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VacuuAir - A New Technology for High Performance Inflatable SUPs

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Abstract

Stand up paddleboarding (SUP) became a rising sporting activity over the last decade. The main categories of the sport can be distinguished into: Leisure, Fitness, Race, Wave, Yoga and River/Touring. Especially the categories Fitness, Race and Wave require high performance SUPs for sportive success. In here the term “high performance” refers to “high bending stiffness” and “precise shape” of the surfboard/SUP. SUPs have a length of about 8 to 14 feet, which causes plenty of inconvenience while travelling with the equipment. A solution to the travelling problem can be found in inflatable SUPs (iSUPs). ISUPs use the so-called Dropstitch technology, invented by the U.S. military. However the fabric did not work sufficiently to keep their boats stiff enough [1]. Dropstitch is a three-dimensional fabric; fibers connect an upper and lower layer, which leads to a flat shape when inflating the object. The Dropstitch material does solve the transportation problem, but the technology is not suitable for high performance SUPs due to the insufficient possibility of forming any camber line. Further, as the fibers, which connect the upper and lower layer, are perpendicular to these layers, the Dropstitch material is not providing high enough bending stiffness. Thirdly iSUPs in Dropstitch construction have one air chamber only, thus buoyancy cannot be guaranteed when the iSUP is damaged. This can lead to dangerous situations for the sportsman.
The VacuuAir-technology (patent pending, [2]) presented in this manuscript solves all previous described problems for iSUPs. The technology is characterized by a two-chamber system: A high-pressure chamber defines the shape and a vacuum-chamber increases the stiffness and guarantees buoyancy. The tubular high-pressure chambers enable the desired high performance shape. The vacuum chambers surround these tubes and are filled with granule. When applying the vacuum the granule is compressed and hard regions are formed, which increases the stiffness. Because of the floating property of the granule, buoyancy can be guaranteed even if both chambers are punctured.
In this manuscript, we will explain the structure of the VacuuAir technology and the Dropstitch technology as well as the consequences regarding shape, safety, pumping effort and packing size. We show a comparison of the bending stiffness of iSUPs in a Dropstitch construction versus iSUPs in a VacuuAir construction.

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1. Introduction

This manuscript shows the differences between the Dropstitch-technology and the VacuuAir-technology, which are used for building inflatable SUPs. After introducing the construction of the two technologies, the aspects *shape*, *bending stiffness*, *buoyancy/safety*, *pumping effort* and *packing size* are discussed for both technologies. The difference of the bending stiffness is shown in a comparative three-point-bending test. The manuscript closes with a discussion of the results and gives directions for future work.

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2. Dropstitch vs. VacuuAir

In this section we want to show the differences between the Dropstitch- and the VacuuAir-technology. Table 1 gives assumptions about the main differences between Dropstitch and VacuuAir construction. These differences lie in the “Shape”, the “Bending Stiffness”, the “Buoyancy/Safety”, the “Pumping Effort”, and the “Packing Size”. Throughout this paper we quantitatively want to prove the assumptions given in the table, especially for “Bending Stiffness”, “Pumping Effort”, and “Packing Size”. Figure 1 shows iSUPs with the new VacuuAir construction.

Table 1. Comparison between Dropstitch- and VacuuAir-technology

	Dropstitch	VacuuAir
Shape	Constant thickness throughout entire board	Varying thickness can be defined throughout entire board
Bending Stiffness	High stiffness can only be reached with high thickness (e.g. 6”)	High stiffness can be reached even with low thickness
Buoyancy/Safety	No buoyancy can be guaranteed if board is damaged	Buoyancy can always be guaranteed
Pumping Effort	About 6 min for a board with 10’ length and 4.5” thickness	About 3 min for a board with 10’ length and a maximum thickness of 4.5”
Packing Size	Very Small	Slightly bigger than Dropstitch but still convenient for transportation with bike, car or airplane

Fig. 1 VacuuAir boards

2.1. Construction

The principle of a Dropstitch construction is shown in figure 1b while the VacuuAir construction is visualized in figure 1a. In a Dropstitch material two layers of fabric are connected with a multitude of fibers of the same length. Most commonly polyester fibers are used. The two layers of fabric are coated with an airtight layer (e.g. PVC or PU). The outline of an inflatable stand up paddleboard is cut out of the Dropstitch material and the side is taped, so that the whole object is airtight. The Dropstitch material is sold by the meter. Manufacturing Dropstitch material with varying thickness is very complicated and thus not efficient. Hence iSUPs are manufactured from material with constant thickness, where *114* mm (*4.5*”) and *152*mm (*6*”) is most common. The connecting fibers have an angle of *90°* to the upper and lower surface and thus, shear forces, which appear during bending stress, cannot be absorbed by these fibers. The bending stiffness can be increased by using thicker Dropstitch material or by attaching extra layers of fabric on top and bottom of the material. Both methods are not satisfying as a higher thickness leads to a lower performance of the board and extra layers increase the weight of the object. A newer material the so-called cross-stitch material increases the bending stiffness by arranging the fibers in an angle, which is not perpendicular to the surface [3].

The VacuuAir technology follows a different approach for an iSUP construction. Here the shape of the surfboard is approximated by inflatable pipes, which are arranged in longitudinal direction of the surfboard like visualized in figures 2a and 3. A varying thickness can be reached by varying the diameter of these pipes, and thus a surfboard-shape like known from hardboards can be built. The inflatable pipes are called high-pressure chamber or air chamber. The space between the pipes defines the vacuum-chamber. The vacuum-chamber is filled with granule, which forms hard regions, when applying the vacuum.

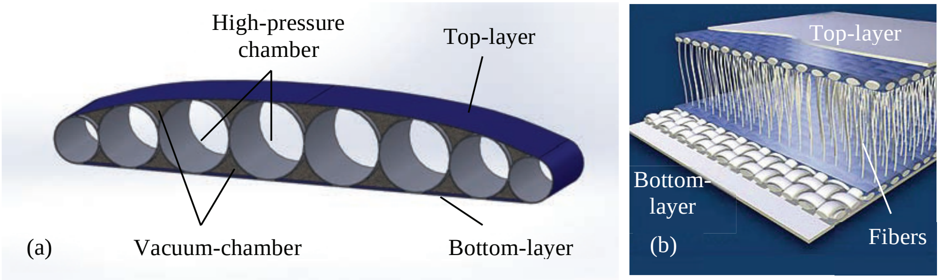

Fig. 2. (a) VacuuAir-construction; (b) Dropstitch-construction [4]

2.2. Shape

The shape of a surfboard is one of the most important aspects when aiming for a high performance surfboard. Good grip in waves can only be guaranteed if the rails (the edges of the surfboard) are thin, or, in other words, have a small radius. A bulky rail will in most cases lead to loosing the grip especially when the wave is steep. Within a Dropstitch construction the radius of the rail is dictated by the thickness of the used material. Furthermore, as Dropstitch material should be at least *114* mm thick in order to have a reasonable stiffness. Therefore sharp rails cannot be achieved with Dropstitch material. Further, when paddling into waves, a thin nose (tip of the surfboard) is helpful to get planing, as a thick nose pushes too much water along. Surfboard-design is a science in itself, and any surfboard designer will have his own philopsophy of how a surfboard must be designed to perform in a specific way. But it is for certain that the shape of a surfboard is crucial for its' performance. A good overview about surfboard-design aspects can be found in [5].

A precise high performance shape can be achieved with the VacuuAir-construction. The thickness of the surfboard can be designed by varying the diameter of the tubular air chambers of the surfboard. A comparison of typical surfboard cross sections of iSUPs in Dropstich construction and VacuuAir construction is shown in Figure 4. An outline of a typical high-performance shape is shown. The cross sections of the VacuuAir technology are similar to cross sections of a hardboard with varying thickness, while the cross sections of the Dropstitch technology show, that it's not possible to approximate a hardboard shape, with varying thickness, with this technology.

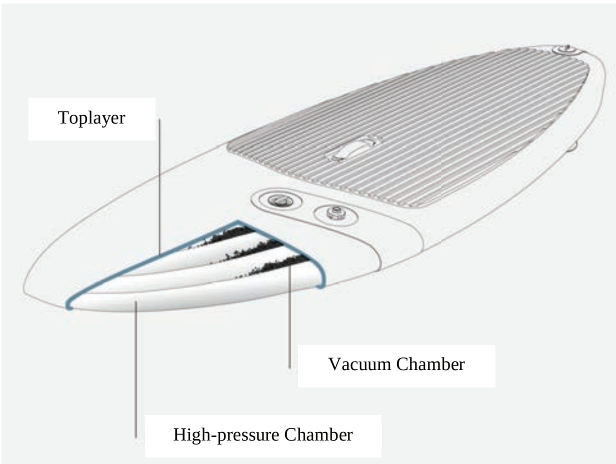

Fig. 3. VacuuAir-construction: chamber arrangement

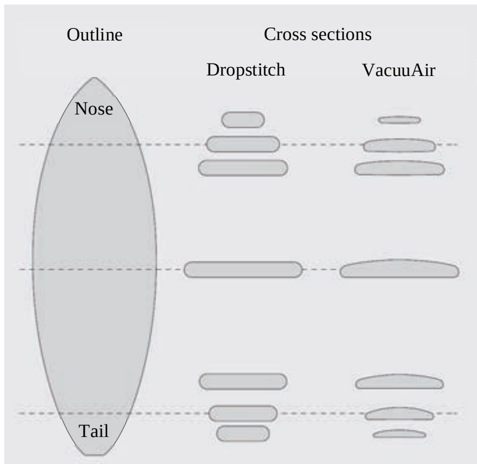

Fig. 4. Shape comparison of Dropstitch and VacuuAir

2.3. Comparison of bending stiffness

In this section we quantitatively compare the bending stiffness of an iSUP in Dropstitch construction with the stiffness of an iSUP in a VacuuAir construction. We therefore performed three-point-bending tests with both types of iSUPs with a distance of *1* m between the supporting points. This distance was chosen in order to be in the range of the gauge (*0* mm … *10* mm). The load was increased in steps of *25* N. The air pressure was set to *0*.5 bar = *0.05* N/mm^2. The vacuum was set to *–0.5* bar = *0.05* N/mm^2. The setup of the experiment is shown in figure 5. The deflection resulting from the load was measured at the bottom of the boards. The deflection as function of the applied force is shown in figure 6. A best-fit line of the measured points shows a considerable difference in the deflections. The deflection *w* subject to force *F* of the Dropstitch board is *w(F) = 0.057* mm/N and of the VacuuAir board *w(F) = 0.027* mm/N. The deflections of the Dropstitch board are more than double as high as the deflections measured with the board in VacuuAir technology. Further reproducibility is higher with the VacuuAir technology. A reason for that could be the good damping features of the granule in the vacuum chamber. On the other hand there are no dampers included in the Dropstitch construction, which also leads to a flabby feeling when surfing the board. A quantitative study of the dynamic stiffness is not considered here. Dynamic stiffness tests, as well as torsion tests, will be done in the future.

Dropstitch:
width: 83cm
thickness (middle): 12cm
thickness (rail): 12cm

VacuuAir:
width: 83cm
thickness (middle): 12cm
thickness (rail): 7cm

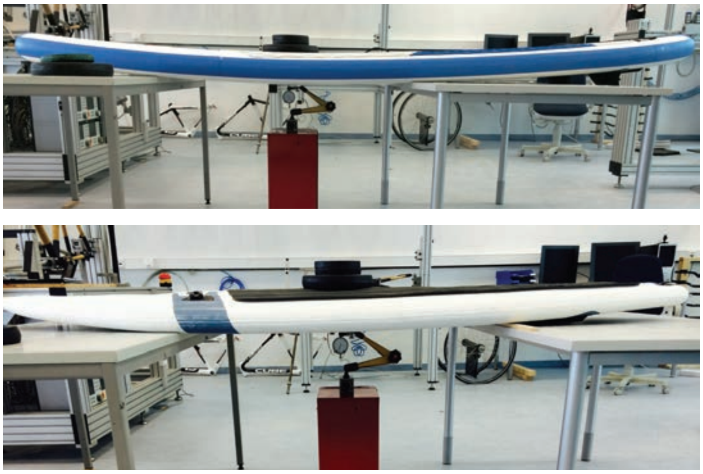

Fig. 5. Three-point-bending test (above: Dropstitch, below: VacuuAir)

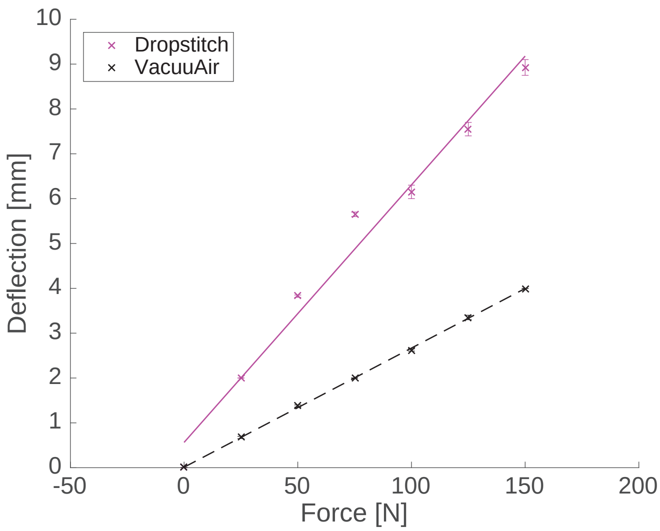

Fig. 6. Deflection as function of the applied force

2.4. Safety

The buoyancy of an iSUP is very important for the safety of the sportsman, as, especially in open seawaters, rip currents can lead to life-threatening situations. Because a Dropstitch board only has one air chamber, no buoyancy can be guaranteed, when the board is damaged and thus these boards are unsatisfying in terms of safety. On the other hand, VacuuAir boards have a two-chamber system and even when both chambers are damaged, the granule provides enough buoyancy to float a person. It is very unlikely that the entire granule is lost when the board is damaged, as membranes, which are permeable to air, separate multiple regions in the vacuum chamber.

2.5. Pumping Effort

To investigate the pumping effort both types of boards were inflated with a double-stroke handpump, which has a volume of 2 liters. To inflate the boards 40 strokes per minute were pumped into the board which means that *40 x 2 x 2* l = *160* l of uncompressed air were pumped into the board per minute. A Dropstitch board (length *3.05* m, thickness *114* mm) was inflated to *0.5* bar in *330* sec, while a concerning VacuuAir board was inflated in *75* sec. To apply the vacuum the same pump was used but, as one has to wait a few seconds after every stroke until the air escapes the vacuum chamber, a lower pumping frequency was used. To deflate the vacuum chamber to *-0.5* bar it took about *105* sec. Thus, the time to setup the VacuuAir board is about half the time to setup a comparable Dropstitch board. Further one has to apply less force when inflating the VacuuAir board as less time is spent in the high-pressure range. The reason for the little pumping effort of the VacuuAir board in comparison to the Dropstitch board is the filigree shape of the VacuuAir board which results in less overall volume. Further, the vacuum chamber takes about $1/5^{th}$ of overall volume and only the volume between the granule particles must be evacuated.

2.6. Packing size

The packing size of a Dropstitch board is smaller than the packing size of a concerning VacuuAir board. As about $1/5^{th}$ of the VacuuAir-board is filled with granule, the board cannot be deflated to a complete flat state. The measurements and weight of a deflated Dropstitch board and VacuuAir board of *3.05* m are is shown in table 2. As many Dropstitch boards use extra layers to increase the bending stiffness, a range is given for the weight of Dropstitch boards. The deflated iSUPs are shown in figure 7.

Table 2. Comparison of packing size and weight

	VacuuAir	Dropstitch
Packing size	0.3 m x 0.6 m x 0.8 m	0.3 m x 0.4 m x 0.9 m
weight	about 11kg	about 9-12kg

Fig. 7. Packing size of 10’ iSUPs (left: VacuuAir, right: Dropstitch)

3. Results

In this manuscript the differences between the Dropstitch technology and the VacuuAir technology were presented. It was shown that the VacuuAir construction outmatches the Dropstitch technology in the considered features *shape*, *bending stiffness*, *buoyancy/safety* and *pumping effort* but the *packing size* of the Dropstitch board is smaller. It was clearified how the shape of a

VacuuAir board can be designed to match the shape of a high performance hardboard and why the shape of a Dropstitch board cannot be designed in detail. The deflection in a static bending test of a VacuuAir board is less than half the deflection that we measured with a Dropstitch construction. For the VacuuAir construction, buoyancy can be guaranteed even when the board is damaged. To inflate a VacuuAir board about half the time is needed in comparison to a Dropstitch board and less force is needed.

4. Conclusions and Future Works

The VacuuAir technology might deliver a real alternative for surfers, who are aiming for high performance equipment with convenient travel opportunities. The VacuuAir technology outmatches the Dropstitch-technology in terms of bending stiffness, precise shape, safety, and pumping effort. The packing size of a Dropstitch board is smaller, but the packing size of a VacuuAir board is still suitable to travel by plane or to store the board in the trunk of a car.

In future works we want to consider the dynamic stiffness of the two technologies. We expect good damping capabilities of the VacuuAir board such that oscillations are damped. Further we want to compare the two constructions in terms of torsion stiffness.

5. Acknowledgements

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