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Surging Motions of a Towed Undersea Cable Plow

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ABSTRACT

Undersea cable that can be struck by objects scraping the seafloor must be protected. It is often placed in a trench for protection. Towing a plow from a surface ship is the most economical method to dig the trench. Cable is passed through the plow and into the trench as it is plowed. It is the current practice to place armored cable under tension in the trench. Installation speed is typically less than 1 knot. There are economic advantages to plowing unarmored cables, at higher speed, but unarmored cable is more difficult to bury because it has low weight. It is shown that tension pulls such cable out of the trench in undulating terrain. This establishes the need for a cable engine on the plow to reduce cable tension in the trench. To keep trench tension low, the cable engine must track the velocity of the plow. A simulation has been developed to establish bounds on plow-velocity excursions during steady state operation. These results will be used in the design of a cable engine, and its control system.

INTRODUCTION

Cable burial is an important part of undersea cable installation. Cable is buried in a trench along all parts of its route where it can be struck by objects that scrape the bottom. For burial distances greater than a few km, burial is most often done with a towed seaplow. A ship tows a plow across the seafloor, and cable is passed through the water column from the ship to the plow. The plow is equipped with a pathway to guide the cable into the trench. Transit speed is typically 0.5 to 1 knot.

In current practice, armored cable, which can survive rough handling, is buried. To avoid running over the cable with the plow, it is buried under tension to keep it suspended ahead of the plow.

Armored cable is expensive; so is the ship operation to bury it. The expense motivates an attempt to bury unarmored cable at a speed greater than 1 knot, with a workboat. Unarmored cable is less expensive than armored cable of the same bandwidth, and higher speed reduces cost simply by reducing the time required for an operation. A converted workboat should be less expensive than a full-size cable ship, but it will have less thrust available to drag a plow across the seafloor.

Burying unarmored cable at high speed presents some new challenges in the design of a seaplow. One challenge is the behavior of the lightweight cables in the water column. A lightweight cable can be swept above and behind the tow cable, introducing operational hazards and making the design of the cable entry point difficult. Burgess (1998) has described this challenge. Another challenge is keeping the cable in the trench. Analysis shows that unarmored cable must be buried with low tension to keep it in the trench in undulating terrain. To keep tension low, the plow must be equipped with a cable engine to isolate cable in the trench from tension in the water column. To be effective, the cable engine must track the plow speed closely. This is the motivation for the work presented here. Design of a plow-cable engine, necessary to keep cable buried in a trench, requires prediction of the magnitude and time duration of plow-surge motions. The prediction facilitates selection of system components that will produce a cable engine with response characteristics that allow it to keep up with plow-velocity fluctuations.

In what follows, the allowable cable tension in a trench in undulating terrain is presented first; it is the proof that a cable engine is needed to bury unarmored cable. This is followed by the description of a computer simulation that reduces the burial system to its essential components. The simulation is then used to estimate the upper limit of plow-surge velocity. Results are presented for sudden changes in soil resistance, in particular the extreme event of a sudden loss of all plow-blade resistance. There are other sources of plow-surge motion, such as changes in seafloor slope. When the bottom slope changes, a component of the plow weight is added or subtracted from the sum of forces acting on the plow. Weight adds to forward thrust on a downward slope, and subtracts from thrust on an upward slope. No structure standing on the seafloor that does not have an embedded foundation will be stable for all inclination angles, so some limit must be set, and in the case of seaplows the inclination angle is often set to 30°. Cable routes are carefully surveyed before the plow operation to ensure that this slope limit is not exceeded. Thus the maximum change in forward thrust on the plow is about $\frac{1}{2}$ the plow weight. The seaplow discussed below has a wet weight of about 111.2 kN, so the maximum change in forward thrust due to seafloor slope change is about 55.6 kN. This is smaller than the worst-case assumption of complete loss of soil resistance, which can be as high as the thrust capability of the ship—in the case considered below, about 135 kN. For the purpose of establishing an upper limit of plow-surge velocity it is only necessary to consider the surge motion due to change in soil resistance.

ALLOWABLE TENSION

The seafloor topography has many forms, from abrupt step-like discontinuities (rock outcroppings) to smoothly varying sand waves. Sand waves can have a variety of forms; they can be smooth, and they can be a series of sharp peaks. To establish a maximum cable tension in the trench, the terrain form is set here to be sinusoidal. Rock outcroppings and sharp peaks will impose a lower maximum tension, but plow burial operations can avoid rocky areas. Sand waves with sharp peaks can also be avoided; if they are not, in many cases the plow will flatten the peaks and

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