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Interactive comment

Interactive comment on "Parametric slat design study for thick base airfoils at high Reynolds numbers" *by* Julia Steiner et al.

Anonymous Referee #1

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General comments

The work described in the paper is a very interesting design approach. The work as such is done in a good scientific manner. The wording is clear and good to read and understand.

Anyhow, the work needs major rework. Specific topics are highlighted in detail in the section with specific comments. In general, significant content that is moved to an appendix should be placed in the main text. Pressure distributions are shown but not discussed to a sufficient extent. Graphics have to be reworked and supported by descriptive captions and should be appropiately discussed in the text. Further on, the paper fails to compare the own work with previous experience (esp. the cited work done by Pechlivanoglou et al., Schramm et al., Manso Jaume and Wild. All of them already

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Discussion paper

addressed the slat design for wind turbine airfoils) to highlight common or contradictory results and thereby to identify specialties of thick baseline airfoils, which are highlighted to be one of the new contributions of the paper.

Specific comments

page 2, lines 27-43: The described methods for stall delay (vortex generators and Gurney flaps) are not part of the study. It should be checked if this information is of any benefit for the paper.

page 2, lines 47-48: The description of the Circlulation Effect is misleading. The first sentence is not describing the soure of the circulation increase. Instead, the circulation on the rear element induces an upward velocity component at the trailing edge of the preceding element. This has to be compensated by the forward element circulation to achieve the Kutta-condition at the trailing edge.

page 2, line 51: The description of the Dumping Effect does not describe the origin of the accelerated flow. It must be described that the high velocity at the forward element trailing edge is induced by the low pressure of the suction region at the leading edge of the downstream element.

page 3, line 57/58: It is a misunderstanding that the slat increases the lift coefficient at the same flow condition (angle of attack). This is usually not the case as long as the slat doesn't significantly increase the overall chord length of the airfoil system. This would be accomplished by a steeper gradient oft he lift curve vs.angle of attack. The lift created by the slat compensates the lift drop at the main element due to the reduction of the suction peak (Slat Effect). The part of the statement "an increase of the lift for all angles of attack and" should be deleted. Consequently, the text in the following paragraphs has to be adopted (delete "increased lift and" in line 63 as well as the sentence line 64/65).

page 3, line 79: The reference to the airfoil numbers is a correct citation of the referred work by Pechlivanoglou. Nevertheless, the notation of the TU Delft airfoil deviates from other known notations. Further on, the NACA 22 airfoil is at first not widely known and the notation suggests to be a mistake as there is no 2-digit NACA airfoil series as such. So it would be benefcial to refer to its origin (first named in Weick and Noyes, NACA TN 451, but designed and first tested by Weick and Wenzinger, NACA TR 407)

page 5, line 131: Is there an explanation why not a GC2 continuity is targeted. Especially in the leading edge region a curvature continous shape would provide smoother pressure distributions.

page 6, line 147: Please state what the authors assume to be a "reasonable" mesh resolution in more detail

page 6, line 151: It is unclear, where a local thickness is imposed.

page 6, lines 161-164: As the optimization framework and algorithms are not described in detail, proper reference and citation has to be given.

page 7, lines 173-174: provide citation of the reference to the codes used. For OpenFOAM make sure to refer also the code version and check-out date as open soure software tends to be changed very rapidly, but the reported results shall be reproducable.

page 7, line 176: Please refer to the airfoil correctly. The airfoil is called NHLP 90 L1T2 (see Woodward Lean, AGARD CP515) and it has been published by Moir as test case A2 for CFD validationdescribed in AGARD AR 303. The correction shall be propagated throughout the manuscript (e.g. page 8, line 201, caption of fig. 4 on page 9) page 7, line 182: Are the six chord lengths sufficient in the view of the authors to eliminate effects on the boundary condition - or is there a vorticity correction at the farfield boundary employed?

page 7, line 191: It is stated that O-mesh topologies are applied although Pointwise is used. Please state, why not a C-mesh is used that would allow an improved capturing of the slat and main airfoil wakes.

page 8, line 200: The authors suspect the experiment to be the reason for the deviations, but it could be the missing resolution of the airfoil wakes, too.

page 8, line 203/204: This is a mistake. The Reynolds number in high-lift mulit-element airfoil cases is based on the "clean chord", which is the cruise airfoil with high-lift system retracted.

page 8, line 204/205: This is another - more common - mistake. Although the Mach number is relatively low, a look on the pressure peaks of this case unveils that the slat suction peak (although not shown here but reported in AGARD AR 303 or AGARD CP 515) gets into sonic speed conditions! Therefore, the choice of an incompressible solver for this airfoil is more than questionable.

page 8, line 208: The over prediction of the stall angle by 6° seems pretty large as the main motiviation of the work is based on the prediction of the stall delay by a slat which is mainly the shift in stall angle.

page 9, line 214: The conclusion that MSES can be used as a substitute for RANS CFD is weak and not supported. MSES is not able to capture confluent oundary layers at all. Due to the small gap and since the optimum slat position is very close to the position where the confluent boundary layer gets dominant (see Woodward and Lean, AGARD CP515, 1993) an optimization procedure neglecting this effect is liekly to predict gaps that are too small.

page 10, line 223: It is fully unclear why the most sensitive parameter for slat design - the gap - is fixed at the beginning. Additionally, the chosen values seem large. According to Woodward and Lean (1993) an optimum gap is strongly depending on the slat angle and can go down to 2-2.5% chord length. In the further (line 230 and following) the reason for the change in performance is most likely more related to the slat angle than the gap. It is consitent, that the optimal slat deflection angle is lower for the higher gap. At least concerning lift, it doesn't seem that a maximum lift coeffcient is clearly detected.

page 10, fig. 6: It is not consistient (and not expected by the reader) to show MSES results in these diagrams. Above it was mentioned, that the designs were optimized by MSES but the performance prediction for the evaluation is done with RANS. Especially, there is no clear max. lift coefficient prediction in the shown data.

page 11, line 258ff: an important description needed to understand the figures and the conclusions should not be placed in an appendix.

page 12, fig. 8: This figure is a collection of all optimization data. It is not very explanative as it overlays too much information. It contains already data (of the integral design) that hasn't yet even been introduced and is decribed much later. This figure should be divided for the different design methods and commented accordingly in the text.

page 12, lines 263-265: This would be a good option to highlight a common result with previous work (see General comments). This result is also in line with the results obtained by Manso Jaume and Wild for the superimposed slat optimization.

page 13, lines 278-281: The statement on the sensitivity of separation on the slat shape is not supported by theory. In constast, a cambered plate is less likely to separate at high angles of attack than a flat plate. Additionally, closing the gap increases the slotted airfoil effects in both directions. In fact, as the slat is moved veritcally, the Slat Effect and the Circulation Effect are expected to get stronger. Only the Dumping effect is expected to be reduced due to the reduction of the suction peak due to the strengthened Slat Effect. In consequence, the slat load is increased (higher circulation and higher trailing edge pressure) resulting in a more cambered airfoil to be more suitable to achieve the circulation without separaton. To verify this, a comparison of the pressure distributions is needed. This conlclusion has therefore to be reworked.

page 13, line 281: Regarding the slat thickness, other preliminary designs are mentioned. It is unclear whether this is previous work (then to be cited) or own unpublished experience. Anyhow, this statement should be reworked to be reproducable by the reader.

page 13, fig. 9: The line legend of figure 9 introduces an undescribed configuration A* in addition (same for fig. 14, and in figs 15-17 configs B*, C*, D*). The meaning and origin is perfectly unclear. It can only be assumed from later reading that this configuration related to the integral design that is described much later (starting from page 15). The pressure distributions shown in the right hand side are not discussed at all in the text.

page 14, line 298: To be precise, none of the airofils is optimized for maximum lift coefficient. The airfoil optimization only targeted a high lift coeffciient at a high angle of attack (here AoA=20°). An airfoil stalling at 19° could have a higher maximum lift coefficient than one not stalled at 20°. To do a maximum lift coefficient optimization it is necessary to detect the naximum lift coefficient of an airfoil by varying the angle of attack.

page 14, line 310: Here it is stated that experimental data for the clean airfoil would be available for comparison. Such a comparison would have been an asset in section 3.1 regarding the validation of the methodology.

page 15, line 318: it should be highlighted that - in contrast to the integrated design work of Manso Jaume and Wild, where the suction side contour of the slat is the contour of the original main airfoil - the integral design here is not restricted by the clean airfoil shapein the same way. This underlined the originality of the present work and its relation to previous work.

page 15, line 334/335: It is mentioned that the main airfoil shape is a consequence of the structural constraints. But it is more expected that this is an implicit result of the main airfoil shape optimization. Due to the higher curvature, the suction peak is more locally concentrated (improving the Dumping Effect and stabilizing the slat flow) and the trailing edge position therefore placed close to the maximum curvature - which is now much furhter upstream. The intragrated design by Manso Jaume and Wild shows a similar main airfoil shape, and there, no structural constraint has been imposed.

page 17, lines 358-360: The discussion describes a "larger leading edge radius". It would be better to descirbe the leading edge as "more blunt". Further on, it is not a larger leading edge radius that shifts the suction peak to the front. A larger leading edge radius alone would reduce the suction peak but not move it. The present description is misleading as the curvature which is responsible for the interaction with the slat is higher (and the radius smaller) and imposes a rduced pressure at the slat trailing edge.

page 17, line 364/365: It is mentioned that the design angle doesn't account for lower side separaiton. This is correct, but anyhow, no clear indication of a lower side separation is seen for the designs with slat even at lower angles of attack.

page 17, lines 367/369: This is a very late explanation for a figure that had been placed on page 12. It is necessary to split-up fig. 8 and to place the related illustrations close to the dicsussion in the text.

page 17, lines 371: As already discussed "more rounded" suggests a smoother curvature distribution, while the opposite is the case for the integral designs.

page 18, lines 374/375: This conclusion is in contrast to a previous statement, where it was concluded that the optimal shape of the slat is not as sensitive to the main airfoil optimization and by this not as affected of the auxilary or integral design method (page 17, lines 356/357).

page 18, lines 383-385: Basically, to show the stalling behavior it is necessary to look at the pressure distribution just at stall onset. Best is a comparison with a very low AoA step before and after maximum lift. The used step of 8° is too large and - depending on the stall onset angle - the stall is developped over the entire configuration but not showing the onset (main wing or slat or both at the same time).

page 18, line 387: It should be discussed, whether the reattachment due to wake displacement is in accorcance with Snith's 4th effect (Off-Surface Pressure Recovery)

page 18, lines 387-389: As the stall onsiet is of primary interest, the discussion of the flow fields should not be placed into an appendix.

page 18, line 391/392: The last statement on this page is not directly supported by figure 15. To see this, it would be better to cross-plot the pressure distributions of both deigns at the same angle of attack on top of each other - and not side-by-side.

page 19, line 393: At least here at the end of all shown pressure distributions, it is necessary to conclude about the suitability of the incompressible solver. Although the flow speed is not mentioned (missing in the case description in Table A.1) the level of the pressure coefficient is less than -15 and imposes the need to check whether this assumption is still valid.

page 19, lines 395-397: The description reverses cause and effect. The high suction peak on the main airfoil is the reason for the low trailing edge pressure at the slat - remind Smith's effects.

page 21, line 428: To conclude on the importance of the gap it should have been used as a design parameter. The limited information on the gap variation (two values only) doesn't allowto draw such abbreviation general conclusion. From other airfoils in literature it is known that the gap is even the most sensitive parameter.

Technical comments

The Reynolds number is stated in the text in a form $Re = XXm$ with m as an abbreviation to "million". As this could easily be mixed up with the unit "meter" a notation of the form $Re = xx \times 10^6$ would be recommended.

The reference to and citation of A.M.O. Smith's work is not proper. In the text, the citation "O. Smith (1975)" should read "Smith (1975)", e.g. on page 2 - line 45, page 3 - line 61. The reference (page 28 - line 507) should read "Smith, A.M.O.: ..."

Figures and captions must be improved. multi-figures are not fully described by captions. Labels (a) and so on are not clearly addressed tot the single figures. Line legends are often missing (especially fig. 8 and fig. 11).

Abbreviations and mathematical symbols shall be explained at their first occurence. Especially introducing abbreviations in figures only (e.g. "OF" in fig. 9) shall be avoided.

The word "subsection" is written with capital letter "S" at several locations. As this is not a name, a lower case "s" should be used (pages 9, 15 and 17).

The references list has to be reworked. DOI numbers appear twice, "https://doi.org" sometimes doubled. Journals are references by volume but not by number.

page 4, line 104/105: The citation "Manso and Jaume" should be replaced by "Manso Jaume and Wild" to be correct ("Manso Jaume" is the full last name of the first author - above in line 99 the citation is correct).

page 6, line 151: A line break before a sentence delimiter has to be avoided.

page 6, line 151: To be consistent in time "Constraints are imposed ..."

page 9, caption of fig. 4: "AGARD" is not a name but an abbreviation and should be written in capital letters

page 20, line 414: "compromises" should be replaced by "summarizes"

page 24, fig. B1: The color scale is unclear (which value plotted?).

page 25, fig. D1 and page 26, fig. D2 include angle of attack in plots. it is not clear whether to read the images left-to-right or top-bottom.

page 28, line 503: There is a mixup in the capital letters for the abbreviation of AGARD.

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