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ORIGINAL ARTICLE

Improved vessel squat modeling for hydrographic and navigation applications using kinematic GNSS positioning

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Abstract The squat phenomenon, that is, the sinkage of a vessel due to its motion can affect the safety of navigation and reduce the accuracy of hydrographic bathymetry. Therefore, it is necessary to model and predict the squat of vessels as a function of cruise speed. We present a Global Navigation Satellite Systems–based squat modeling method for both hydrographic and navigation applications. For implementation of the proposed method, onboard GPS antennae configurations are offered to model bow squat for full-form ships such as supertankers or ore–bulk–oil carriers as well as stern squat for fine-form vessels such as passenger liners or container ships. In the proposed methodology, the onboard GPS observations are used to determine cruise ground speed, heave, attitude, and controlling the quality of kinematic positioning via fixed baselines. The vessel squat is computed from ellipsoidal height differences of the onboard antennae with respect to a reference state, after removal of all disturbing effects due to roll, pitch, heave, tide, vessel load, and geoidal height variations. The final products of the proposed approach are the analytical squat models usable for hydrographic and navigation applications. As the case study, the method is applied to a survey vessel in the offshore waters of Kish harbor. Numerical results indicate that the experimental precision of the derived analytical squat models is in the range of 0.003–0.028 m. The computed navigation squat of the test vessel at a speed of 12.64 knots is 30 % of the vessel draft and about twice its hydrographic squat. Although the field test was performed on a survey vessel, the method can be applied to any ship at any waterway. The proposed method can address the inevitable demand of reliable squat models for delicate hydrographic projects and high-speed marine traffic.

Keywords Ship squat modeling · GNSS · Hydrographic surveying · Safety of navigation · Bathymetry · Marine traffic

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Introduction

The vessel squat, that is, the vertical drop caused by water pressure fall beneath the keel of a moving vessel, can increase the draft and the risk of grounding by reducing the under keel clearance (UKC). The squat effect in hydrographic surveying can also reduce the accuracy of bathymetry if it is not considered and removed from the observations. The sinkage of a vessel due to the squat can be accompanied by changes in pitch and roll, which makes the maximum squat to appear at either port or starboard sides of bow or stern of the vessel depending on its structural characteristics. Generally, full-form ships such as supertankers or ore–bulk–oil carriers, which are technically characterized by the block coefficient $C_b > 0.7$, have bow squat, while fine-form vessels such as passenger liners or container ships ($C_b < 0.7$) experience stern squat (Derrett 1999). Figure 1 schematically illustrates UKC, draft, stern squat, and bow squat.

The squat in confined channels depends on the breadth and depth of the channels, in addition to cruise speed (Briggs 2006; Maynord and Briggs 2006; Delefortrie

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