Provisional Patent Technical Overview

Overview

Autonomous underwater vehicle (AUV) docking technology has been a long-term goal at MBARI and in the underwater vehicle research community. Experience to date with docking and re-charging has exposed two major unsolved challenges. The first is unique to torpedo-shaped cruising vehicles and involves the need to bring these vehicles to rest quickly, which is necessary because these vehicles lose controllability at low speed. The second is the need to rigidly align the vehicle to the docking structure for power transfer through traditional underwater connectors or inductive charging. The combination of these requirements has typically resulted in fairly large seafloor installations that often require ROV access for installation. For torpedo shaped cruising vehicles, relatively crude compliant cone shapes are usually used to bring the vehicle to rest within one vehicle length or so, which is a fairly violent deceleration.

To address these challenges, MBARI has been working to implement a dock that utilizes the Niobicon material in a novel manner that allows a less violent deceleration of the vehicle, and a smaller sea-floor installation that does not require ROV manipulations for installation and service. Figure 1 illustrates the MBARI LRAUV on this dock, and shows the relatively small size and weights of the components involved, which allows deployment from the surface without ROV interventions. This figure shows the dock being powered by a seafloor cable to a nearby power source such as the anchor of a surface buoy or sub-surface power node.

Docking is accomplished by outfitting the vehicle with a side hook that catches a vertical rod as the vehicle flies by. The result is that the relatively large amount of kinetic energy of the vehicle is dissipated by deflection in the dock itself, and by the resulting yaw motion of the vehicle as it swings around the vertical mooring rod. After docking however, the vehicle is not rigidly constrained and is free to float up and down according to how neutrally buoyant it is, and swing around the rod freely in response to currents. The mechanism by which power is transferred in this loosely constrained arrangement relies on the Niobicon material as described below.

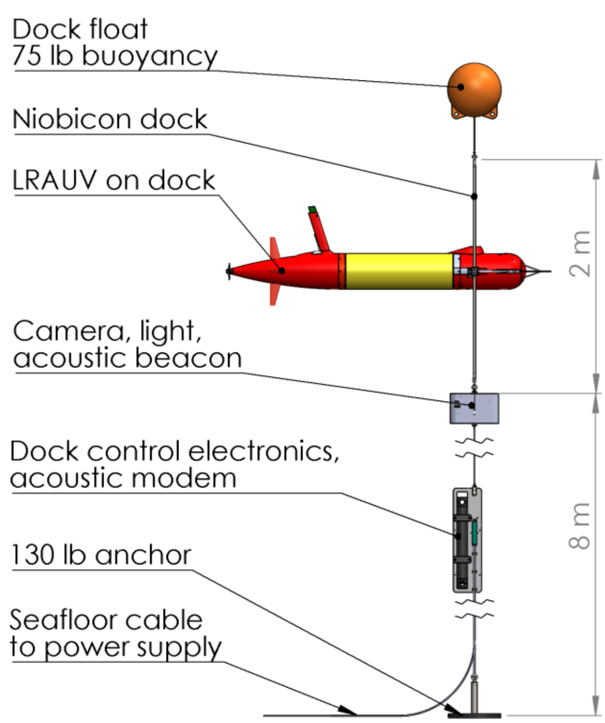

Figure 1: Niobicon-based AUV dock

Technical Approach to Power and Data Transfer

The fundamental concept of this docking approach relies on a Niobicon-brush arrangement on the vehicle that maintains constant contact with two Niobicon electrodes on the docking rod when the vehicle is on the dock. This results in electrical current being present in at least two of the three brushes as the vehicle rotates, the changing polarity of the current is rectified for battery charging by a diode bridge. Figures 2-4 illustrate this basic concept and show some of the mechanism details. The unique and enabling details of this design are the “make-before-break” nature of the brush arrangement, such that current flowing has an uninterrupted path, and the diode-bridge arrangement. The Niobicon material properties are critical for the operation of this device in water; without the self-insulating properties of this material, an unacceptably large amount of current would short-circuit through the water and energy transfer to the vehicle would be impractical. Technical details of the design include the exact brush design in terms of surface area and spring force that is pushing the brushes against the vertical rod, and the brush arrangement that rectifies the resulting current.

To date 500 Watts has been demonstrated and higher power levels appear possible, limited somewhat by the detrimental arcing that occurs at higher electrical currents. It is expected that these power levels can be increased with a refined brush design, or possibly with a refinement to the Niobicon material. Similarly, brush wear is an issue when faced with extreme motions of the vehicle on the dock. In addition to power transfer, digital communications alongside the power on these conductors has been demonstrated, but further refinement is needed to contend with noise issues before implemented in an at-sea prototype.

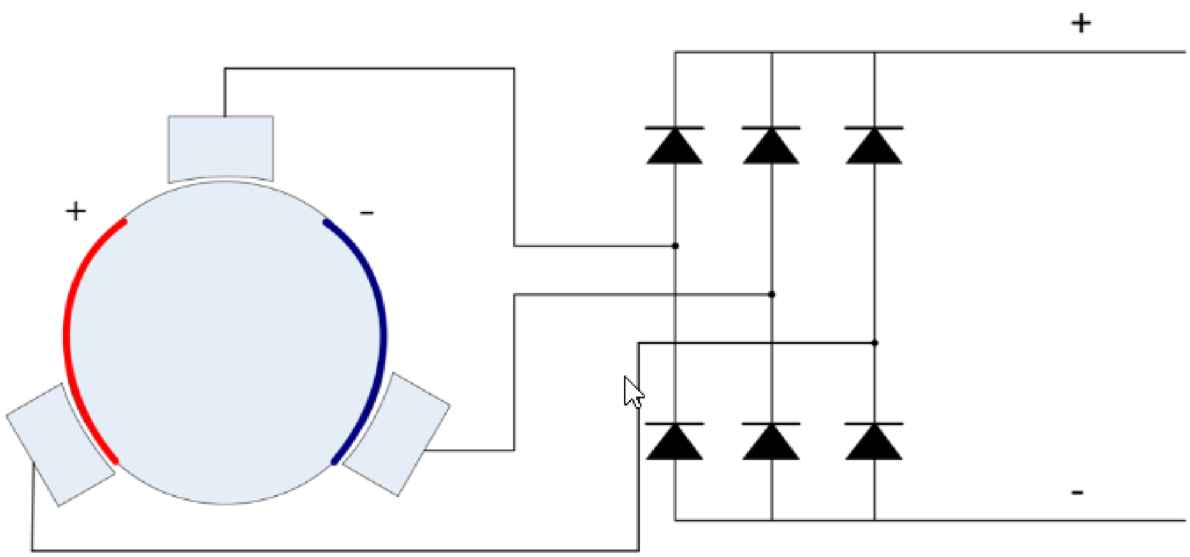

Figure 2: Basic electrical concept of AUV docking connector. The circle on the left is a cross-section of the 0.75” diameter docking rod, and has two Niobicon electrodes embedded in the surface with a smooth transition to the non-conducting sectors of the circle. The brushes are notionally shown here and connected electrically to the bridge-rectifier.

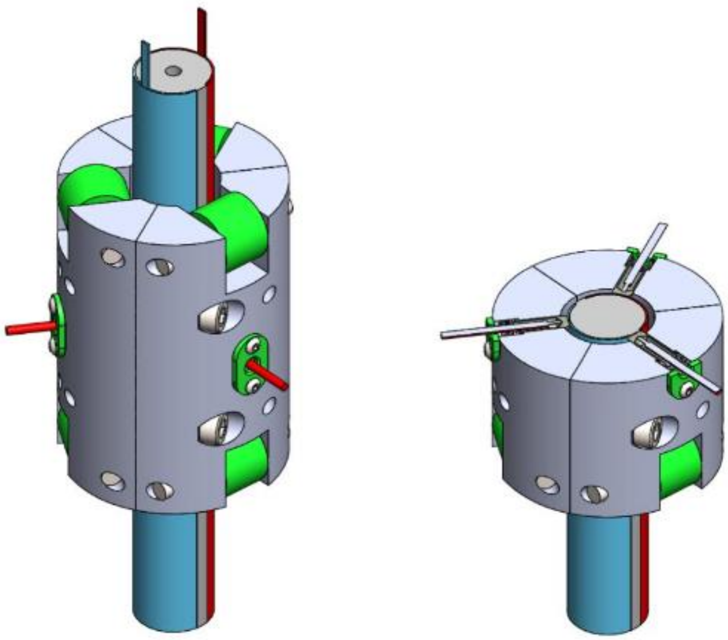

Figure 3: Illustration of the Niobicon brush arrangement allowing contact while the connector rotates and translates up and down. Cut-away view on right shows spring-loaded brush detail.

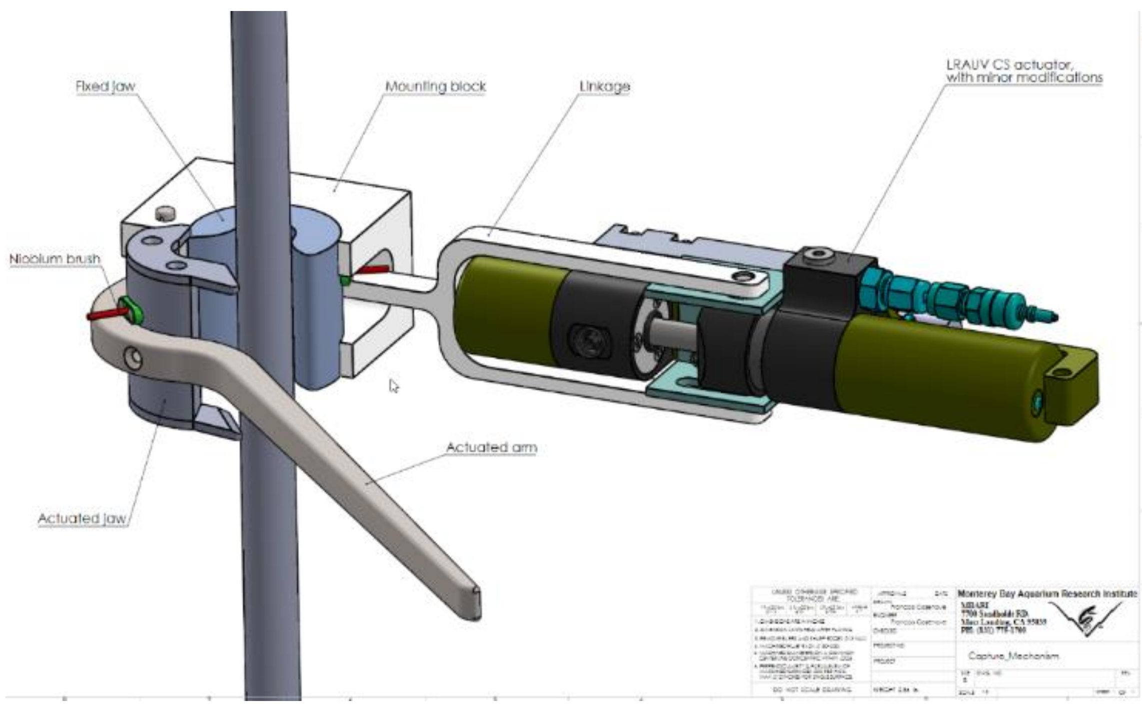

Figure 4: Illustration of the prototype mechanism to allow latching/unlatching of the AUV from the vertical rod. This mechanism is mounted on the side the AUV which promotes a yawing motion of the vehicle to dissipate the kinetic energy of the vehicle after docking. The side-latch also maintains the availability of the nose area of the vehicle for sensors, many of which require that volume for operation. The mechanism shown has been implemented on MBARI's LRAUV's but is applicable to any AUV (torpedo or hovering).