Manuscript Changes and Point-by-Point Responses

Manuscript wes-2025-248

Method for using spectral flow data to predict vortex-induced vibration onset of static structures

---

This contains 1) a summary of relevant manuscript changes, 2) the response lists previously posted publicly for CC1, RC1, and RC2 which are point by point.

Summary of Relevant Manuscript Changes

Revisions to the manuscript are summarized below. There are no additional technical claims and the point-by-point responses following contain more specific details in addition to the differenced PDF submitted.

- **Notation, symbols, and units (RC1.1–4, RC1.9; RC2.1, RC2.3–4).** The characteristic length was changed to c_n so that L remains reserved for lift; V_{inf} was standardized to V_∞; "Hz" and non-breaking spaces before that unit were standardized; wind-speed units were changed to m/s; and A_k and ϕ_k were defined.

- **Spectral processing definitions (RC1.6, RC1.8; RC2.3–4).** The manuscript now states that the mean is removed before PSD computation and retained separately for reconstruction, defines $C_F = \sqrt{C_L^2 + C_D^2}$ for PSD ranking and peak selection, and defines the amplitude and phase terms used in reconstruction. It also clarifies the one-sided DFT and cosine-reconstruction convention, including DC, interior-frequency, and Nyquist scaling.

- **Source-data traceability (RC1.5; RC2.5, RC2.10).** The text and captions identify the preliminary NACA 0018 CFD force-history data distributed with VorLap, cite the source, describe the repository preprocessing workflow, distinguish the demonstration data from validation data, and state that future work will include a higher-quality CFD spectral dataset.

- **Strouhal and Reynolds-number interpretation (RC1.7, RC1.10; RC2.2, RC2.6).** The revision states the Reynolds-number regimes associated with the cited Strouhal data, explains the Reynolds-number calculation and viscosity used for the example, describes the expected high-angle-of-attack Strouhal scale, and identifies the +0.07 Strouhal shift as an illustrative preprocessing offset rather than a universal correction. The frequency shift is $\Delta f = 0.07\, V_\infty / c_n$. The offset should be zero for validated data; application-matched data should replace it, or it should be treated as a sensitivity parameter.

- **Parked-flow kinematics and Figure 4 (RC1.11–12; RC2.7, RC2.12; RC2 readability comment 4).** The manuscript clarifies that the local angle of attack and inflow are evaluated for parked, quasi-static conditions; defines how a rotating case would differ; labels V_∞, V_c, and V_n; restores the original VorLap geometry rendering to avoid ambiguous manual overlays; revises the Figure 4 text and caption; and includes the global-axis triad. The stated convention is inflow direction $(1, 0, 0)$ and rotation axis $(0, 0, 1)$.

- **Algorithm terminology and filtering (RC1.13–14; RC2.8).** The wording around the ranked peak index was simplified, and the manuscript defines the frequency-overlap difference, the retained

highest-risk or "worst" case, the spectral-depth limit, the combined-force amplitude cutoff, and frequency filtering.

- **Purpose and assessment of force reconstruction (RC1.15; RC2.9).** An early methods statement now explains why reconstruction supplies time histories and phase information beyond frequency matching. The unsupported "within 5%" statement was removed and replaced with the Pearson correlation coefficient $r = 0.90$ between the demeaned time histories over the plotted 0–2 s window.

- **Interpretation of the overlap heatmaps (RC1.16).** The verification and heatmap discussion was rewritten to address the isolated overlap comparison and the surrounding heatmap. The revision also states that such high inflow velocities would require very stable conditions to exhibit shedding behavior.

- **Scope and limitations (RC1.17–18).** The revision states that percent frequency difference is a screening indicator that must be interpreted in the context of damping and lock-in bandwidth, and that the reconstructed loads exclude motion-induced VIV, lock-in, and aerodynamic damping.

- **Source-spectral sensitivity (RC2.11).** A sensitivity subsection explains how Strouhal uncertainty shifts frequency-overlap predictions, how amplitude scales reconstructed loads, how phase affects time-domain superposition, and why URANS alone may be inadequate for resolving separated high-angle-of-attack wake-shedding spectra. The example is framed as a deterministic demonstration rather than probabilistic uncertainty quantification.

- **Readability and presentation (RC2 readability comments 1–4).** The opening introduction and airfoil-shedding motivation were rewritten, the inflow range in Table 1 was changed to "1–16 m/s in 1 m/s increments," and the local chordwise and normal unit-vector description was revised.

- **Bibliography (RC2.13).** The listed references and related metadata or DOI issues for Horcas et al., Zhang et al., and Benner et al. were corrected, and Ebstrup et al. was added for the source-spectral-sensitivity discussion.

The CC1 response additionally documents three completed manuscript edits: the description of Grinderslev et al. (2022) was revised so it refers to multiple attainable limit-cycle amplitudes at a given frequency rather than different frequencies or harmonics, the forced-motion sensitivity discussion was attributed specifically to Grinderslev et al. (2023), and the two Grinderslev references supplied by the commenter were updated.

The CC1, RC1, and RC2 wordings are reproduced below.

Response to Community Comment CC1

Comment from Georg

Dear authors,

Thank you for referring to our work on vortex-induced vibrations (Grinderslev et al., 2022 and 2023).

I just want to clarify, that in Grinderslev et al. 2022, we observed that different limit cycle amplitudes for oscillations at a given frequency can be reached depending on initial conditions.

Investigating different frequencies or harmonics was not part of that work. However, it could certainly be possible that vibrations at different frequencies would build up depending on initial conditions.

I also would like to correct the references to those articles, which should be:

Grinderslev C., Sørensen N.N., Pirrung G.R., Horcas S.G.: Multiple limit cycle amplitudes in high-fidelity predictions of standstill wind turbine blade vibrations, *Wind Energy Sci.*, 7, pp. 2201–2213, https://doi.org/10.5194/wes-7-2201-2022, 2022

Grinderslev C., Houtin-Mongrolle F., Nørmark Sørensen N., Raimund Pirrung G., Jacobs P., Ahmed A., Duboc B.: Forced-motion simulations of vortex-induced vibrations of wind turbine blades – A study of sensitivities, *Wind Energy Sci.*, 8, pp. 1625–1638, https://doi.org/10.5194/wes-8-1625-2023, 2023

Best regards,

Georg

CC1 Response

Georg,

Thank you for reading our manuscript and for clarifying the scope and key conclusion of Grinderslev et al. (2022). We agree with your point that the 2022 study demonstrates multiple attainable limit-cycle amplitudes at a given frequency depending on initial conditions, and that investigating different frequencies or harmonics was not part of that work. Our earlier wording could be read as implying otherwise; we revised it to reflect your finding accurately and to present any discussion of frequency/harmonic build-up as a broader possibility rather than a result shown in Grinderslev et al. (2022). We also ensured that forced-motion sensitivity discussion is attributed specifically to Grinderslev et al. (2023).

Thank you as well for the corrected references. We updated the paper's references to those you provided.

Best regards,

Kevin Moore

Response to Referee Comment RC1

Original submission note

We thank the reviewer for the thoughtful and constructive feedback. The manuscript has been revised to improve clarity, reproducibility, and interpretation, and will be uploaded soon as directed by WES. A concise, point-by-point response is provided in the attached file.

Point-by-point response

The abbreviated comment headings below are retained from the existing RC1 point-by-point response; the response wording is unchanged.

1. *Comment summary:* Eq. 1–2: L used for lift and length.

   Response: Revised notation to avoid conflict: lift remains L, and the characteristic length is now c_n (flow-normal projected chord/major axis).

2. *Comment summary:* Use of V_{inf}.

   Response: Replaced with standard V_∞ throughout for consistency.

3. *Comment summary:* Capitalization of Hz.

   Response: Standardized to "Hz" across the manuscript.

4. *Comment summary:* Non-breaking space before Hz.

   Response: Added non-breaking spaces (e.g., "1.8 Hz") to keep units with numbers.

5. *Comment summary:* Data source for Figs. 1–3.

   Response: Added an explicit citation to the NACA 0018 CFD dataset included with VorLap and clarified dataset in captions and text.

6. *Comment summary:* PSD and mean removal.

   Response: Clarified that the mean (DC component) is removed prior to PSD computation to avoid large near-zero values; the mean is retained separately for reconstruction.

7. *Comment summary:* Strouhal offset (+0.07).

   Response: Specified which datasets motivated the alignment (flat-plate and stalled-airfoil references), added citations, and explained the impact: a uniform shift in predicted shedding frequencies of $\Delta f = 0.07\, V_\infty / c_n$. Emphasized this is a preprocessing parameter and should be zero for validated datasets.

8. *Comment summary:* Use of $\sqrt{C_L^2 + C_D^2}$.

   Response: Added the explicit definition of $C_F = \sqrt{C_L^2 + C_D^2}$ and clarified that PSD ranking and peak selection are based on this combined force coefficient.

9. *Comment summary:* V_∞ vs V_{inf}.

   Response: Unified notation to V_∞ everywhere.

10. *Comment summary:* Reynolds number consistency in Fig. 3.

    Response: Added the chord Reynolds equation and a description of the density and viscosity used. We halved the viscosity (using 9e-6 instead of 18e-6) to increase the Reynolds number in the solution, which is confusing, but we have included this clarification in the manustript.

11. *Comment summary:* Static vs rotating inflow in Sec. 2.2.

    Response: Explicitly stated that local AoA/inflow are evaluated for parked (quasi-static) conditions; rotation is used only to sweep azimuthal orientation. Noted how rotating cases would be handled.

12. *Comment summary:* Add parameters to Fig. 4 vectors.

    Response: Updated the figure caption to explicitly reference V_∞, V_c, and V_n. The figure itself was also updated to include these.

13. *Comment summary:* Language clarity; "sorted level."

    Response: Replaced "sorted level" with "ranked peak index (sorted by PSD magnitude)" and simplified surrounding text throughout.

14. *Comment summary:* Algorithm 1: "worst" cases and thresholds.

    Response: Added better definitions for "worst" as the minimum absolute percent frequency mismatch across harmonics and shedding peaks; clarified filtering by (i) peak-depth limit (how many of the ranked frequencies are used) and (ii) combined-force amplitude cutoff.

15. *Comment summary:* Why force reconstruction is required.

    Response: Added an early statement in Sec. 2 explaining that reconstruction provides time histories and phase information needed for load synthesis and one-way coupling beyond frequency proximity, a much lower cost solution than full fluid structure interaction.

16. *Comment summary:* Heatmaps persisting at higher velocities.

    Response: Rewrote this section to explicitly go through the verification comparison for the single isolated overlap frequency and the heatmap surrounding it. Also added a description that such high inflow velocities would require very stable conditions to exhibit shedding behavior.

17. *Comment summary:* Damping/resonance bandwidth not included.

    Response: Added a limitation statement: percent frequency difference is a screening indicator for the potential of onset and should be interpreted in the context of structural damping/lock-in bandwidth.

18. *Comment summary:* Rigid-body vs motion-induced VIV forces.

    Response: Added a clear limitation that reconstructed forces represent rigid-body shedding excitation only, excluding motion-induced VIV, lock-in, and aerodynamic damping.

Response to Referee Comment RC2

Original submission note

Thank you for your time and valuable comments. We have revised the manuscript as recommended and look forward to sharing the revision. A succinct summary of itemized details can be found in the attached pdf.

Thank you for the careful reading and constructive comments. We have revised the manuscript to improve notation, source-data traceability, figure clarity, uncertainty discussion, and bibliography as suggested.

Specific Comments

1. *Reviewer comment:* Please use the unit of wind speed as m/s instead of ms^{-1} throughout the paper.

   Response: A previous editor requested the compact $\mathtt{ms}^{-1}$ notation, but we also prefer `m/s`; we now use `m/s` throughout the manuscript, captions, and tables.

2. *Reviewer comment:* In line 44, please explain the relevant Reynolds number regime for Strouhal number mentioned.

   Response: The introduction now states the Reynolds-number regimes for the cited Strouhal data and clarifies that $St \approx 0.2$ is only a first-pass cylinder screening value, not a universal airfoil value.

3. *Reviewer comment:* The variable A_k, as shown in equation 5, is not explained in Section 2.1.

   Response: Section 2.1 now defines A_k as the one-sided peak amplitude for the kth frequency bin and relates it to the magnitude of X_k.

4. *Reviewer comment:* Please introduce/explain the variable ϕ_k in Section 2.1.

   Response: Section 2.1 now defines $\phi_k = \arg(X_k)$ and uses it in the reconstruction equation.

5. *Reviewer comment:* Please cite from where the data is taken for Figures 1–3.

   Response: The text and captions now state that Figures 1–3 use preliminary NACA 0018 CFD force-history data distributed with VorLap and converted with the repository preprocessing workflow. We also state that these data are used only to demonstrate the method, not as validation data, and that future work will include a high-quality CFD spectral dataset.

6. *Reviewer comment:* In line 112, what is the actual expected Strouhal number for the datasets and why exactly is the Strouhal number increased by 0.07? Also show/cite the datasets for better understanding.

   Response: We added the expected high-AoA Strouhal scale of approximately 0.15–0.16, citing Chen and Fang and Bidadi et al. We also clarified that the +0.07 shift is an illustrative offset for the preliminary NACA 0018 example spectra, not a universal correction, and should be replaced by application-matched data or treated as a sensitivity parameter.

7. *Reviewer comment:* Improve Figure 4 by clearly marking the corresponding velocity vectors explained in the section.

   Response: We restored the original VorLap geometry rendering to avoid ambiguous manual vector overlays, revised the text/caption to match the generated figure, and retained a small global-axis triad using the verified VorLap convention for this case: inflow direction $(1, 0, 0)$ and rotation axis $(0, 0, 1)$.

8. *Reviewer comment:* Please explain Algorithm 1 further, including the terms worst and above filter thresholds.

   Response: Algorithm 1 now uses clearer wording. The text defines the normalized frequency-overlap difference Δ_f, the retained highest-risk case, and the filter thresholds for spectral depth, force-coefficient amplitude, and frequency filtering.

9. *Reviewer comment:* Figure 5 shows that the reconstructed signal is in good agreement with the original (within 5%). How is this calculated?

   Response: We removed the unsupported "within 5%" statement. The manuscript now reports the Pearson correlation coefficient between the demeaned original and reconstructed time histories over the plotted 0–2 s window, $r = 0.90$, which better reflects the time-series agreement visible in the figure.

10. *Reviewer comment:* Please mention the dataset source in line 254.

    Response: The demonstration setup now states that the turbine example uses the preliminary VorLap NACA 0018 CFD force-history dataset described in the methods section.

11. *Reviewer comment:* How sensitive are the predicted frequency-overlap metrics and reconstructed loads to uncertainties in the source spectral data, such as URANS versus IDDES Strouhal discrepancies?

    Response: We added a source-spectral-sensitivity subsection explaining that $f_{\text{shed}} = St\, V_{\text{eff}}/L$, so Strouhal uncertainty directly shifts overlap predictions. We also note that coefficient amplitudes scale reconstructed loads, phase affects time-domain superposition, and URANS alone may be inadequate for resolving separated high-AoA wake-shedding spectra. The manuscript now frames the case as deterministic demonstration rather than probabilistic uncertainty quantification.

12. *Reviewer comment:* The turbine global directions mentioned in lines 310 and 311 can also be represented in Figure 4 for better visualization.

    Response: Figure 4 now includes a small x–y–z global-axis triad.

13. *Reviewer comment:* Please correct the listed references because the DOI is broken or the author list/paper name is wrong.

    Response: We corrected the listed reference metadata and also fixed related DOI-format and metadata issues for Horcas et al., Zhang et al., and Benner et al. We added Ebstrup et al. for the new sensitivity discussion.

Readability Comments

1. *Reviewer comment:* Grammar needs to be checked for line 29–31.

   Response: We rewrote the opening introduction sentences for clarity.

2. *Reviewer comment:* The lines 33–36 need rephrasing, as it is tough to read.

   Response: We rephrased the airfoil-shedding and wind-energy motivation paragraph.

3. *Reviewer comment:* A better representation is appreciated to show the inflow velocity range in Table 1.

   Response: Table 1 now reports the range as "1–16 m/s in 1 m/s increments."

4. *Reviewer comment:* The lines 297–301 need a grammar check and improvement for better readability.

   Response: We revised the paragraph to define the local chordwise and normal unit vectors more directly.

We appreciate the reviewer's suggestions. They led to a clearer and more traceable manuscript. We look forward to uploading and sharing the revised manuscript.