A note on sea state parameters for DP testing by simulation

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# Sea state parameters and DP testing

It is of interest to test the performance of stationkeeping systems in terms of standard deviation of positioning and cost of operation (thrust usage or fuel consumption) in various sea states. Here, relevant sea state parameters are given.

## Environmental parameters

The sea state is parametrized by significant wave height which is correlated to typical wind speed according to statistical data at different locations around the world. In addition, a slowly varying ocean current force, typically , is exposed to the vessel dynamics. The waves, wind, and current spectra and formulas are given by:

* **Waves:** JONSWAP, Torsethaugen, Pierson-Moskowitz, regular waves, etc.
* **Wind:** Harris, Blendermann [18], NORSOK.
* **Current:** Modeled as a Markov process.

The sea state codes are defined in Table 1, see [6]. The peak wave frequency and correlated wind speed (10 m above sea level) have been calculated from an expected value based on statistical data from the North Sea [7]:

This relationship should be used for testing with respect to North Sea offshore conditions. See references in [6] for more details.

An alternative relationship between and is the relationship of Pierson-Moskowitz (1963) for fully developed wind-generated seas resulting from analysis of wave spectra in the North Atlantic. This is given as:

where is the wind speed at height above sea level and is the acceleration of gravity. This gives slightly different numbers than those in Table 1, and it is recommended to use it for testing with respect to inshore locations.

## References

[1] IMO, “Guidelines for Vessels with Dynamic Positioning Systems,” MSC/Circ.645, June 6, 1994.

[2] IMCA, “Guidelines for The Design & Operation of Dynamically Positioned Vessels,” IMCA M 103, February 1999.

[3] IMCA, “Guidance on Failure Modes & Effects Analyses (FMEAs),” IMCA M 166, April 2002.

[4] IMCA, “Dynamic Positioning Station Keeping Incidents: Incidents reported for 2000,” IMCA M 165, Dec. 2001.

[5] IMCA, “Station Keeping Incidents Reported for 2001,” IMCA M 169, February 2003.

[6] Fossen, Thor I., “Handbook of Marine Craft Hydrodynamics and Motion Control,” Wiley, 2011.

[7] Johannessen, K., T. S. Meling, and S. Haver, “Joint Distribution for Wind and Waves in the Northern North Sea,” Int. J. Offshore and Polar Eng., Vol. 12, No. 1, March 2003.

[15] Sørensen, A. J., “Marine Cybernetics: Modelling and Control,” NTNU lecture notes in TMR4240, Norway, 2012.

[16] Rensvik, E., A. J. Sørensen, and M. Rasmussen, “Maritime Industrial IT,” Proc. 9th Int. conf. Marine Eng. Systems (ICMES), Helsinki, Finland, May 19-21, 2003.

[18] Blendermann, W., “Die Windkräfte am Schiff,” Technical report Bericht Nr. 467, Inst. Für Schiffbau der Universität Hamburg, My 1986 (in German).

**Table 1: Definition of Sea State (SS) codes.**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Sea State Code:** | **Description of sea:** | **Observed wave height Hs:** [m] | **Peak wave frequency:** (Northern North Sea)[rad/s] | **Wind speed:** (Northern North Sea)[m/s] | **Probability** [%] | | |
| **World wide:** | **North Atlantic:** | **Northern North Atlantic:** |
| 0 | Calm (glassy) | 0.0 | 0.01 | 0.00 | 11.2486 | 8.3103 | 6.0616 |
| 1 | Calm (rippled) | 0.0 – 0.1 | 10.0 – 1.11 | 1.76 - 2.33 |
| 2 | Smooth (wavelets) | 0.1 – 0.5 | 1.11 − 0.93 | 2.33 - 3.76 |
| 3 | Slight | 0.5 – 1.25 | 0.93 − 0.79 | 3.76 - 5.84 | 31.6851 | 28.1996 | 21.5683 |
| 4 | Moderate | 1.25 – 2.5 | 0.79 − 0.68 | 5.84 - 8.77 | 40.1944 | 42.0273 | 40.9915 |
| 5 | Rough | 2.5 – 4.0 | 0.68 − 0.60 | 8.77 – 11.87 | 12.8005 | 15.4435 | 21.2383 |
| 6 | Very rough | 4.0 – 6.0 | 0.60 − 0.53 | 11.87 - 15.62 | 3.0253 | 4.2938 | 7.0101 |
| 7 | High | 6.0 – 9.0 | 0.53 − 0.46 | 15.62 - 20.78 | 0.9263 | 1.4968 | 2.6931 |
| 8 | Very high | 9.0 – 14.0 | 0.46 − 0.39 | 20.78 - 28.60 | 0.1190 | 0.2263 | 0.4346 |
| 9 | Phenomenal | 14+++ | 0.39 − 0.30 | 28.60+++ | 0.0009 | 0.0016 | 0.0035 |

## Parameters for DP testing

The following table gives parameters that can be used for standardized testing:

**Table 2: Sea state code environmental parameters used in testing.**

|  |  |
| --- | --- |
| **Environmental condition:** | **Simulation; assuming vessel keeps heading North. For model testing; relative to incoming wave direction in basin. For sea trials testing; see SS PREVAILING.** |
| **Sea State Code 0:**  GLASSY | **Waves:** Hs: 0.0 m, Direction 0˚ (north)  **Wind:** Vw: 0.0 m/s, Direction 0˚ (north)  **Current:** Vc: 0.0 m/s, Direction 0˚ (north) |
| **Sea State Code 1:**  RIPPLED | **Waves:** Hs: 0.1 m, Direction 180˚ (south)  **Wind:** Vw: 2.0 m/s, Direction 180˚ (south)  **Current:** Vc: 0.05 m/s, Direction 180˚ (south) |
| **Sea State Code 2:**  SMOOTH | **Waves:** Hs: 0.4 m, Direction 270˚ (west)  **Wind:** Vw: 3.0 m/s, Direction 330˚ (north-north-west)  **Current:** Vc: 0.1 m/s, Direction 270˚ (west) |
| **Sea State Code 3:**  SLIGHT | **Waves:** Hs: 1.0 m, Direction 180˚ (south)  **Wind:** Vw: 5.0 m/s, Direction 240˚ (south-west-west)  **Current:** Vc: 0.15 m/s, Direction 180˚ (south) |
| **Sea State Code 4:**  MODERATE | **Waves:** Hs: 2.0 m, Direction 15˚ (north-north-east)  **Wind:** Vw: 8.0 m/s, Direction 0˚ (north)  **Current:** Vc: 0.2 m/s, Direction 15˚ (north-north-east) |
| **Sea State Code 5:**  ROUGH | **Waves:** Hs: 3.5 m, Direction 195˚ (south-south-west)  **Wind:** Vw: 11.0 m/s, Direction 195˚ (south-south-west)  **Current:** Vc: 0.3 m/s, Direction 195˚ (south-south-west) |
| **Sea State Code 6:**  VERY ROUGH | **Waves:** Hs: 5.0 m, Direction 0˚ (north)  **Wind:** Vw: 15.0 m/s, Direction 0˚ (north)  **Current:** Vc: 0.5 m/s, Direction 0˚ (north) |
| **Sea State:**  PREVAILING | The environmental parameters are given by the situation, e.g. by the actual sea state during sea trials. The environmental parameters should in these cases be recorded in the test results to make reconstruction possible. |
| **Other parameters:** | **Wave spectrum:** JONSWAP  **Mean wave frequency:** ωp = 2π/(4.883 + 2.68\*Hs0.54)  **Wave spreading factor:** 1 (ITTC recommended)  **Wind spectrum:** NPD (NORSOK)  **Wind gusts:** On (if possible)  **Current fluctuations:** On (if possible)  **Wave drift:** On (if possible) |