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Risk-Based Decisions for Entrance Channel Operation and Design

Andrew L. Silver and John F. Dalzell
Naval Surface Warfare Center, Carderock Division, Bethesda, Maryland, USA

ABSTRACT

Economic and environmental pressures have required the U.S. Navy to minimize dredging when determining the depth of entrance channels for deep-draft ships. To maintain the capability of these deep-draft ships transiting shallow entrance channels safely, the Navy has developed a risk-based methodology to aid in grounding avoidance and minimizing required channel depth. This methodology generates a prediction of the underkeel clearance of the ship during transit of a channel of a defined depth and calculates the associated risk. The risk of the ship touching the channel bottom is calculated based upon the uncertainties in each of the major parameters contributing to the underkeel clearance prediction. A summary of the details of the underkeel clearance prediction, the risk model, and its application in an operational system and channel depth determination is provided.

INTRODUCTION

Some of the U.S. Navy's large deep-draft ships have home ports in harbors whose entrance channels are both shallow and exposed to waves. Economic and environmental pressures have required minimizing the amount of dredging of the channels. This has resulted in less than fully accessible channels for these ships. To respond to these constraints, the Navy has developed an operational system, known as the Environmental Monitoring and Operator Guidance System (EMOGS), to predict the net effective clearance between the keel of the deep-draft Navy vessels and the channel bottom before they transit the shallow entrance channel. A risk analysis has been developed for the system and applied to aid in assessing the amount of risk of grounding for the calculated underkeel clearance. Additionally, the methodology has been used to determine the optimum channel depth for a deep-draft ship. The optimum channel depth is defined as the depth that allows the maximum accessibility with the least amount of dredging. This paper will provide a full description of EMOGS as it currently is configured, the operational risk model, and the channel depth determination methodology.

EMOGS DESCRIPTION

The operational system to warn ships of dangerous transit conditions of shallow entrance channels is EMOGS, which predicts the estimated underkeel clearance during a given transit of a shallow water channel for a specific ship. This underkeel clearance can then be used to evaluate the risk of the ship's keel impacting the channel bottom. The effective underkeel clearance, C_{eff}, is calculated by taking the difference between the effective channel depth and the effective dynamic draft of the ship. The major parameters used in determining the effective channel depth and dynamic draft are illustrated in Fig. 1 and identified in Eq. 1.

$$C_{eff} = (E_{ch} + E_{at} + E_{mt}) - (T_j + S_j + A_j) \quad (1)$$

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In Eq. 1, E_{ch} is the estimated channel depth at mean lower low water (MLLW); E_{at} is the predicted change in the water level from MLLW due to astronomic tides; and E_{mt} is the change in water level from MLLW because of extreme wind speed from an offshore or onshore direction and/or extremes in barometric pressure. The variables T_j, S_j, and A_j represent the static draft, sinkage (or squat) and motions allowance at either the bow or stern, j, respectively. As shown in Fig. 1 and described above, the effective water depth in the channel is dependent upon three major parameters. The first and primary factor is the depth of the water at MLLW during the time of transit. The value for this parameter is input by the EMOGS user. The value can be either obtained from results of the U.S. Army Corps of Engineers surveys of the channel, or set as the project depth (guaranteed depth) of the channel at MLLW. If the matrix of depths from the Corps of Engineers surveys are used, they are statistically analyzed to determine the *controlling depth* for different sections of the channel. These channel sections are determined from changes in the channel orientation and sedimentary regimes. The result of the statistical analysis of the channel survey yields the 99th percentile shallowest depth for each section. The statistical analysis also identifies all recorded depths and corresponding locations that are shallower than the controlling depth and notes them as "hot spots." Because the frequency of the surveys was not set, the chance was high of using a deeper water depth from an old survey than actually existed at the time of transit. Therefore, the preferred method of calculating effective channel clearance is by using the project depth. The effect of different sediment types on the effective channel depth was not taken into account because, for the channels for which EMOGS was designed, the channel bottoms are composed of coarse sand.

The second major factor in determining the effective water depth of the channel is the variation in water level due to astronomic tides. The value of this factor is calculated by a program fully integrated in the EMOGS software, which predicts the change in the astronomic tide levels from MLLW for the time and date of the estimated time of arrival of the ship to the channel entrance. The program also tracks the change in water level from MLLW through the entire transit. This program is based on accepted astronomic prediction theory (Shureman, 1940) by accounting for the most significant of the 37 major tidal constituents in the area of the channel. The predicted tide levels for St. Mary's Inlet were calibrated, with tide data obtained from a