High Speed Craft

Prepared by: American Institute of Marine UnderwritersTechnical Services Committee

Introduction

High-speed craft are creating considerable excitement and opportunity in the marine industry.

Fast ferries are becoming a vital component of the international transportation industry.

The construction of high-speed craft, such as ferries, has been a boom for the marine design and construction industry. Currently, it is estimated that North American shipyards hold a thirty percent (30%) market share of the worldwide construction orders for High-Speed-Craft.

Successful commercial high-speed craft have been operating internationally since the late 1950s. Examples include monohulls, hydrofoils, and surface effect vessels such as the British Hovercraft. Since the 1960s the English Channel crossing from Dover to Calais was performed on the British built SR.N4 Hovercraft. This vessel could carry 254 passengers and 30 cars at a service speed of 65 knots. Interestingly, the 42-knot, 260-person hydrofoil that operates from Hong Kong to Macau was designed and constructed by Boeing Marine in the 1970s.

On July 20, 1998 "CAT-LINK V", a wave-piercing catamaran constructed and designed by INCAT of Australia, set a new speed crossing record and was awarded the Hales trophy, the Blue Ribbon of the North Atlantic. "CAT-LINK V" traveled from New York to Bishop Rock in 2 days, 20 hours and nine minutes at an average speed of 41.284 knots. The voyage included a two-hour deviation to assist with a search and rescue operation looking for a ditched plane. The 34,000 horsepower ferry is 91.3 meters length overall and has the capacity to carry 800 passengers and 200 cars. (Although to many, the true champion will always be the SS "United States," that ran at a speed of 35.59 knots on its maiden voyage in 1952.)

There is no standard definition of a high-speed craft. The International Maritime Organization (IMO) has a definition, but this is only for vessels engaged in international routes. The US Coast Guard has no specific definition. Certain classification societies, including ABS, have developed special rules for the construction of high-speed craft, and have developed complicated formulas for determining whether a vessel is considered one. Determination is a function of length, displacement (weight) and the speed of the vessel.

For purposes of this paper, high-speed craft are defined as commercial vessels capable of a service speed in excess of 25 knots and the ability to carry a minimum of 35 passengers and/or commercial cargo. The focus of this paper is on vessels under 125 meters LOA, engaged in domestic service; otherwise, the super liners such as SS "UNITED STATES" and the "QE2" would require comment.

Domestic applications for HSC are primarily in the passenger ferry service. Some are used on protected inland waters, for commuting purposes, such as the Washington State Ferries, and others are built for offshore service, shuttling passengers along coastwise routes. An example would be Fox Wood Casinos, with 47' catamaran fast ferry service between Long Island and Connecticut. There are also plans for HSC ferry service between the Florida Keys and Miami.

Although this paper seeks to limit its discussion to vessels under 125 meters in length, there are some recent developments in high-speed ocean freighters that are noteworthy.

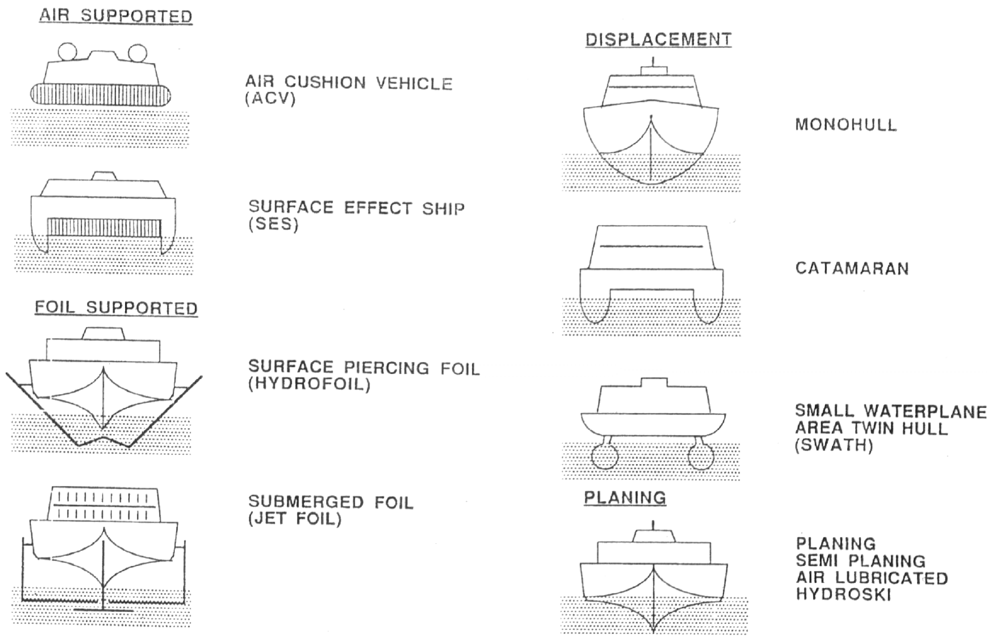
FastShip Inc., a Philadelphia-based business venture, plans to build and operate high-speed container ships. These ships will operate between Philadelphia and France and are designed to provide Atlantic crossings in four (4) days. FastShip is attempting to serve those customers that cannot afford the high cost of air freight, but need faster service than what can be provided by conventional container ships. FastShip has obtained MARAD Title 11 loan guarantees, received design approval from Det Norske Veritas (DNV) and has awarded a contract to NASSCO for the construction of its ships, which are expected to be delivered in 2002.

Swiss based Norasia has announced the design of a new ship called "Pentamaran," by Britain's's Nigel Gee & Associates, Ltd. The ship is a long, slender container ship that uses outriggers called outer sponsons, which are designed to stabilize the ship in high seas. According to Norasia, the vessels also designed for Atlantic service are capable of carrying 13,000 tons of cargo at an average speed of 37.5 knots.

High-speed craft represents a growing segment of the maritime industry. Currently, there are over 100 HSC in service domestically, with another 15 under construction. This paper will review the types of these high-speed craft, including the hull construction, propulsion systems and current certification and inspection requirements. The paper will also discuss a few recent losses, involving high-speed craft, and conclude by commenting upon some of the unique exposures that these vessels present to underwriters.

TYPES OF HIGH-SPEED CRAFT

High-speed craft can be classed in two broad categories, Air-Supported and Displacement type. Air supported craft include Air Cushion Vehicles (ACV), Surface-Effect Ships (SES) and Foil Supported craft such as hydrofoils and jetfoils. Displacement type vessels include conventional monohull, catamaran, trimaran, small waterplane-area twin-hull (SWATH), and air lubricated hulls. While each type of vessel has its own unique characteristics, they all suffer from the common problem of limited payload and a sensitivity to wind and sea state.



Air-Supported Vessels:
An Air Cushion Vehicle (ACV) is a craft that is entirely supported by air pressure, in close proximity to the surface. It is suitable for use over water or land. Its versatility makes it a vehicle of choice in situations where area remoteness, inadequate water depth, or lack of suitable shoreside facilities is a problem. To retain the cushion of air beneath the vessel, it is outfitted with a flexible seal called a skirt. This allows a clearance between the vehicle and the surface it is traveling over and allows objects such as rocks to pass safely beneath the vehicle. Air does leak out from beneath the skirt but this is made up for by lift fans. Load balance in this type of vessel is critical in order to properly balance the air pressure beneath the vehicle.

Surface Effect Ships (SES): A Surface Effect Ship operates solely over water and a small percentage of its displacement, about 10%, is supported by catamaran-like sidehulls. This type of vessel has a shallower draft than a conventional catamaran and due to the lower displacement, creates considerably less wake. Due to the rigid sidehulls, a SES has flexible seals only at the bow and stern and requires less lift capacity than an ACV.

Foil Supported Craft: Foil Supported Craft, such as hydrofoils and jetfoils, have a deeper displacement than ACV's and SES's and tend to be more stable, providing a smoother passenger ride. Hydrofoils are not hovercraft. Hydrofoils fly on wings in the water: whereas, hovercraft float on a layer of air above the water. Due to their deeper displacement they are also more susceptible to damage from floating debris.

Hydrofoils: A proven design with many built to service international inshore and near coastal routes since the 1950s. Foils extend from adjustable arms that act as the lifting surface at operational speeds. The foils create a lift that fully raises the monohull out of the water. The raised hull will experience less drag and the effects of the seas are reduced. Hydrofoil configurations can be divided into two general classifications, surface-piercing and fully submerged. Newer designs incorporate computers, which can adjust the foils during operation to attain performance improvements. A hydrofoil must be able to operate safely during both hullborne mode, during takeoff, and foilborne operation. Propulsion systems are typically a variation of surface piercing and submersible outdrives.

<u>Displacement Type</u>:
Conventional Monohull: Adapted from the military, the high performance monohull design can be clearly seen in destroyers and other fast frigates. These vessels are characterized by slender narrow hulls, high speed and the ability to operate in varied weather conditions. While highly maneuverable, this type of vessel is sensitive to wind and wave action unless stabilizers are utilized. The FastShip design is an example of a high performance monohull design, and Norasia is an example of a monohull with stabilizers (outriggers). This design offers the most cargo carrying capacity per displaced ton. Most conventional monohulls operate on the comparatively lower spectrum of speed.

Catamaran and Trimaran Hulls: A catamaran is a displacement vessel with two slender hulls. (Trimarans have 3 hulls) The use of two hulls results in a vessel with a lot of space. It is particularly well suited for carriage of passengers and low-density cargoes. The twin hull design produces a very stable platform, which makes it particularly suitable for use in fast ferries.

Asymmetrical Catamarans: The most basic version of a multihull. It is simply a monohull vessel with a slot cut out in the middle. Asymmetrical catamarans were more popular in the 1970's than today.

Symmetrical Catamarans: An improved catamaran design with numerous hull shape variations that feature two symmetrical hulls. This improves upon the performance and directional stability of the asymmetrical catamaran. The hulls of the vessel are designed to operate as displacement/semi-displacement hulls with the deck area elevated above the operational waterline. Often the main deck is higher out of the water in comparison to the asymmetrical catamaran, an improvement in rough sea operation.

Wave-Piercing Catamarans: INCAT of Australia has popularized this design. It is a symmetrical catamaran hull with an extended bow section. The bow section designs have many versions, most end in a noticeable aggressive taper. The bow section is designed to operate below the water surface and the after sections operate in a displacement/semi-displacement mode. Since water is more stable below the surface, the wave-piercing catamaran has excellent exposed water performance.

SWATH (Small Waterplane-Area Twin-Hull): This is a modification of a catamaran design. SWATH design is distinguished by two tubular submerged lower hulls, connected to the upper catamaran hull by narrow struts. The torpedo-shaped hulls operate below the waterline. The concept is to put the ship’s buoyancy beneath the sea surface and provide minimal surface area at the waterline for waves to act upon, producing excellent sea-keeping ability. Although not generally as fast as a pure catamaran design, due to its excellent stability characteristic, this type of vessel is extremely well suited for service as an excursion or dinner cruise vessel.

Air Lubricated Hull: This type of hull is more commonly known as a planing hull. At higher speeds the bow lifts out of the water and is supported by the passage of air beneath it, while the stern is in a displacement mode and is supported by the sea. It operates the same as smaller yachts and personal watercraft.

Design and Construction Issues

Most classification societies have criteria for high-speed craft construction. Studies are being undertaken to improve upon international standards pertaining to high-speed craft.

The latest versions of high-speed craft are highly engineered, technically sophisticated, and specialized craft. In general, the hulls are constructed utilizing weight-saving materials. Weight has a detrimental effect on speed and efficiency. Every pound of weight saved in structure, outfitting and machinery means added performance as well as weight available for payload and fuel. During the design process, the stress analysis of the hull is looked at very carefully. Ultimately, the hull has to be as stiff and light as possible. To accomplish this, most hulls are constructed utilizing marine grade 5000 series aluminum and/or composites. If steel is utilized, it is typically a high tensile variety. Composite construction, utilizing carbon fiber or other high tech materials, is the lightest and most expensive construction method due to the cost of the raw materials, and the expenses involved with molds, tooling, lamination and curing processes. Typically, composite hulls are found on vessels less than 30 meters LOA where speed and efficiency is at a premium.

Steel is used to reduce the cost of the construction when the design is less weight sensitive. Designs often integrate numerous construction materials. An example of this would be an aluminum hull with a composite superstructure. The process to join aluminum to steel has improved.

Most multi-hull designs have less speed loss in rough seas than conventional vessels due to reduced pitching motion. Directional stability and maneuverability at both low and high speeds are reported to be good due to the separation of the hulls and the outboard location of propulsion units. Passenger comfort is improved due to reduced pitching/rolling motions. Multihulls, in general, have reduced cargo carrying capacity per displacement ton than mono-hulls. Due to the higher center of gravity (lower GM) weight distribution is more sensitive. Several multi-hull designs, such as SWATH vessels, have considerable drafts. Additionally their molded depth creates substantial windage.

High-speed craft have abundant specialized equipment such as stabilization units to increase passenger comfort. They depend upon computers and chip technology to assist with the control and operation of many high-speed craft. The passenger accommodation areas often feature aviation seating.

In most circumstances the vessels are designed for specific geographic operations and services. The intended utilization is analyzed pertaining to route, service, speed, passenger/cargo capacity, passenger comfort, and local environmental and operational issues. The specific design parameters of a particular vessel may make it difficult to modify its use and specific service during its expected life cycle.

Underwriters should pay special attention to the design and construction of high-speed craft. Designs and construction from reputable firms and yards are favored. Classification status from a reputable Society is important. The ability for a vessel to remain afloat after a casualty should be reviewed; paying particular attention to hull compartmentation and reserve buoyancy is recommended. If the vessel is not new, its previous service history should be requested. Special attention to recurring problems or downtime should be made. Many designs have largely been unproven over a period of time and service. The rational life cycle of the design may be unknown. Hull failure resulting from cyclic loading has been reported. The dynamic stresses sustained to the hull during high-speed operation in changing conditions may not be fully accounted for in computer models and tests during the design phase. The specific design of a vessel may make it suited for utilization in very limited geographic areas. This requires that any changes of service be analyzed carefully to ensure that the vessel is suitable for its intended purpose. Several of the designs utilizing narrow struts and appendages may be more susceptible to cyclic failures or exaggerated damages due to a casualty, especially at high operational speeds.

Propulsion of High Speed Craft

Hull designs are important, but only substantial horsepower can propel the craft. Fuel economy is not associated with high-speed craft. The power-to-weight ratio is an important consideration for engines to be used in high-speed craft. The most common main engines are medium and high-speed diesels. These engines typically are turbo-charged and often are equipped with digital electronic controls to squeeze the maximum horsepower from the unit. When the power-to-weight ratio is of utmost priority, and performance is more important than fuel economy, gas turbine engines are used for primary or auxiliary power.

Traditional propeller configurations have a tendency to cavitate and lose efficiency at higher speeds. To maintain propulsion efficiency, designers have utilized a variety of propulsion packages including specially designed propellers, variable pitch propellers, surface drive outdrive units, and jet drives. Water jets have become the most common means of propulsion, for HSC.

As mentioned, the propulsion of a high-speed craft can be by either the conventional shaft and propeller, or by water jet propulsion. Both designs can be powered by a conventional diesel engine or by a gas turbine. To propel large ships at high speed requires the use of a high-power propulsion plant.

1. Conventional Shaft/Propeller

   New propeller designs, like the super-cavitating or surface-piercing propellers, are often the most fuel-efficient alternative for high-speed ocean going vessel propulsion. The propulsion is basically the same as found on other ships, however, larger prime movers are required.

The high-speed craft perform more like a planing craft. The longitudinal center of gravity is further aft compared to lower speed vessels.

Tests on high-speed craft have shown that a "hump" in the resistance versus speed performance is present, especially in heavily loaded conditions. When increasing the speed from low speed to 35 to 40 knots a change in the vessel's trim can be observed as the vessel accelerates. Conventional propellers tend to exhibit cavitation or thrust breakdown at these speeds, which can dramatically reduce their efficiency. The use of water jet propulsion at these speeds and load conditions appears to be a good match.

2. Water Jets
   Water jets are apparently the propulsion of choice for most high-speed craft. With careful hull integration, they can reduce power requirements relative to an open screw propeller. They eliminate the need for rudder and appendages and create a favorable propulsion/hull interaction.

Another advantage is related to the mechanical transmission systems. Water jets typically rotate at higher speeds than sub-cavitating propellers. The reduction ratio is therefore reduced, which means a smaller and lighter gearbox can be utilized.

The water jet system basically consists of the following:

1. The prime mover (diesel engine or gas turbine)
2. The reduction gear
3. The shafting
4. The pump unit
5. The inlet duct
6. The steering and reversing gear

All the above are controlled by a central control system. For reference purposes, a system overview of a water jet propulsion system is attached to this report, as well as some examples of different propeller designs.

1. The Prime Mover
   While the prime mover can be one or more diesel engines, gas turbines provide the power densities necessary to reach the high power levels to drive large vessels at high speed.

   Existing gas turbines for marine application develop up to 67,000 horsepower @ 3,600 rpm. A larger version for non-marine purposes develops 125,000 shaft horsepower, and it is most likely only a matter of time and market demand before such a gas turbine will be developed for marine use.

It is our opinion that the risks from these systems for Hull and Machinery underwriters are not much greater than with the present systems. Diesel engines and steam or gas turbines have been on board vessels for some time, and should be familiar to qualified engineers. Domestically, however, there is a lack of qualified and/or experienced engineers with these new types of propulsion systems. This can be a crew training and licensing issue, which is discussed in the following section.

INSPECTION & CERTIFICATION

IMO's High-Speed Craft Code applies only to vessels engaged in international trade service. Domestically, HSC passenger carrying vessels are required to be US Coast Guard inspected; however, the Coast Guard does not differentiate HSC from other passenger vessels. Consequently, HSC passenger vessels would typically fall under the regulatory standards for subchapters T or K. This is an example of regulations not keeping pace with technology. Not the least of the concerns is the lack of any specific requirements for crew training, relative to the operation of HSC.

In recognition of this, the HSC industry has formed the High Speed Commercial Craft Safety Board, which is comprised of membership from the major operators of HSC, the US Coast Guard and certain port authorities. This committee is establishing voluntary training guidelines for the operation of HSC.

Similarly, the Passenger Vessel Association (PVA) and the US Coast Guard have recently announced that they have agreed to sign a charter to establish a Natural Working Group (NWG) for industry standards. These standards would apply to passenger vessels engaged in domestic trade, that are not covered by the IMO High Speed Craft Code. The NWG's objectives will be to produce the following deliverables:

- Definition of High Speed Craft
- Industry recommended guidelines for crew training
- Industry recommended content for vessel operations manuals
- Minimum carriage recommendations for bridge navigation and communications equipment

Most of the major classification societies do have special design and construction requirements for HSC. Here, High-Speed-Craft is defined by a formula that considers the vessel's length, displacement and speed. Some of the unique design and operational requirements include:

- Operating distance from a port of refuge
- Limited service due to weather and sea state operating restrictions
- The high speed of the craft
- Approved maintenance and repair schedules
- The use of probability concepts and failure mode effects to determine relevant safety criteria

LOSS EXPERIENCE

The most common type of losses reported with HSC is damage to the propulsion and/ or outdrive units, due to striking debris in the water. In the northern environments, ice can create similar problems. The propulsion machinery, in general, is subject to a higher frequency of failure than convention propulsion units. Obviously, due to the higher operating speeds, when losses do occur, they can be more severe.

The following is a brief summary of some of recent losses, involving HSC, which the committee members have reported.

1. A high-speed offshore, SWATH design vessel sank during its maiden voyage. The sinking occurred in approximately 12-foot seas. The crew abandoned to life rafts, and there was no loss of life. The vessel was a total loss and was never raised. It was reported that structural damage had occurred to one of the pontoons, in way of a connecting strut. It was suspected that the vessel was pounding in heavy seas, traveling at too great a speed. Contributing to the loss was the loss of electric power, due to flooding of a machinery space through ventilation openings in the hull. The vessel also had ventilation cowlings built into the watertight door, leading to the generator room, which compromised the integrity of the door. Subsequent investigation revealed the vessel to be a non – load lined ("Rule Beater design) design.

2. A collision recently occurred between a commercial fishing vessel and a high-speed ferry. The HSC was a 300' wave-piercing catamaran. The collision resulted in a fatality to the Captain of the fishing vessel and extensive hull damage.

3. An incident was reported involving a high-speed passenger ferry. The vessel was underway when it encountered a rogue wave. The vessel dove down into the wave with the wash covering the main deck. The windows about the passenger area were shattered and fifteen (15) people were injured by flying glass. Subsequent investigation revealed that the windows were built with tempered glass instead of shatterproof safety glass.

4. A 47-foot fast passenger ferry (catamaran hull) had its wheelhouse windows blown out, when it "dove" into a wave. This resulted in sea water swamping the wheelhouse and some flooding, causing extensive electrical and interior damage.

UNDERWRITING CONCERNS

There are several policies that are typically attached to a high-speed craft risk. The following is a brief discussion of specific concerns that accompany this class of vessel.

Hull & Machinery:

When considering these hulls for underwriting purposes, the underwriter should bear in mind a number of factors. Due to their unique design and manufacture, the hull values are apt to be significantly higher than a conventional hull. Spare parts for engines may not be readily available. Personnel to maintain and service the engine may need special training and costs of repair are apt to be higher. Most damage due to collision or allision is likely to be severe due to the high speed involved.

The specialized construction of the vessels' hulls will complicate the repair process and result in more expensive claims than would result with similar damage to conventional hulls. Many local repair yards may be unable to service these vessels. This may require transporting the vessel considerable distances for repairs, or may require mobilizing repairers to local yards. This may reduce the potential for competitive bids to perform repairs. Licensing of designs may require that a licensed repairer perform work to maintain warranties. The width of the vessels may prohibit dry-docking in local yards. Factory representatives may only service some specialized engines and propulsion systems; this can increase machinery repair costs. The maximization of horsepower from a given engine package may reduce the time between overhauls and the life expectancy of the engine.

Protection & Indemnity:
Although relatively stable at high speed, these craft tend to be more sensitive to rolling motions while slowing down, increasing the possibility of slip and fall injuries. Personal injury due to a collision is likely to be severe due to high-speed impact. Injury while embarking/disembarking is not uncommon. Crew should be available at the gangway to provide assistance.

Another unique concern with this class of vessel is the potential for wake damage to other craft and shoreside structures. Although most of these vessels create a relatively small conventional wake, due to their comparatively small hull displacement, studies suggest that these vessels can create a significant shock wave beneath the surface, which can travel a considerable distance. This underwater shock wave has been termed a "mini Tsunami," and reportedly has resulted in instances of small craft being capsized.

Liquor Liability:
An increasing number of these high-speed ferries serve alcohol to commuters. All normal precautions, such as bartender training, should be observed.

Business Interruption:
The unique design of a vessel may effect her value, if she has limited use outside of her designed purpose. The start up costs of a new high-speed vessel service is considerable and operational costs are high, as well. These costs contribute to a fairly high failure rate of startup private commercial operations.

Due to the high costs, Business Interruption coverage is normally requested. Business Interruption will occur due to a vessel problem or due to a disruption at the berthing facility. Regular maintenance is the best protection against vessel failure. Ideally a formal written maintenance plan is in place with a regular schedule of overhaul activity for the engine. In order to mitigate a loss, alternative vessels, such as excursion boats or whale watchers, that can possibly be put into temporary service should be identified. Disruption of the berthing facility due to storm damage is a very real possibility. Alternative sites should be identified.

Environmental Exposures:
Environmental issues include the vessels’ wake characteristics, exhaust, noise levels and aggravation to sea life. Concerns pertaining to excessive noise levels and hydrocarbon pollutants have been raised in addition to wake issues, concerning aggravation to sea life and coastline erosion.

Here again, there is not only a wake issue, but the submerged shock wave that can be generated by HSC. This underwater wave travels considerable distances before it batters the shoreline and associated structures. Out of concern for the potential for environmental damage, some states have placed speed limits on HSC, operating in their waters.

CONCLUSION

In conclusion, the boom in this segment of the domestic shipbuilding industry, combined with the unique design and construction of high-speed craft, creates an opportunity and challenge for underwriters. The high-speed craft industry is constantly changing, and risk takers should stay abreast of developments and utilize diligent and informed underwriting. To this effect, the committee hopes that this paper will serve as a useful framework for better understanding these types of vessels and the risks associated with them.

Attachments:

- Water Jet System Overview
- Propeller Designs

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