Hybrid vehicle for hull and pipe inspection

A new hybrid concept incorporates the attributes of both the autonomous unmanned vehicle (AUV) and the tethered remotely-operated vehicle (ROV)

Boston-based SonicWorks has developed a concept vehicle and support systems necessary to implement a comprehensive underwater robotic solution to what it perceives as the future of the oil and gas field service industry. A major element of this programme is its Hybrid AUV/ROV called the *Bee*. This concept vehicle is derived from SonicWorks high-speed automated scanning ROV used for hull inspection.

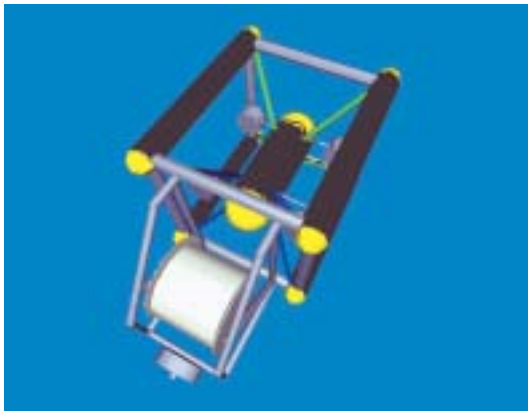
SonicWorks' hybrid concept incorporates the attributes of both the autonomous unmanned vehicle (AUV) and the tethered remotely-operated vehicle (ROV).

The hybrid distributes vehicle mass and flotation equally, a major departure from the conventional ROV model where flotation is positioned high in the frame and counter balanced with weight on the base. The conventional ROV achieves its stability through this mass and flotation placement resulting in very little pitch, roll or yaw during thrusting. However, this stability comes at a cost – higher hydrodynamic drag, larger vehicle size and limited accessibility.

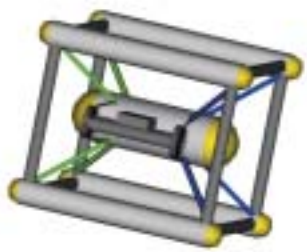
The drag profile of the typical ROV favours fore and aft motion for lateral or vertical ability. These tradeoffs limit the vehicle's ability to hold position or make headway with lateral currents.

The hybrid's optimised hydrodynamic drag profile exhibits a lower surface area in all directions, giving it the ability to direct full thrust at any angle. This allows the vehicle to operate efficiently in all conditions.

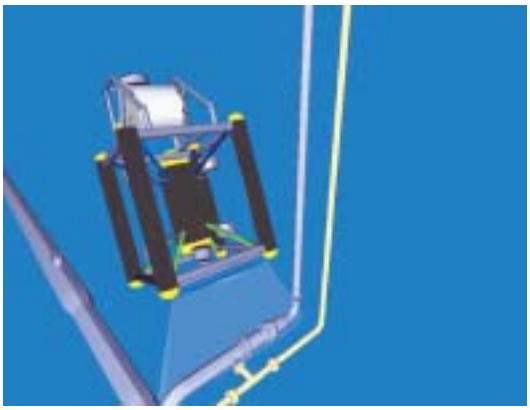
The second major departure of the SonicWorks vehicle is in the use of articulated thrusters. Four steerable thrusters control



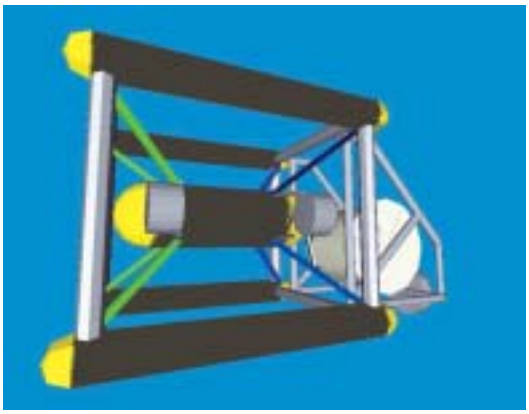
The Bee with cart



The Bee vehicle



Bee valve inspection



Side view of the Bee with its cart

both direction of motion and vehicle attitude. Since the control scheme is too complex for direct human control, a fly-by-wire system has been developed. This endows the vehicle with the ability to operate at any attitude and with currents exceeding six knots.

The control computer handles vehicle position and attitude and effects of current while the pilot directs the desired flight path. The hybrid vehicle will also have the ability to fly pre-programmed fight paths and automatically follow contours.

The fly-by-wire control is accomplished through support of the SonicWorks Acoustic Positioning System (APS) and an integrated IMU (inertial management unit). The SonicWorks APS provides centimetre accuracy for real-time position and attitude control.

The APS forms a precision underwater navigation equivalent of terrestrial GPS. The positioning system is designed to provide wide area network control for water volumes up to 1km and local area network with precision control in volumes of 100m. The network cell can be chained like modern cellular phone systems to achieve position and control in any volume of water. The system is line of site and uses multiple network stations to illuminate what would normally be shadowed, insuring uninterrupted coverage of the work area.

In conventional low frequency acoustic positioning systems, accuracy and update rates are limited by ambient noise, reflection and coupling of acoustic energy. With conventional systems, where accuracies are measured in meters and update rates in minutes, active vehicle control is not a consideration. These systems are further frustrated by speed of sound coupling problems when operated near underwater structures.

The speed of sound through water is the basis on how all these systems work. The coupling of nearby steel structures where the speed of sound is roughly four times higher, produces wild fluctuations causing the positioning system to fail where its needed the most, close-in work.

To combat these limitations, SonicWorks APS uses multiple high frequencies and power control to prevent sonification or overdriving. The system incorporates advanced signal processing to recover position and control data from otherwise noisy environments. The SonicWorks hybrid, like its hull inspection vehicle brother, will operate reliably and precisely for close-in work.

The hybrid concept vehicle also supports operation of multiple vehicles within the same control area. This is a major enhancement over conventional positioning and control for operation of vehicles in current oil and gas fields. The combination of USB (ultra short baseline) positioning systems used in current ROV positioning, sonar and altimeter systems prevents operation of more than one vehicle system at a time. The workaround, assigning operating periods, is hard to coordinate and cannot support simultaneous vehicle operation.

The SonicWorks APS has the ability to co-exist with current LBL (long base line) and USB positioning systems and can be both passively or actively integrated into an overall position network.

The Bee is designed to operate from a tether or free fly. The free-flight mode is powered by battery and controlled through pre-programme or under acoustically transmitted commands. For the long descent from the platform to the work site and the trip back, the vehicle flies a pre-programmed course. The flight is accomplished as a controlled glide to conserve power. Drop weights are used to control descent and assent rates. The thruster cones act as rudders steering the vehicle along its course while the fans remain inactive. During travel to and from the work site, the vehicle carries a light weight tether management system. The tether cart is designed to attach to an under sea power port and deploy up to 50m of 9mm tether.

Typical subsea operations will use the tether system and power from the subsea docking interface. In some circumstances, it will be necessary to free fly and leave the tether behind. During free flight at the work site, the hybrid vehicle must be able to carry on two-way acoustic communication. The APS provides the control source to direct its flight and establish its position over a 230k baud acoustic modem. The communication system supports simultaneous command and control with compressed video transmission. Full resolution video, still images and scan data are stored in onboard memory. Upon docking, the vehicle downloads its data and recharges its batteries. This interface has been designed to provide reliable coupling and years of service. The interface and position control stations will be located throughout the subsea structures and use current umbilical technology for power and data transmission.

While operating at the work site, the vehicle uses a virtual overlay of the sea floor and structures. The operator is presented with a virtual presence created from computerised engineering drawings and/or surface scan data generated by the vehicle systems. This vision augmentation would insure safe operations in the inevitable clouds of bottom

Bee launched from pool

debris and low light environment. The combination of precision positioning and as-built CAD models creates virtual 'keep out zones,' preventing collision which could damage the vehicle or structure.

Operations

A hybrid concept AUV/ROV presents a huge reduction in support costs. The support systems for typical heavy work class vehicles cost many times that of the actual vehicle. The tether management system and heave compensators necessary to support operation in 5000ft of water are complex and expensive. The support ship needs special power systems and active positioning control add this complexity. Assembling and maintaining the skilled workforce to operate all of these systems is also a daunting task. The hybrid AUV/ROV offers the opportunity to reduce the need for such systems to only the heavy-duty intervention tasks.

The concept vehicle and tether cart comprise a dry weight of just over 50 kg and measures 1.5m^2. The system is designed to be launched and recovered by docking pole through the moon pool. Upon launch, the vehicle proceeds to the work site on its flight path. At recovery, the vehicle docks with the pole and the assembly is raised to the deck.

Inspection

Long-term undersea facilities require a comprehensive inspection program designed to support systems for many years. The hybrid would be equipped with the SonicWorks scanning system, which performs acoustic imaging, coating and plating thickness measurement and weld scanning. The scanning system is a non-contact process that sweeps the inspection area with a surface speed up to 1m/sec. The scan system creates a CAD map of the inspected structures, which is overlaid with data. Subsequent inspections can then directly compare historical scan data quickly, effectively and accurately.

The inspection process must include the ability to clean surfaces for visual and ultrasonic testing.

Intervention

Normally, a vehicle as light as the hybrid would only have limited (light duty) intervention capability. The 'Bee' and its articulated thrust system could perform tasks equal to a much larger machine. A conventional ROV equipped with a heavy duty manipulator capable of 250lbs of push-pull or rotational torque would have a multi-ton displacement.

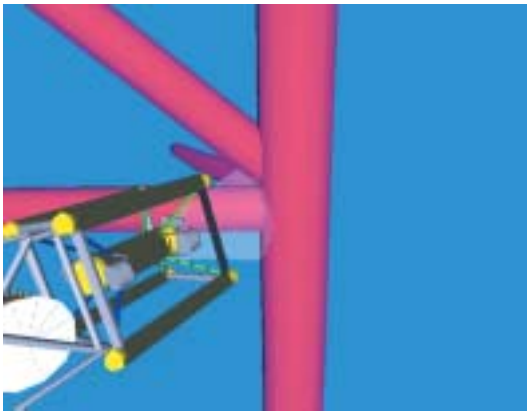
The light-weight hybrid's articulated thrusters are capable of 300lbs push-pull and rotational torque of 250ft/lbs. With a simple gripper, the vehicle can perform the same operations as a heavy work class vehicle. It can work in tighter areas while eliminating the risk of damage inherent in close operations by a heavier vehicle.

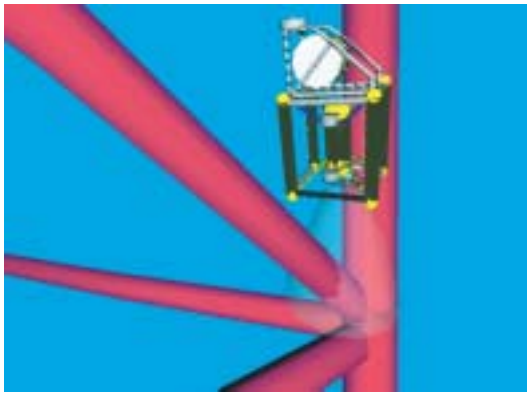
New Abilities

Beyond the ability to operate in confined areas, the hybrid's agility can present new possibilities in underwater intervention. The hybrid is capable of supporting water jetting for removal of marine growth, coating and corrosion.

Where a conventional ROV would not be able to handle the reaction forces of wet jetting, the hybrid articulated thrust and precision control allows precise stabilisation necessary to operate a jetting system. This same dexterity will allow the hybrid to apply displacement coating to the cleaned surfaces and perform precision sleeving operations.

With the ability to support multiple vehicles within the same work site, more complex tasks can be accomplished, and conventional intervention handled faster and more efficiently. The combination of hybrid vehicle, precision positioning and navigation control open up a world of possibilities and SonicWorks looks forward to turning concept into reality.





Left and Right: platform scanning