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Forensic Engineering Analysis of a Kite Surfing Accident

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Abstract

The investigation of recreational accidents often involves an analysis of unique circumstances and unique equipment not commonly found in more traditional forensic engineering investigations. In the case of the kite surfing accident which is the subject of this paper, it was alleged that the quick-release mechanism failed to function properly, which caused the user to be dragged to a rocky shore causing injuries. The engineer had to familiarize himself with the various components of the kite and harness system, how the interaction of those components under the control of the user led to the accident, and how the accident could have and should have been avoided. Conditions specific to the subject accident were investigated, including the user's familiarity with equipment and emergency protocols, wind patterns present at the time of the accident, and geography of the accident location. Finally, research revealed that there were no standards or regulation of the kite surfing industry in the United States, but that the manufacturers of the equipment claimed compliance with a foreign standard. The equipment was then tested to determine whether it was in compliance with that foreign standard.

This paper will address the proper operation of the kite surfing equipment, and will describe the testing that was performed by the engineer to determine the effectiveness of the quick-release component of the system. It also addresses actions that were taken by the user to attempt avoidance of the accident.

Keywords

Kite Surfing, Kiteboarding, quick release, water sports, wind analysis, adventure sports

Introduction

Kite surfing, also known as kite boarding is an adventure sport which harnesses the power of the wind to propel participants across the water on a specially designed board. It combines elements of surfing, wake boarding, windsurfing, and water skiing. Users, sometimes referred to as kiters, fly large inflatable kites which provide enough power to pull them across the water, with

Figure 1
Kite surfing example

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skilled kiters performing spectacular acrobatic jumps that might last for several seconds. Kite surfing is a highly technical activity which requires knowledge and understanding of wind speeds and patterns, geography of the area, complex control system that allows the user to increase and decrease speed and power, and emergency protocols and systems that are designed to allow the user to escape dangerous situations created by gusty winds and harsh geography. A photograph showing a kite surfer is shown in Figure 1.

The kite system that was the subject of this investigation was manufactured overseas, and sold by a local distributor. The distributor was named as the defendant in the litigation as the party responsible for the systems that they sold to the public.

Figure 2
Accident Location Map

Accident Description

The accident that was the subject of this investigation occurred between 5:00 and 6:00 PM on a summer afternoon in the southeastern United States. An individual was kite surfing in the area shown in Figure 2. The kiter reported that a sudden gust of wind came up and started dragging him toward the rocky area shown in Figure 3. He then reported that he held on tight to the control bar while attempting to activate his quick-release system in an effort to de-power his kite and avoid crashing into the rocky shore. He reported that the quick-release failed to activate, and that he was dragged onto the rocks, causing injury.

Figure 3
Accident Location

Kite Surfing Equipment

Typical kite surfing equipment includes a specialized board (Figure 4), a harness (Figure 5), a control bar (Figure 6), and an inflatable kite (Figure 7). The complete system in use by a kiter is shown in Figure 8.

Figure 4
Typical kite board

Figure 5
Kite surfing harness

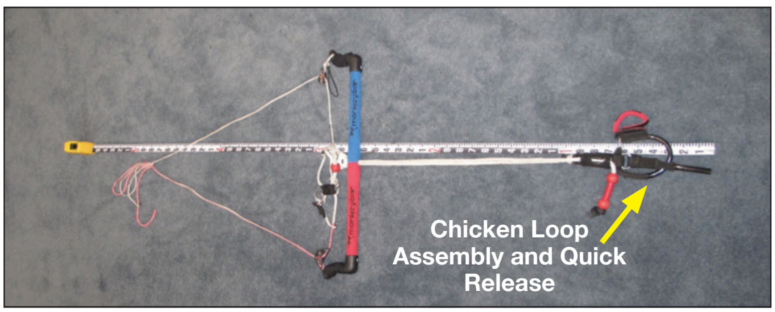

Figure 6
Control bar system

Figure 7
Kite surfing inflatable kite

The board (Figure 4) has foot holds to keep the kiter connected to the board, and is the only piece of equipment that is not physically connected to the rest of the kite system. It also has a leash that connects to the kiter's ankle to keep the board close by in the event the kiter is separated from the board. The harness (Figure 5) is worn around the kiter's waist connecting the kiter with the kite. The kite applies force through the harness so that the pulling force is approximately through the kiter's center of mass, and so that the kiter's body, rather than his arms (as in water skiing) receives the pulling force of the kite.

The control bar and lines (Figure 6) connect the kiter with the kite. A set of static lines pass through a hole in the center of the control bar and connect to the leading edge of the kite. Additional lines are connected to the ends of the control bar and extend to the trailing edge of the kite. This allows the kiter to change the pitch of the kite by pulling or pushing the control bar. Changing the pitch of the kite in this manner exposes more of the face of the kite to the wind when the bar is pulled toward the kiter and increases the speed and power generated by the kite. Changing the pitch of the kite by pushing the bar away exposes less of the face of the kite to the wind, thus decreasing speed and power. The kiter may also change the yaw angle of the kite by pushing or pulling only one end of the bar in a steering motion. This allows the kiter to maneuver the kite in different directions and to different elevations to optimize the pulling forces according to their desired kiting style.

The kite (Figure 7) is a large light-weight nylon structure with inflatable struts to maintain the kite's shape. Most kites used for kite surfing are 7 to 12 square meters. The size of kite will vary based on the size and weight of the kiter, and the speed of the wind. Many experienced kiters will have two or three kites which allows them to enjoy kiting under various wind conditions.

Figure 8 shows all components of the kite system in use. One can see the kiter's feet secured in the board. The kiter wears a harness around his waist, and it can be seen that the tension in the lines running from the harness to the kite are supporting much of the kiter's weight. The kiter's hands are on the control bar where he can control the pitch and yaw angles of the kite. The bar is only used for controlling the kite, and not for "hanging on." It can be seen that the lines that run through the center of the control bar connect with the leading edge of the kite, and the lines that connect to the ends of the control bar connect with the trailing edge of the kite.

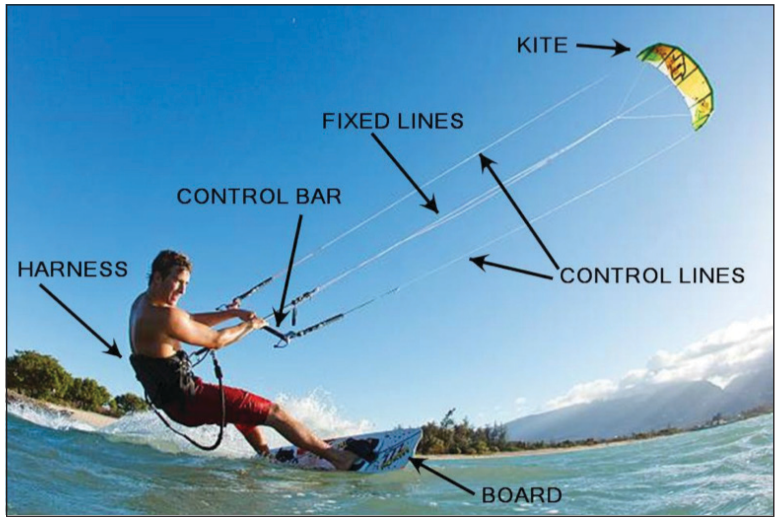

Figure 8
Kite surfing equipment

Emergency Systems

Because winds can often be unpredictable and can change abruptly, kite harness systems are equipped with several emergency systems to protect kiters from out-of-control kites. The first safety system is the ability to simply let go of the control bar. This extends the lines that connect to the trailing edge of the kite which then flattens the kite, causing it to lose lift and power. When the kiter releases the bar, the kite will generally, under regular wind conditions, fall to the ground and the water. In most emergency situations a kiter may escape safely by releasing the bar.

Sometimes in gusty or high winds, letting go of the bar fails to adequately de-power the kite, and a kiter may continue to be dragged toward a hazard. To provide kiters with an additional escape mechanism through a quick-release handle where the kite system connects with the harness. The kite connects with the harness with a "chicken loop" shown in Figure 6 and Figure 9, in which the loop connects to the harness hook shown in Figure 5. The loop is secured with the "monkey stick" which passes through both the chicken loop and the harness hook. A wrapped Velcro strap with a pull handle is placed adjacent to the chicken loop. When the handle is pulled, the Velcro separates, and the chicken loop opens as shown in Figure 9, separating the lines from the kiter. Once the lines are separated from the kiter, the lines lose their tension, and the kite generally crashes to the water or the ground. The kiter remains connected to the kite through a safety leash. In the event that the kite still flies after the quick-release is activated,

Figure 9a
Quick-release handle is ready to connect to the harness hook (Figure 5)

Figure 9b
Quick-release handle has been pulled

Figure 9a
Quick-release handle is ready to connect to the harness hook (Figure 5)

Figure 9b
Quick-release handle has been pulled

Figure 9
Quick-release handle at various stages of opening.

a “last resort” handle, with a similar Velcro loop as the quick-release may be pulled which severs the safety leash, completely separating the kiter from the kite.

Thus, the protocol to avoid injury when losing control of the kite follows the following steps in order:

1. Let go of the control bar
2. Pull the quick-release handle, opening the chicken loop and releasing tension in the kite lines
3. Pull the “last resort” handle to completely separate from the kite

Training and Operation

As part of the analysis of this matter, the author elected to take kite surfing lessons as shown in Figure 10. The lessons started with a two-hour classroom session which covered the basic equipment and operation. Students were placed in a harness and were given repeated opportunities to practice the use of the quick-release and the last-resort handles. Instruction was given that the quick-release system should be tested prior to every kiting session. Videos were shown to instruct in the operation of the kite, and to illustrate what happens when the kiter releases the control bar. Students were instructed in wind analysis, learning the optimal direction and velocity of winds for kite surfing.

Figure 10
The author taking a break from kite surfing lessons.

Students then spent time learning to fly a trainer kite, a small kite with similar controls, but without the surface area to lift, carry, or drag users. Once the operation of the trainer kite was mastered, students then learned to fly full-size kites from the water, without being attached to a board. Part of the training included repeatedly navigating the kite into the wind to achieve maximum power, and then release the control bar to de-power the kite. This exercise was repeated many times; sometimes intentionally, and sometimes unintentionally, but always with the instructor yelling to let go of the bar. This was done to develop a natural reaction to release the bar when in trouble. This was important training as there is a natural tendency to "hang on" in an emergency. However, during a kite surfing emergency hanging on typically makes things worse as the act of hanging on typically pulls the bar toward the kiter, increasing the power of the kite.

The various controls of the kite were practiced while "body dragging" through the water, still without attempting to use a board. It became very clear during training that pulling on the control bar would increase the power of the kite, and releasing the control bar would de-power the kite and cause it to fall to the water or the ground. Finally, students repeatedly practiced the activation of the quick-release while dragging through the water. Only after mastering the operation of the kite did students start learning to use the board.

Wind Analysis

When kite surfing, the most dangerous winds are direct onshore winds (wind blowing perpendicular to and toward the shore) and direct offshore winds (wind blowing perpendicular to and away from the shore). Even though when kite surfing kiters tend to travel back and forth approximately perpendicular to the wind (similar to a sail boat), onshore winds tend to push kiters toward the shore, and can quickly drag the kiter onto the shore in a heavy gust. Similarly, with offshore winds, kiters tend to be carried away from shore, and inexperienced kiters could have difficulty navigating back to the shore. Heavy gusts could quickly carry kiters even further from shore.

Optimal wind direction for kite surfing is side-onshore winds (winds blowing at an angle toward the shore) and side-offshore winds (winds blowing at an angle away from the shore). In both these scenarios, as kiters travel back and forth they do so along a diagonal line, perpendicular to the wind direction, moving in and out away from and toward the shore. Preferred wind speeds range from approximately 15 to 30 miles per hour. Multiple apps and websites provide both historical wind data and wind forecasts that are watched closely by kiters.

Using a website www.ikitesurf.com we obtained historical wind data for the date of the accident. The analysis indicated that winds were out of the east and east-northeast with average wind speed ranging from 15 to 20 miles per hour, with gusts ranging from 17 to 21 miles per hour as shown in Figure 11. Figure 12 is an aerial photograph of the accident location showing that the wind direction at the time of the accident was a direct onshore wind. Thus, while the wind velocity was ideal, the direction of the wind was the least favorable for kite surfing. Figure 13 is an example of wind activity from a dif-

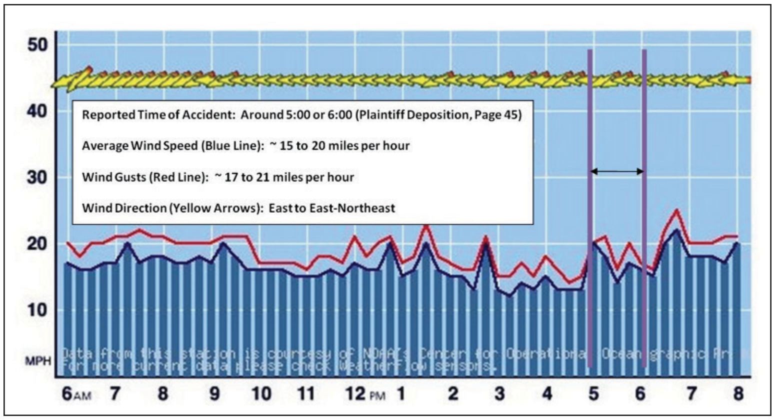

Figure 11
Wind data for the date of the accident. Wind speeds reported in miles per hour. The blue line indicates average sustained winds, while the red line represents wind gusts. The yellow arrows at the top indicate wind direction with north being up.

Figure 12
Accident location showing the direction of onshore winds at the time of the accident.

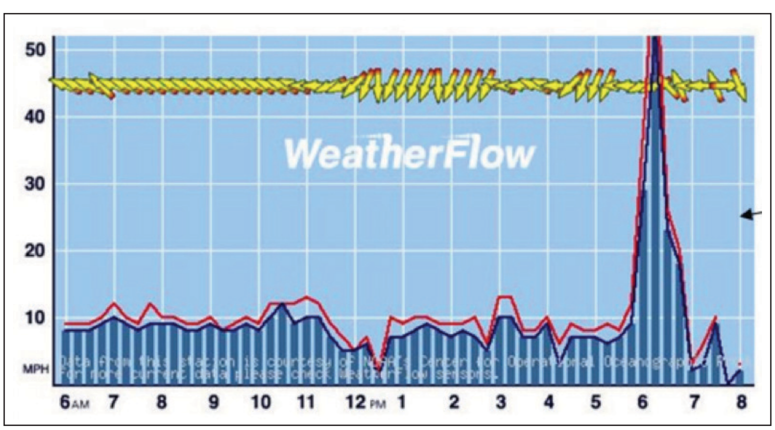

Figure 13
Example wind chart, not from the day of the accident, showing sudden heavy winds resulting from a passing storm.

ferent day from the accident, in which a passing storm caused a sudden and severe increase in wind speed which would create a hazardous kite surfing situation. If a kiter were surprised by such a wind event they would certainly have the opportunity to activate some, if not all of the emergency systems.

Accident Analysis

The accident occurred during a period of direct onshore winds that ranged in speed from 15 to 20 miles per hour, with maximum gusts of 21 miles per hour. Wind data for the date and location of the accident did not indicate any sudden or severe wind gusts. However, the injured kiter indicated that he lost control of his kite when a sudden gust of wind dragged him toward the shore. He indicated that he attempted to pull the quick-release handle, but that it failed to work. He also indicated that he had never taken any kite surfing lessons, and that he had never practiced the use of his quick-release handle. He indicated that as he was dragged toward the shore he held on tight to the control bar.

It was determined that while the wind speeds were mild for kite surfing, the onshore direction of the wind at the accident location meant that he was kite surfing under the most dangerous wind direction. By never taking lessons he never had the opportunity to repeatedly practice the act of releasing the bar to de-power the kite. Rather by hanging on tight to the control bar, he actually pulled the bar closer, increasing the pitch of the kite and therefore increasing the power behind his kite. And having never practiced the use of the quick-release system, he was not familiar with the amount of force or the proper manner to pull the handle to open the release.

Kite Surfing Standards

At the time of the investigation of this incident there were no standards in the United States related to kite surfing systems and the accompanying quick-release. However, promotional materials provided with the equipment used when the incident occurred claimed compliance with a French standard. The French standard included the following:

1. If the kiter loses control, he must be able to slow down or stop the pulling force of the kite at the main hooking point by triggering the safety mechanism.
2. If after slowing down or stopping the pulling force of the kite (depowering), the kiter still finds himself in danger or if he encounters a different hazardous situation, he must have the option to abandon his kite.
3. Mechanical devices must allow the kiter to completely abandon the kite at the kiter's own command; this device is activated by a command dedicated solely to this action.
4. The maximum force to apply the release command must be no more than 10 dekanewtons (22.5 pounds).
5. For dry testing the equipment is to be agitated in a mass of sand for 10 seconds prior to testing.
6. For wet testing the equipment is to be submerged in a container of water holding 10% salt water solution mixed with 75% sand and agitated for 10 seconds.
7. When you are still on land, prior to launching, test that the safety release, whose purpose is to allow you to abandon your kite in an emergency situation, is in good working order.

Quick-Release Testing

Several quick-release mechanisms were tested under both dry and wet conditions as indicated by the French standard. A testing frame, shown in Figure 14, was constructed to measure the pull force required to activate and open the quick-release while controlling and measurement the tension in the harness system. The spreader bar was secured and connected to the chicken loop, which was then con-

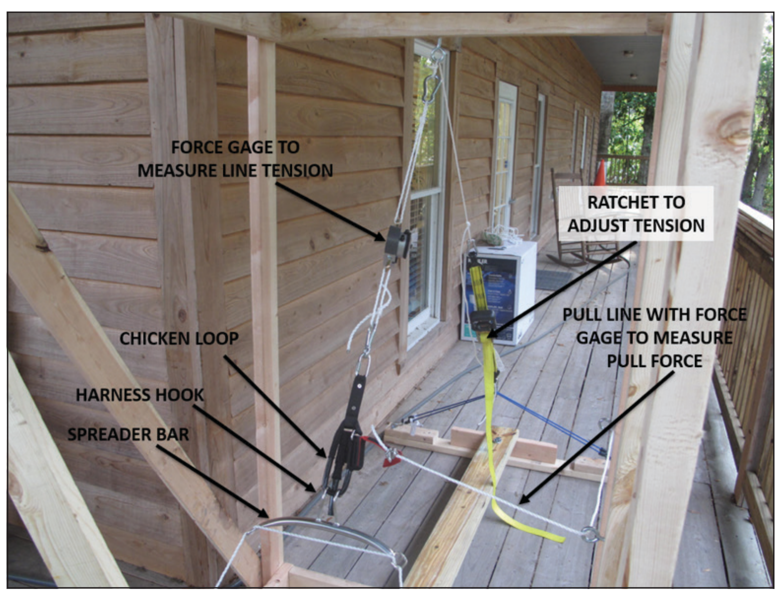

Figure 14
Testing frame constructed to measure pull force required to activate and open quick-release.

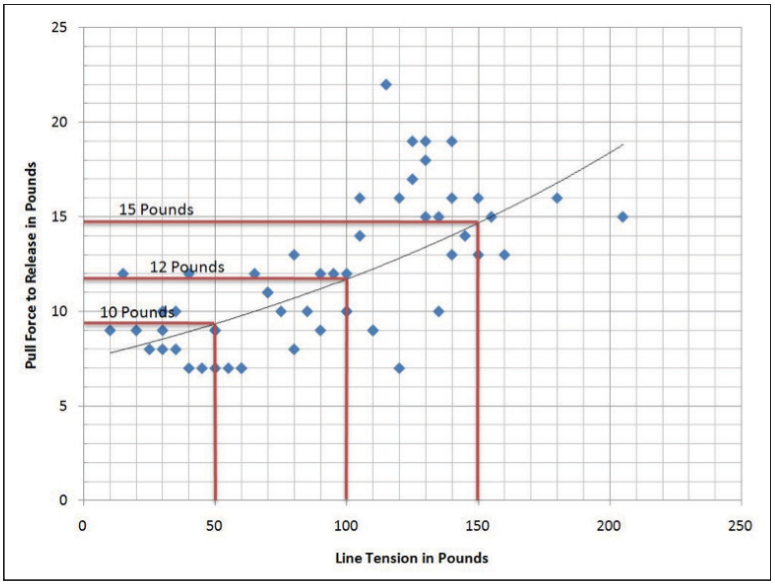

Figure 15
Results of quick-release dry testing.

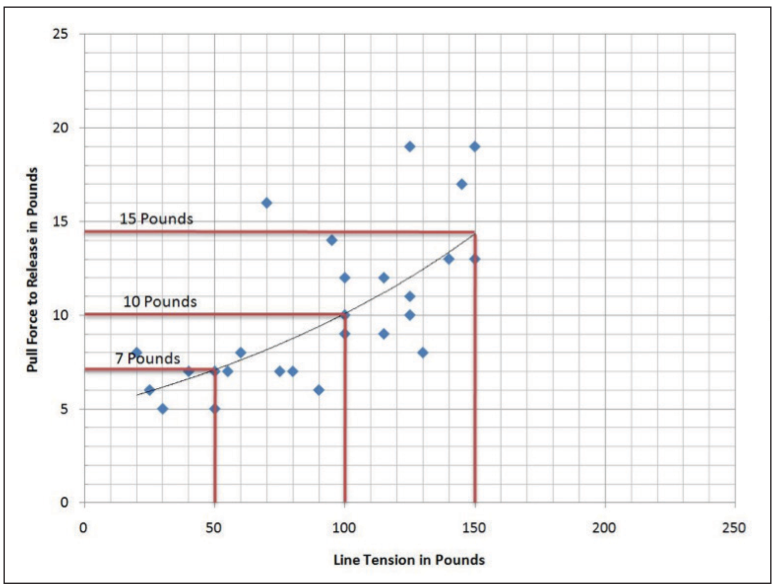

Figure 16
Results of quick-release wet testing.

nected to a tension line. A force gage was placed in the tension line to measure and document line tension. A ratchet placed in the line allowed the tension to be varied. The end of the ratchet was connected to bungee cords to allow movement in the line similar to what would exist under actual operating conditions. A pull line was attached to the quick-release handle with a force gage in line to measure pull force. The pull line was pulled slowly to eliminate spiking in the force gage. While the slowly increasing pull eliminated artificial spiking of the pull force measurements, it did not replicate actual quick and hard pulling that would occur during an actual emergency situation.

Figure 15 illustrates the results of the dry testing of the quick-release system, and Figure 16 illustrates the results of the wet testing of the quick-release system. It is seen that virtually all tests required less than the 22.5 pounds of pull force mandated by the French standard. It is also interesting to note that when the line tension was higher, a greater pull force was required to activate the quick-release system.

The opposing expert in the case performed similar tests of the system, but observed pull forces higher than the 22.5 pound requirement of the French standard. A comparison of methodologies revealed that they performed fewer tests, and their tests were performed with a brand new release with Velcro that had not been subjected to repeated openings and closings. A similar result was observed by the author during various practice tests while setting up the testing system, while the documented testing was performed only after repeated applications of the Velcro. Since the kiter indicated that he never tested or practiced the use of his quick-release system, the testing by the opposing expert may have more accurately represented the condition of the quick-release at the time of the accident. While not quantified by either expert, these observations suggest that new Velcro requires greater pull force to open than older Velcro that has been opened and reapplied repeatedly. This would suggest that if the kiter had tested his quick-release system prior to each kiting session, the Velcro would have weakened and would have been easier to open when required by an emergency.

Opinions and Conclusions

The analysis of this case resulted in the following opinions and conclusions:

1. The kiter failed to properly educate himself by not taking kite surfing lessons. By taking lessons, the kiter would have:
   a. Learned proper emergency protocols, including releasing the control bar to de-power the kite,
   b. Practiced the use of the quick-release under simulated emergency situations.
2. The kiter never practiced the use of his quick-release system, which should be tested prior to each kiting session.
3. The accident occurred during on-shore winds which is a dangerous kite surfing condition.
4. There were no unusual or high gusts of wind that would have created an unusually dangerous condition.
5. The testing of the quick-release system by the author indicated that the system complied with the French standard. The testing by the author was conducted after the Velcro on the quick-release had experienced repeated applications.
6. The testing of the quick-release system by the opposing expert indicated that the system did not comply with the French standard. The testing by the opposing expert was conducted with new Velcro that had not been subjected to repeated applications.
7. New Velcro requires greater force to release than used Velcro that has been subjected to repeated applications.
8. The quick release system required less force to activate under the wet testing protocols than under the dry testing protocols.

The case was tried before a jury in the State Court system where testimony was presented by the plaintiff, various medical doctors, and by engineers for both the plaintiff and the defendant. The jury found the distributor of the kite system liable for the emergency systems that the plaintiff was unable to operate, and awarded monetary damages to the plaintiff.

Kite surfing is a new and rapidly changing and evolving sport. By the time this case went to trial, changes had been made in the design of quick-release systems. Many newer systems have eliminated the use of Velcro, and now use a pin-release system that requires a more consistent force applied to a graspable plastic or rubber anchor. The sport continues to evolve with kiters participating in the equipment design process to improve the safety systems that are such important components of kite surfing equipment.