MEASURING SHIP CONTROLLABILITY GNSS for Sea Trials



The effective seakeeping performance of any watercraft is vital for safe navigation. Due to the long maritime tradition in Greece, the National Technical University of Athens (NTUA) has been a key player in developing tools and practices for conducting sea trials in open water. Since the introduction of the Mini-Ranger many years ago through to the recent introduction of the modern GNSS sensors, a number of new-built and commissioned surface ships of various sizes have been tested either in the interests of the shipbuilder or the owner. Currently, new navigation tools and techniques are being set in place to fulfil the demand for increased accuracy and reliability measures.

Ship controllability includes all aspects of regulating vessel kinematics (trajectory, speed and attitude). Sea trials are essential in the verification of critical course keeping and

course changing capabilities, as well as emergency manoeuvrability characteristics, while others are intended to demonstrate the performance of vital machinery and regulatory requirements. With regard to the testing of the navigation capabilities of a ship, three distinct areas are involved; i.e. course keeping or steering, manoeuvring and speed changing trials. The first category aims to check the ship's ability to maintain a straight path in a predetermined course direction. Typical testing involves the execution of the Z-manoeuvre and direct / reverse spiral trials (Figure 1). Course changing or turning tests assess the manoeuvrability features of a boat. In this case, the turning circle and Z-manoeuvre are used to characterise the turning and yaw-checking potential of a vessel. Finally, speed changing tests demonstrate the ability to control vessel speed including emergency / inertia slowing, stopping and backing. Here, critical manoeuvre parameters relate to the ease, rapidity and travelled distance associated with a change. In addition, speed tests that characterise ship MiniRanger III shore station performance in relation to engine horsepower and propeller capacity are required.

^{configuration.} The procedures applied (in many cases adopted by flag states as national requirements) for conducting sea trials primarily rely on guidelines and standards produced by the Society of Naval Architects (SNAME) and the International Maritime Organisation (IMO). The last one provides (interim) standards for the planning, conducting and reporting of sea trials, as well as a set of parameter criteria used to assess seakeeping performance. Critical parameters for the turning circle of large ships require the "advance" (distance travelled along the direction of the initial course) at 90° change of heading and "tactical diameter" (transfer) at 180° change of heading to be less than 5 and 4.5 ship lengths respectively. A key parameter to assess the stopping ability of a vessel is the "track reach" (the distance travelled along a path until ahead speed changes sign) which should not exceed 15 ship lengths. Similarly, the "overshoot angle" (the exceeding angle of the ship's heading between the point the rudder is deflected and the point the ship's change of heading reverses) is used to assess the yaw-checking ability.

Past Practices

The first sea trials conducted by the NTUA go back to the early 80s. The test area is located in Saronikos Gulf, some 30 km west of Athens, Greece. The area has been a test site for NTUA since 1978, when the officially measured nautical mile was established nearby Diaporia islands (Figure 2). The site was carefully selected due to its adequate water depths, low current strength, proximity and the generally good weather conditions. The limited accuracy of long-range, hyperbolic positioning systems at that time (such as Loran-C) could not match the precision requirements for the tests. Instead, the MiniRanger III short-range, pulse navigation system was used. The system employed four reference stations on shore (Figure 2 and 3), from which the distances from the shipboard station were measured via interrogation-to-reply time delay. The ranges were recorded in real time with final positions calculated at a later time. The on-board section consisted of the receiver / transmitter, a range console and a digital printer. The system operated in the 5.6 GHz frequency band producing ranges of about ±3 m accuracy over ranges of up to 30 km. If more than two ranges were available, final positions were computed using least squares adjustment, resulting in absolute position uncertainties less than 10-12 m (95% confidence level). Part of this error could be attributed to the time delay involved in multiple ranging, given that simultaneous observations could not be precisely taken. In effect, as shown in Figure 2, final navigational accuracy was also subject to the number and relative geometry of the reference stations had to be periodically calibrated for signal strength loss by measuring the turn-around delay for each beacon from a number of known locations.

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