The authors would like to thank the reviewers for the constructive recommendations and comments which will help improve the current and future work. In the following, the authors would like to respond to the reviewers’ comments. The addressed comments are included in italic font.

<u>Answers to reviewer 1:</u>

1. T*he paper still is lacking in terms of scientific content/quality for publication and requires additional work. As it is, the paper would be OK for a conference with the emphasis more on the chain of tools that they use rather than on the actual problem solved. The mooring system is not treated and the overall problem is quite simple with out of the box tools that are interconnected. There is a good amount of prior art in this space and it is unclear that this work really moves beyond the state of the art in a substantial way. For spar optimization, also including the controller in some cases, there is some work out there that is not fully addressed by the authors. Some examples:*
    - *Hegseth JM, Bachynski EE. 2019. A semi-analytical frequency domain model for efficient design evaluation of spar floating wind turbines. Marine Structures*
    - *Dou S, Pegalajar-Jurado A, Wang S, Bredmose H, Stolpe M. 2020. Optimization of floating wind turbine support structures using frequency-domain analysis and analytical gradients. Journal of Physics: Conference Series*
    - *Souza CES, Hegseth JM, Bachynski EE. 2020. Frequency-dependent aerodynamic damping and inertia in linearized dynamic analysis of floating wind turbines. Journal of Physics: Conference Series*
    - *Hegseth JM, Bachynski EE, Martins JR. 2020. Integrated design optimization of spar floating wind turbines. Marine Structures*

   Please consider extending the analysis complexity and/or demonstrating more clearly how this work extends substantially beyond the state-of-the-art.

   The paper goes beyond the common approaches for spar optimization, not by focusing on including more aspects but rather by considering alternative – more innovative and novel – design solutions. This novel content of the paper and novel approach, which is different to existing studies and work in the literature, is emphasized in more detail by adding in the introduction section, as well as in the abstract, that novel structural realization approaches are considered for the resulting optimized geometries and also alternative ballast materials are taken into account. The final sentence in the abstract is, furthermore, reformulated into:

   > Thus, the presented design optimization example emphasizes the advantage of following a freer optimization formulation and allowing for novel structural approaches, by which means innovative floater designs, optimized with respect to the global system performance, can be obtained.

   Furthermore, the following paragraph is added at the end of Section 2.1, which demonstrates clearly how this work extends current and existing research and goes beyond the common approaches:

   > Within this study, however, the definition of an advanced spar-type floater is further extended and goes beyond the main objectives to reduce the draft of the floater and the cost of the overall system. Thus, additionally, alternative materials are investigated, which are from an economic point of view comparative to currently used materials, however, positively influence the final

floater design due to their different material properties and characteristics. Furthermore, the term advanced spar-type floater - used in this study - not only addresses the floating structure itself, but also includes the consideration of novel structural approaches which might be more promising than the common approach of welding cylindrical and tapered sections together and allow a widening of the design space for such innovative and advanced floater designs. The specific steps taken for addressing the definition of an advanced spar-type floater in a broader sense are described in detail in Sect. 2.4.

With respect to the exemplary additional literature, proposed by the reviewer, these are included in the paper as follows: (Hegseth and Bachynski, 2019) does not focus on an optimization approach, however, addresses the aspect of a reduced draft spar-buoy floater and, hence, is referenced in the third paragraph of the introduction. (Hegseth et al., 2020) is referenced in several parts of the paper: 1) in the introduction section, presenting an optimization approach, which aims for a reduced draft, focuses on several aspects and components, uses gradient-based methods, and includes limits on the maximum allowable taper angle for conventional manufacturing approaches; 2) in Section 5.4, as 15° are considered as maximum inclination angle for a parked spar-type floating wind turbine system in extreme environmental conditions; and 3) in the discussion chapter, addressing the considered limits on the maximum allowable taper angle based on conventional manufacturing approaches. (Dou et al., 2020) is added now as well in the introduction section, as this addresses the optimization of a spar-buoy.

2. *Also, there are some typos – make sure to do another proofread before resubmitting.*

Throughout the paper some typos are corrected and the sentences are simplified, shortened, or split up into several separate sentences to improve the readability of the paper.

3. *More detailed notes include:*
   - *Page 8, advanced – strong adjective for simple formulation*
   - *Page 9, advanced - why advanced? seems a simple sizing problem with few variables, mooring is excluded*
   - *Page 11, optimized advanced spar-type… - see prior comments*
   - *Page 12, advanced – see prior comments*
   - *Page 22, advanced – see prior comments, need to justify this better*
   - *Page 33, advanced – remove the use of the word advanced or quality further why it s so, the optimization itself is not demonstrably advanced compared to the state of the art*

The following paragraph is added at the end of Section 2.1, which demonstrates clearly why the strong adjective "advanced" is used in this paper and what specifically is meant and comprised in this term:

> Within this study, however, the definition of an advanced spar-type floater is further extended and goes beyond the main objectives to reduce the draft of the floater and the cost of the overall system. Thus, additionally, alternative materials are investigated, which are from an economic point of view comparative to currently used materials, however, positively influence the final

floater design due to their different material properties and characteristics. Furthermore, the term advanced spar-type floater - used in this study - not only addresses the floating structure itself, but also includes the consideration of novel structural approaches which might be more promising than the common approach of welding cylindrical and tapered sections together and allow a widening of the design space for such innovative and advanced floater designs. The specific steps taken for addressing the definition of an advanced spar-type floater in a broader sense are described in detail in Sect. 2.4.

4. *More detailed notes include:*
    - *Page 8, by addressing… - you could get sub optimal designs, or less optimized since the optimal solutions can not be achieved with a guarantee (GA is used)*

    The beneficial properties of using NSGAII are outlined in Section 4.3.2. There, it is also added that evolutionary algorithms are highly suited to find the global optimum of a defined optimization problem for such a complex engineering system, as a floating wind turbine is – based on the following added reference:

    > Mishra, S.; Sahoo, S.; Das, M. Genetic Algorithm: An Efficient Tool for Global Optimization. Adv. Comput. Sci. Technol. 2017, 10, 2201–2211.

5. *More detailed notes include:*
    - *Page 9, as, however, this distribution… - repetition*

    The repetition is removed and the two consecutive sentences are rephrased as follows:

    > The resulting allowable total height of the BC has to be distributed to the three partitions; however, no restrictions prevail and also the option of utilizing not all three BC parts is possible. Thus, the minimum allowable value for the height of each of the BC parts is machine epsilon (10^{-15} m) - as a zero value is unfeasible from a modeling point of view.

6. *More detailed notes include:*
    - *Page 11, fully-coupled complex floating offshore wind turbine system – what do you mean by complex?*

    The word complex is removed there, as the term “fully-coupled” already implies the complexity of such a system and the coupled motions and system responses.

7. *More detailed notes include:*
    - *Page 12, x1, the diameter of BCup – lot of page space – why?*

    The space was just due to the enumeration of the single design variables. As more information on the design variables (including a formal expression, the allowable value ranges, as well as the corresponding constraints) are added, the list is transformed into a table (now Table 2. Definition of the seven design variables.) and the page space no longer exists.

8. *More detailed notes include:*
    - *Page 18, nsgaII… - these are typically used for multi-objective optimization FYI*

    Yes, this aspect is addressed in Section 4.3.2, where it is also stated that such a genetic algorithm can deal with both formulations of an optimization problem: single-objective and multi-objective. Thus, NSGAII can also be used for this single-objective optimization problem and at the same time it is taken benefit from the high suitability of NSGAII for such a floating wind turbine system optimization problem, as well as from the good performance and capability of parallelization in a highly efficient manner – as stated in the first paragraph of Section 4.3.2.

9. *More detailed notes include:*
    - *Page 30, these – the results?*

    The sentence is rephrased as follows:

    > In addition to the results presented, analyzed, and discussed in Sect. 5, more details on these results are addressed in the following and further aspects are discussed.

10. *More detailed notes include:*
    - *Page 13, complex optimization problem with seven design variables and 25 constraints – again, not complex*
    - *Page 21, development of the design variables… the problem converges very quickly, 20 iterations is very small*
    - *Page 26, development of the objective function throughout the iterative optimization process, again, converged in 20 iterations.... what are the convergence criteria then for the opt analysis?*
    - *Page 26, zooming into the objective - for a genetic alg it is quite a simple problem… only 7 variables and mostly linear constraints (not of system response). the challenge here is the system response evaluation done externally with a Modellica model*

    The complexity of the presented optimization problem is considered in comparison to the first-stage design optimization application example (Section 4.3.2). In this section, it is also stated that "the convergence is checked separately when post-processing the simulation results". Thus, the optimum solution is taken based on the individual, which exhibits the lowest value for the structure material volume and at the same time complies with all constraints (Section 5.3.). Even if, as the reviewer states, the objective function has already converged significantly after around 20 iterations, there is still a large spread in some of the design variables (and also the objective function), including as well several individuals per generation that do not comply with all constraints.

<u>Answers to reviewer 2:</u>

1. *One of the main concerns relates to the estimation of the hydrodynamic loads on these generic hull forms. It is difficult to accept that the MacCamy-Fuchs formulation + Froude-Krylov forces in heave will give representative loads for these geometries with multiple horizontal surfaces. At the very least, the hydrodynamic characteristics of the optimized design should be studied in i.e. WAMIT or NEMOH, and a comparison of the performance should be given. This is discussed to some extent in section 6, but a re-analysis would provide much more information.*

    The authors agree with the reviewer that a more detailed hydrodynamic analysis would be required for such a completely different shape. Based on the hull shape, the obtained optimum floater design is right now lying between the common floater designs and ship structures. Thus, the authors furthermore believe that a separate sensitivity study would be required to elaborate the relevance and degree of necessity of advanced panel-based tools to be used for the design development of such innovative and novel floater designs. Such a detailed sensitivity study, utilizing and comparing different tools, like the currently used ones, the suggested tools WAMIT or NEMOH, or even CFD, however, goes beyond the scope of this paper and would rather be the scope of a separate stand-alone subsequent research study and paper.

2. *The approach for selecting the wall thickness in the present work may also be questioned. The steel mass per displaced volume is selected based on traditional spar designs, and yet applied to very different designs. At a minimum, hydrostatic pressure and the horizontal plates (top and bottom of the cylindrical sections) need to be considered. For the selected design, if I understand correctly, there are significant areas of the outer structure (which are subjected to hydrostatic and hydrodynamic pressures) which are simply accounted for by a very thin cap. This means that the optimizer will unrealistically reward designs with large diameter. In reality, such a design will require stiffeners and bulkheads (as well as expensive welding for the truss section which might replace the middle part of the column).*

    The authors understand the reviewer's concern and agree with the comment raised. As stated in the paper (among others in Section 5.3 and Chapter 6), the obtained optimum design "would not directly be technically feasible, both from a manufacturing point of view and with respect to structural integrity" and "plated partial bulkheads for load transfer" would be required to be added. The main purpose of this rather freer optimization approach is to allow for a widened design space and to enable the detection of alternative design solutions, which are better performing from a global system performance and cost point of view compared to the common designs that are more stringently restricted, as only conventional manufacturing approaches (welding cylindrical and tapered sections together) are allowed. The final design is not yet to be taken as the final realistic solution. However, this will serve as basis for discussions with manufacturers, what options exist and which ways can be taken to realize structures of such or similar shapes. With these inputs and information, a second optimization round – taking new constraints for such alternative manufacturing solutions into account – has to be performed subsequently to find the final optimum, but still novel floater design solution.

3. *The mooring system assumptions are also confusing to me: are the fairlead locations maintained at z=-70m regardless of the draft of the design? This also has important consequences for the mean pitch motions.*

   The resulting mooring system properties from the original system design are taken and used, still accounting for the motion of the floater (last paragraph of Section 2.3). As discussed in the second paragraph in Chapter 6, a subsequent optimization of the mooring system properties and layout design can further improve the performance of the floating system, including the pitch motion – corresponding to the system inclination.

4. *Some additional information about the optimizer would also strengthen the present work. For example, how are the variables coded? What strategies are employed to introduce variation (mutation, immigration, others)? Could the performance be improved by "culling" the initial population so that (at a minimum) the geometric constraints which are cheap to compute are satisfied? It would be nice to distinguish between bounds and constraints in the optimization definition.*

   - The coding of the variables is straight-forward, as the design variables are variables which exist in the model. The same is valid for the other variables addressed in the constraints and the objective function. These are determined within the numerical model and defined as outputs of the simulation, so that these can directly be evaluated by the optimizer, following the equations presented in the paper.
   - With respect to the details for the strategies for representing the evolution, the following item is added to the bullet point list in Section 4.3.2:

     The individuals are randomly generated. When evaluating the objective function and constraints, the dominant individuals - each selected based on a comparison of two individuals - form the basis for the next generation, which is created without using any variator. These are the default generator, selector, and variator settings of NSGAII in Platypus.

     Furthermore, the additional information that "the tournament selector for evaluating the dominance is used" is added in Section 4.3.3.
   - With respect to the suggested improvement of the performance, the authors have to state that the geometric constraints are already satisfied, based on the followed approach. This is due to the fact, that the optimizer selects the new individuals just based on the allowable value ranges, specified in the corresponding constraints. This is described in Section 4.3.3. This is also again stated in Section 5.1: "The first 14 constraints for the allowable value ranges of the design variables are excluded, as they are not constraints that are evaluated after the simulation but are taken into account ahead of the simulations when the optimizer selects the design variables for the new individuals and, hence, are never violated."
   - The definition of the optimization problem, given at the beginning of Section 3, follows the commonly used formal description, using the design variable vector, the objective functions, as well as the constraints, where the bounds are also included. To better distinguish between bounds and constraints, the enumeration of the

design variables in Section 3.1 is changed into a table (now Table 2. Definition of the seven design variables), in which more details, such as the allowable value ranges – hence, the bounds – as well as the corresponding constraints, are provided. Furthermore, in the table presenting the constraints (now Table 3), it becomes clear from the description that g_1 to g_{14} are constraints specifying the bounds for the design variables and, additionally, g_{21} and g_{22} are the constraining bounds for the ballast density.

5. *The introduction/text should be updated to account for the state of industry FWT farms (i.e. WindFloat Atlantic).*

   The introduction is updated, considering the recent technology and industrial steps that had happened since the last submission of the revised paper. Thus, WindFloat Atlantic is included, the overall number of floating foundation concepts is updated, and also the expected date for the TetraSpar demonstrator installation is updated.

6. *The paragraph beginning on line 35 is rather unwieldy and could be shortened – perhaps a table or other approach could be used to summarize the literature in a more efficient way? At a minimum, this paragraph should be separated into several shorter paragraphs.*

   This paragraph had been extended based on the request from other reviewers for a more in-depth and detailed literature review. The authors can fully understand the reviewer's concern. Thus, the paragraph is broken down into single shorter paragraphs and structured as follows:
   - the relevance for enhancing the common spar-buoy design from a more general point of view;
   - approaches for advanced spar-buoy floater designs by modifying the floater itself;
   - approaches for advanced spar-buoy floater designs adding and modifying other components (and not the floating structure itself);
   - common design optimization approaches for enhancing the common spar-buoy design;
   - going beyond the common approaches by considering novel structural realization approaches and alternative ballast materials – the approach presented in this paper).

7. *I think it would make the reader's life easier if table and figures referred to physical variable names (for example $DBCup$) rather than optimization variable names xi, which are more difficult to remember.*

   To make the transfer between the design variables x_i and corresponding physical variable names easier, the list of the design variables in Section 3.1 is changed into a table (now Table 2. Definition of the seven design variables), in which also the formal expression is added. Thus, the reader does not need to search for any description in the text but can just look up the corresponding physical variable name and description in the table.

8. *In general, the paper would also benefit from an effort to shorten and simplify the sentences.*

Throughout the paper some typos are corrected and the sentences are simplified, shortened, or split up into several separate sentences to improve the readability of the paper.