SMUGGLER AND PIRATE GO-FAST BOATS

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The boats used by smugglers over the ocean are often capable of high speed and are known as “go-fast” boats. They are based on the design by Donald Aronow for offshore powerboat racing and his design has been adopted by smugglers to transport cigarettes illegally into Canada; therefore they are sometimes known as cigarette boats. The improvement in planing hull design occurred in 1959 when the so-called "deep-V" for ocean racing put a definite dihedral or dead rise angle in an otherwise flat planing hull bottom. The change became popular and was widely copied as it greatly improved directional stability for open ocean operation. However, the improvement did not affect slamming or pounding by the forward portion of the hull in waves. The latest models are still characterized by hard chines, V-bottoms, and broad transoms to carry maximum planing surfaces as far aft as possible; planing hulls provide a notoriously rough ride in any waves.

The hulls are usually made of fibreglass with a sharp, vertically rounded bow and a transom stern. They are typically 30 to 50 feet long with a narrow beam and powerful engines delivering up to 1000 hp. This gives speeds of greater than 80 kts in calm waters, 50 kts in choppy waters and 25 kts in 1.5 to 2 m Caribbean seas. Because of their speed they can be difficult to apprehend by the coast guard and helicopters are often used as in figure 1. This shows a typical ocean going go-fast boat during a USCG exercise. The forward part of the boat is covered to avoid shipping water when there are significant waves.

Another type of go-fast boat is used by smugglers crossing the St. Lawrence in the Cornwall area of Ontario. The passage between the US and Canada is very narrow and the waters are usually calm so that the deep-V design can be replaced by a flat bottomed skiff version. A crossing can be made in less than one minute and the boats appear and disappear into large areas of reed; this makes it very difficult for the RCMP and the USCG to catch the smugglers.

Operations in rivers, which are generally calm, do not require a covered forward hull as shown in figure 2. This figure shows the sharp bow that tapers off into a dihedral bottom; the dead rise angle is typically a few degrees. There is a hard chine or edge where the bottom meets the sides, which are nearly vertical. The chine ensures that the large volumes of spray created at high speeds are not easily blown into the boat by the wind. The boats achieve their high speeds by planing; the hull area in contact with

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the water surface is minimized by the action of dynamic forces in bearing the weight of the boat and its contents.

Sometimes trim tabs are installed at the transom to offset extreme squat. This has a similar effect to the former use of wedge-shaped blocks under the transom to force the water down and push the stern up toward a more horizontal position. Appendages such as trim tabs have only a limited effect, as they function at the expense of economy and speed. They reduce speed by adding to wetted surface and increase parasitic drag. Reverse curves or warped planes have the same adverse effect by increasing the area of skin friction and distorting the free flow of water past the hull[2].

Figure 1. Typical go-fast boat with helicopter in pursuit.

The RCMP and the USCG also use Rigid-Hulled Inflatable Boats (RHIB); Zodiac is the trade name usually associated with these. Their hulls are also planing hulls but their speeds tend to be limited by insufficient engine power as a result of costs. Smuggling can be so profitable that costs are not an issue for the smugglers and engines are sometimes damaged by driving the boats directly on to the backs of trucks

[2] http://www.globalsecurity.org/military/systems/ship/hydroplane.htm

parked partially in the water. Figure 3 shows a "deployable pursuit boat" tried by the USCG in the Caribbean. They are "Fountain" racing boats[3] with twin 420 hp engines and are capable of over 50 kts. In the year 2000, they were deployed operationally in pairs. They were armed with a prototype light machine gun, the M240. With a crew of two, the boats could carry up to four boarding team members[4].

Figure 4 shows a Zodiac of the type used by the RCMP. (The RCMP boats usually have a deckhouse.) This is powered by two 250 hp Yamaha engines[5]. Figure 5 shows a go-fast boat that was eventually boarded by DHS personnel. This vessel had 3 engines.

Figure 2. US Navy Seals training in Mississippi.

Piracy is common in the Gulf of Aden. The vessels engaged in piracy are typically based in Somalia and many commercial ships and their crews have been taken hostage and subsequently ransomed. The pirate boats are small and only need the ability to catch commercial ships that can travel at speeds up to about 30 kts. The go-fast design is an advantage but is not strictly necessary because many ships

[3] www.fountainpowerboats.com

[4] http://lexingtoninstitute.org/865.shtml

[5] Specifications can be found at www.zodiacmilpro.com.

probably travel at speeds between 16 and 22 kts. An example of a Somali pirate go-fast boat planing is shown in figure 6. This has twin engines and the forward part of the hull is uncovered; the sea is calm.

Figure 3. “Fountain” racing boats.

Figure 4. Zodiac.

Figure 5. Go-fast boat carrying cocaine; boarded by Customs and Border Protection (DHS).

Figure 6. Example of Somali pirate go-fast boat.

The pirate boat shown in Figure 7 has a broader beam and no chine but it still has two engines for speed. This hull is not optimized for speed but this is probably not important. Figure 8 shows a small boat with a single outboard engine. From the shape of the boat buttock, this is likely to be a semi-displacement hull capable of only moderate speed. Note that one of the pirates is holding a rocket propelled grenade and others have small arms.

The pirate boats also include the RHIB type shown in figure 9. They can also have the appearance of fishing vessels as shown in figure 10; with high powered engines these can reach high speeds by planing.

Figure 7. Somali pirates surrendering in general purpose planing hull boat.

Figure 8. Pirates in small planing hull boat with single engine.

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Figure 9. Zodiac style pirate vessel.

Figure 10. Pirate vessel in the dhow style.

Planing Hulls

Boats designed for planing act as displacement vessels at low speeds. As the speed increases the dynamic water pressure tends to lift the forward part of the hull so that part of the weight is compensated by this force. With further increases in speed, the angle of attack (the trim angle) increases causing additional increase in the dynamic lift force, so that there is typically a rapid transition from displacement to planing. Because the lift force helps to balance the boat weight, which is fixed, the area of the boat in contact with the water surface tends to decrease with additional speed increases. To minimize the wetted area, a transom stern is an advantage. Since only a small volume is under water, wave making resistance is likely to be relatively small compared to a displacement ship; in the Kelvin wake, the predominant waves at high Froude numbers are the divergent waves.

The advantage of planing is that, at high speed, viscous drag forces are reduced because the area of the hull in contact with the water is small. However, there is a component of the lift force opposite to the direction of travel. This can be substantial but it is proportional to the boat weight. Therefore, it does not limit the speed.

The disadvantage of planing is that it requires high propulsion power because a part of this power is devoted to lifting the boat's weight. Some hulls fall into a class of "semi-displacement" or "semi-planing". To achieve planing the quarter beam buttock angle should be less than 2 degrees [1]. This angle is a measure of how much the bow must be lifted in a planing configuration; if it is greater than 7 degrees, it will be almost impossible to achieve planing.

As noted by Saunders [2-3], the forces acting on the hull during high speed planing are as follows:

1. The boat weight acting vertically downwards.
2. The dynamic lift force acting perpendicularly to the bottom.
3. The viscous drag force on the bottom and parallel to it.
4. The thrust due to the propeller, which need not be directed parallel to the propeller shaft due to water flow around the hull.
5. A small dynamic retarding force parallel to the bottom due to the fact that the boat is constantly running uphill, effectively on its bow wave.
6. Wave making resistance from the stern area, which may be small.
7. Appendage form and viscous drag.
8. Buoyancy force, which is vertical but small.
9. Wind forces, which are usually small.
10. Spray forces, which tend to be fractionally small compared to the other drag forces.

As noted, the bottom of a planing vessel typically has a V-shape. This V-shape assists in sea keeping and manoeuvrability. The bow is sharp to assist in stability in waves. Many boat hulls exhibit a hard chine, at which the bottom of the hull joins the sides at a discrete edge. This determines the separation points for the flows.

The analysis of planing is complicated because it depends critically on the hull shape and the flow of water past it. The choice of a propeller on various boats, including planing boats has been discussed by Gerr [3]. There is an empirical expression, due to Crouch, relating the shaft horse power, P, the weight of the boat, W, including contents and the maximum speed, U_{max}. This is:

$$U_{\max} = C\sqrt{P/W}$$

where P is the SHP, W is the weight in lb, U is in knots and C is a constant with the value ranging from 150 up to 230 or more depending on the percentage of propeller slip[6]. It seems that this formula is used by Mercury Marine and by Evinrude. As an example, consider the Bayliner 205 power boat of length 20.5 ft, beam 8.2 ft and draft 3.1 ft with dry weight 3045 lbs and maximum load 1200 lbs. With 220 shp at the propeller, the maximum speed of this boat using 190 as the constant is 43 kts[7]. (This constant is appropriate to high-speed runabouts.) Clearly such a power boat would be more than adequate for the purposes of piracy.

Single screw boats usually have a right handed propeller while twin screws are always counter rotating; they are never co-rotating because handling would become extremely difficult. The counter rotation typically causes outward flows at the surface rather than inward flows because this results in greater stability during manoeuvres. However, inward flow is occasionally used to increase flow over a rudder to enhance manoeuvrability. Sometimes three propellers are employed. In this case the centre propeller would be right handed and the outer propellers matched and counter rotating.

Hydrodynamic Wakes

When there are twin screws the motors must be matched so that the screws are counter rotating; For example, Yamaha supplies left and right handed screws for matched motors. Specifications for motors can be found at the Yamaha web-site[8]. The diameter of the propeller is important and for go-fast boats usually lies in a range from 15 in to 18 in[9].

[6] This formula is also given in http://www.go-fast.com/boat_speed_predictions.htm.

[7] This can be compared with 49 kts at http://www.lakesidemarinetopeka.com/site_page_10934/item_392166.html. However vendors are often optimistic.

[8] http://www.yamaha-motor.com/outboard/products/subcatspecs/82/specs.aspx

[9] See http://www.bblades.com/info/therightprop.cfm.

When choosing a fixed pitch propeller for a go-fast boat, the pitch must be matched to the wide open throttle characteristics of the engine. The engine must be able to turn the propeller at its design speed with the throttle wide. Determination of the propeller size includes the hull type, the hull length, the number and type of engine, the shaft HP power, the maximum propeller rpm and the gearbox ratio. A useful calculator has been provided by Castlemarine[10]. For the Bayliner, this program gives a maximum speed of 38.7 kts with a single standard 3-bladed propeller rotating at 3000 rpm and with a diameter of 15.25 in.

High speeds result in heavy propeller loading, which inevitably produces cavitation. To minimize blade erosion, the propellers may be of the supercavitating type. These have specially shaped blades so that the cavitation bubbles do not implode on the blade surface.

Substantial advantage can also be obtained through the use of "surface propellers", which are designed to entrain air and this prevents erosion. The surface propeller is designed to be operated so that each blade penetrates the water surface once per revolution. Aeration implies a small loss of propeller efficiency. The propeller diameter tends to be greater than that of a normal propeller by up to 30 percent [1].

Go-fast boats are likely to produce long visible wakes associated with spray and foam on the water surface. The propeller wake will be significant for a few hundred meters but, because it is likely to comprise waves with high frequencies and short wavelengths, these will die out rather quickly due to viscous dissipation. On the other hand, excitation due to slamming into ambient waves is likely to be very significant and, because the frequencies are likely to be of the order of 1 Hz, the wake is likely to be very persistent, lasting for distances of several kilometres. Such wakes are very likely to be observed in Synthetic Aperture Radar (SAR) imagery.

References

[1] D. Gerr, Propeller Handbook, International Marine, Camden, ME, 2001.

[2] H.E. Saunders, Hydrodynamics in Ship Design, Vol. 1, SNAME, 1957.

[3] H.E. Saunders, Hydrodynamics in Ship Design, Vol. 2, SNAME, 1957.

[10] A useful calculator can be found at http://www.castlemarine.co.uk/pitch.htm.