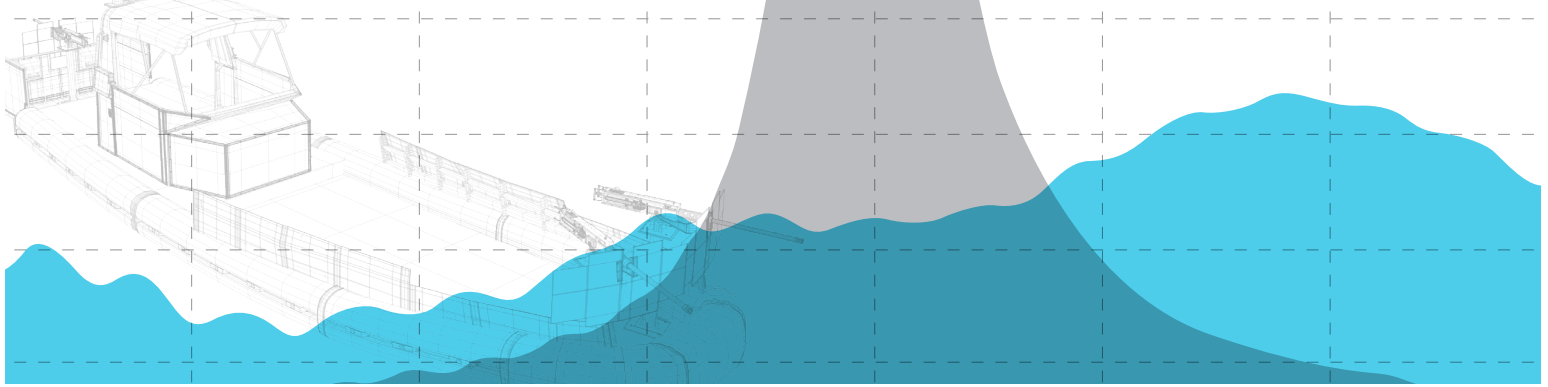


Maximizing Performance in High-Speed Craft with Advanced Shock Mitigating Decking Materials

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Abstract

It has become increasingly apparent that operating and riding in high-speed water craft can be dangerous, both short term, through wave impacts, and long term, through exposure to repeated shock. The immediate dangers of muscle fatigue and decreased operator effectiveness from being on the water have created a significant need for technologies that mitigate the shock and impact transmitted through the deck. While this is seen as a widespread problem, identifying potential solutions has been complicated by the difficulty of collecting meaningful data due to the unpredictable and inconsistent marine environment.

Utilizing its knowledge in shock mitigation in marine craft and land vehicles, SKYDEX Technologies, Inc. (SKYDEX) has developed its Boat Deck product line to address these concerns experienced during high-speed craft operations. By significantly reducing shock transfer, SKYDEX's high-performance products increase comfort on the water, optimize operational effectiveness, and minimize risk and injury.

Introduction

As boats travel through water at high speeds, they crest waves then slam back to the surface, sending shock through the hull of the boat into the occupants. Exposure to such forces can lead to discomfort, performance degradation, and injury. In a survey of Special Operations craft operators, 62 percent reported an injury they incurred on the water.¹ Teamed with days lost to hospitalization, sick leave, limited duty, and loss of physical conditioning time, this growing issue demands attention.

With an emphasis on building more powerful boats, increased operational tempo, and greater fast boat usage by law enforcement, commercial entities, and civilians, solutions need to be identified and integrated to reduce the force transferred through the deck to craft occupants.

In 2003, SKYDEX began manufacturing boat decking focused on shock mitigation for marine craft utilizing its patented impact absorbing technology. With assistance from members of the U.S. Navy and U.S. Marine Corps, SKYDEX Boat Deck was continually improved to help operators withstand harsh marine environments and provide a deck cushioning layer to protect those using high-speed, rigid-hulled, inflatable boats and other water craft.

¹ Ensign, W., Hodgdon, J.A., Prusaczyk, W.K., Shapiro, D., and Lipton, M. 2004. A survey of self-reported injuries among special boat operators. Naval Health Research Center: San Diego, C.A. (U.S.A.). No. 00-48.



The Problems Related to Shock and Impact on Water

Potential Health Risks Associated with High Speed Marine Craft

Exposure to high levels of shock and impacts on the water are proven to cause serious health effects. Combined with the demand for faster boats and increased operational tempo, the chances for both long term and short term injuries increase dramatically. Some potential injuries caused by these factors are:

- Strains and sprains of the knees, ankles, back, and shoulders
- Back muscle spasms and cramps
- Degenerative disc disease and misalignment
- Pulled or torn ligaments
- Head symptoms, including fatigue and headaches
- Loss of hand-eye coordination and balance
- Abdominal pain and disorders of the gastrointestinal system

Types and Causes of Injury

Injuries experienced on the water can be divided into two types: (1) single impact injuries and (2) repetitive trauma injuries.

Single impact injuries are a result of a high force impact or several high force blows over a short period of time, known as “wave slamming.” These impacts force a craft’s occupants to slam into the boat’s deck, seats, or other fixed equipment causing immediate diagnosable injury. Examples of serious injury from single impacts have been recorded on the *Celtic Pioneer*² and *Ocean Ranger*³ by the U.K. Marine Accident Investigation branch.

Repetitive trauma injuries are viewed as chronic and are a result of longer term exposure to shock and impact. These injuries can occur in a matter of hours or as a result of decades spent on the water. Repetitive trauma is a more significant issue for craft operators and crew than the occasional passenger. Research has also been performed on chronic injuries and is highlighted in *A Survey of Self-Reported Injuries Among Special Boat Operators*,⁴ and *High-Speed Craft Biodynamics and Human Performance*,⁵ a presentation given by Ron Peterson and Eric Pierce in 2005.

² Marine Accident Investigation Branch. 2009. Report on the investigation of injury to a passenger on board the RIB Celtic Pioneer. Report No. 11/2009. Southampton, U.K.

³ Marine Accident Investigation Branch. 2009. Ocean Ranger. St. Brides Bay, U.K.

⁴ Ensign, W., Hodgdon, J.A., Prusaczyk, W.K., Shapiro, D., and Lipton, M. 2004. A survey of self-reported injuries among special boat operators. Naval Health Research Center: San Diego, C.A. (U.S.A.). No. 00-48.

⁵ Peterson, R. and Pierce, E. 21 Feb. 2005. High Speed craft biodynamics and human performance. Naval Surface Warfare Center, Panama City, F.L. Presented at ONR IFO HSC HF Workshop, Poole, England.

Single Impact Injuries

Celtic Pioneer

A passenger on board the 9m rigid inflatable boat, *Celtic Pioneer*, suffered a lower back wedge compression fracture while participating in a one-hour recreational boat trip. The injury occurred when the passenger landed heavily on her seat after she was momentarily lifted into the air due to the motion of the craft. She was treated and fitted with an external spine brace and underwent a six-month recuperation program. As a direct result of wave impact, spinal compressions and shoulder damage are common injuries in these types of incidents.

Ocean Ranger

The leisure vessel, *Ocean Ranger*, was involved in a serious incident when the vessel slammed heavily as it dropped off the back of a large steep-sided wave. Passengers were briefly suspended above their seats before landing heavily back in them. One passenger suffered a shattered vertebra; another, a fractured sternum. The other passengers suffered less serious back injuries and bruising. As a result of the wave slam, passengers also experienced loss of balance, knee injuries, head injuries, and back and neck injuries from falling to the deck or hitting permanent fixtures on the craft.

Repetitive Trauma Injuries

A Survey of Self-Reported Injuries

Among Special Boat Operators.

This study concluded that within the Special Operations community, Special Boat operators have a unique set of risks.



High-Speed Craft Biodynamics and Human Performance

Fatigue, even as a result of a short boat ride of one hour or less, can result in reduced mission effectiveness for operators when they disembark. Human performances examined include:

- Grip strength
- Upper-body strength
- Leg strength
- Shooting skills
- Manual dexterity

The Solution

SKYDEX Boat Deck is a complete, high-performance boat decking product line that uses patented energy-absorbing geometries to mitigate impacts and minimize potential for injury to crew and passengers due to wave slam in high-speed craft operations.

SKYDEX Boat Deck helps maximize your performance by improving:

- Force effectiveness
- Risk mitigation and injury avoidance
- Operational readiness (OR)

Durable and proven, the product line features proprietary technology, composed of thin sheets of high-grade, resilient, engineered plastic to provide maximum impact performance in the thinnest profile. SKYDEX Boat Deck absorbs 60 percent more force than common foam cushioned decking, and its open airflow design prevents freezing and hardening under normal temperature variations. Also, its surface serves as an additional mitigation system to spread the force of the impact.

Other core product benefits of SKYDEX Boat Deck include:

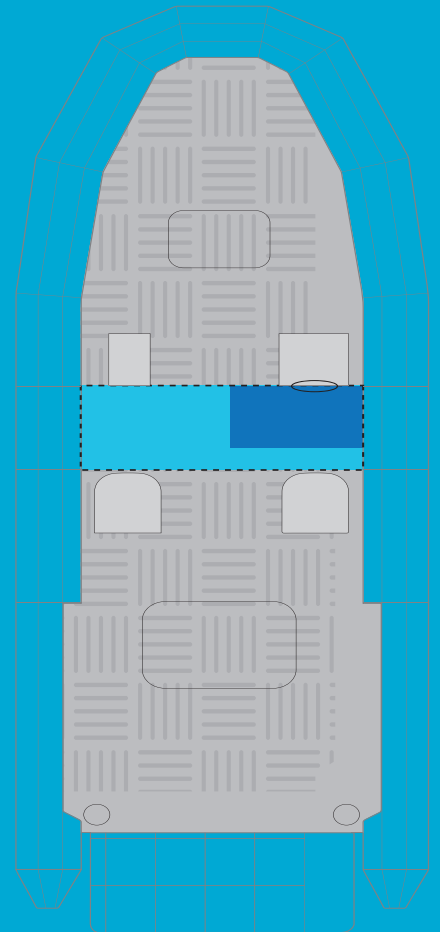
- Shock and impact mitigation
- Easy installation and minimal maintenance
- Durable and proven products
- Stability underfoot
- Self-draining and anti-slip
- Traction surface for deck cargo
- Resistant to fuel damage and UV tolerant
- Puncture and tear resistant
- Lower cost alternative to shock-mounted/suspension marine seating

Available in four products based on the desired level of deck coverage and customization required, SKYDEX Boat Deck Max Coverage, Helm Custom, Helm, and Personal, all feature the same SKYDEX shock mitigating technology.

Military Proven Technology

SKYDEX has been providing protective technologies for the military for over 10 years and has become the leader in energy attenuating decking. SKYDEX Convoy Deck has been fielded in over 20,000 armored vehicles worldwide and is the go-to solution for high energy threat mitigation from under body blasts. It has proven to increase war fighter survivability and resist the rigors of combat.

SKYDEX Boat Deck Products

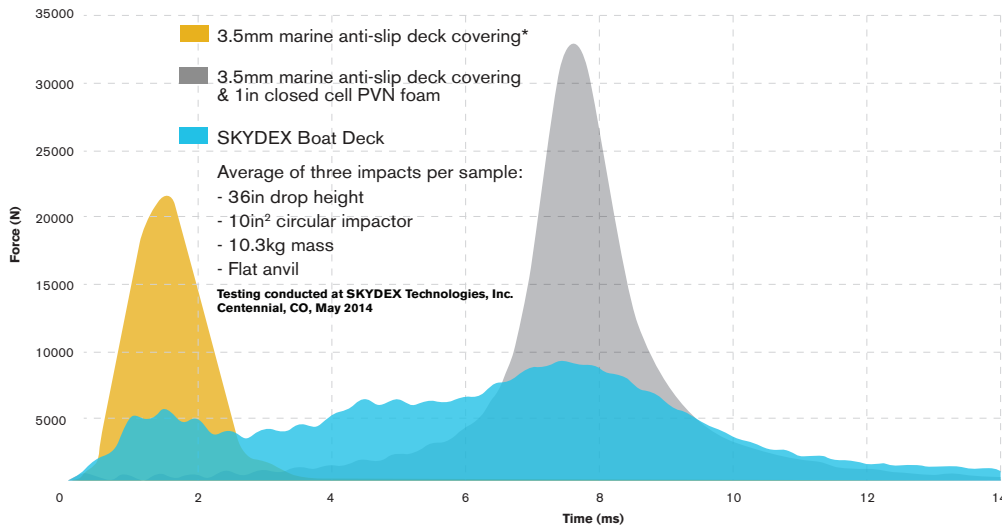


Testing the Problem and Solution

Laboratory testing demonstrates that the shock transfer to humans from non-cushioned deck surfaces is significant in moderate and severe sea states and in calm seas with small craft traveling at high speed. The hulls of high-speed marine craft are manufactured primarily from aluminum and composite materials, which are not designed to absorb these forces. In fact, some composite materials add to the shock felt by those riding in marine craft.

SKYDEX Boat Deck for Shock Mitigation

Impact testing was performed using a state-of-the-art high speed impact machine from CEAST-Instron capable of impact speeds from 2 to 24m/s and 3 to 70kg impact mass. The sample was placed on a rigid base while the force was measured by a load cell located in the impactor. For these tests, a 10kg mass was chosen to simulate a partially supported person combined with a 3.54" diameter flat impactor to simulate the approximate area of the average military boot heel. The direct output is a force time plot. High-speed video, 5000fps, was also used to help in the data analysis.



*3.5mm marine anti-slip deck covering was only tested to a drop height of 12in to avoid damaging the test equipment

SKYDEX Boat Deck

has been tested to and passed the following:

- FST – FMVSS302* and has been tested in accordance with:

- BSS 7239*

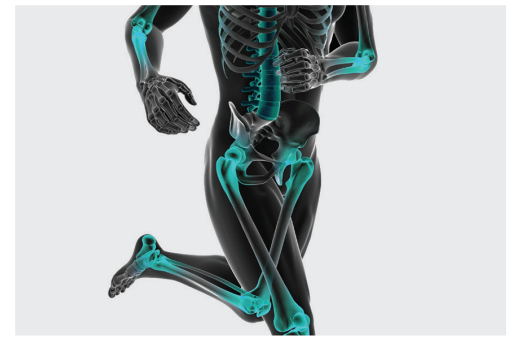
The traction surfaces have been tested in accordance with:

- Slip Test – ASTM F1677**
- UV Exposure – ASTM G154-06
- Salt Spray Resistance – ASTM B117-03

in addition to SKYDEX corporate testing for temperature cycle, cold crack, hot melt, bond strength, and accelerated temperature.

*Applies to Max Coverage product

**Applies to Max Coverage, Helm & Helm Custom products



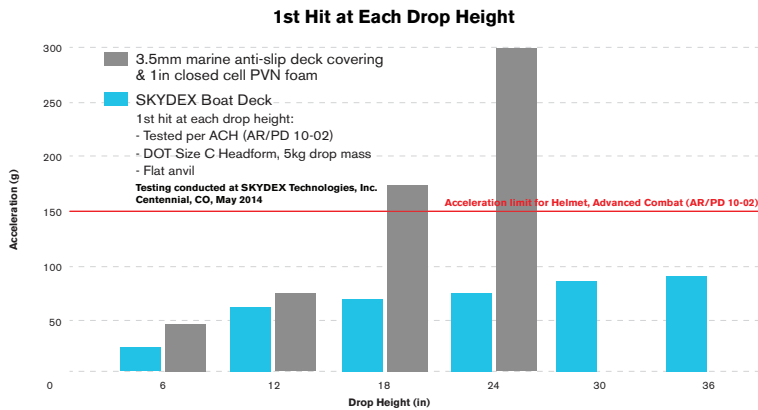
Testing has shown that the human body takes 50 milliseconds to react to shock and prepare for impact.⁶ SKYDEX Boat Deck proves that it not only mitigates impact, but it also extends the event over a longer period of time by using the energy of impact to deform the technology before that energy can be transmitted to the occupants. By extending the duration of the event, SKYDEX Boat Deck is able to absorb the same energy at a lower peak force.

⁶ Skurvydas, A., Gutnik, B., Zuoza, A.K., Nash, D., Zuoziene, I.J., and Mickeviciene, D. 2009. Relationship between simple reaction time and body mass index. Journal of Comparative Human Biology. Vol. 60, Issue 1.

SKYDEX Boat Deck for Impact Absorption

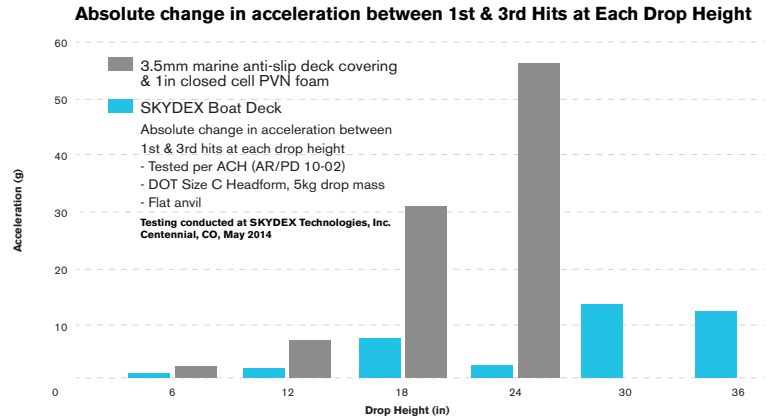
The unpredictable nature of the marine environment has made it difficult to establish set criteria for impact standards on marine craft. Impacts are not only caused by energy transmitted through the deck during wave slam, but craft occupants can also be thrown onto the deck or other fixed features on the craft in rough water.

To relate impact absorption to deck cushioning, testing was performed per the Advanced Combat Helmet Impact Standard (AR/PD 10-02). Using a DOT headform, outfitted with an accelerometer, the test measured the acceleration acting on the head form via impact on a Cadex monorail impactor. Three drops were performed on each material in 6" height intervals. The 3.5mm anti-slip deck covering was excluded from this test due to the lack of any impact mitigation layer.



*3.5mm marine anti-slip deck covering & 1in closed cell PVN foam was only tested to a drop height of 24 inches to avoid damaging the test equipment

SKYDEX Boat Deck showed consistent results across all three drops while the foam backed anti-slip mat did not. In addition, the SKYDEX Boat Deck is made from highly durable materials that can withstand multiple impacts with limited change in performance.



Summary

While the hazards caused by shock experienced on the water are widely known, the ability to effectively analyze the problem and evaluate solutions is difficult in the unpredictable marine environment. As boats are becoming more powerful and craft occupants are spending more hours on the water, there is an even greater need for an effective and efficient solution.

SKYDEX Boat Deck has proven to mitigate shock levels and severe impacts while providing a stable walking surface for marine craft occupants. By lengthening the duration of the event, therefore reducing the peak acceleration which results in a reduced force experienced by the occupant, SKYDEX's high-performance products increase comfort on the water, optimize operational effectiveness and better protect occupants of high-speed craft against the proven factors that lead to injuries.

About SKYDEX® Technologies, Inc.

SKYDEX, an ISO 9001:2008 registered, privately-held technology company, is an industry leader in developing protective materials that mitigate shock, dampen vibration, and provide superior cushioning for the most demanding military and commercial uses. With superior durability, cleanability, and performance, its innovations include blast-mitigating flooring for combat vehicles, padding for military helmets, shock-absorbing decking for high-speed boats, personnel protection equipment, and footwear. SKYDEX serves consumer, commercial, and military customers, and is a leading global supplier to the armed forces. Inspired by its motto 'Protecting Things that Matter', SKYDEX utilizes its patented geometry-based technologies to help clients maximize the performance and long-term value of their most important assets-that-matter. For more information, please visit www.SKYDEX.com.

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