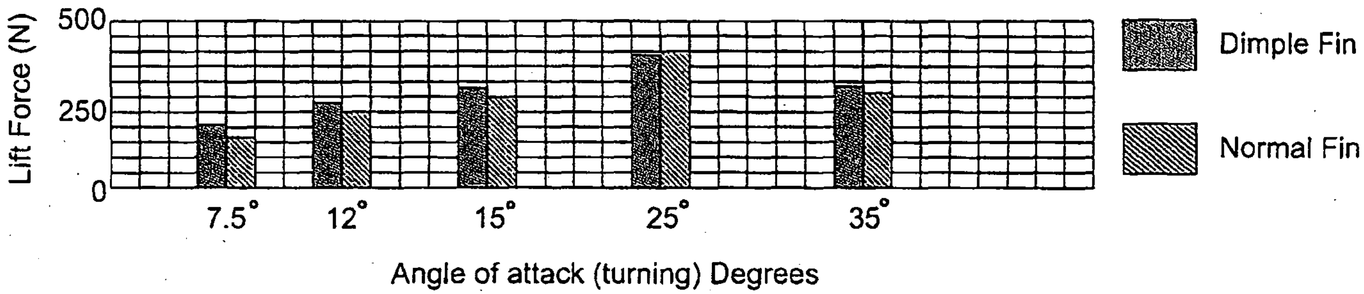


Fig 28b

Computer Flow Dynamic Results comparing the Lift Force (N) of the a Fin with Dimples with the same Fin design without Dimples



Computer Flow Dynamic Lift Force (N) Data Results

Dimple Fin Lift	**Normal Fin Lift**
7.5 Degree's = 172.08	7.5 Degree's = 158.43
12 Degree's = 254.35	12 Degree's = 225.47
15 Degree's = 305.59	15 Degree's = 272.47
25 Degree's = 403.478	25 Degree's = 407.83
35 Degree's = 317.389	35 Degree's = 297.73

Fig 29

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2013/000548

A. CLASSIFICATION OF SUBJECT MATTER

B63B 35/79 (2006.01) B63B 35/00 (2006.01)

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

1. WPI, EPODOC: IPC, CPC B63B 35/79, B63B 35/00 and keywords (watercraft, fin, dimple) and like terms.
2. Google Patents and Espace: Keywords (Watercraft, surfboard, fin, dimple) and like terms.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Documents are listed in the continuation of Box C	

[X] Further documents are listed in the continuation of Box C [X] See patent family annex

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
2 July 2013	02 July 2013

Name and mailing address of the ISA/AU	**Authorised officer**
AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA Email address: pct@ipaustralia.gov.au Facsimile No.: +61 2 6283 7999	Dr Arun Sharma AUSTRALIAN PATENT OFFICE (ISO 9001 Quality Certified Service) Telephone No. 0262223642

INTERNATIONAL SEARCH REPORT

International application No. **PCT/AU2013/000548**

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2009/070852 A1 (FOSTER, JOHN GENE) 11 June 2009 Whole document, particularly Figures 1, 2; Page 3, Page 3, lines 12-16; line 17; Page 6, line 19-Page 7, line 8;	1-19
A	US 6415730 B1 (BARKER) 09 July 2009 Whole document	1-19
A	US 2261558 A (ORLOFF) 04 November 1941 Page 1, column 1 line 4; page 2, column 1, lines 3-25; column 2, lines 42-55; page 2,column 1, lines 3-25; column 2, lines 42-55	2-10, 13-15, 19
A	US 5167552 A (JOHNSON,III) 01 December 1992 Whole document, particularly - Column 2, lines 8-13, column 4, lines 5-9	2-10, 19
A	US 5238434 A (MORAN) 24 August 1993 Whole document, particularly - column 5, lines 26-52; column 5, line 27-column 6, line 52	2-10, 19
A	US 5378524 A (BLOOD) 03 January 1995 whole document, particularly - column 3, line 31-column 4, line 21	2-10, 19

INTERNATIONAL SEARCH REPORT Information on patent family members	International application No. **PCT/AU2013/000548**

This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document/s Cited in Search Report		Patent Family Member/s	
Publication Number	**Publication Date**	**Publication Number**	**Publication Date**
WO 2009/070852 A1	11 Jun 2009	None	
US 6415730 B1	09 Jul 2009	AU 2002228964 B2	13 Oct 2005
		US 2002062777 A1	30 May 2002
		US 6415730 B1	09 Jul 2002
		WO 0244014 A1	06 Jun 2002
US 2261558 A	04 Nov 1941	None	
US 5167552 A	01 Dec 1992	US 5167552 A	01 Dec 1992
US 5238434 A	24 Aug 1993	AU 1103492 A	01 Oct 1992
		US 5238434 A	24 Aug 1993
US 5378524 A	03 Jan 1995	US 5378524 A	03 Jan 1995

End of Annex

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.