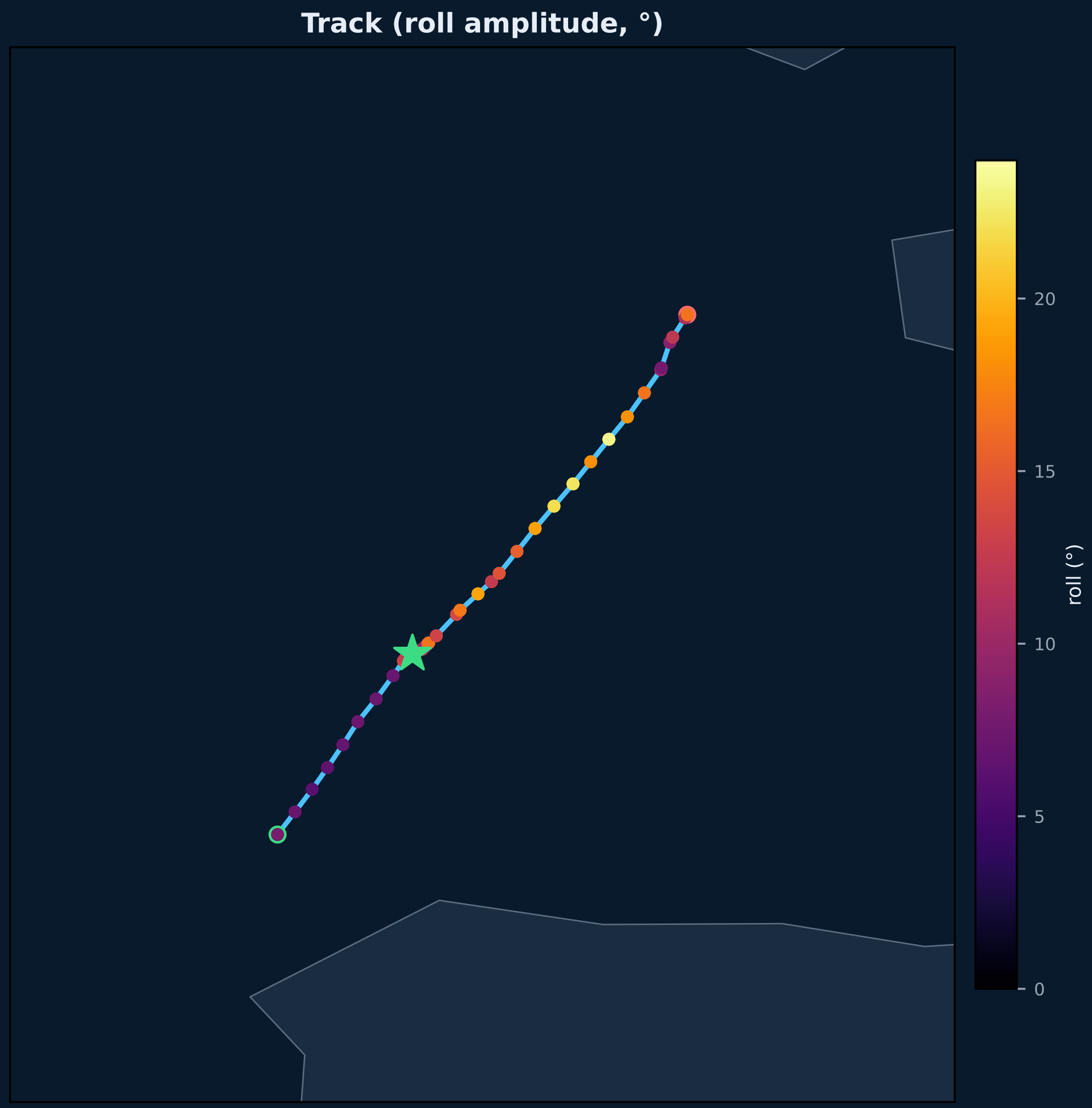
Synchronous Rolling Study on an MR Tanker — Bay of Biscay, 27 Jan 2026

Reconstruction · ECDIS track + ERA5 (ARCO) wave spectrum + ship stability data



LOADING (incident)

GM	**1.6 m (tender)**
Draft F / A	**10.6 / 11.7 m (trim 1.1 m aft)**
Displacement	**~49,700 t**
Natural roll period	**18.3 s (IMO IS-Code)**

STORM (00:00 UTC)

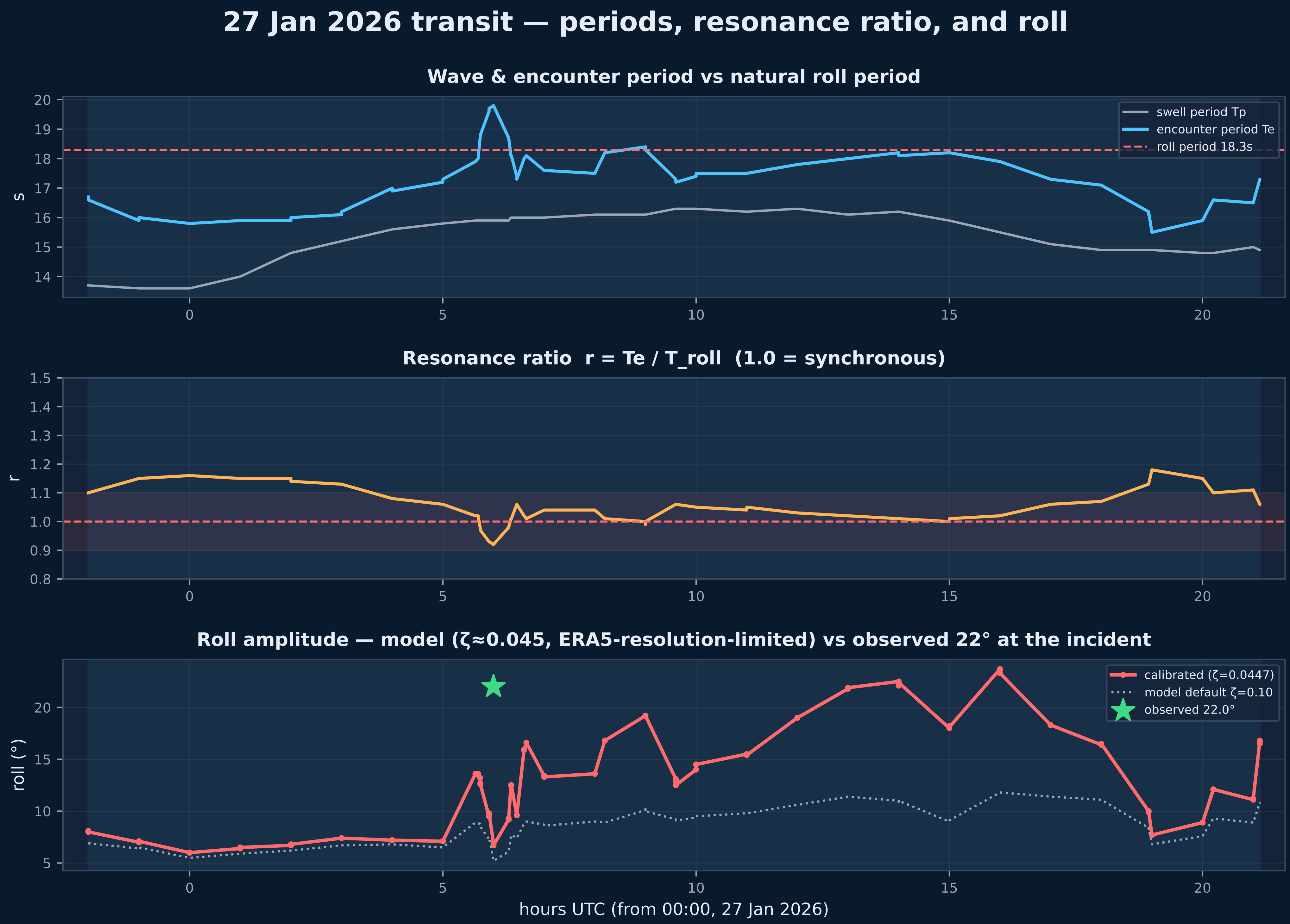
Peak wind	**46 kn (ERA5 36)**

SEA @ roll peak 06:00 UTC / 07:00 local

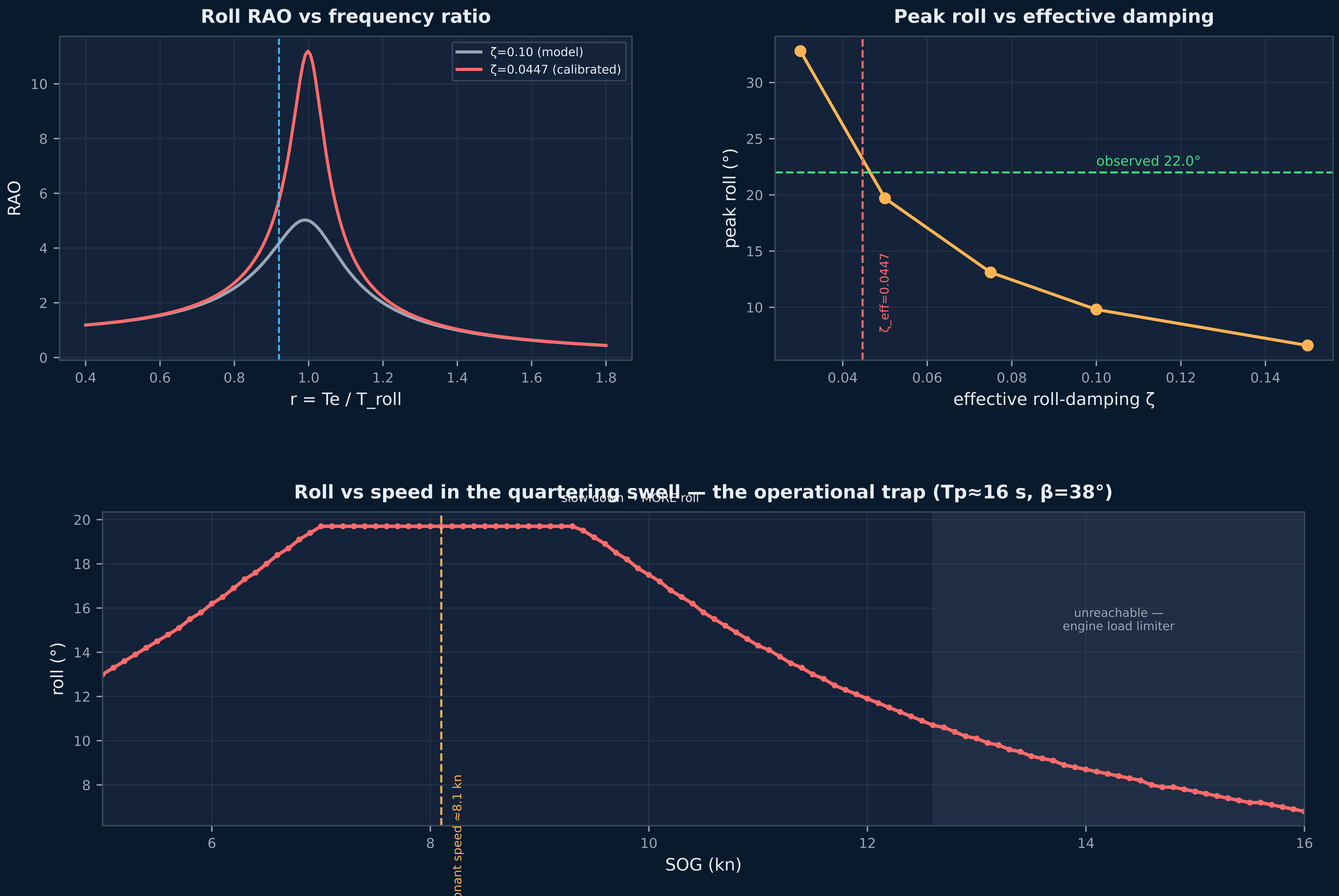
Combined Hs	**6.9 m**
Swell Tp / from	**15.9 s / W ≈267° (port quarter)**
Encounter period	**19.8 s (β=38°)**
Ratio r = Te/Troll	**0.92 → SYNCHRONOUS**
IMO MSC.1/Circ.1228	**synchronous + quartering**

OUTCOME

Observed peak roll	**22.0° (bridge log)**
Effective roll damping	**ζ ≈ 0.0447**
Default ζ=0.10 (at resonance)	**9.8° (×2.2 under)**
Kernel RAO cap (≤10) tops at	**19.7° (< observed)**


27 Jan 2026 transit — periods, resonance ratio, and roll
Wave & encounter period vs natural roll period
s
swell period Tp
encounter period Te
roll period 18.3s
Resonance ratio r = Te / T_roll (1.0 = synchronous)
r
Roll amplitude — model (ζ≈0.045, ERA5-resolution-limited) vs observed 22° at the incident
roll (°)
calibrated (ζ=0.0447)
model default ζ=0.10
observed 22.0°
hours UTC (from 00:00, 27 Jan 2026)

Resonance mechanism & damping calibration



Synchronous Roll Resonance — Model and Interpretation

MR tanker · Bay of Biscay · 27 January 2026 · WindMar seakeeping reconstruction

1 Data

- Track, heading and SOG from the ship ECDIS voyage log (27 Jan 2026, 108 fixes through the Bay of Biscay).
- Loading (master): GM 1.6 m; drafts 10.6 m F / 11.7 m A (mean 11.15 m, 1.1 m trim by the stern); 71 RPM; displacement ≈ 49,700 t from the vessel hydrostatics.
- Sea state: ERA5 reanalysis (Google ARCO, 0.25°, hourly) — combined sea plus swell and wind-sea partitions, sampled at every track fix.
- Wind: ECDIS anemometer (storm peak 45.9 kn at 00:00 UTC). Observed peak roll 22° (bridge log), ~06:00 UTC / 07:00 local.

2 Model

Roll is treated as a forced single-degree-of-freedom oscillator. The natural roll period follows the IMO IS-Code weather criterion; the encounter frequency and the dynamic amplification (RAO) set the response:

$$T_{\text{roll}} = \frac{2\,C\,B}{\sqrt{GM}} = 18.3 \text{ s}$$

$$\omega_e = \left| \omega - \frac{\omega^2\, V\cos\mu}{g} \right|, \quad r = \frac{\omega_e}{\omega_{\text{roll}}}$$

$$\varphi = \frac{\pi H_s}{\lambda}\, |\sin\mu| \cdot \frac{1}{\sqrt{(1-r^2)^2 + (2\zeta r)^2}}$$

with H_s the significant height, λ the wavelength, μ the encounter angle, V the speed and ζ the fraction of critical roll damping. ζ is calibrated to the observed 22°.

3 Findings

- A persistent W/WSW swell (≈14 s mean, ≈16 s dominant, building to Hs 7 m) ran on the port quarter. With the tender GM the encounter period stayed near the 18.3 s roll period for the whole transit (r ≈ 0.9-1.2): a synchronous-roll resonance (IMO MSC.1/Circ.1228). At the incident (06:00 UTC / 07:00 local) r = 0.92 — just below 1, the long-encounter side.
- Excitation is the full sea (Hs ≈ 7 m): the swell and wind-sea response variances add. The hazard was swell-driven — the roll peaked after the 02:00 wind peak, on the residual long swell.
- Calibrated $\zeta \approx 0.0447$ reproduces 22° at synchronous resonance; the default $\zeta = 0.10$ gives 10° (×2.2 under).
- The deployed kernel also floors the RAO denominator at 0.1 (RAO   10), so it tops out at 20° here — structurally below the observed 22°. The cap should be raised/removed and damping calibrated.
- Speed trap: in quartering seas the encounter period lengthens with speed. Slowing drove the ship toward the ≈8 kn resonant speed (more roll); the speed-up escape was blocked by the engine load limiter. The remaining lever was a course alteration.

4 On the low damping

$\zeta \approx 0.045$ is physically reasonable for this hull: a tender, long-period (18.3 s), full-form tanker radiates little wave energy and its bilge keels are modest against the roll inertia. As an equivalent-linear value it also stands in for transient wave-group build-up and spectral spreading the steady-state model omits, so the underlying hydrodynamic damping may be slightly lower; either way it is far below the model's $\zeta = 0.10$ default.

5 Limitations

- Single-DOF, steady state (no transient group build-up). ERA5 0.25° wind is smoothed (figures from ECDIS); ERA5 waves are sound (Hs 7 m confirmed). ECDIS wind direction reads reciprocal to the FROM convention (flagged).

Conclusions

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1 The incident

- Synchronous roll resonance, not a wind event: the tender loading (GM 1.6 m $\rightarrow$ 18.3 s roll period) and a long W swell (~16 s dominant) on the port quarter held the encounter period on the roll period ($r \approx 1$) for essentially the whole transit; observed peak 22°.
- Swell-driven and decoupled from the wind — the wind peaked at 00:00 UTC and had eased by the incident (06:00 UTC / 07:00 local); the residual long swell was the danger, not a gale.
- A speed trap: at the incident $r = 0.92$ (just below resonance), so slowing drove the ship toward resonance (worse) while speeding up — the correct escape — was blocked by the engine load limiter. The only remaining lever was a course alteration off the quarter (IMO MSC.1/Circ.1228).

2 Seamanship

- Static stability is not dynamic roll: the tender low-GM condition gave a long roll period that matched the long swell. The danger metric is the ENCOUNTER period vs the roll period — set by course and speed, not wave height — and in a tender quartering-swell condition it must be broken decisively by heading change.

3 Model fidelity (actionable)

- Compute the roll period from the actual GM per voyage (18.3 s here, not the fixed 14 s default).
- Calibrate roll damping (Ikeda-style, amplitude/loading-aware): the constant $\zeta = 0.10$ default over-damps and under-predicts the resonant roll $\times 2.2$.
- Raise/remove the kernel RAO cap (denominator floor $\rightarrow$ RAO ¤ 10): it structurally tops the roll at ~20° and cannot represent the observed 22°.
- Surface the encounter, swell and roll periods per leg, and route to keep the encounter period clear of the roll period.

4 On the damping vs literature

- Effective $\zeta \approx 0.045$ (bracket 0.03-0.05) sits in the LOW-MIDDLE of the tanker range (bilge-keeled 0.05-0.10; bare/full-form 0.02-0.05) — lightly damped, but NOT a robust 'underdamped' claim.
- It is a single-point, steady-state inference: transient wave-group build-up would raise the true value and excitation attribution brackets it, so a genuine damping deficit is unproven — confirm with a roll-decay test or an Ikeda component computation.

5 Method

- Fully reconstructable from routine sources (ECDIS track + free ERA5/ARCO the stability booklet). ERA5 0.25°/hourly is a sound diagnostic of the resonance but, being coarse, is not a standalone roll predictor.