Submersible Hull Vessel (SHV™) Concept

Executive Summary

The Concept is for a separation of a vessel, whether mono or multi hull, at about the waterline with the upper superstructure part being raised by a jacking method above the lower hull part while the lower hull part is ballasted down to lower the hulls beneath the surface and below the high energy area of waves and swell.

Applicable to mono and multi hull vessels it is believed that concept is scalable right up to vessels in the hundreds of thousands of tons. Adaptations of the concept could be used to provide additional stability to vessels such as passenger ferries or cruise liners as extendable stabilisers. The split hull form could have military applications to provide more stable gun platforms or launch platforms for aircraft or minor vessels.

What this concept does is to provide buoyancy devices, the deployment of which changes the displacement volume of the vessel and alters the centre of gravity and metacentric heights. Every other vessel, whether surface displacement or semi-submersible, have fixed internal volumes. In this concept the vertical members and lifting mechanisms are part of the internal volume of the vessel in hull-up mode, but when in extended hull-down mode they become external to the vessel and therefore increase the total internal volume. This then becomes additional available buoyancy volume.

One application, which is being investigated initially for proof of concept, is for a high speed catamaran with a system to separate the hulls and the superstructure allowing the hulls to be submersed thus becoming a Semi-Submersible vessel providing high stability in heavy seas.

United Kingdom patents pending (GB 2489935).
International patents applied for (WO2012/136980).

The Problem of Wind and Waves.

Waves have a significant energy content which is dependent on two factors, wave height and wave period.

In simple terms energy in a wave increases by a factor of double the height. If a wave of one meter has one unit of energy, a wave of two metres has four units and a wave of three metres has nine units.
How far into the water column this energy extends is a factor of the wave period. Affected depth is half the period. So a 2 metre wave with a period of twenty metres will show typical cyclic energy effects down to ten metres.

However, the energy dissipation is not linear, more than half the energy is expended in the top one third of the energy dissipation zone, so for a 20 metre period that is in the top 3-4 metres.

This is a very simplistic overview, other factors such as depth of water change the dynamics, energy compression, wave height and cyclic motion and affect vessels in different ways.

Ships, by their very nature, floating on the sea, ‘live’, as it were right in the middle of this high energy wave zone and are consequently affected by all the forces generated in waves.
This concept allows a vessel to move from a ‘normal’ surface displacement mode to a semi-submersible mode, and so place the hull either below the energy zone or at least in the lower half where less than a third of the energy resides, whilst raising the superstructure above the wave tops.
Submersible Hull Catamaran (SHC™)

The first such SHV will be targeting the offshore wind energy service and maintenance market, and for that reason is called the SHC Wavedancer™.

This vessel will:

- Have high transit speeds, estimate up to fifty (50) knots.
- Working stability in more than 3m seas.
- Be a safe and stable platform for a personnel transfer system.
- Accommodate a full maintenance crew for at least four weeks at sea.
- Have workshops and ROV inspection capability.

The vessel would use its wave piercer hull design to transit to the field at high speed, then once on site the vessel superstructure will rise above the hulls on hydraulic rams or some other jacking system while the hull is flooded to fully submerge beneath the waves providing a stable working platform.

Internal capacity
This vessel would have high capacity in terms of internal area available for people, much like a high speed catamaran ferry which can carry a lot of people. Though it is envisaged that the numbers may not be high, perhaps 20 or so maintenance people plus crew, the size of the vessel would therefore provide good transit accommodation for daily runs to the field, such as showers, bunks for rest, lounge area, etc. or good accommodation for longer field durations.

Upper Decks
The deck space on the upper deck aft of the bridge because of the size would allow room for FRCs, Life rafts, survival suits, and light equipment / freight, as well as from two to four small maintenance craft for use in good weather to maximise the number of wind towers which could be serviced.

The deck will also have on the stern a stable transfer system to reach the walkway access on the wind tower (or platform). This could be a hydraulically stabilised gangway or ‘cherry picker’ system as shown in the animation.

Size
The vessel is envisaged to be long and wide, probably in the region of seventy (70) to one hundred (100) metres long with a wide beam. This is to give a long hull form for the wave piercer in transit mode and to further dampen residual wave induced motion when in hull submerged mode.
The beam would be as wide as possible, since it is believed that this would aid stability in the submerged mode as well as providing ample internal spaces for accommodation, workshops and deck area.

**Hull Type**
The hull type is a catamaran based on a wave piercer design such that the hulls will go through waves in transit rather than over them allowing high transit speeds. Though SWATH may be considered the propulsion energy requirements for SWATH can be higher than a surface hull model.

The hulls are fully submersible and would contain unmanned, fully automatic engine rooms and compartmentalised flooding systems and high pressure air buoyancy recovery systems to lift the hulls to the surface and above water.

It may be that in the submerged mode extendable stabilisers from the hull could be used to further dampen any residual wave motion.

**Propulsion**
The main engines would most likely be of the Hamilton water jet type, using water pressure for thrust. Each hull would have bow and stern thrusters for low speed manoeuvring, both in hull up and hull down mode. These could be an azimuth system though this would need to be retractable for high speed hull up operations.

Possibly the engines will be fully electrical with the generators either in the hulls or in the superstructure above. If the latter then probably a central compartment on the lower deck would be the generator space for the whole vessel. Also in this case the main propulsion units could be in the superstructure part and be raised out of the water when in submerged hull mode.

If the generators are in the hull then the vertical members to each hull on which the superstructure moves would provide both exhaust venting and personnel access, though it is stressed that in the submerged mode access is only envisioned in an emergency (mechanical/electrical failure).

The vessel would ideally be DP2 or at least DP1, though could be operated in joystick mode.

**Hull Separation**
The mechanics of this would need to be fully investigated, but it is thought that the cross braced scissor jack structure may be most stable, but other forms of jacking could also be suitable.

For the scissor jack there would be hydraulic rams along the top, and of each hull operating horizontally from the centre to the bow and stern, these will push the large cross brace fore or aft as shown. As these are pushed the hull separates from the superstructure and the hulls submerse. Alternatively the hydraulics could be located in the superstructure, or both. Such questions would
be answered in detailed design. Residual buoyancy would be in the design of this bracing and the vertical members so that there would always be an upward lift to the vessel as a whole.

On arrival in the field the hull and superstructure would separate and the hulls submerse. This is another reason for the length of the vessel. The length of about seventy (70) metres would allow for the moveable, hydraulically operated, braces to be about fifteen (15) metres long, giving a hull/superstructure separation of about twelve (12) metres. The ideal separation would be determined in detailed design with wave testing, but this would allow, for example, 6-7 metres below average sea level for the hulls in submersed mode, keeping them under the highest energy parts of wave and sea, and 5-6 metres above the average sea level for the superstructure, keeping it above the wave crests.

This could allow for operations in up to 4-5 metre significant seas.
Transverse Stresses
One problem with this concept is containing the stresses in a multi hull, primarily in high speed transit mode, but also in the hull down mode. Unlike normal large catamarans the superstructure cannot be considered as an integral part of the structural integrity of the hulls, so, effectively the hulls, the connecting structure and the vertical connectors on which the superstructure rides, is the vessel.

Fig-5: This is, effectively, the vessel.

Considering it in that way the superstructure becomes a separate unit which could be changed, the vessel is effectively a hull structure with all the propulsion units onto which different superstructures are placed depending on the function required. This allows standardisation of construction with associated reductions in costs.

The connecting braces could slot in to cavities under the superstructure and lock in place for transit mode operations. To provide for absorption of stresses perhaps some sort of lattice structure could be used.

Operational Criteria
The vessel will need to be able to transit to the furtherest offshore facility (e.g. Dogger bank) and maintain itself at sea for at least 30 days. The distance to the Dogger bank sites is about 150 Nm, so with a transit speed of around 40 Knots that would give less than four hours for transit, in good conditions, but should be able to transit even in moderately rough weather.
Once in the field the vessel could remain in hull-down mode (the amount of separation dependent on the wave height) and could act as comfortable accommodation for personnel on site for a duration of a month or more and sustain operations in quite high sea conditions. Alternatively, for sites closer to shore the maintenance could be done on a daily run from shore because of the high transit speeds.

The high transit speed, large passenger capability and stability for transfers would make this a viable alternative to helicopter transfers to offshore oil and gas platforms, particularly when the costs for helicopter usage is considered.

**Personnel Transfers**

The transfer system will be a motion stabilised system. This does not need to be engineered to cope with the larger vessel movements a normal hull form (non semisub) would make. Even in only 2-3 metre seas dynamically stabilised systems are complex to design and mechanically difficult to try and compensate for extremes of motion. By taking most of the motion out using the vessel makes any transfer system designed to those levels safer to operate because it would never reach the extremes of its operating range.

The operational transfer mode will be stern to the structure so that the vessel is always in line with wind and sea and downwind from the structure. Therefore any mechanical problem and the vessel is in a ‘blow off’ situation and can easily move away from the structure, or drift off in case of total power failure.

**Other Possible Applications**

Mention was made in the Executive Summary to other applications, some possibilities are:

- Very large heavy lift vessels (mono or multihull) allowing normal vessel transit speeds and access to normal ports in hull up mode, while providing stable working platforms in hull down mode.
- Military vessels for fast transit and stable platforms for operations.
- Dive support vessels for stability, and increased bottom time.
- General offshore supply vessels / platform support vessels.
- Hydrographic survey vessels giving a very stable survey speed platform with acoustic sensors deployed well below the thermal mixing and swell noise zone.
- Oceanographic vessels giving a stable platform for deployment and recovery of equipment.
- Cable or pipelay vessels (particularly reel variety) giving fast transits for re-spooling and extended weather windows for laying.
- Variations on the patent also allow for other possible stability uses for large vessels such as cruise liners.