Wind Energ. Sci. Discuss., referee comment RC3
https://doi.org/10.5194/wes-2022-49-RC3, 2022


# Comment on wes-2022-49

Anonymous Referee #3

---

Referee comment on "Flight trajectory optimization of Fly-Gen airborne wind energy systems through a harmonic balance method" by Filippo Trevisi et al., Wind Energ. Sci. Discuss., https://doi.org/10.5194/wes-2022-49-RC3, 2022

---

This paper contains two contributions. First, it is the first academic work where the harmonic balance method is applied to compute power-optimal trajectories of an AWE system. As a case study, the authors apply the method to a low-fidelity point-mass model from the literature, adapted here to model Fly-Gen AWE systems. Second, the method is applied to compute power-optimal trajectories for varying objectives and constraints, in order to investigate the influence of different physical effects (e.g. electrical efficiency of on-board turbines, gravity,...) on the trajectories, and compare them to idealized analytic solutions from the literature.

The paper is well-structured. The authors provide a good overview of the available literature. The harmonic balance method is an interesting candidate method for AWE trajectory optimization. The authors present an efficient problem formulation while always checking for accuracy (discretization sensitivity is computed for all examples). It provides a good basis for further work on different system types, trajectory shapes and maybe also higher fidelity models. The thorough and illuminating analysis of different Fly-Gen trajectories is a fine illustration of the power of optimal control in AWE system dynamic analysis.

The paper is technically sound. Here are some suggestions to improve the quality of the manuscript:

1 Introduction
--------------------

L. 82-83: It is stated (also e.g. in the abstract) that working with Fourier coefficients instead of a time series allows to "reduce the problem size significantly". Although the intuition behind this statement is clear (particularly for Fly-Gen), there is no previous work on this, nor do the authors provide a comparison with a time-domain OCP of similar accuracy. In the example, an HB-OCP is solved with N_x =10, leading to (2*N_x + 1) nx = 21 times nx variables in the NLP. For a time period of ~12 s, one can imagine a time-domain multiple-shooting NLP with 20 intervals (and identical control parametrization) that solves this problem with similar accuracy. The relative performance of harmonic balance will be highly problem-dependent. Hence my suggestion is to weaken the claim: "... to potentially reduce the problem size significantly depending on the problem at hand". Or, of course, to include a comparison, which would be highly interesting.

In my opinion, the main benefit of the harmonic balance method lies in how it facilitates interpretation of the optimal result, as ilustrated in this paper.

In any case, an indication of computation times would be an interesting addition to the text.

2.2. Frequency Domain Formulation
--------------------------------------------------

- see first comment

L. 159: "the capability of solving for both stable and unstable (unlike time integration methods) branches of periodic solutions in an efficient way". It is unclear what is meant here. In the time domain, also unstable periodic orbits can be computed efficiently with multiple shooting or direct collocation transcriptions.

L181-189: This is a crucial paragraph (derivation of Eq. 23). All the steps that are now described only in words should be written here in formulas to allow for re-implementation by others.

2.3 Optimal Control Problem (OCP)
-------------------------------------------------

L.193: X^{\star} = arg min (instead of min) obj(X)

L. 204-206: Given that with algorithmic differentation (and the ubiquitous AD tools), you can get the gradient of any function for free, I would not advertise analytic gradients as a significant advantage of the harmonic balance method.

5.2 Optimizing for the Mean Thrust power considering Gravity
----------------------------------------------------------------------------------------

L. 284-285: The absolute value of the AWES velocity is imposed to be constant. It is unclear why?  Also, in L. 348 it says that in Section 5.2, the AWES velocity was found to be constant? Please clarify if it is imposed (and why) or if it is found to be optimal to be constant.

L. 313: OPC --> OCP