IEA Wind Task 37 on System Engineering in Wind Energy
WP2 - Reference Wind Turbines

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Abstract

This report describes two wind turbine models developed within the second work package (WP2) of IEA Wind Task 37 on Wind Energy Systems Engineering: Integrated RD&D. The wind turbine models aim at acting as references for future research projects on wind energy, representing a modern onshore wind turbine and a next generation offshore wind turbine. The onshore design is a Class IIIA geared configuration with a rated electrical power of 3.35 MW, a rotor diameter of 130 meters and a hub height of 110 meters. The offshore design is a Class IA configuration with a rated electrical power of 10.0 MW, a rotor diameter of 180 meters and a hub height of 119 meters. For the offshore turbine both a geared configuration and a direct drive configuration are presented.

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1 Introduction

During the design of complex systems such as wind turbines, innovations, improved methods, and research findings are often made at the level of a single component, or discipline. One must then determine what the positive impact will be on the rest of the system if any. If this evaluation can be made by modifying a reference system, whose behavior has been well characterized, then the results may be readily understood, and compared against other relevant results. This helps to solidify the scientific basis, such as reproducibility and benchmarking, of the findings. Also, from a purely practical standpoint, it helps to adopt reference configurations for all reporting activities.

Reference turbines have aided the research community for some time. One of the most well known reference turbine is the "NREL 5-MW" reference turbine developed in 2005 using a combination of commercial turbine data and parameters of other reference turbines available at the time [34]. Designers and researchers around the world have used that reference turbine, and while there are a number of turbine OEMs who have developed a 5-MW turbine (Repower, Areva, Bard, XEMC, Goldwind, and Gamesa), all of these turbines vary in rotor size (115-152 m) from the original reference.

However, wind turbine technology has significantly advanced since 2005, making the 5-MW reference turbine less useful as a reference that were to reflect modern technology. In addition, current offshore technology has scaled beyond 5-MW. Siemens Gamesa and GE have deployed a 6-MW turbine, while Samsung and Vestas have 7- and 8-MW models, respectively, and MHI (a Mitsubishi and Vestas joint venture) is now selling an 8-MW turbine [36]. 10-MW turbines have been proposed by Senvion, AMSC and Siemens Gamesa. Most recently, GE has introduced their Halide-X 12-MW design that they expect to commercialize in the coming years [35]. The 5-MW reference turbine has a high speed drive train, while most offshore wind turbines have moved toward medium-speed or direct-drive architectures. The 5-MW reference also has a high specific power of nearly 400 W/m2, which will skew the predicted annual energy production (AEP) leading to higher levelized cost of energy (COE) estimates when this turbine is used as the basis for economic assessments. In contrast, the new Halide-X proposed by GE has a specific power of 315 W/m2 and an estimated capacity factor of 63% when placed on a tower of approximately 150 m in height [35]. Structurally, the reference turbine rotor and nacelle are also much heavier than modern turbine designs, having implications in tower and support structure design. In addition, the design was always intended as an offshore wind turbine but has been used extensively for land-based research studies due to the lack of alternatives. For both land-based and offshore applications, there is a need for new reference turbines that better reflect current technology.

In 2013 DTU Wind Energy released the "DTU 10 MW" Reference Wind Turbine, which is a Class IA offshore turbine [43]. The turbine was not designed to represent the state-of-the art or incorporate innovative technologies, but was meant to be a baseline for benchmarking new technologies. The turbine is described with high detail, including blade geometrical data needed for both BEM based and CFD codes, as well as detailed structural data relevant for FEM codes. The turbine is currently being used widely in the research community and as of April 2018 had over 1000 users. It has been used and adapted in a number of Danish national and European projects such as INNWIND, MareWint and IRPWind. However, early use and adoption of the DTU 10-MW reference turbine found some shortcomings as well - in particular the specific power which was also high with a value of 400 W/m2. This motivates the need for updated references for large-scale offshore wind turbine applications.

One of the core activities of the IEA Wind Task 37: Integrated RD&D [9]: is to develop reference turbines that reflect current wind turbine technology. The consortium, that included research and industry partners from China, Denmark, Germany, The Netherlands, Norway, Spain, United Kingdom and USA reached a broad agreement on the typical application areas and top level characteristics of two reference wind turbines that could be used immediately by the research and broader wind community including:

- Onshore locations with moderate winds: a 3 MW IEC Class III turbine, with a large rotor for a high capacity factor, and a geared drivetrain.
- Next generation of offshore wind turbines: a 10 MW Class I turbine with both a geared and direct drive configuration.

A survey was conducted to further explore the use cases and needs for reference wind turbine designs for research and development applications and to more specifically define the design characteristics of each reference turbine. Having defined the specifics of the configurations for each turbine based on input from the research community and industry, a team of IEA Wind Task 37 participants developed the turbines in an iterative process with design reviews held at intermediate points along the development path. This report is meant to detail the development process and the resulting two new IEA Wind Task Reference turbines. For further details and data for the designs see the IEA Wind Task 37 software and data website or go to the next url: `http://github.com/IEAWindTask37`. It is important to note that as the task continues its work, there are plans to develop additional reference turbines that align with evolving trends in commercial wind technology for land-based and offshore applications. The two described in this document are the first in the series of IEA Wind Task 37 reference turbines.

This document first reviews the results of the survey in Sect. 2 and then introduces in Sect. 3 the design tools and methodologies adopted for the design development of the wind turbine models. Then, the onshore configuration is presented in Sect. 4, while the offshore configuration is presented in Sect. 5.

2 Survey on Reference Turbine Use Cases and Needs

In the fall of 2016, a survey was conducted to identify the uses cases and needs for reference wind turbines in research and development applications. In total, 81 respondents completed the survey that represent a broad cross section of users from universities, research institutes, wind turbine manufacturers, wind farm developers, and consultancies. The bulk of the responses came from universities and research institutes who have been historically the largest user group for reference turbine designs. Figure 1 shows the breakdown of respondents by type of organizational affiliation.

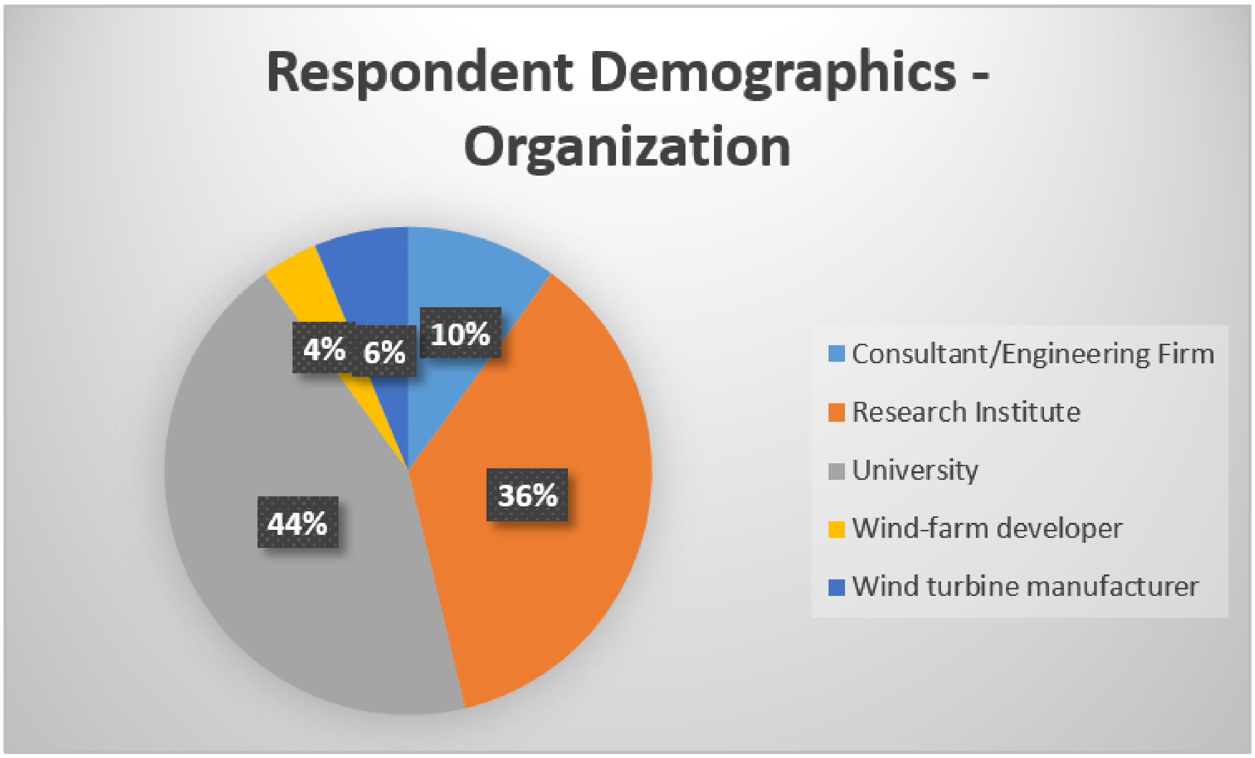


Figure 1: Representation of different organizations in the survey response pool. Only one respondent chose to abstain from providing their organization type.

In terms of application, a large number of respondents work in the fields of aerodynamics, aeroelastics and loads analysis, controls engineering, offshore support structure design and analysis and MDAO / systems engineering for wind energy.

Respondents were first asked to identify what reference turbines they had used in the past and to characterize the strengths and weaknesses of those designs. In a second section, respondents were asked to provide input to the key turbine configuration characteristics they would like to see for the new set of reference turbines developed under the IEA Wind Task 37.

2.1 Historical Reference Turbine Use and Evaluation

Of the 81 responses, 78 respondents had prior experience using a reference turbine. 65 respondents had experience with the NREL 5-MW reference turbine and 55 had experience with the DTU 10-MW reference turbine. A small number of respondents had used other reference turbine designs including variants of the DTU 10-MW design used by European research projects as well as older designs from the early 2000s and before (notably the NREL Phase VI turbine [42] and WindPACT 1.5-MW reference turbine [38]).

The majority of respondents, 76, had used the reference turbines for research purposes while almost half, 34, had also used them for educational purposes. Only a small number, 13, had used them for commercial applications but this is a direct reflection of the survey demographics since only 16 of the survey respondents were from commercial organizations.

In terms of use cases, the respondents responded with a relatively broad set of applications. Respondents were able to select multiple use cases and the majority selected 2 or more. The dominant uses, not surprisingly, were in aeroelastic analysis, structural analysis, and aerodynamic studies. Historic reference turbine designs have focused on the aeroelastic description of the machine to enable analysis of machine performance and loads. The second most dominant area of use was in the offshore support structure and tower/foundation design. Reference turbines are particularly valuable as test cases for design of these major components since the detailed aspects of commercial wind turbine designs are not often available. Beyond these primary use cases, other notable uses include blade design, controller design and multi-disciplinary design, analysis and optimization where reference turbines provide test beds or baselines for design activities. Less common responses included plant flow, wake and wind farm modeling which could be due to selection bias in the survey respondent set or reflects the fact that these are new and growing research areas where the detailed aspects of the turbine design were less important. As the emphasis on modeling wind plants with higher fidelity wind turbine representation grows, we expect the user base at the plant modeling level to grow and this trend has been seen in the last several years in the wind research community. Table 1 summarize the results from the respondents on use cases for referenc turbines.

Table 1: Summary uses cases of interest to survey respondents.

Use Case	Number of Responses
Aerodynamics study	34
Aeroelastic analysis	48
Blade design study	25
Controller design	25
Drive train design	7
Tower/foundation design	21
Offshore support structure design	38
Structural analysis	40
Multidisciplinary design/analysis (MDAO)	22
Wake modelling	14
Plant flow modelling and controls	3
Wind farm design	10
Cost modelling	14

Thus, the respondents of the survey have had significant experience with reference wind turbines for a variety of use cases and with the dominant two open-source reference turbine designs of the NREL 5-MW and DTU 10-MW reference turbines. The work has resulted in an extensive number of research papers. In just this survey alone, nearly 250 conference papers and journal articles were identified by respondents that leverage one or more reference turbines. This is likely a small sample of the actual number. The next series of questions focused on the evaluation of these two historical reference turbine designs.

2.1.1 NREL 5-MW Reference Turbine

Each reference turbine was evaluated based on the sufficiency in scope (in terms of the sub-systems modeled) and model fidelity. For the NREL 5-MW reference turbine, the vast majority of respondents found that the rotor aerodynamic design was sufficiently specified while most also found the rotor structure, controller, drivetrain and tower design to be sufficiently specified. On the other hand, a larger number of respondents, 30% and 23% respectively, found the controller and drive-train designs to be under-specified.

Specific critiques of the NREL 5-MW design included:

- The blade design as provided in original documentation included only the blade properties and not details of the geometric design. Sandia National Laboratories reverse engineered a blade design later on, but this was seen as short-coming from the original design. [40]
- One respondent described the controller as provided with the model to be ”jurassic” and many others critiqued the lack of detail on the controller and electrical design. A more detailed controller was later provided by Bossanyi but again not part of the original design. [41]
- Particulars of the hub design dimensions and blade root mass being too small, the blade torsional stiffness being unrealistic, displacement response of dampers that does not match higher fidelity models, use of older airfoil families, blades being too heavy for modern designs, and a specific rating that is too high.
- Detailed reporting of the fatigue analysis was cited as something that would be useful for future designs.
- Lack of version control when releasing the design.

No reference turbine will ever be perfect nor reflect exactly commercial wind turbine designs along with full design specifications, but all of these insights are helpful in terms of the development of new reference designs. Many respondents created their own variations of the NREL 5-MW reference turbine design to address the shortcomings as described above.

2.1.2 DTU 10 MW Reference Turbine

The DTU 10 MW reference turbine was much more recently developed than the NREL 5-MW and also developed using a formal optimization framework. Thus, it was expected that the design would be evaluated more favorably. Indeed, over 90% of respondents found the aerodynamic design to be sufficiently specified and over 75% found the rest of the machine, blade structure, controller, drivetrain and tower design, to be sufficiently specified. This reflects the improved capabilities in developing reference turbines that represent current technology with sufficient detail.

However, even given the strengths of the design, respondents found several areas for potential improvement including:

- Many respondents still found the controller to not be sufficiently developed and also wanted the controller to be available in different file formats.
- The design lacks a detailed drivetrain design which impedes its utility in cost analysis. Users would also like to see a direct-drive version of the design.
- The detailed structural design of the blade was commented to be unrealistic by a few users without further reasoning. One respondent suggested Reynolds number dependent airfoil polars would be a useful addition.
- Some respondents wanted clearer and more consistent documentation and also found the CAD files to be problematic and some expressed a desire for CFD meshes to be provided. The same comment about version control was also expressed.

While some of these critiques are quite particular, a few have surfaced multiple times including the need for a better controller for reference turbine designs, more detailed blade structural design information, more detailed drivetrain designs, and better documentation and version control. The team tried to address several of these common criticisms in the development of the IEA Wind Task 37 reference turbines.

2.2 Specifications for New Reference Wind Turbines

Having evaluated past designs, the respondents were next asked to provide their inputs to the characteristics of new reference turbine design. This included the high-level configuration for the turbine including rated power, rotor diameter, specific power, maximum tip speed, hub height and drivetrain design as well as additional design considerations.

2.2.1 Land-Based Reference Wind Turbine

For the land-based reference wind turbine, Figure 2 shows the results around the key turbine configuration parameters of rated power and associated specific power.

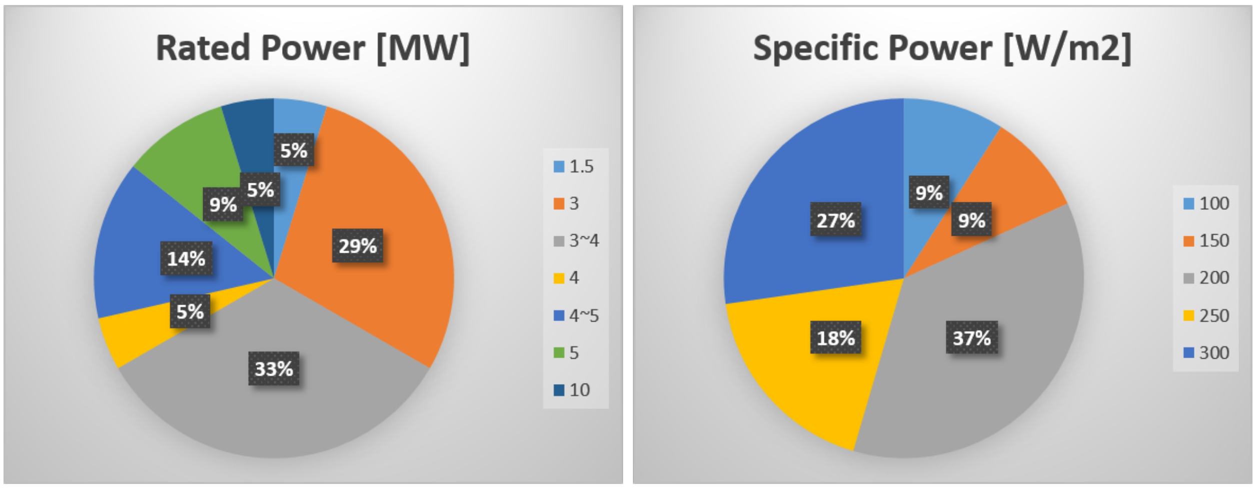


Figure 2: Input into the new land-based reference turbine design in terms of rated power and specific power.

The majority of respondents suggested a 3-MW or 3- to 4-MW rated power for the new reference turbine which aligns well with many of the recent commercial product offerings that turbine manufacturers have introduced in the last several years. For specific power, most respondents suggested a lower specific power of under 250 W/m2 or even less. This shows also the trend toward low-wind-speed turbines in industry with much higher capacity factors and better performance in low-wind-speed sites. Ranges for suggested rotor diameters fell between 100 to 170 m and generally aligned with respondents suggestions around appropriate rated power / specific power combinations.

For drivetrain design, surprisingly most respondents favored a direct-drive configuration with the second highest scoring design configuration a high-speed geared configuration with a doubly-fed induction generator. Maximum tip speed was recommended by most respondents to be between 80 and 90 m/s and hub height was recommended to be between 120 to 150 m. The latter suggestion around hub height aligns with developments especially in Europe where tall towers are increasingly used. However, design challenges for tall towers and the use of novel configurations called into question whether such a large height were warranted for the reference design.

To further inform the design specifications, the responses from the larger survey were used to solicit input from a small number of industry representatives. The results of that process finalized the reference turbine design configuration. The final design would be a 3- to 4-MW range for rated power with a lower specific power (at most 250 W/m2), a maximum tip speed of at most 90 m/s and a geared drivetrain with doubly fed induction generator and a hub height of around 100 m. Final design decisions related to the exact values for the configuration were left to the lead engineer for the reference turbine development.

2.2.2 Offshore Reference Wind Turbine

For the offshore reference wind turbine, Figure **??** shows the results around the key turbine configuration parameters of rated power and associated specific power.

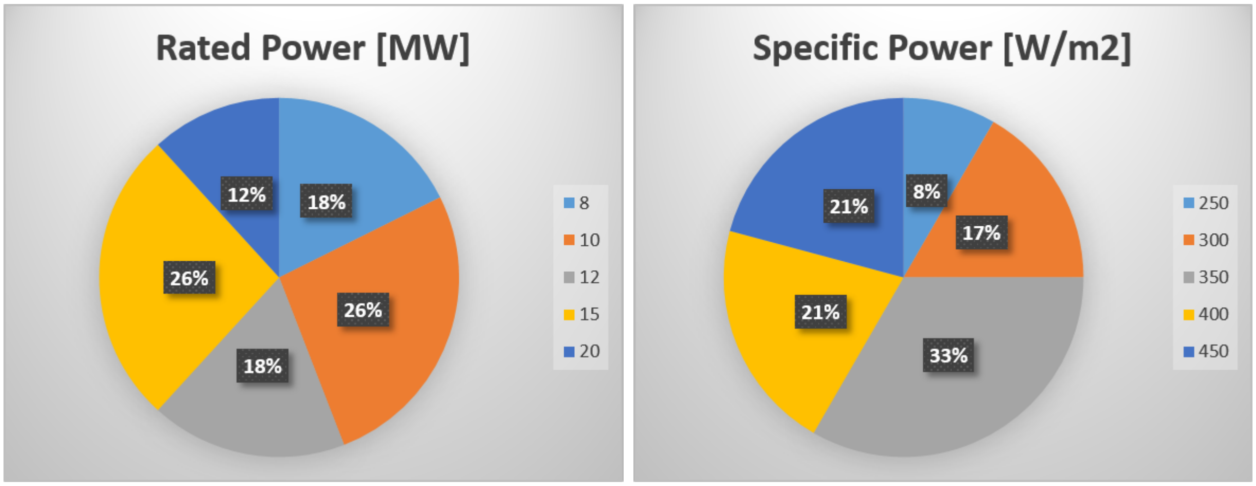


Figure 3: Input into the new offshore reference turbine design in terms of rated power and specific power.

For offshore, there was quite a range of interest in rated power from 8-MW all the way to 20-MW. Many respondents recommended a 10- to 12-MW turbine while quite a large number recommended even larger sizes of 15- to 20-MW. For the first design iteration, given limited resources, it was decided to do a redesign of the DTU 10-MW reference turbine rather than a completely new larger design. The development of a larger reference turbine will likely follow. For specific power, most respondents suggested a value lower than 350 W/m2. Thus, the most significant change to the DTU 10-MW reference turbine recommended was to reduce the specific power from the current value of 400 W/m2. For maximum tip speed, between 90 to 110 m/s was recommended and a hub height of 140 m was the most popular response. Over half of the respondents recommend a drivetrain configuration of direct-drive with a synchronous generator though about a third of respondents also suggested a medium-speed geared drivetrain with a synchronous generator.

Taking into account additional input from IEA Wind Task 37 industry participants, the final design was chosen for the DTU 10-MW reference turbine with a specific power of under 350 W/m2 , a maximum allowable tip speed of up to 110 m/s and a direct-drive drivetrain with a synchronous generator. Final design decisions related to the exact values for the configuration were left to the lead engineer for the reference turbine development.

Note that the design of the support structure was not discussed here and is an important consideration for the overall design. The reference turbine developed by DTU used a land-based tower and the reference wind plant track within IEA Wind Task 37 (work package 2.2) is developing a tower/monopile support structure for the turbine in 30 m of water-depth using site-specific met-ocean conditions. That design will be handled in a separate report.

3 Design Tools and Methodologies

The design of a wind turbine is a complex task that has to account for the tight interactions existing among multiple disciplines and the presence of several concurrent and often contrasting design requirements. For such challenge, automated systems engineering tools greatly simplify and speed-up the exploration of the solution space, and improve the understanding of the effects of design choices and trade-offs across various sub-systems of the turbine. For the development of the reference turbine, formal multi-disciplinary design, analysis and optimization (MDAO) methods were employed to help achieve designs that more closely represent commercial wind turbine designs than past reference turbine designs.

In this project three frameworks have been used to develop the reference turbines: the Code for Performance Maximization `Cp-Max` ([3, 4, 5, 6, 2] among others) developed at the Wind Energy Institute of Technische Universität München (TUM), the Multidisciplinary Horizontal Axis Wind Turbine Optimization Tool `HAWTOpt2` [30] developed by Technical University of Denmark (DTU) and the Wind-Plant Integrated System Design and Engineering Model `WISDEM` [8] developed by the National Renewable Energy Laboratory (NREL) in the U.S. The frameworks are shortly described in the paragraphs below, while readers interested in the details of the formulations should refer to the bibliography publicly available.

3.1 Cp-Max - TUM

The design methodologies implemented in the `Cp-Max` framework, which is continuously upgraded and expanded, perform the overall sizing of a wind turbine in terms of rotor diameter and tower height, while simultaneously generating a detailed sizing of the aerodynamic and structural components of the machine, ultimately aiming at the minimization of the cost of energy (CoE). During the design process, the control laws governing the machine are updated automatically, as they play a central role in determining the performance and loading of a wind turbine. The design approach is based on multi-fidelity modeling of the system, where 2D cross sectional models, multibody-based aeroservoelastic models and full 3D FEM models are used at different stages of the overall process. The use of the various fidelity models is motivated by the need to balance accuracy with computational cost. The design methodology respects the certification guidelines prescribed by international standards [12]. The output of `Cp-Max` is a complete aeroservoelastic model of the machine together with its control laws, the associated FEM models, the detailed geometry and material properties of rotor and tower (including a bill of materials), and all relevant performance information, including nominal and turbulent power curves, ultimate and fatigue loads at a user-defined number of control points on the machine, a complete vibratory analysis including a Campbell diagram, acoustic emissions as well as CoE and its breakdown according to a cost model. The code has been recently upgraded with new modules to further enlarge its scope and generality. The latest additions include the possibility to model and optimize the prebend curvature of the blades, the modeling of arbitrary blade sweep and lastly the ability to treat composite materials as design variables.

3.2 HAWTOpt2- DTU

HawtOpt2 is an multidisciplinary design tool built around analysis codes for prediction of the structural properties of the turbine and the aeroelastic response of the turbine. For the aeroelastic analysis, HAWTOpt2 has interfaces to HAWC2 [14] and HAWCStab2 [15], which are both developed at DTU. For prediction of the structural properties of the turbine, HAWTOpt2 interfaces to BECAS [1, 31], which is a finite element cross sectional tool. To handle the definition of the optimization problem, workflow, dataflow and parallelization of simulation cases, HAWTOpt2 uses OpenMDAO v1.x [32], which is a Python based open source framework. Using this framework allows us to efficiently make use of high performance computing clusters, with MPI parallelisation of both cases within the objective function (e.g. design load cases), as well as the evaluation of finite difference gradients. OpenMDAO provides an interface to PyOptSparse [33] which has wrappers for several optimization algorithms. In this work, the open source gradient-based interior point optimizer IPOPT [29] is used. Ultimate loads simulations within the optimization loop are carried out using the aero-hydro-servo-elastic software package HAWC2 on a reduced set of design load cases as per IEC 61400-1 Ed3,

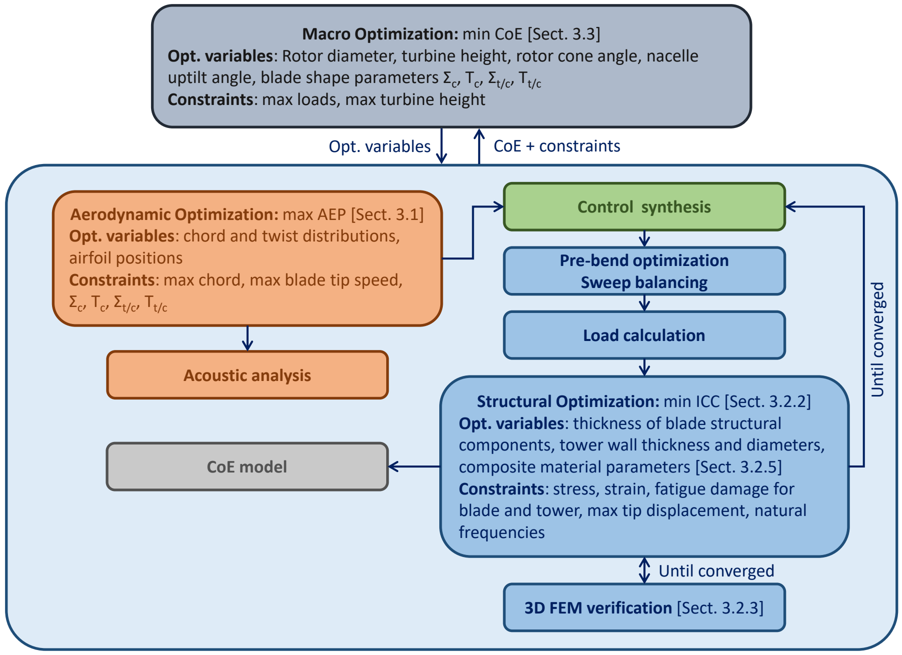


Figure 4: Scheme of the algorithmic structure of Cp-Max.

while the final designs are evaluated using the full design load basis described in ref. [?].

Figure 5 shows a so-called extended design structure matrix diagram (XDSM) [?] of the workflow in HawtOpt2. Overlaid boxes indicate components that are executed in parallel for each cross-section/load case. At the upper level, the entire workflow is parallelised to enable parallel gradient evaluation. All of these parallelisations are embarrassingly parallel and thus this scales linearly with the number of CPUs available. A typical optimization will use 20 cores per objective function evaluation, and be parallelised according to the available resource with n number of concurrent FD gradient evaluations.

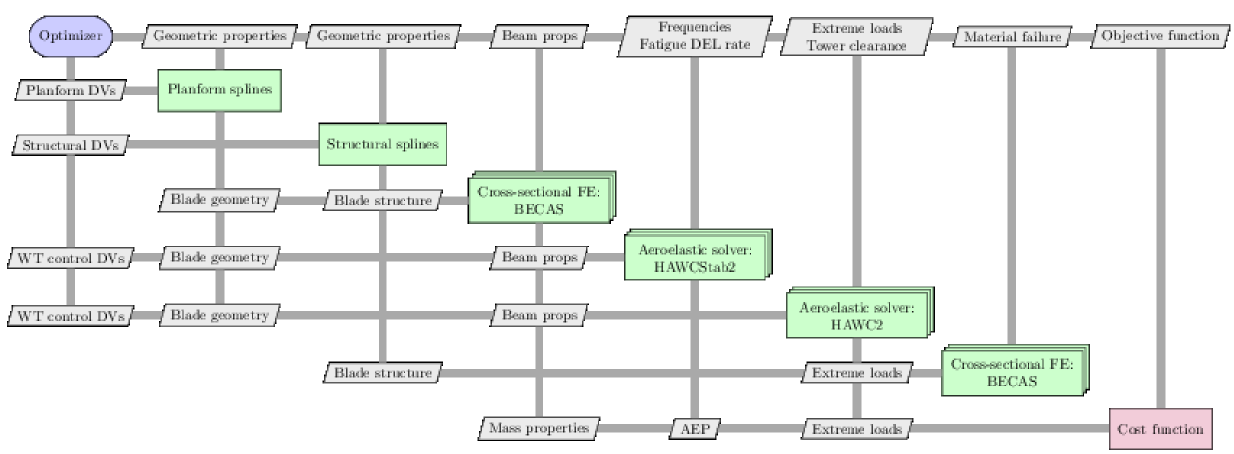


Figure 5: Extended Design Structure Matrix diagram of the workflow of HAWTOpt2.

3.3 WISDEM - NREL

The WISDEM toolkit for MDAO of wind turbines and plants is a completely open-source toolkit (see http://github.com/WISDEM) that is highly modular, incorporates a set of models to do complete wind turbine and plant design for cost of energy, and whose software modules have been tailored in their development to optimization applications. There are models for each of the turbine sub-system designs as well as turbine cost, plant costs, plant energy production and links to dynamic models for loads analysis. Figure 6 shows the full set of models within the WISDEM framework. Each model can be used in a stand-alone mode or coupled with other models based on the users particular analysis or design problem. Furthermore, WISDEM is developed to use the Framework for Unified Systems Engineering and Design of Wind Plants (FUSED-Wind) which has been co-developed by NREL and DTU Wind Energy with contributions from other organizations as well [39]. This framework helps standardize the flow of information in MDAO workflows for wind energy applications for improved model interchangeability and sharing of data. Underlying WISDEM and FUSED-Wind is OpenMDAO - a software environment to support MDAO developed by NASA Glenn Laboratories [32]. As mentioned previously, OpenMDAO supports optimization applications with many different disciplines and fidelity levels involved.

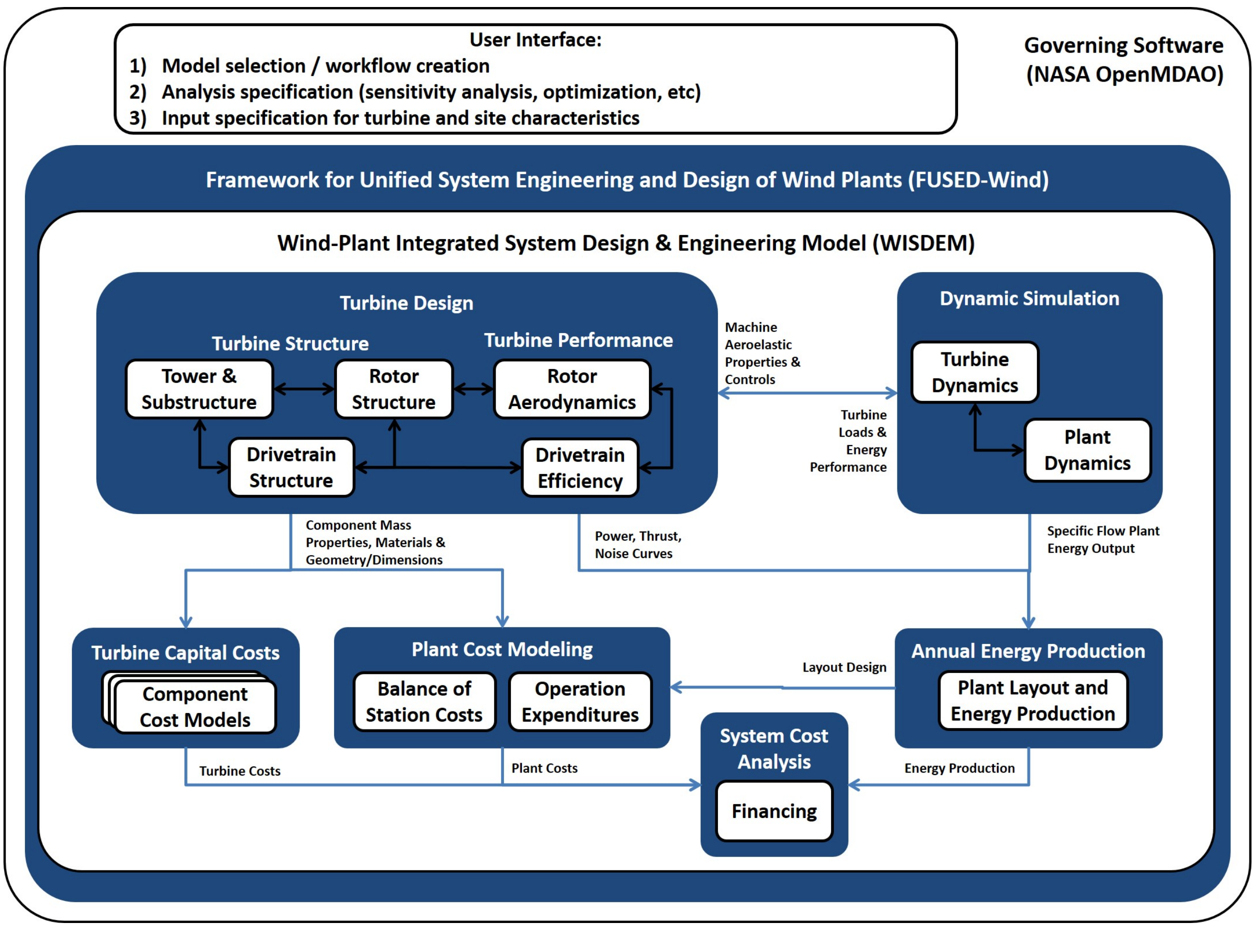


Figure 6: The Wind-Plant Integrated System Design and Engineering Model.

For the purposes of the reference turbine development, NREL was responsible for the development of the drivetrain designs for both of the turbines. The two models from the WISDEM framework employed for the drivetrain design are DriveSE that sizes the major load-bearing components of a geared drivetrain [11] and

GeneratorSE that can be used to design multiple types of generators for wind turbine applications including both synchronous and induction type generators [17]. Details of the drivetrain modeling can be found in the subsequent sections on individual turbine design.

4 3.35 MW Onshore Wind Turbine

Cp-Max is the tool mostly adopted for the development activities of the onshore wind turbine. Here, the design work aims at developing a class 3A onshore wind turbine model characterized by a rated electrical power of 3.35 MW, a rated aerodynamic power of 3.6 MW, a rotor diameter of 130 meters and a hub height of 110 meters. These values have been selected by the project partners with the expectation that these will establish as standards within the onshore wind energy market.

4.1 Design Process

The wind turbine is designed against a set of critical design load cases (DLCs), selected to be run within the structural optimization loop of Cp-Max, including standard operating conditions in normal turbulence (1.1), operation under extreme turbulence (1.3), shut down cases in turbulent wind (2.1) and steady wind with gusts (2.3), as well as storm conditions (6.1, 6.2, 6.3) [12]. DLC 1.1 and DLC 1.3 are realized with three seeds, while the others with one, for a total of 151 dynamic simulations.

The aerodynamic design comprises 24 optimization variables describing twist at eight stations, chord at nine stations and the position of the seven airfoils along blade span. The structural design is based on 50 variables parameterizing the skin, the two spar caps, the two webs and the leading and trailing edge reinforcements at nine stations along blade span, as well as the diameter and wall thickness of ten tower sectors. In this reference design exercise, the mechanical properties of the composites are kept fixed, while sweep curvature, angles in the composite fibers and offset in the spar cap positions are all set to zero. After a total computational time of approximately 100 hours running on a workstation equipped with 56 logical processors, Cp-Max converges to the solution that is here presented.

In addition, several others assumptions have been taken within the different fields of wind turbine design. The main wind turbine characteristics are summarized in Table 2, while the next section presents all the details in terms of rotor aerodynamics, rotor structure, hub, nacelle and drivetrain, tower and controller.

Table 2: Summary of the configuration of the onshore wind turbine.

Data	Value	Data	Value
Wind class	IEC 3A	Rated electrical power	3.35 MW
Rated aerodynamic power	3.60 MW	DT & Gen. efficiency	93.0%
Hub height	110.0 m	Rotor diameter	130.0 m
Cut-in	4 m/s	Cut-out	25 m/s
Rotor cone angle	3.0 deg	Nacelle uptilt angle	5.0 deg
Rotor solidity	4.09%	Max V_{tip}	80.0 m/s
Blade mass	16,441 kg	Tower mass	553 ton
Blade cost	120.9 k$	Tower cost	829.7 k$
Aerodynamic AEP	14.99 GWh	Electrical AEP	13.94 GWh
ICC	4,142.1 k$	CoE	44,18 $/MWh

4.2 Rotor Aerodynamics

The rotor aerodynamic design of the onshore wind turbine is developed adopting a list of pre-defined airfoils, which are reported in Table 3 and whose coordinates and polars can be found in Appendix A.2 in Tables 26-66. The spanwise positions of each profile is automatically adjusted by the aerodynamic design procedure. In addition, a value of 2.6 meters is assumed for the blade root diameter.

Table 3: Set of airfoils adopted for the rotor aerodynamic design of the 3.35 MW wind turbine.

Airfoil	Thickness	Airfoil	Thickness
Root circle	0.0%	FX77-W-500	50.0%
FX77-W-400	40.0%	DU00-W2-350	35.0%
DU97-W-300	30.0%	DU91-W2-250	25.0%
DU08-W-210	21.0%	DU08-W-180	18.0%

The planar shape identified by `Cp-Max` as aerostructural optimum is shown in Fig. 7. The blade aerodynamic shape is described by chord, twist, relative thickness, absolute thickness, pitch axis positioning and prebend distributions along blade span as reported in Fig. 8. It is here worth highlighting that chord and prebend, reported respectively in Fig. 8a and Fig. 8f, are constrained by assumed maximum allowable values of 4.3 meters and 2.5 meters, respectively, chosen to ensure transportability. In addition, the aerodynamic optimizer of `Cp-Max` discards airfoil DU08-W-180, favoring thicker ones. As shown in Fig. 8c, the minimum relative thickness along the blade is 21%, a value that guarantees a better trade-off between aerodynamic and structural performance compared to thinner profiles. Moreover, the blade is modeled with no sweep, while the non-monotonic distribution reported in Fig. 8e of the pitch axis positioning along blade span is adjusted to guarantee a straight leading edge from blade root to blade tip.

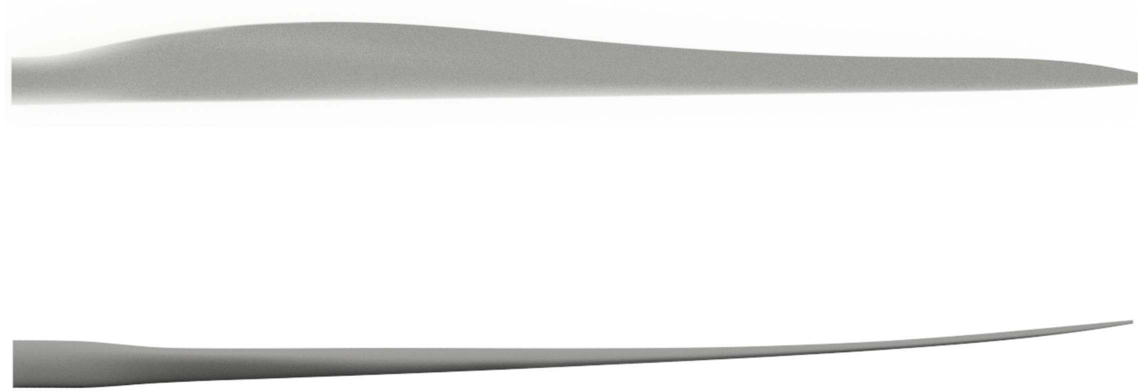
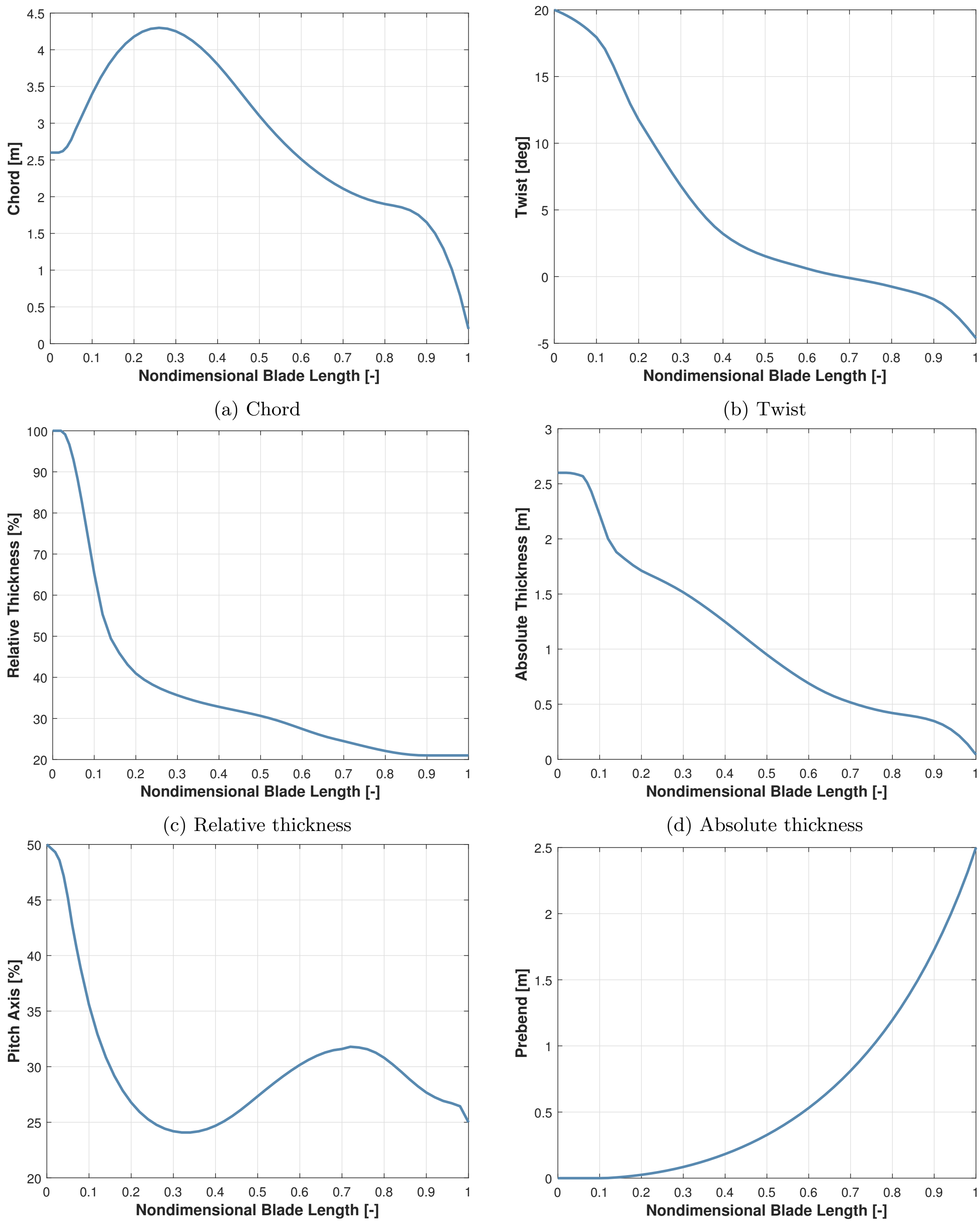


Figure 7: View from the pressure side and from the leading edge of the onshore wind turbine blade



(a) Chord

(b) Twist

(c) Relative thickness

(d) Absolute thickness

(e) Pitch axis positioning

(f) Prebend

Figure 8: Aerodynamic blade shape of the onshore wind turbine.

4.3 Rotor Structure

The structural design process adopts the composites used in the blade of the INNWIND.EU 10 MW wind turbine [13]. The data of the composites are listed in Table 4. In terms of blade topology, the structural components are the same as for a 2 MW wind turbine described in Ref. [2], i.e. a traditional configuration with two spar caps and two webs running from 10% to 94% of blade span. Webs are modeled straight and placed perpendicular to the chord line at the point of maximum chord along blade span (η=0.26). In addition, leading edge (LE) and trailing edge (TE) reinforcements are modeled running between 10 % and 80% of blade span. The chordwise positions of spar caps and webs as well as the extensions from the LE and the TE of the LE and TE reinforcements have been scaled linearly with the rotor diameter from the values of the 2MW wind turbine. These values are reported in Tables 40 and 41 in Appendix. In addition, a lower bound of 65 mm for the composite laminate at blade root is assumed to guarantee a sufficient thickness to host the bolted connections.

The structural optimization module of `Cp-Max` converges to the composite thicknesses reported in Tables 42 and 43 and shown in Fig. 10. A panel based formulation estimates the nonstructural masses sizing the necessary core to prevent buckling of the sandwich panels both in the outer blade surface and in the two shear webs. The thicknesses are reported in Table 44 and shown in Fig. 11.

For this blade structural layout, the 2D cross sectional solver `ANBA`, which implements the theory of Giavotto et al., 1983 [10], predicts the stiffness and mass properties listed in Tables 45, 46, 47 and 48. The mass distribution listed in Table 45 also includes the distribution of non-structural masses (sandwich core, paint, resin uptake, bonding lines, lightning protection) predicted by `Cp-Max`. The structural characteristics are expressed in the structural reference frame (see Fig. 12), whose axes are twisted with respect to the aerodynamic axes of the angle $\Delta\Theta$.

- T_{11} = edge-wise shear stiffnesses $[N]$ along the x_S axis;
- T_{22} = flap-wise shear stiffnesses $[N]$ along the y_S axis;
- EA = axial stiffnesses $[N]$;
- E_{11} = flap-wise stiffnesses $[Nm^2]$;
- E_{22} = edge-wise stiffnesses $[Nm^2]$;
- GJ = torsional stiffnesses $[Nm^2]$;
- Centroid = coordinates of the centroid wrt the structural reference frame $[m]$;
- $\Delta\Theta$ = angle between the aerodynamic and the structural reference frames $[deg]$;
- Shear Center = coordinates of the shear center wrt the structural reference frame $[m]$;
- Mass = masses $[kg/m]$;
- J = moments of inertia $[kgm^2/m]$, along the axis normal to the section (i.e. polar inertia) and the two x_S and y_S axes, respectively;
- Center Of Mass = coordinates of the center of gravity wrt the structural reference frame $[m]$;

The blade is modeled without point masses along blade span.

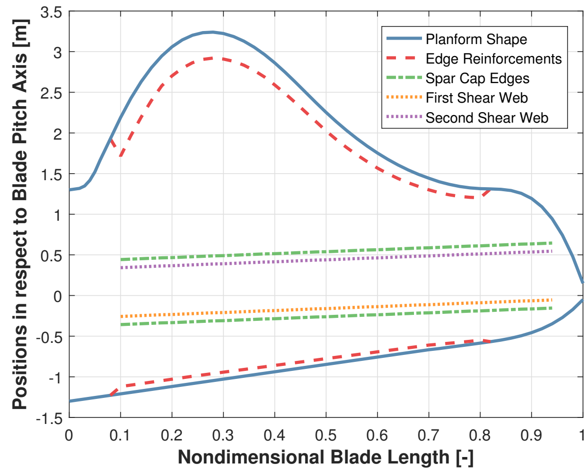


Figure 9: Positions along blade span of the various structural components

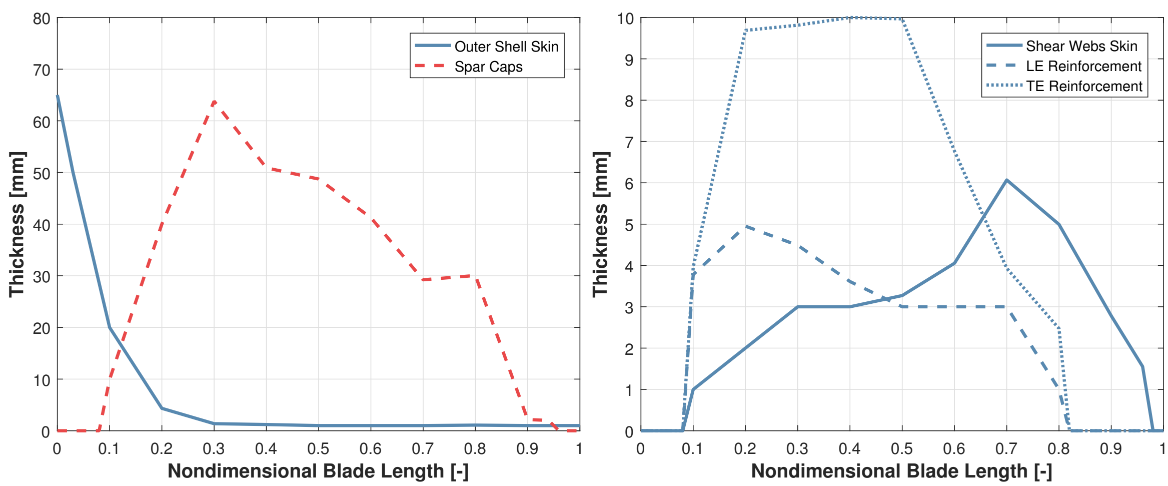
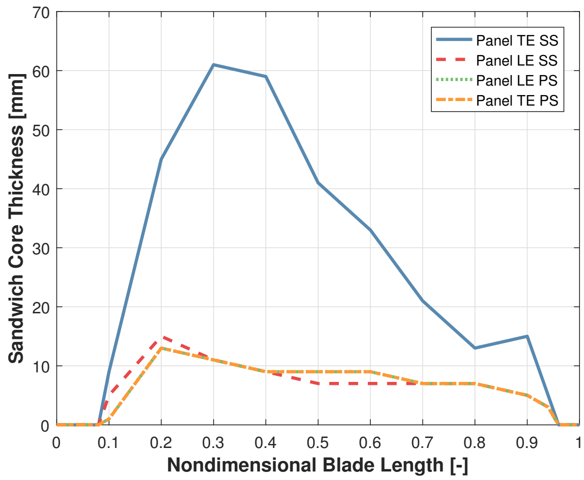
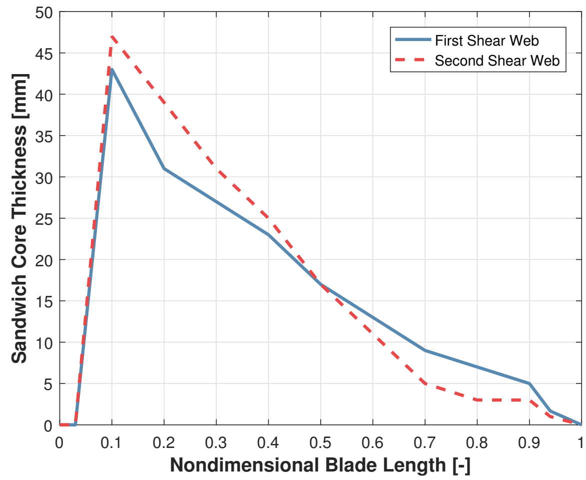


Figure 10: Thicknesses of the structural components of the blade of the onshore wind turbine.



(a) Outer Shell Panels



(b) Shear Webs Panels

Figure 11: Thicknesses of the core in the sandwich panels of the blade of the onshore wind turbine.

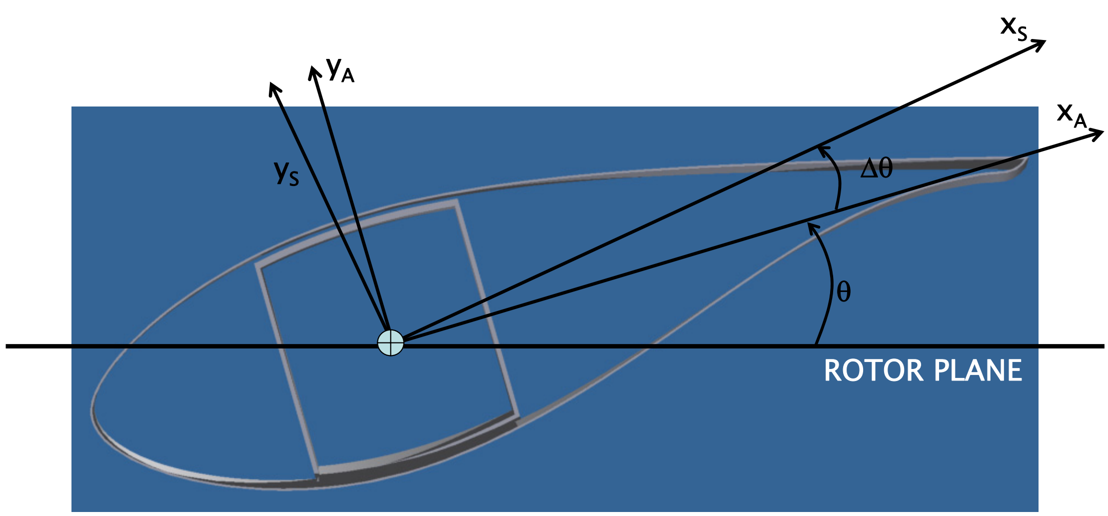


Figure 12: Sectional references frames. Aerodynamic: x_A, y_A; structural: x_S, y_S.

Table 4: Properties of the composites adopted in the blade

Value		Outer Shell Skin Triax GFRP	Spar Caps UD GFRP	Webs Skin Biax GFRP	TE-LE Reinf. UD GFRP
E_{11}	[MPa]	21790	42000	13920	41630
E_{22}	[MPa]	14670	12300	13920	14930
v_{12}	[-]	0.48	0.31	0.53	0.24
G_{12}	[MPa]	9413	3470	11500	5047
$\sigma_{11,\ \mathrm{max}}$	[MPa]	480.4	868.0	223.2	876.1
$\sigma_{11,\ \mathrm{min}}$	[MPa]	393.0	869.0	209.2	625.8
$\sigma_{22,\ \mathrm{max}}$	[MPa]	90.4	53.7	223.2	74.0
$\sigma_{22,\ \mathrm{min}}$	[MPa]	152.7	160.0	209.2	189.4
τ_{max}	[MPa]	114.0	45.8	140.3	56.6
$\epsilon_{11,\ \mathrm{max}}$	[%]	2.20	2.19	1.60	2.10
$\epsilon_{11,\ \mathrm{min}}$	[%]	1.80	2.00	1.50	1.50
$\epsilon_{22,\ \mathrm{max}}$	[%]	0.62	0.49	1.60	0.50
$\epsilon_{22,\ \mathrm{min}}$	[%]	1.04	2.19	1.50	1.27
γ_{max}	[%]	1.21	5.00	1.22	1.12
N	[-]	10	10	10	10
fvf	[-]	0.48	0.53	0.48	0.53
ρ_{epoxy}	[kg/m^3]	1150	1180	1150	1150
ρ_{fabric}	[kg/m^3]	2600	2620	2600	2600
ρ_{laminate}	[kg/m^3]	1845	1940	1845	1916
$\$_{\mathrm{epoxy}}$	[$/kg]	4.67	4.67	4.67	4.67
$\$_{\mathrm{fabric}}$	[$/kg]	2.97	2.11	2.97	2.11

4.4 Hub, Nacelle and Drivetrain Properties

The design of hub, nacelle and drivetrain properties has been developed by coupling two of NREL's systems engineering sizing tools namely, DriveSE and GeneratorSE [8]. The aerodynamic loads measured at the hub were the main inputs for designing a four-point suspension drivetrain, a common configuration choice in the wind industry for turbines rated 2MW and beyond. The four-point suspension is a separated design characterized by a main shaft supported by two main bearings. Torque arms resist the torque while the remaining loads travel to the bedframe via the main bearings. The main bearings were assumed to be of standard Spherical roller configurations.Figure 13 shows the layout of the nacelle.

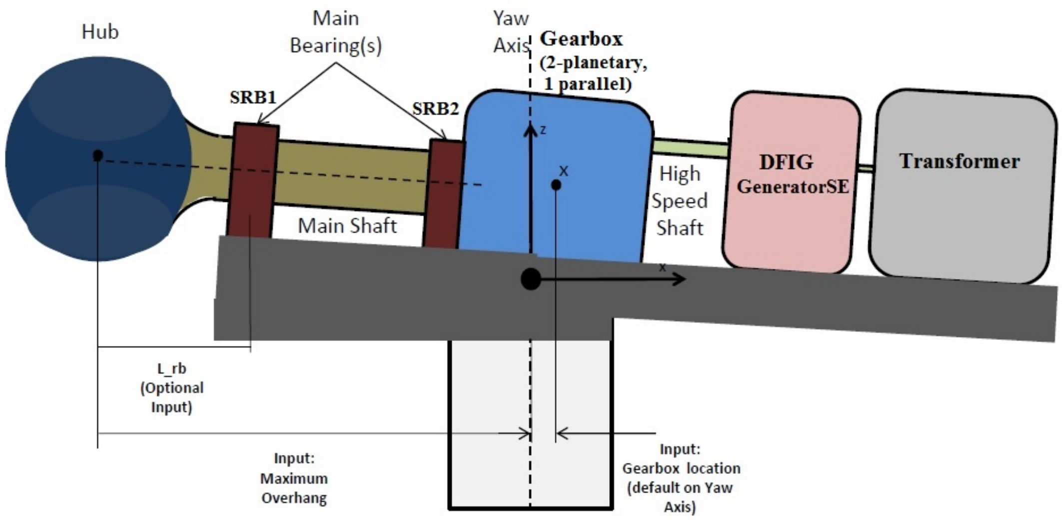


Figure 13: Drivetrain layout.

The gearbox was assumed be a typical three-stage gearbox, with two-stage planetary and one parallel shaft arrangement. The high speed shaft was coupled to a doubly fed induction generator(DFIG) controlled by a partial rated power electronic converter. An uptower transformer was assumed to step up the generator voltage to the grid.

DriveSE employs analytical models for sizing the major load-bearing components (the low-speed shaft, main bearings gearbox, and bedplate) and provides mass properties for the overall nacelle including and yaw system using system configuration parameters as well as the aerodynamic loads from the rotor. DriveSE accepts maximum rotor loads measured at the hub and gearbox design inputs for main bearings, transformer, and gearbox location. The The main shaft and bearing were sized first by determining the length from deflection limitations imposed by main bearings, which were selected based on shaft geometry. Each component within DriveSE was designed based on a set of assumptions, design variables, and constraints for allowable stress (using industry-recommended safety factors), deflection (to ensure proper geometric alignment with bearing and gear-tooth meshing) and center of mass (CM) of nacelle to optimize each sub-component for the minimum weight. The gearbox design was optimized for the minimum weight by optimizing the speed ratio of each stage up to three stages with different combinations of planetary and parallel stages. The bedplate size is approximated as two parallel I-beams carrying weights and centre of mass of the drivetrain components. The yaw system was modelled with a friction plate bearing at the nacelle tower and several yaw motors. For more information on the model formulation, refer to the DriveSE model report [11]

The high speed section of the gearbox was coupled to GeneratorSE that provided estimates for a doubly fed induction generator optimized for the drivetrain.

We used a decoupled approach [18] to optimize the designs for the drivetrain and the generator independently with the overall gear-ratio used as the main parameter linking the two designs. The optimization was based on the premise that the lightest generator design resulted in the lightest nacelle mass. This decoupled optimization accepted design variables to size the gearbox and other mechanical elements, and the generator through a nested approach where the main components are sized with their own sub-optimization routines. This approach represents a more traditional design process that best reflects the current industry practice.

For the drivetrain, the overall gear ratio was chosen to be 1:97. For the generator, the air-gap radius, core length, maximum slip, magnetic loading, and excitation were allowed to vary satisfying requirements for minimum overall efficiency and terminal voltage.

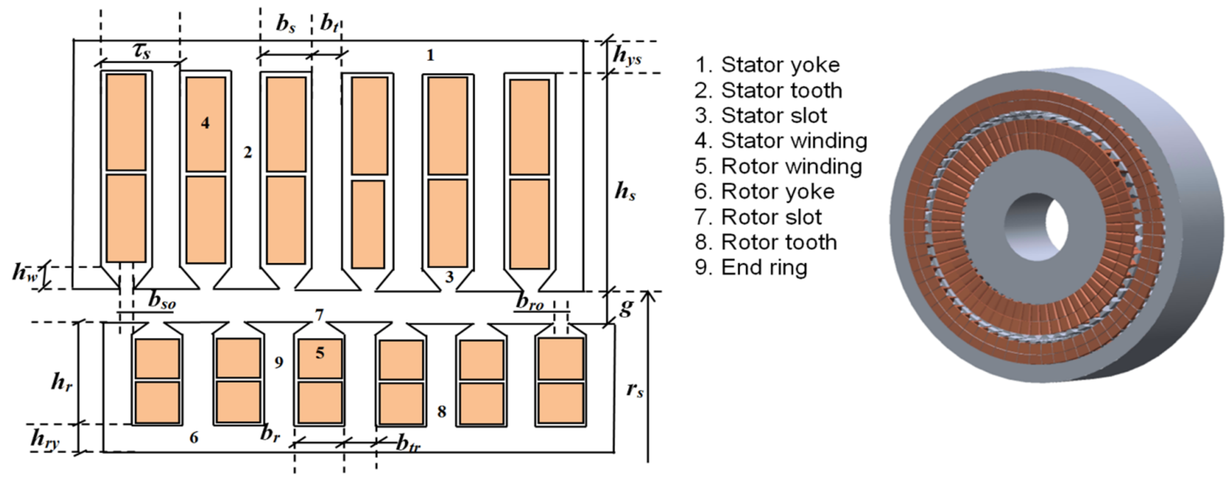


Figure 14: DFIG module within GeneratorSE : design dimensions and CAD illustration reproduced from [17]

Figure 14 shows the CAD illustration of the main design dimensions of the DFIG as used by GeneratorSE [17]. For the given power rating, the high-speed shaft speed (determined by the gear ratio) was the fundamental element used to calculate the torque and the design dimensions required to overcome the tangential stress. Table **??** lists the mass properties of the main elements of the drivetrain

Table 5: Drivetrain properties

Description	Units	Value
Rated rotor speed	rpm	11.753
Rated Generator speed	rpm	1140.04
Gearbox Ratio		97:1
Generator Inertia about high speed shaft	kgm^2	2744.27
Electrical Generator Efficiency	[%]	98.08
Main Bearing 1 Mass	Tons	4.08
Main Bearing 2 Mass	Tons	4.08
Low speed shaft Mass	Tons	26.55
Gearbox Mass	Tons	41.05
Generator Mass	Tons	16.89
Transformer Mass	Tons	10.4
Bedplate Mass	Tons	60.99
HVAC System	Tons	0.28
Nacelle Cover	Tons	9.23
Yaw System	Tons	4.46
Overall Nacelle	Tons	191.85

4.5 Tower Properties

The tower of the onshore wind turbine is modeled as a sequence of hollow conical sectors made of steel. The properties of the material are reported in Table 6. Notably, the density of the material is artificially increased to account for some secondary structures such as ladders, elevator, external paint, etc. The structural design of the tower in terms of sector diameters and wall thicknesses are shown in Fig. 15 and reported in Table 49, while the resulting stiffness and mass properties are shown in Fig. 16 and reported in Table 50.

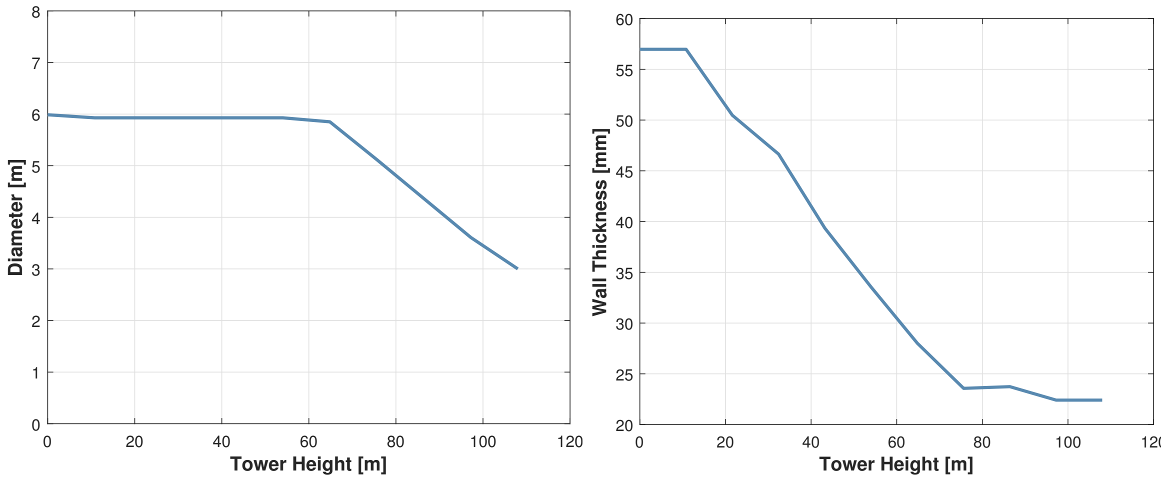
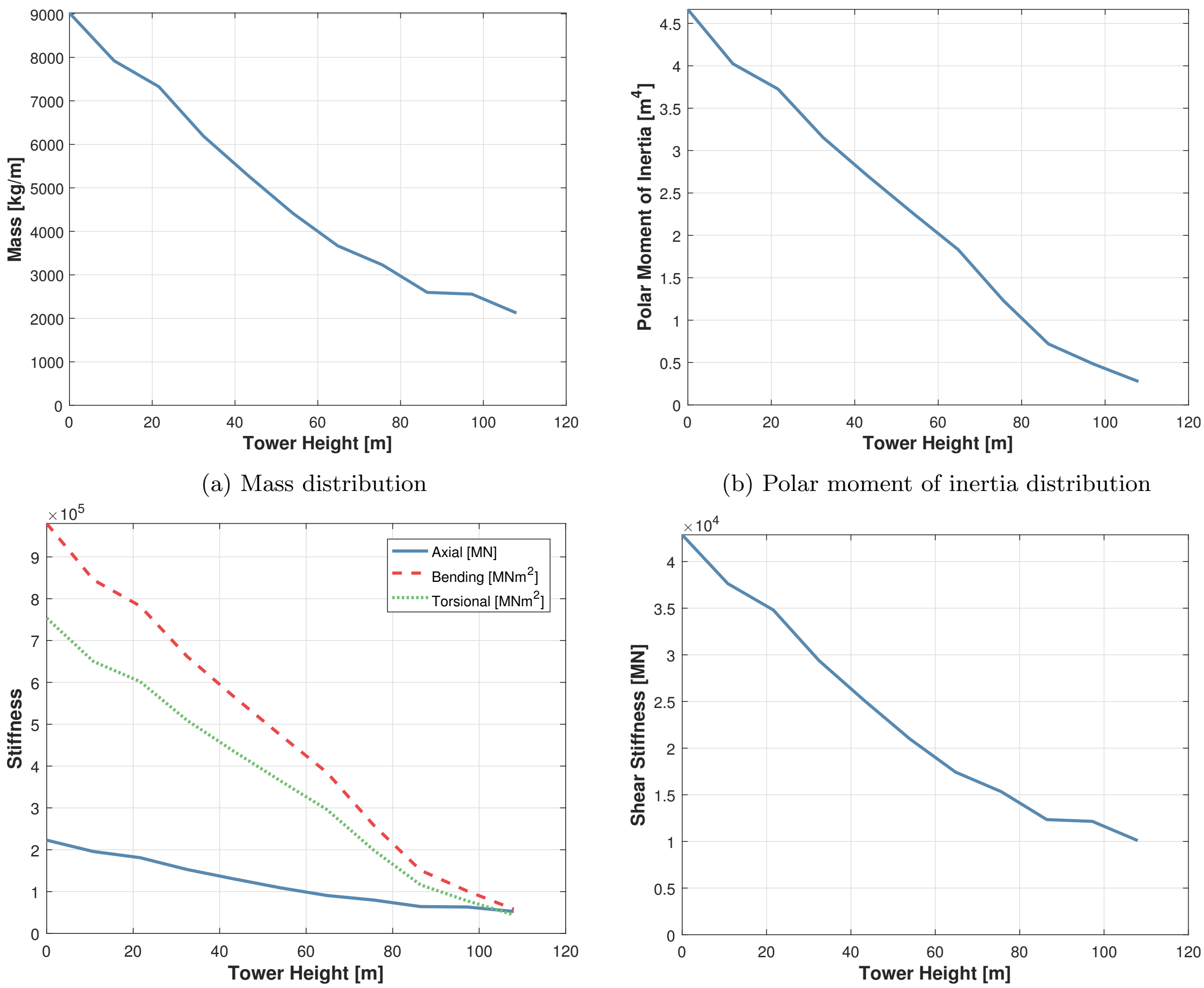


Figure 15: Structural design of the tower for the onshore wind turbine.

Table 6: Static and fatigue mechanical properties of the steel adopted in the tower of the 3.35 MW wind turbine.

Data Static	Value	Data Fatigue	Value
Youngs Modulus [GPa]	210	Cycles number in S-N diagram at slope change [-]	5.00E+06
Poisson Coefficient	0.3	Normal stress value in S-N diagram at slope change [MPa]	65.7
Density [kg/m^3]	8500	Slope of first part of S-N diagram [-]	3
Yield Strength [MPa]	355	Slope of second part of S-N diagram [-]	5
Ultimate Strength [MPa]	400	Cycles number in S-N diagram at cut off [-]	1.00E+08
		Shear Stress value in S-N diagram at cut off [MPa]	46.2



(a) Mass distribution

(b) Polar moment of inertia distribution

(c) Axial, bending and torsional stiffness distributions

(d) Shear stiffness distribution

Figure 16: Elastic properties of the tower for the onshore wind turbine.

4.6 Control and Actuators

The design of the onshore wind turbine has been supported by a model based controller, which is described in details in Ref. [7]. The controller adopts a constant TSR-pitch strategy below rated conditions (region II) and a constant power strategy above rated conditions (region III). It also respects a limitation on the maximum allowable blade tip speed of 80 m/s by imposing a region II1/2, where C_p is maximized while maintaining constant rotational speed Ω. An overview of the operational data of the rotor is reported in Table 7 and graphically shown in Fig. 17.

Table 7: Operational data of the rotor.

Data	Value	Data	Value
Maximum C_p [-]	0.481	Pitch Rated [deg]	1.09
TSR Rated [-]	8.16	Omega Rated [rpm]	11.75
Torque Rated [MNm]	2.925	Max Tip Speed [m/s]	80.0
Cut In Wind Speed [m/s]	3.0	Cut Out Wind Speed [m/s]	25.0
Wind Speed Region II1/2 [m/s]	9.3	Rated Wind Speed [m/s]	9.8
Min Rotor Speed [rpm]	3.8	Max Rotor Speed [rpm]	12.9

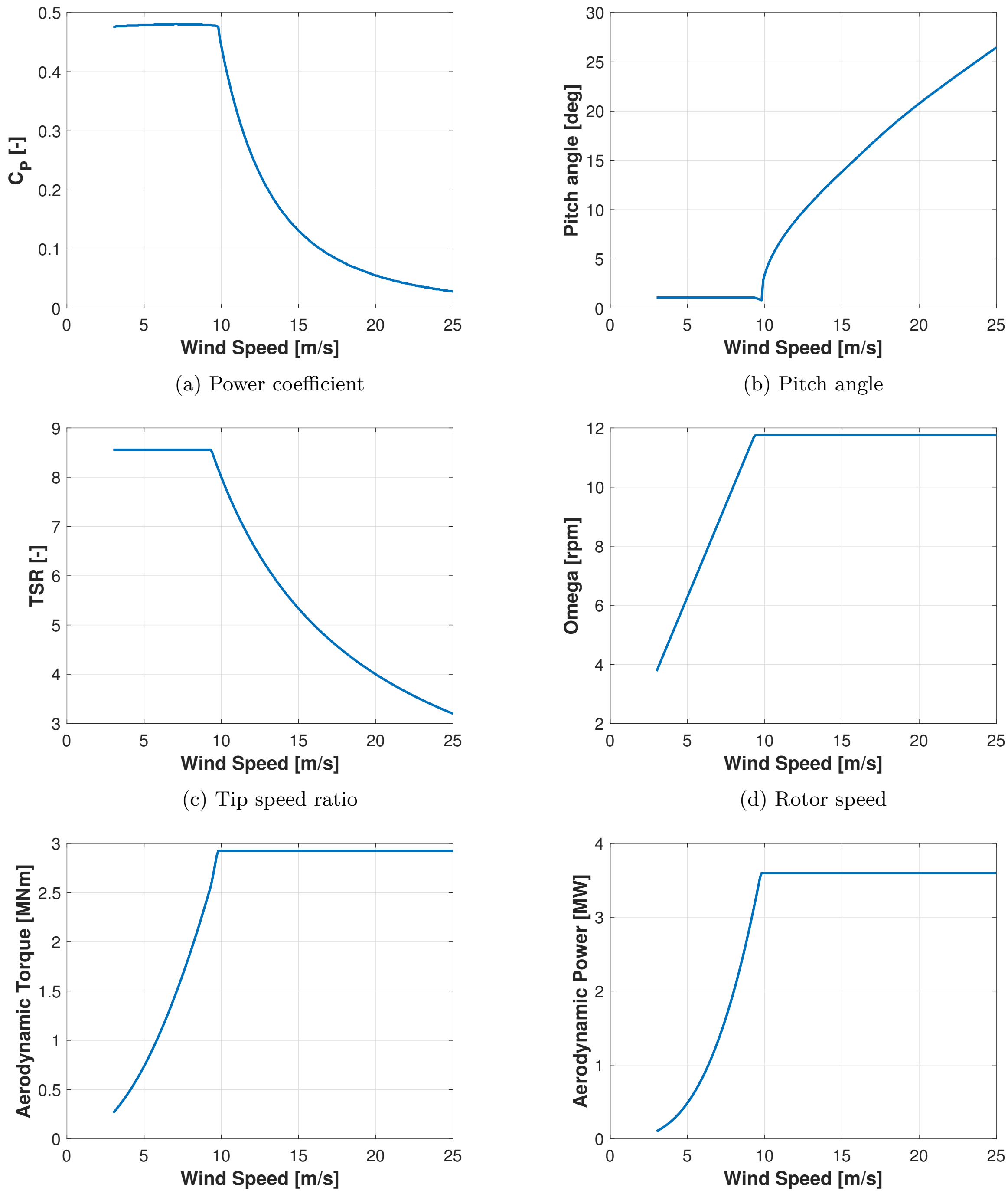
The turbine adopts collective pitch control with a maximum pitch rate of 7 deg/s and a maximum yaw rate of 0.25 deg/s. The pitch actuators have been modelled as second order actuators with a natural circular frequency ω_n of 10 and a damping factor ζ of 0.8:

$$y + 2\zeta\omega\dot{y} = \omega^2(x - \ddot{y}), \tag{1}$$

where x is the actuator input and y the actuator output. The generator and the yaw actuator have been instead modeled as first order systems:

$$\tau\dot{y} + y = Gx, \tag{2}$$

where τ is the actuator time constant and G the output gain. τ and G have been assumed equal to 0.01 and 1 in the generator model and 0 and 1 in the yaw actuator respectively.



(a) Power coefficient

(b) Pitch angle

(c) Tip speed ratio

(d) Rotor speed

(e) Aerodynamic torque

(f) Aerodynamic power

Figure 17: Operational data of the onshore wind turbine.

4.7 Frequency Analysis

A frequency analysis of the onshore wind turbine is performed with the multi-body based aeroelastic solver `Cp-Lambda`. The results of the simplified analysis, which does not include the whirling modes, are listed in Table 8 and in Fig. 18.

Table 8: Natural frequencies of the omshore wind turbine.

Rotor speed [rpm]	Tower FA 1st [Hz]	Tower SS 1st [Hz]	Rotor 1st [Hz]	Rotor 1st [Hz]	Rotor 1st [Hz]
0.00	0.305	0.310	0.601	0.622	0.660
11.5	0.306	0.310	0.638	0.663	0.704
	Tower FA 2nd	Tower SS 2nd	Rotor 2nd	Rotor 2nd	Rotor 2nd
0.00	0.809	0.813	1.552	1.623	1.665
11.5	0.823	0.828	1.593	1.675	1.714
	Eigen Value 11	Eigen Value 12	Eigen Value 13	Eigen Value 14	
0.00	1.786	2.147	2.177	2.359	
11.5	1.843	2.150	2.190	2.392	

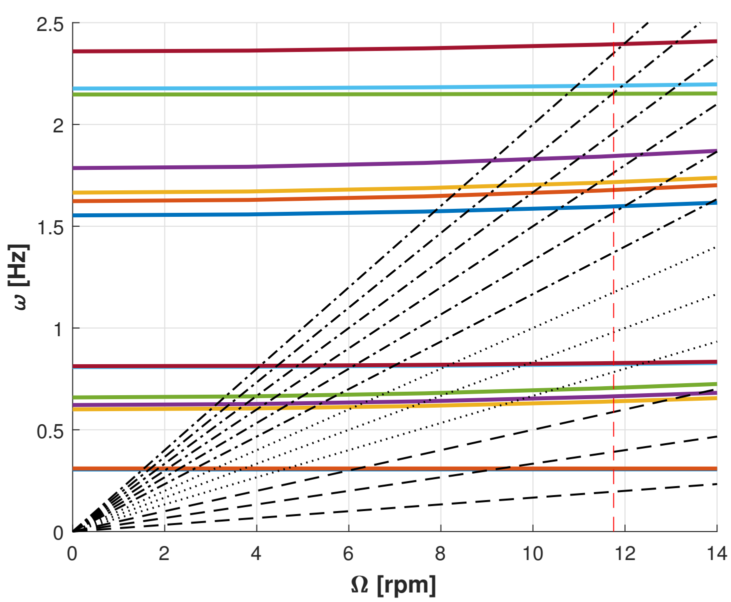


Figure 18: Simplified Campbell diagram for the onshore wind turbine.

4.8 Load Assessment and Design Drivers

As discussed in Sect.4.1, the design of the onshore turbine has been obtained running a subset of 151 aeroelastic simulations. The loads obtained during these simulations have been used to size the various components. The most important design drivers that are identified are:

- Blade - Maximum tip deflection, equal to 10.3 meters and 1.51 meters in flapwise and edgewise directions respectively, drives the blade flapwise stiffness and therefore the design of the spar caps. A second design drivers is generated by natural frequency of the blade, which is imposed 16% higher than the 3P. As visible in Fig.18, this design driver is also active and influencing the blade structure, especially in the spar caps. In addition, fatigue damage drives the thickness of the composite skin of the shear webs and of the outer shell, while foam cores are sized to prevent buckling of the sandwich panels. Ultimate loads are not generating any active design driver.
- Tower - Fatigue drives the thickness of the sections made of steel. In the lower section of the tower, diameters are constrained by the upper bound of 6 meters. Finally, in order of importance, buckling and ultimate loads are the following design drivers. These are however not active.
  - Nacelle components
  - Gearbox and Generator - The rated torque drives the design of the wind turbine gearbox and generator. The design criteria for the gearbox was the surface durability recommendend in ISO/AGMA standards. The key criteria for generator sizing was the maximum shear stress required to overcome at rated torque.
  - Low speed shaft and main bearings -The design of the main shaft and main bearings were driven by extreme rotor aerodynamic loads and gravity. The main shaft was designed to meet the requirements on deflections and rigidity. Stress calculations were performed for both upwind and downwind bearings and bearings were selected with bore diameters that matched the shaft diameter.

5 10 MW Offshore Wind Turbine

The overall characteristics of the offshore turbine designed for the IEA Wind Task 37 were based on the feedback gained from the many users of the DTU 10MW RWT, as well as the surveys carried out by the IEA Task 37 project group. The turbine was developed to have a rated electrical power of 10 MW, and designed for the wind class 1A, but unlike the DTU 10MW RWT, this turbine features a direct-drive generator.

5.1 Design Process

The wind turbine was not designed in a fully integrated manner, in that the rotor aerostructural design was made firstly, using the DTU 10MW RWT platform and overall loads envelope as guidance, followed by the design of a new tower and drive-train. The new rotor design is in several ways based on the experience with the design process and use of the DTU 10MW RWT, and the several design studies carried out after its release. However, contrary to the design of the DTU 10MW RWT rotor, which was aerodynamically optimized, followed by the structural design, this design was developed using an integrated design tool, ensuring a more balanced aerostructural design tailored to minimize loads.

The rotor was designed to maximize annual energy production with blade length as a free parameter, subject to constraints on several loads sensors, ensuring that these loads did not exceed the envelope of the original DTU 10MW RWT. Additionally, necessary constraints on material strength and blade tip to tower clearance were enforced. The design load cases used in the optimization loop were greatly simplified compared to a full IEC design load basis, but included gust response in normal operation and during fault situations, as well as standstill cases, all simulated without time resolved turbulent inflow.

The parameterized description of the aerodynamic and structural geometry of the blade used a total of 52 design variables, all simultaneously active during the numerical optimization process. 17 related to the aerodynamic geometry, 34 related to the structural geometry, and one related to the power regulation of the turbine, namely the tip speed ratio. These design variables are summarized in Table 10.

The design is based on a converged optimization using IPOPT which after 120 major iterations did not improve the objective function further. The overall design was not modified significantly in postprocessing, with only small smoothening of the root transition. The materials in the blade were also in used directly from the optimization, leaving the thicknesses of laminates as continuous quantities, and therefore not realistic.

5.2 Airfoil Data

Airfoil data for each of the FFA-W3 airfoils was generated for a target Reynolds number of $Re = 10 \times 10^6$. To compute the aerodynamic coefficients in the range [-32:32] deg., the 2D incompressible Navier Stokes solver EllipSys2D was used CITE. The meshes were generated using the hyperbolic mesh generator HypGrid2D CITE, with 512 cells along the surface and 256 cells in the direction normal to the surface. Polars assuming fully turbulent and freely transitioning boundary layers were computed using the $k-\omega$ SST turbulence model CITE and the Drela-Giles transition model CITE. 360 degree extrapolation was done using AirfoilPreppy CITE. 3D corrections were not applied to the polars during the design process since the spanwise distribution of relative thickness was a free design variable. Figures xx to yy show the polars for the three original FFA-W3 airfoils. Note that two additional polars were also computed for intermediate airfoils of thicknesses 27% and 33%. These were added to ensure relatively smooth transitions in characteristics as function of relative thickness.

5.3 Rotor Aerodynamics

The blade planform is shown in Figure 19, with plots of the spanwise distributions of chord, twist, relative and absolute thicknesses, prebend, and chordwise offset as percentage of chord. Also included in the plots are the equivalent quantities of the DTU 10MW RWT for comparison. Figure 20 shows the lofted shape of the blade seen from the pressure side and the leading edge.

Parameter	Value	Comment
Wind Regime	IEC Class 1A	Same as DTU 10MW RWT
Rotor Orientation	Clockwise rotation - Upwind	Same as DTU 10MW RWT
Control	Variable Speed	Same as DTU 10MW RWT
	Collective Pitch	Same as DTU 10MW RWT
Cut in wind speed	4 m/s	Same as DTU 10MW RWT
Cut out wind speed	25 m/s	Same as DTU 10MW RWT
Rated wind speed	11 m/s	Optimized
Rated electrical power	10 MW	Same as DTU 10MW RWT
Number of blades	3	Same as DTU 10MW RWT
Rotor Diameter	198.0	Optimized
Airfoil series	FFA-W3	Same as DTU 10MW RWT
Hub Diameter	4.6 m	Reduced from 5.4 m
Hub Height	119.0 m	Same as DTU 10MW RWT
Drivetrain	Direct drive	Changed from Medium Speed, Multiple-Stage Gearbox
Minimum Rotor Speed	6.0 rpm	Same as DTU 10MW RWT
Maximum Rotor Speed	8.68 rpm	Constrained by max tip speed
Gearbox Ratio	N/A	Direct-drive
Maximum Tip Speed	90.0 m/s	Same as DTU 10MW RWT
Hub Overhang	7.1 m	Same as DTU 10MW RWT
Shaft Tilt Angle	6.0 deg.	Increased from 5 deg
Rotor Precone Angle	-4 deg.	Increased from -2.5 deg
Blade Prebend	6.2 m	Increased from 3.2 m
Blade Mass	47,700 kg	12% increase from DTU 10MW RWT
Nacelle Mass	542.600 kg	See Section **??**
Tower Mass	628,442 kg	Provisional, same as DTU 10MW RWT

Table 9: Key parameters of the new 10 MW compared original DTU 10MW RWT.

The optimized design achieves an 11% increase in blade length, with a significantly more slender chord distribution. The twist distribution is very similar, which is a consequence of using the same airfoil family. The tip twist is, however, different with a sharp decrease in twist, which results in a reduction in loading. The relative thickness distribution favours the thinnest 21% airfoil only on the very outer part of the blade, increasing to 24% at 70 m blade length. At 40 m span, the relative thickness is 33%, significantly higher than that of the DTU 10MW RWT. Turning to the absolute thickness, it is evident that the optimized blade has an overall lower thickness, which is possible thanks to the design being aerostructurally tailored to reduce peak loads, but also due to the fact that the static tip clearance was increased significantly through increased prebending of the blade, combined with a shaft tilt angle of 6 deg. and a rotor cone angle of 4 deg., leading to a significantly more flexible blade. The chordwise offset of the cross-sections along the blade was also a free parameter in the optimization. This degree of freedom is used to balance the torsional loads and structural characteristics, in particular the shear center, which is further forward compared to the DTU 10MW RWT.

Parameter	# of DVs	**Comment**
Chord	5	Root chord fixed
Twist	4	Root twist fixed
Relative thickness	4	Root and tip relative thickness fixed
Blade prebend shape	3	-
Blade length	1	-
Tip-speed ratio	1	-
Trailing edge uniax	3	Symmetric lower/Upper side
Trailing edge triax	3	Symmetric lower/Upper side
Trailing panel triax	3	Symmetric lower/Upper side
Spar cap uniax	6	Symmetric lower/Upper side
Leading panel triax	3	Symmetric lower/Upper side
Leading panel uniax	3	Symmetric lower/Upper side
Leading edge triax	3	Symmetric lower/Upper side
Leading edge uniax	3	Symmetric lower/Upper side
Spar cap width	2	Linear taper from root to tip
Spar cap offset upper	2	Linear offset from root to tip
Spar cap offset lower	2	Linear offset from root to tip
Mold angle	1	Reference system angle for laying out spar cap and webs
Total	52	

Table 10: Design variables used in the optimization.

5.4 Rotor Structure

5.4.1 Structural Layout

The structural layout of the blade is fairly traditional, consisting of two main load carrying spars placed according to a straight line connecting the root and the tip, along with reinforcement along the trailing and leading edges. The blade has three shear webs, two attached to the main spars and one placed aft of these extending from 5% span to 50% span. Figures 21 and 22 show a top view and tip view of the blade, respectively.

Spar cap widths	Linear taper 1.44 m (r=9.6m) to 0.53 m (tip)
Trailing edge panels width (upper+lower)	Linear taper 0.80 m (root) to 0.2 m (tip)
Leading edge panel width (upper+lower)	Linear taper 1.0 m (root) to 0.4 m (tip)
Shear web angle relative to rotor plane	6.61 deg

Table 11: Overall properties of internal structure.

The internal structure is parameterised according to the schematics in Figures 23 and 24. To define the structural reference plane, the blade is firstly rotated by the so-called structural mold angle, defined positive according to the right hand rule around an axis normal to and centered around the blade root center. The vertical reference plane is then formed that passes through the root center and the blade tip. Note that the structural mold rotation is applied on the lofted blade that includes both aerodynamic twist and possible prebend and sweep. The spar caps are then placed on the suction side (SS) and pressure side (PS) with a given horizontal offset with respect to the reference plane, and with a given width. Likewise, the shear webs are placed vertically with a given offset with respect to the reference plane. The width of the trailing edge reinforcement is defined relative to the suction and pressure side trailing edge points, respectively, and the leading edge reinforcement is placed relative to the leading edge. The leading edge is defined as the point along the surface with maximum distance from the trailing edge. The complete data to lay out the main structural components are provided in Appendix B.3.

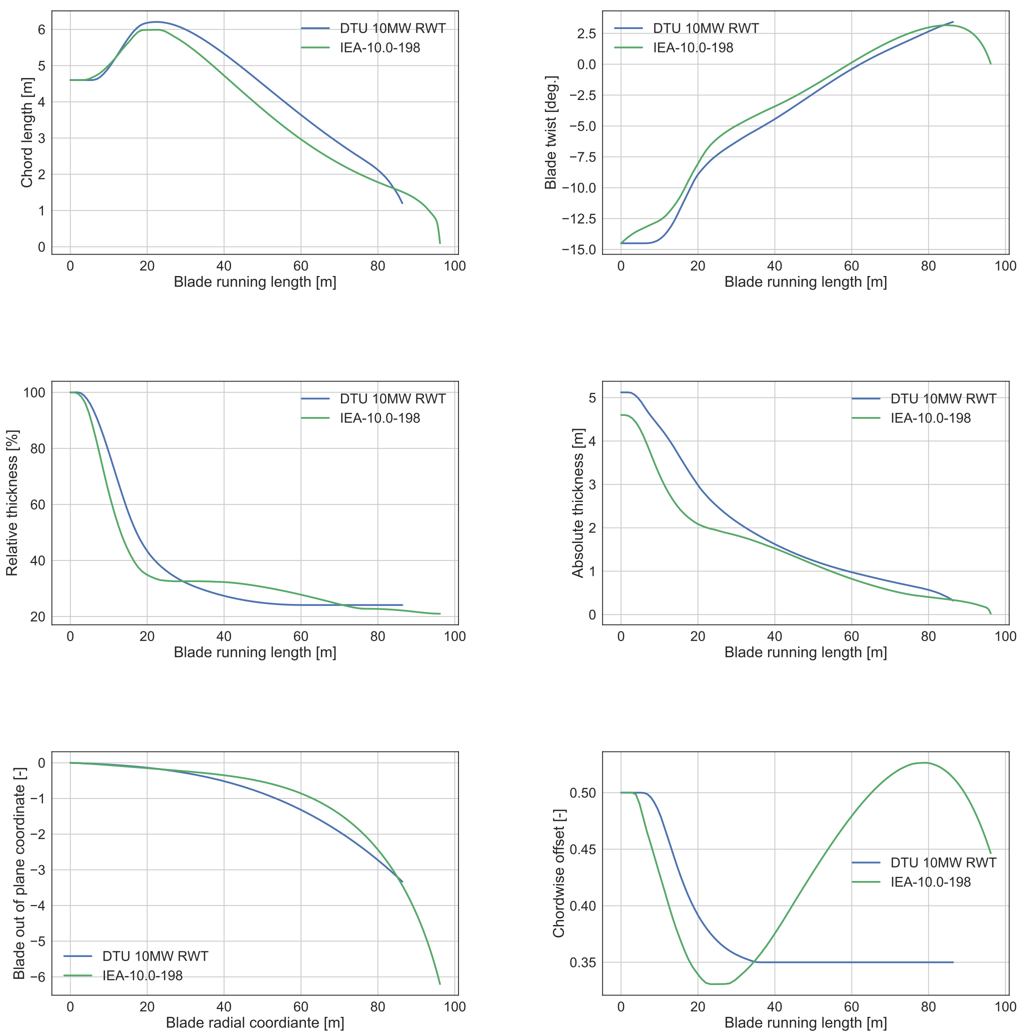


Figure 19: Optimized 10 MW blade planform compared to the baseline DTU 10MW RWT.

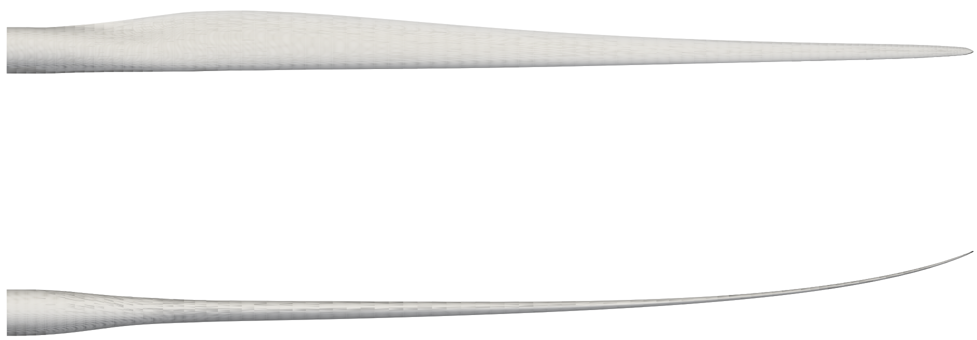


Figure 20: View from the pressure side and from the leading edge of the offshore wind turbine blade.

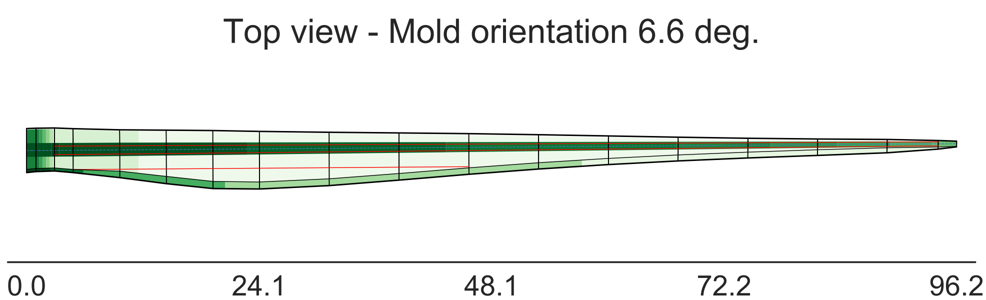


Figure 21: Topview of the 10MW blade showing internal structural geometry.

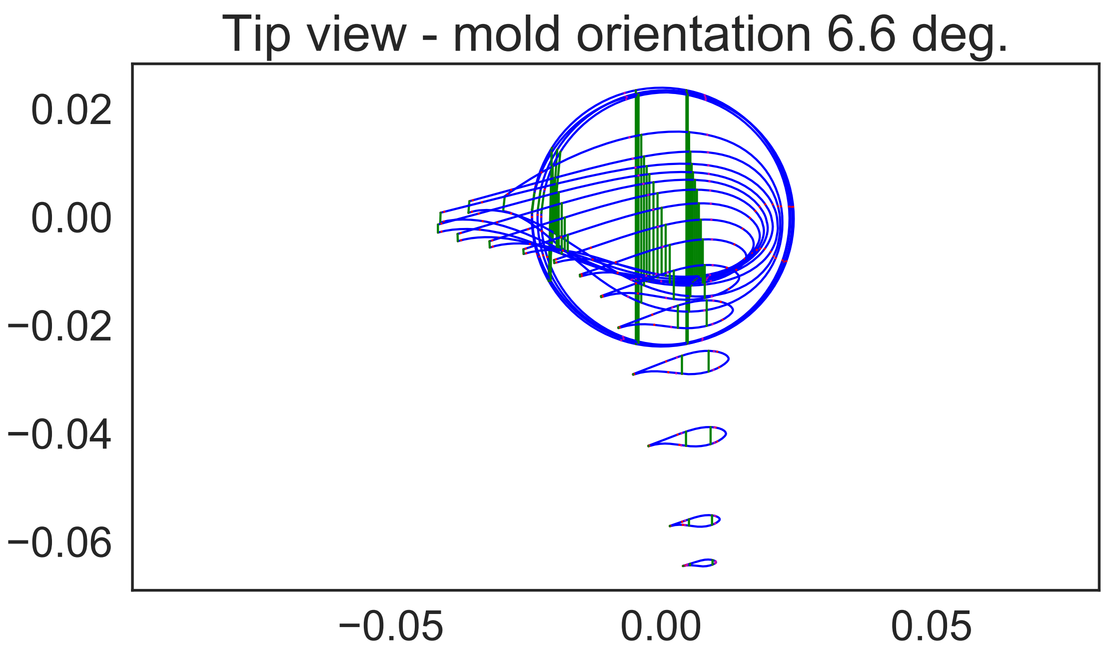


Figure 22: Tipview of the 10MW blade showing internal structural geometry.

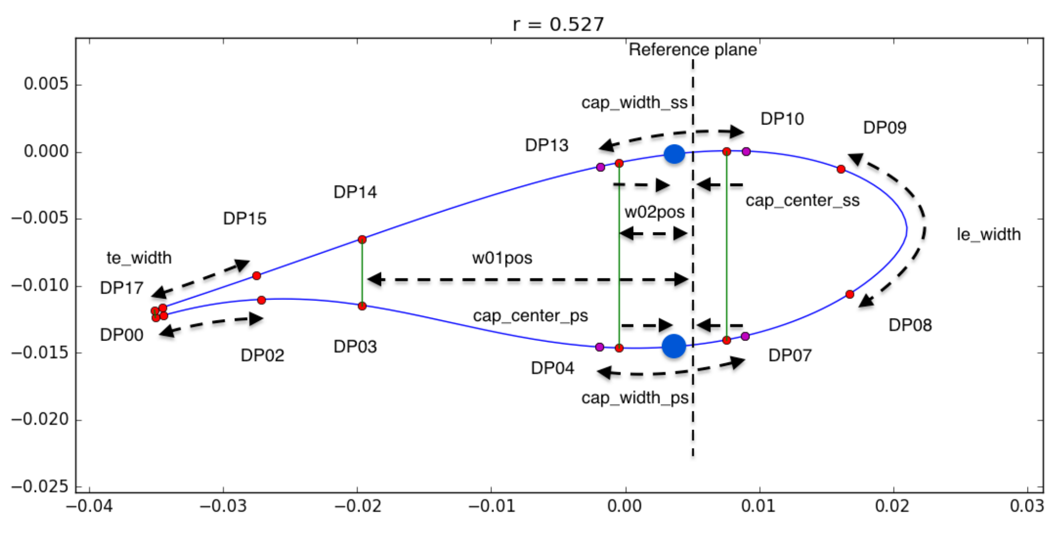


Figure 23: Schematic showing the geometric parameterisation of the blade structure for the 10 MW rotor.

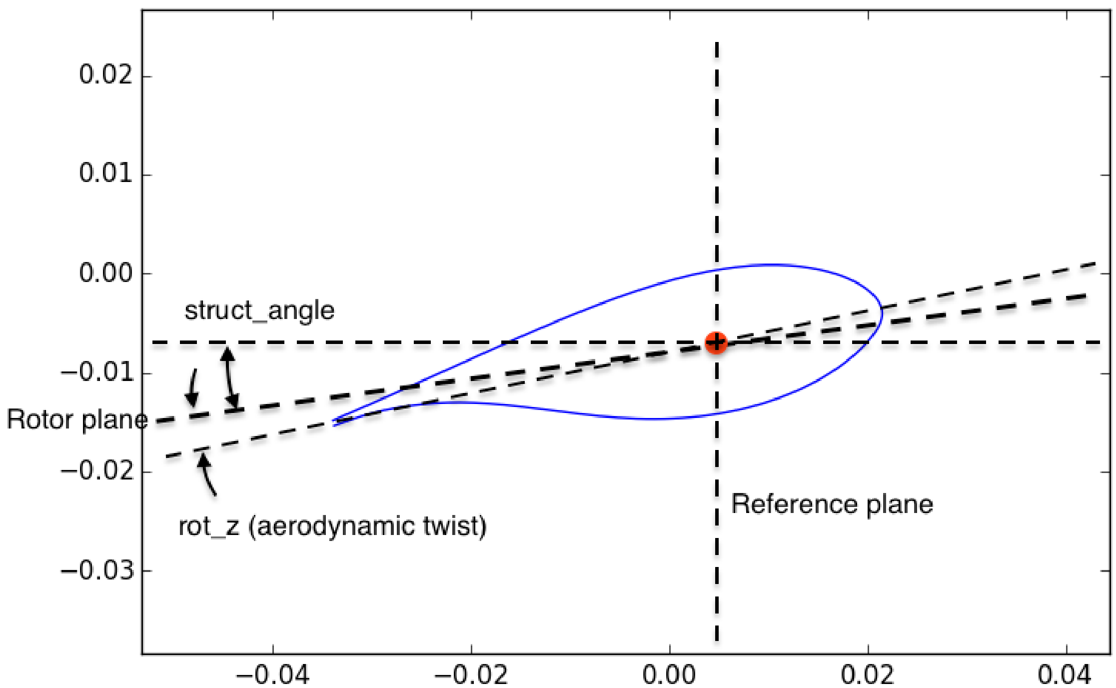


Figure 24: Schematic showing the definition of the structural angle for the 10 MW rotor.

5.4.2 Material Properties

The material properties used for the blade where those defined for the DTU 10 MW RWT (for more details, see [43]). Table 12 lists the apparent mechanical properties of the multidirectional plies used and Table 13 lists the properties for the balsa core material.

Multidirectional Ply	Uniax	Biax	Triax	
Fiber volume fraction V_f	0.55	0.5	0.5	-
Unidirectional lamina	Lamina 2	Lamina 1	Lamina 1	
$0°$ fibers	95	0	30	%
$90°$ fibers	5	0	0	%
$+45°$ fibers	0	50	35	%
$-45°$ fibers	0	50	35	%
Young's modulus E_1	41.63	13.92	21.79	GPa
Young's modulus E_2	14.93	13.92	14.67	GPa
Shear modulus G_{12}	5.047	11.50	9.413	GPa
Poisson's ratio ν_{12}	0.241	0.533	0.478	-
Shear modulus $G_{13} = G_{23}$	5.04698	4.53864	4.53864	GPa
Mass density ρ	1915.5	1845.0	1845.0	kg/m^3

Table 12: Fiber orientation and apparent mechanical properties of the multidirectional plies. Reproduced from [43].

Design strength properties are also defined for these materials and are listed in Table 14.

5.4.3 Material Layup

The material is placed in the blade according to regions that each have a chordwise extent given by the structural layout described in the Section 5.4.1.

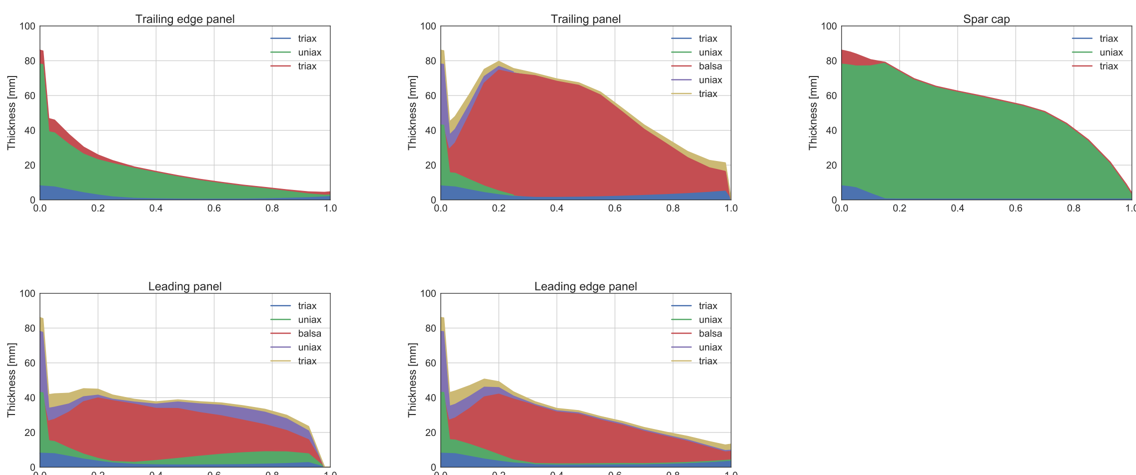


Figure 25: Material stacking sequence for each region along the optimized blade.

Property	Balsa direction	Value	Unit
Young's modulus E_1	radial	0.050	GPa
Young's modulus E_2	tangential	0.050	GPa
Young's modulus E_3	axial	2.730	GPa
Shear modulus $G_{12}{}^{(a)}$	radial-tangential	0.016 67	GPa
Shear modulus G_{13}	radial-axial	0.150	GPa
Shear modulus G_{23}	tangential-axial	0.150	GPa
Poisson's ratio ν_{12}	radial-tangential	0.5	–
Poisson's ratio ν_{13}	radial-axial	0.013	–
Poisson's ratio ν_{23}	tangential-axial	0.013	–
Mass density ρ		110	kg/m^3

$^{(a)}$ Computed assuming trans. isotropy: $G_{12} = E_1/(2(1+\nu_{12}))$.

Table 13: Mechanical properties of balsa wood [46] [47]. The indices 1, 2 and 3 refer the the blade's longitudinal, transverse and out-of-plane direction, respectively. Reproduced from [43].

	σ_{11}^t	σ_{22}^t	σ_{33}^t	σ_{11}^c	σ_{22}^c	σ_{33}^c	τ_{12}	τ_{13}	τ_{23}
Biax	69.3	69.3	69.3	64.9	64.9	64.9	55.9	55.9	55.9
Uniax	360.0	24.8	24.8	257.0	63.5	63.5	16.6	16.6	16.6
Triax	186.0	30.5	30.5	152.0	51.5	51.5	42.3	42.3	42.3

Table 14: Design strength properties of the multidirectional plies.

Multidirectional Ply	Uniax	Biax	Triax	
Longitudinal tensile failure strain ε_1^T	2.10	1.60	2.20	%
Longitudinal compressive failure strain ε_1^C	1.50	1.50	1.80	%

Table 15: Characteristic values of the longitudinal tensile and compressive strain to failure of the multidirectional plies (5% fractile values with a confidence level of 95%). Reproduced from [43].

5.5 Hub, Nacelle and Drivetrain Properties

The rotor nacelle assembly was chosen based on a range of commercial direct drive generator designs and implementations available in the industry at multi-megawatt level [21]. The selected generator employs an outer rotor design based on Gensys design mounted upstream of the tower. The generator design is realized using permanent magnets (PM) mounted on an external rotor with housing supported by the main shaft supported by two main bearings and by an additional bearing mounted outside the nacelle nose. The design was conceived using NREL's generator system engineering design tool, GeneratorSE [?]. The hub, drive . The bedplate design and turret has a complex topology and was assumed to be stiff. The hub design was taken to be the baseline version described by Bak et al. [22]

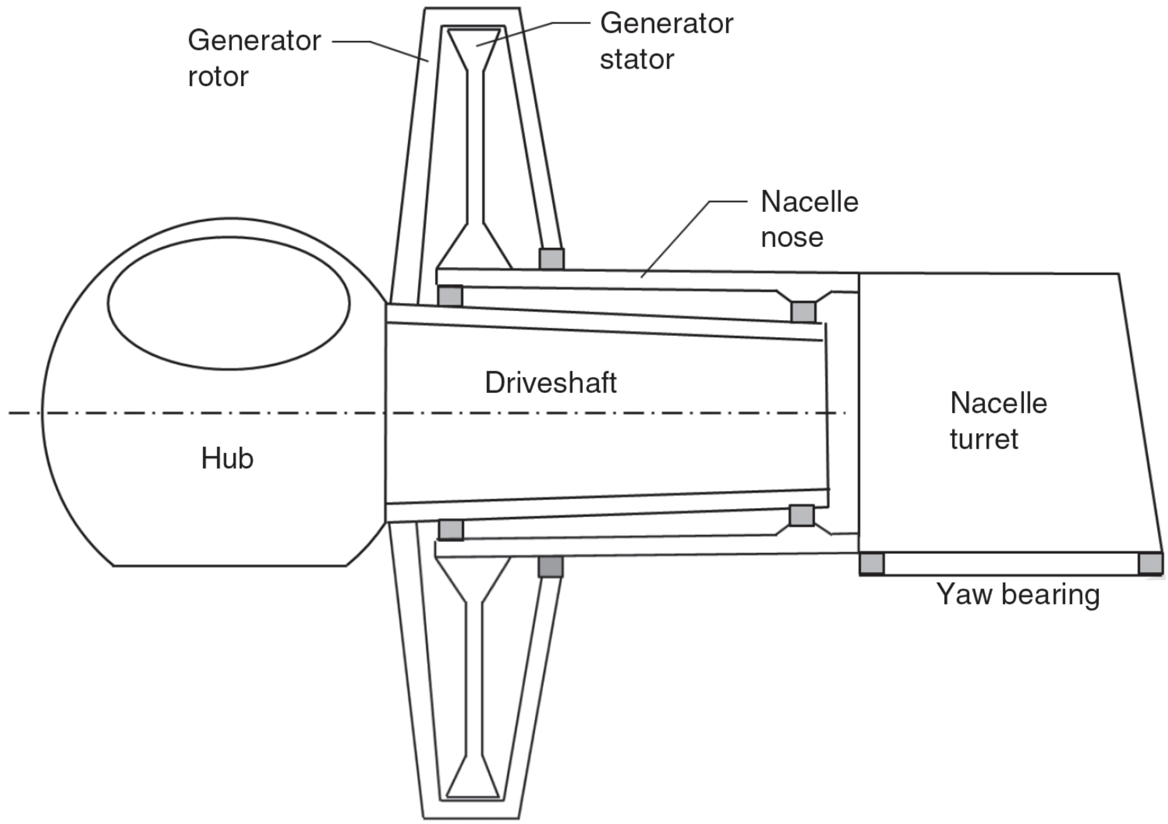
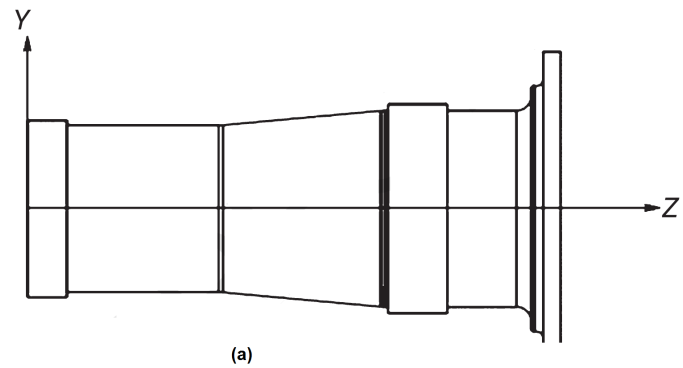


Figure 26: A sketch of the Nacelle layout of the 10MW direct drive wind turbine; not to scale with structural details omitted. Blades(not shown), hub, driveshaft and generator rotor rotate. Bearings are shaded grey.

Some key dimensions of the main shaft and nacelle nose as shown in Figure 27 are listed in tables 16 and 17. These dimensions are based on designs by Khan [19] and Klair[20]. The design for the remaining drivetrain components including hub, bedplate and bearings are derived from the rotor nacelle assembly for the NOWITECH turbine [21].



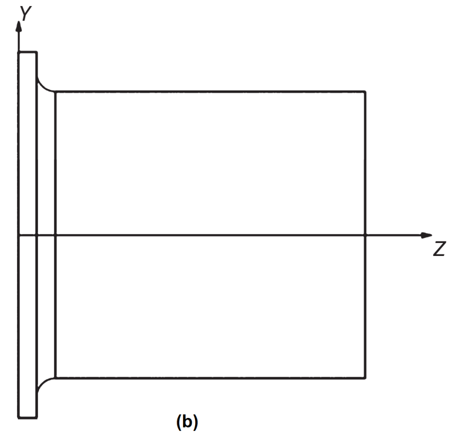


Figure 27: (a). Driveshaft (b). Nacelle Nose [E=170 GPa,G=67 Gpa]

Table 16: Dimensions of the driveshaft

Location	z	D_o	D_i	Ixx= Iyy	J
[-]	[m]	[m]	[m]	[m^4]	[m^4]
	0.000	1.700	1.350	0.2469	0.4939
Bearing 1	0.414	1.700	1.350	0.2469	0.4939
	1.958	1.700	1.350	0.2469	0.4939
	2.286	1.760	1.380	0.2930	0.5859
	2.615	1.820	1.410	0.3446	1.6891
	2.943	1.880	1.440	0.4021	0.8043
	3.271	1.940	1.470	0.4661	0.9322
	3.600	2.000	1.500	0.5369	1.0739
Bearing 2	4.242	2.000	1.500	0.5369	1.0738
	4.450	2.000	1.500	0.5369	1.0738
	4.600	2.000	1.200	0.6836	1.3672
	4.940	2.000	1.200	0.6836	1.3672
	5.116			(rigid flange)	
	5.4			(rigid flange)	

Table 17: Nacelle Nose dimensions

Location	z	D_o	D_i	Ixx= Iyy	J
[-]	[m]	[m]	[m]	[m^4]	[m^4]
	0.000		(rigid flange)		
	0.150		rigid flange)		
	0.350	3.130	2.720	2.025	4.049
	0.600	3.130	2.720	2.025	4.049
	0.743	3.130	2.720	2.025	2.187
	2.875	3.130	2.930	1.094	2.187
	3.025	3.130	2.525	2.716	5.432
	3.150	3.130	2.820	1.607	3.214
Bearing	3.750	3.130	2.820	1.607	3.214

5.6 Bedplate and other drivetrain component properties and assumptions

A solution containing two main shaft bearings and bedplate design based on extreme loading were used from [21]. The highest acceptable equivalent stress in the component was set to 200MPa under the extreme aerodynamic loads. The main purpose for the bedplate was to support the rotor nacelle assembly components and transmit the aerodynamic loads to the tower. Ultimate loads were estimated for extreme turbulence conditions with a 50 year recurrence period and combined to represent multi-axial loading under these conditions, as suggested by the IEC 61400-1. These combined loads have been used as dimensioning cases The bedplate was assumed to be made out of cast steel, this required the component to be divided into two components with a max mass limit of 50tons per component.Ultimate strength analysis was performed for the determined extreme loads, where the highest von Mises stress was found to be 208.3MPa. This design requires additional stiffness for the transition to the yaw bearing.Figure 28 shows the CAD illustration of the optimized bedplate.

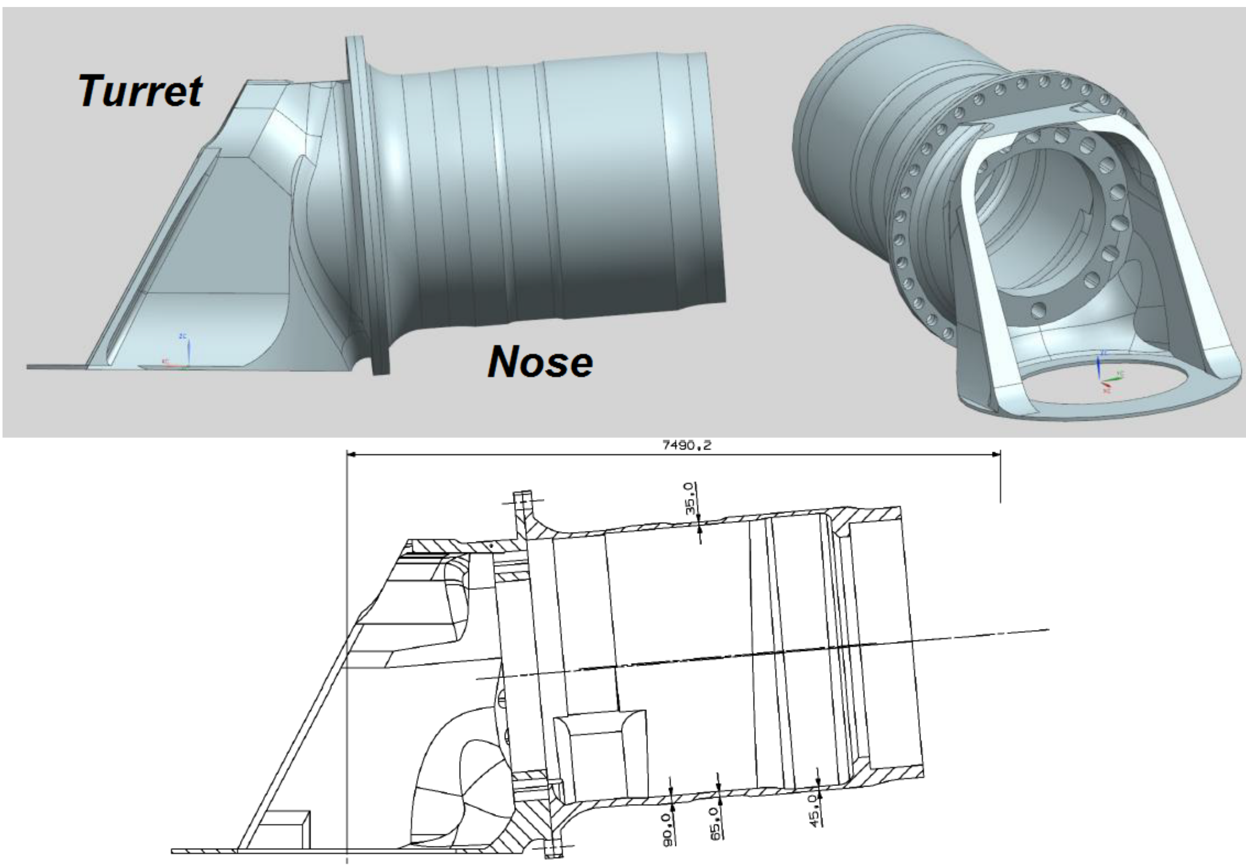


Figure 28: A CAD illustration of the bedplate

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The uneven nose profile causes high horizontal bending moments to induce high stresses on the nose. The load effect located on the bottom of the turret in the transition to flange is compressive and is considered to dominate the structure for most of its lifetime based on the weibull distribution

5.7 Main shaft bearings

A basic lifetime estimation using highest encountered design loads obtained from DLC 1.3 was used to determine the main shaft bearing solution. The loads from the aero elastic simulations were converted into bearing forces, which consists of one axial force and two radial forces. These forces were assumed to be directly transmitted to the bedplate structure. Bearing load calculation followed the method described in DNV guideline for wind turbine design.A paired fixed-floating configuration of double-row tapered bearing and a spherical bearing has been proposed. As the loads distributed on the bearings are significantly higher for the front fixed bearing, a smaller bearing is suggested for the floating bearing to reduce weight for the bedplate and main shaft, overall having a significant impact on the tower head weight.

5.8 Generator

The generator design optimized using GeneratorSE is a compact generator with an outer diameter of 10m, stack length of 1.77m and an efficiency of 94.4%. The weight of the generator was estimated to be 277tons, where 94.5 tons are expected to be active materials. Conservative estimates for support structure design with 90.9 tons for rotor and 91 tons for stator have been selected. The generator design was torque driven and was assumed to transmit the driving torque directly to the bedplate structure as well. The generator rotor was assumed to load the main shaft and bedplate frame equally. It has been assumed that the bedplate will weigh 100tons (see table 18). The center of gravity for the bedplate was obtained with the "measure body" function in NX, and was found to be very close to the backend bearing. Bedplate weight was applied as a bearing load in the back bearing, as a simplification. Table 18 lists the main drivetrain commponent masses.

Table 18: Drivetrain component masses

Component	Mass
[-]	Tons
Generator rotor	139
Generator stator	158
Hub	83.6
Bedplate	100
Main Shaft	45
Fixed bearing (upwind)	11
Floating bearing (downwind)	3
Rotor bearing (downwind)	3

5.9 Generator Design, Power converter and Transformer

NREL's GeneratorSE [17] was used to design and optimize a 10 MW direct drive synchronous generator adapted from a previous work by Norwegian University of Science and Technology [23].The generator construction features an external rotor radial flux topology machine with surface mounted permanent magnets (PM). The stator design is realized with fractional slot layout double-layer concentrated coils allowing for maximizing the fundamental winding factor. The outer rotor construction facilitates a simple and rugged structure allowing easy manufacture, short end-windings and better heat transfer between windings and teeth [24].

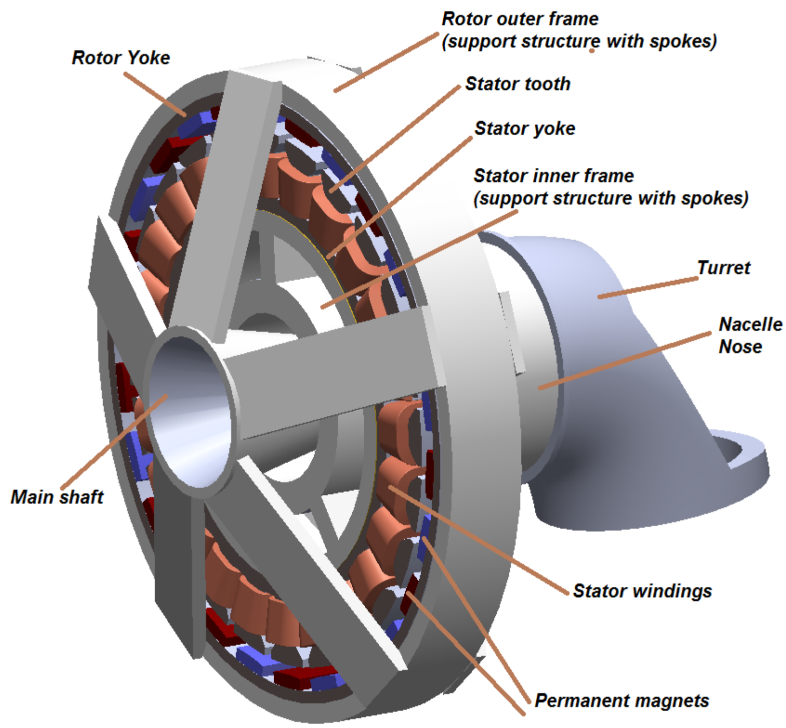

Figure 29: Outer rotor direct drive generator - A CAD illustration

The reference generator design (Figure 29) is made of electromagnetically active and inactive parts including the following main elements:

Active	Inactive
1. Stator yoke (back iron)	7. Stator inner frame (structure with spokes)
2. Stator teeth	8. Rotor outer frame (structure with spokes)
3. Stator slot winding	
4. Air-gap	
5. Permanent magnets	
6. Rotor yoke (back iron)	

The estimates for the main dimensions of the machine including electromagnetic and structural properties were determined using a hybrid optimization approach combining analytic methods for electromagnetic design and basic thermal design in GeneratorSE and commercial finite element software (ANSYS) for structural design. This design was an adaptation of NTNU's original design created using SMartMotor(now Rolls Royce) SmartTool generator design software and was updated in order to provide 10 MW at the output terminals when operated with the DTU 10MW reference wind turbine rotor. The primary modification was an increase in the stack length, to compensate for a reduction in rotor speed.Other main generator parameters for the active parts were determined from conventional magnetic circuit laws and equivalent circuit models as described in [24] and generator design handbook [25]. These were optimized satisfying certain electromagnetic performance requirements(such as magnetic loading) and user-specified constraints on generator terminal voltage and efficiency. GeneratorSE provided magnetically required minimum generator dimensions (such as air gap diameter and core length) which were then used to generate and assess and optimize parametrized spoke arm support structures that provided the required structural integrity and air-gap stiffness.

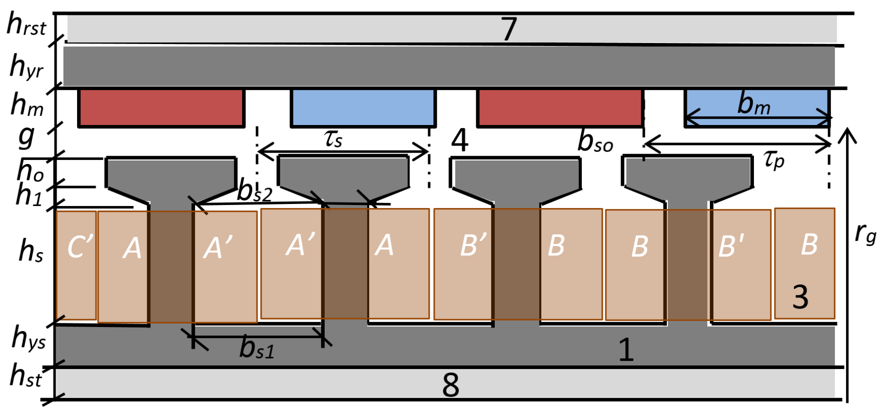

Figure 30: Electromagnetic(and structural) design parameters

Figures 30 and 31 shows the simplified cross-section for the active and structural parts of the generator. The electromagnetic design of the generator depends essentially on the operating modes, power, and output voltage range [25]. Due to these variations, for achieving a practical design, the air gap radius, magnet height, pole count, stator slot height, yoke thicknesses and tooth flux density were treated as design variables. The minimum required efficiency was set at 93% and generator terminal voltage was constrained to be under 5kV. To determine the magnetically required generator diameter and stack length, a shear stress of 40 kPa was assumed for the maximum rated torque required by the design. The minimum aspect ratio (core length/D_g) was constrained at 15%. Several assumptions were made in deriving the slotting, winding design and pole count. The magnet width was considered to be at least 70% of the pole pitch. Stator slots were designed to accommodate double layer concentrated windings with 65% fill factor. A slot/pole combination of 6/5 with q_1=0.4 slots per pole per phase were considered to provide a reasonable tradeoff for fundamental winding factor and the need to minimize peak-peak cogging torque [24]. The slot aspect ratio h_s/b_s was limited to be in the range of 4-10.It is mentioned that GeneratorSE did not consider detailed thermal design as part of the optimization process, however, to limit excessive temperature rise, the winding current density and the specific current loading were limited to 6 A/mm^2 and 60 kA/m respectively. Magnetic loading at various parts of the machine was limited to be under 2 Tesla and the minimum required yoke thickness was determined. In determining the efficiency, the fundamental core loss and copper losses were the main components. In addition, 300W was assumed for specific losses from magnets. Stray losses due to leakage flux

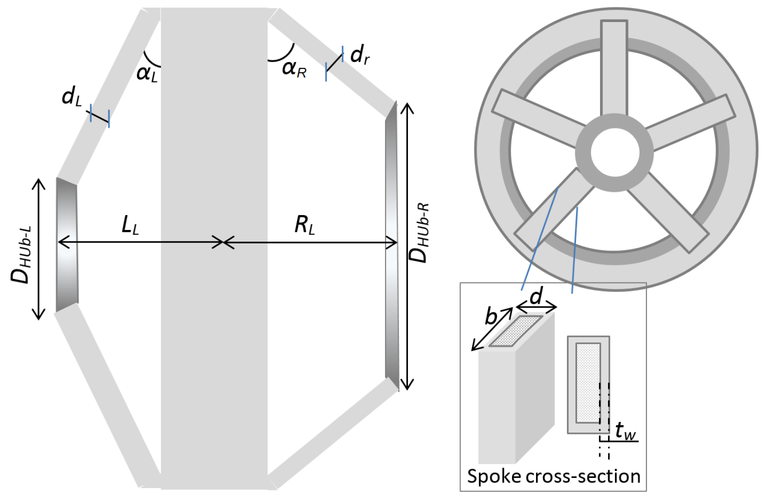

Figure 31: Structural design parameters

contributed upto 20% of iron losses. Mechanical losses from bearings were neglected. Figure 32 shows the flux density contour obtained from the optimized electromagnetic design using FEMM [26]. The maximum difference in peak magnetic loading was found to be less than 20%.

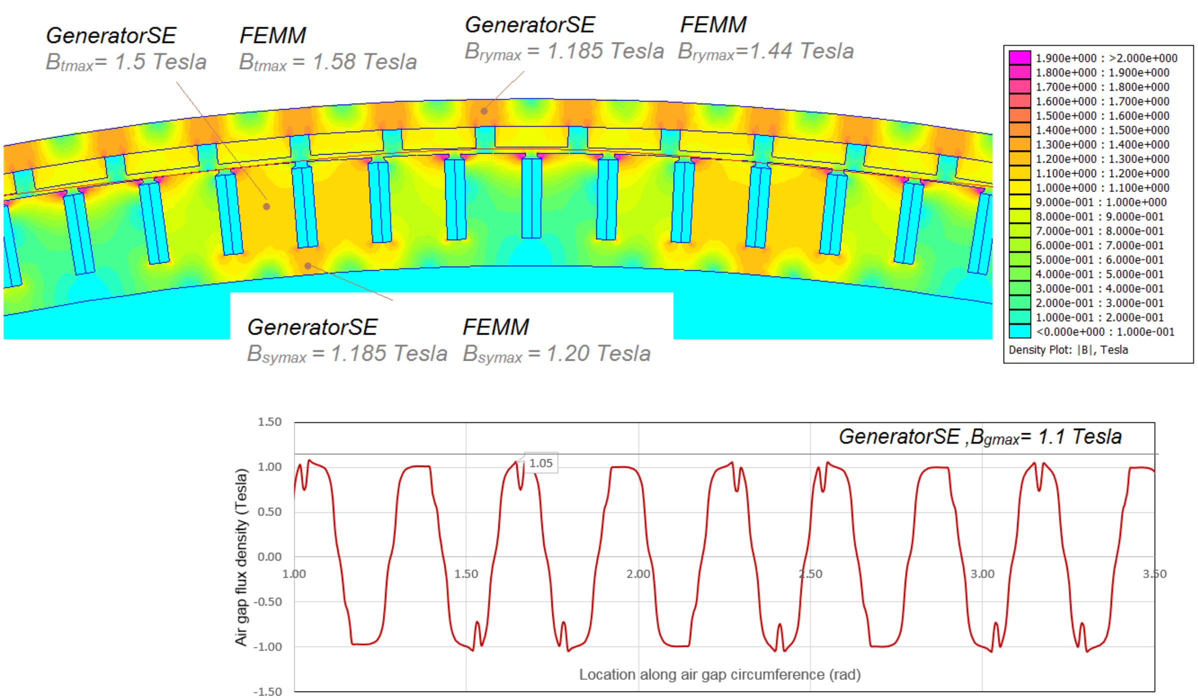

Figure 32: Validation of electromagnetic design

For determining the structural mass and design (stator and rotor frame thicknesses and spoke dimensions), the magnetically required diameter and yoke thicknesses served as the base dimensions. The stator and rotor frames (thicknesses) and spokes served as additional reinforcements to the yoke. A structural optimization was carried out in ANYSS with frame thicknesses, number of spokes, spoke arm depths and thicknesses as the main design variables to realize overall machine dimensions that withstood magnetic loading, torque and gravitational loading. The minimal required structural stiffness was ensured by limiting the maximum radial deformation to be under 10% of the air gap length, axial deformation to be 20% of the core length and tangential deformation to be under 0.05° in accordance with [27].

Figure 33 shows the radial component of structural deformations for the rotor and stator frames obtained from ANSYS. The rotor interior and stator exterior surfaces were subjected to a maximum normal stress of 0.48 MPa from magnetic loading. The maximum radial deformations are within permissible limit of 0.48mm.

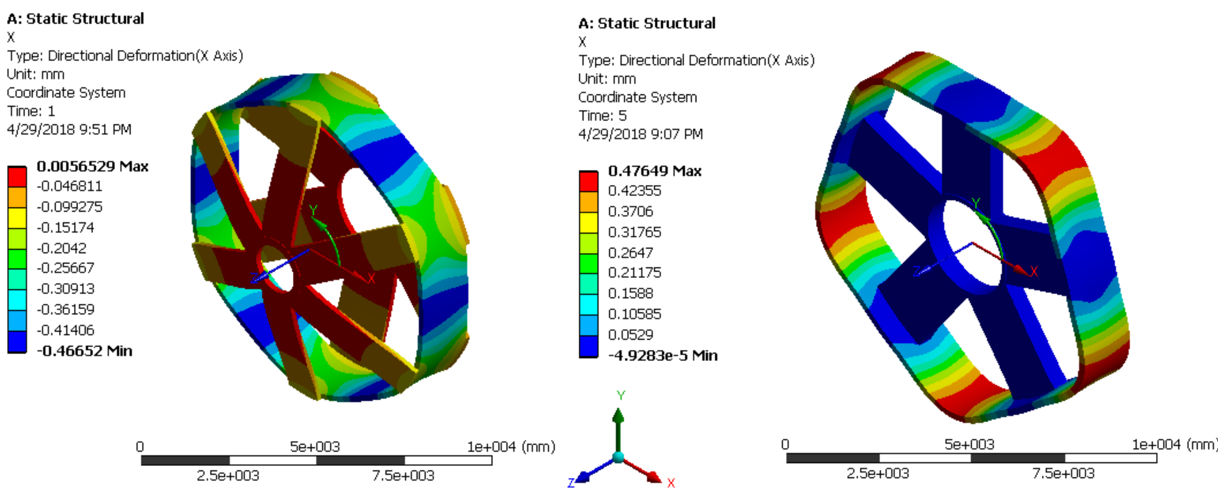

Figure 33: Validation of structural design

The total generator mass including structural supports was estimated at 277 Tons. Table 20 lists the optimized values for the design dimensions and key performance parameters.

Table 19 lists the physical parameters of the converter and transformer needed for an equivalent circuit representation. The shunt impedance of the transformer is neglected.

Table 19: Physical parameters for the converter and transformer of the 10MW reference turbine

Parameter	Description	Value	Units
C_{DC}	DC link capacitance	0.00437	Farad
η_c	Converter Efficiency (applies to each of the inverter and rectifier)	99.25	%
N_s/N_p	Transformer turns ratio	8.75	
L_p	Primary winding inductance	0.153	mH
L_s	Secondary winding inductance	11.7	mH
R_p	Primary winding resistance	0.0030	Ω
R_{st}	Secondary winding resistance	0.23	Ω

Table 20: Parameters for the 10MW reference direct drive generator

Parameter	Description	Value	Units
P_r	Rated Power at generator terminals	10	MW
ω_r	Rated speed	1.005	rad/s
f_e	Electrical frequency	16.000	Hz
T_r	Rated Torque	9.960	MNm
	Electromagnetic design		
r_g	Air gap radius	4.800	m
l	Core length	1.770	m
g	Air gap length	9.600	mm
p	Poles	200	-
S	Stator Slots	240	-
h_{ys}	Stator yoke thickness	45	mm
h_{yr}	Rotor yoke thickness	45	mm
τ_p	Pole pitch	150.8	mm
τ_s	Slot pitch	125.4	mm
h_s	Slot height	130.0	mm
b_s	Slot width	32.3	mm
b_t	Tooth width	92.46	mm
h_m	Magnet height	34	mm
b_m	Magnet width	120.64	mm
V	RMS line voltage	3981	V
I	Nominal winding current(RMS)	842	A
R_s	Stator winding resistance per phase	0.17	ohm
N_s	Stator winding turns per phase	320	turns
$\hat{B}_g$	Peak air gap flux density	1.1	Tesla
J_s	Winding current density	4.66	A/mm^2
A_1	Specific current loading	53.7	kA/m
η	Efficiency	94.42	%
M_{Iron}	Iron mass	78.89	Tons
M_{Cu}	Copper mass	6.00	Tons
M_{Magnet}	Magnet Mass	9.5	Tons
M_{Active}	Total Active Mass	94.41	Tons
	Structural Design		
D_{HUBL}	Hub diameter (Upwind)	2.02	m
D_{HUBR}	Hub diameter (Downwind)	3.13	m
L_L	Distance of generator center from Upwind Hub	1.219	m
L_R	Distance of generator center from Downwind Hub	1.09	m
α_L	Angle of upwind spoke with rotor plane	4.09	deg
α_R	Angle of downwind spoke with rotor plane	3.55	deg
h_{st}	Stator frame thickness	130	mm
n_L	Number of upwind spokes	5	-
n_R	Number of downwind spokes	5	-
d_L	Upwind spoke depth	150	mm
d_R	Downwind spoke depth	150	mm
tw_L	Upwind spoke wall thickness	40	mm
tw_R	Downwind spoke wall thickness	40	mm
h_{rst}	Rotor frame thickness	160	mm
n_r	Number of stator spokes	5	-
d_r	Stator spoke depth	500	mm
tw_r	Stator spoke arm thickness	50	mm
M_{SStru}	Total Rotor Structural Steel Mass	90.9	Tons
M_{RStru}	Total Stator Structural Mass	91.8	Tons
M_{Gen}	Estimated Total Generator Mass	277	Tons

5.10 Tower Properties

The tower, monopile foundation and transition piece were designed based on frequency considerations. The expected first natural frequency of 0.24 Hz is placed above the most severe ocean-wave frequency band and below the oceanwave frequency band and below the 3P blade passing frequency, which is 0.3 Hz when the turbine is operating in low wind conditions. The tower height was chosen such that the yaw bearing of the ORT is located 115.63 m above the ocean surface, giving a hub height of 119 m, which matches the hub height of the DTU 10 MW reference wind turbine. The monopile foundation has a diameter of 9 m, near the maximum that is available with todays installation technology. Table 21 lists some of the important dimensions and stiffness properties of the combined foundation (including the transition piece) and tower.

Table 21: Some key properties and dimensions of the tower and foundation

Location	z	D_o	D_i	Ixx= Iyy	J
[-]	[m]	[m]	[m]	[m^4]	[m^4]
Yaw bearing	145.63	5.50	5.44	2.03	4.07
	134.55	5.79	5.73	2.76	5.52
	124.04	6.07	6.00	3.63	7.26
	113.54	6.3 5	6.26	4.67	9.35
	103.03	6.63	6.53	5.90	11.80
	92.53	6.91	6.80	7.33	14.67
782.02	7.19	7.07	8.99	17.98	
	71.52	7.46	7.34	10.9	21.80
	61.01	7.74	7.61	13.08	26.15
↑	50.51	8.02	7.88	15.55	31.09
tower	40.00	8.30	8.16	15.55	31.09
foundation	40.00	9.00	8.70	34.84	69.68
↓	38.00	9.00	8.70	35.74	71.48
	36.00	9.00	8.70	36.66	73.32
	34.00	9.00	8.70	37.59	75.18
	32.00	9.00	8.69	38.54	77.08
waterline	30.00	9.00	8.69	39.51	79.01
	28.00	9.00	8.69	40.49	80.97
	26.00	9.00	8.69	41.48	82.97
	24.00	9.00	8.69	42.5	85.00
	22.00	9.00	8.69	43.53	87.05
	20.00	9.00	8.69	44.05	88.10
	16.00	9.00	8.80	28.09	56.18
	12.00	9.00	8.80	28.09	56.18
	8.00	9.00	8.80	28.09	56.18
	4.00	9.00	8.80	28.09	56.18
mudline	0.00	8.80	28.09	56.18	
	-8.400	9.00	8.80	28.09	56.18
	-16.800	9.00	8.80	28.09	56.18
	-25.20	9.00	8.80	28.09	56.18
	-33.60	9.00	8.80	28.09	56.18
	-42.60	9.00	8.80	28.09	56.18

5.11 Controller Properties

Simple physical models of the blade pitch actuators and generator/converter system have been developed and disccused in great detail by Merz [28]. The equations for the simple physical models including internal control loops were derived and compared against the alternatives of no models where the actual pitch and Torque are assumed to be equal to the desired values, and equivalent filter functions recommended by DTU in the context of aeroelastic models. To demonstrate and evaluate the physical models, a 10 MW direct-drive generator using NREL's GeneratorSE was designed for use with the DTU 10 MW Reference Wind Turbine. The design is based on earlier work on the NOWITECH 10 MW Reference Wind Turbine; but significant modifications were necessary to increase the torque to the level required by the DTU turbine. The generator design is described in some detail, and may be useful as a reference case for future research.The model used for the generator has been simplified by the assumption of a sinusoidal mmf at the fundamental frequency. The time delay in sampling and filtering measurements of shaft speed and electrical power is critical. Clearly, it is difficult to damp an oscillation at 18 Hz [13] if the time constant of the filtered sensor measurement corresponds to 20 Hz.

The steady state operational data for the 10 MW turbine is listed in Table 22. The rotor operates with a minimum rotational speed of 6 rpm to avoid interference with the tower natural frequency, and reaches rated rotational speed of 8.68 rpm at 8.5 m/s, resulting in a maximum nominal tip speed of 90 m/s. The rotor operates with pitch setting of 0 degrees at design tip speed ratio, but operates with positive pitch at low wind speeds in order to track maximum power. The rotor starts pitching at the rated wind speed of 10.75 m/s.

Table 22: Operational summary of the 10 MW rotor.

Data	Value	Data	Value
Maximum C_p [-]	0.49	Design Pitch [deg]	0.
Design TSR [-]	10.58	Omega Rated [rpm]	8.68
Torque Rated [MNm]	11.7	Max Tip Speed [m/s]	90.0
Cut In Wind Speed [m/s]	4.0	Cut Out Wind Speed [m/s]	25.0
Wind Speed Region II1/2 [m/s]	8.5	Rated Wind Speed [m/s]	10.75
Min Rotor Speed [rpm]	6.0		

Figure 34 shows the rotor steady state performance and operation. Table 23 shows the operational data for the rotor computed using HAWCStab2 [15] including deflections.

For the design loads evaluation of the 10 MW turbine the Basic DTU Wind Energy controller [44] was used. The controller is available open source, see [45]. For detailed inputs used to evaluate the design loads, see Appendix B.4.

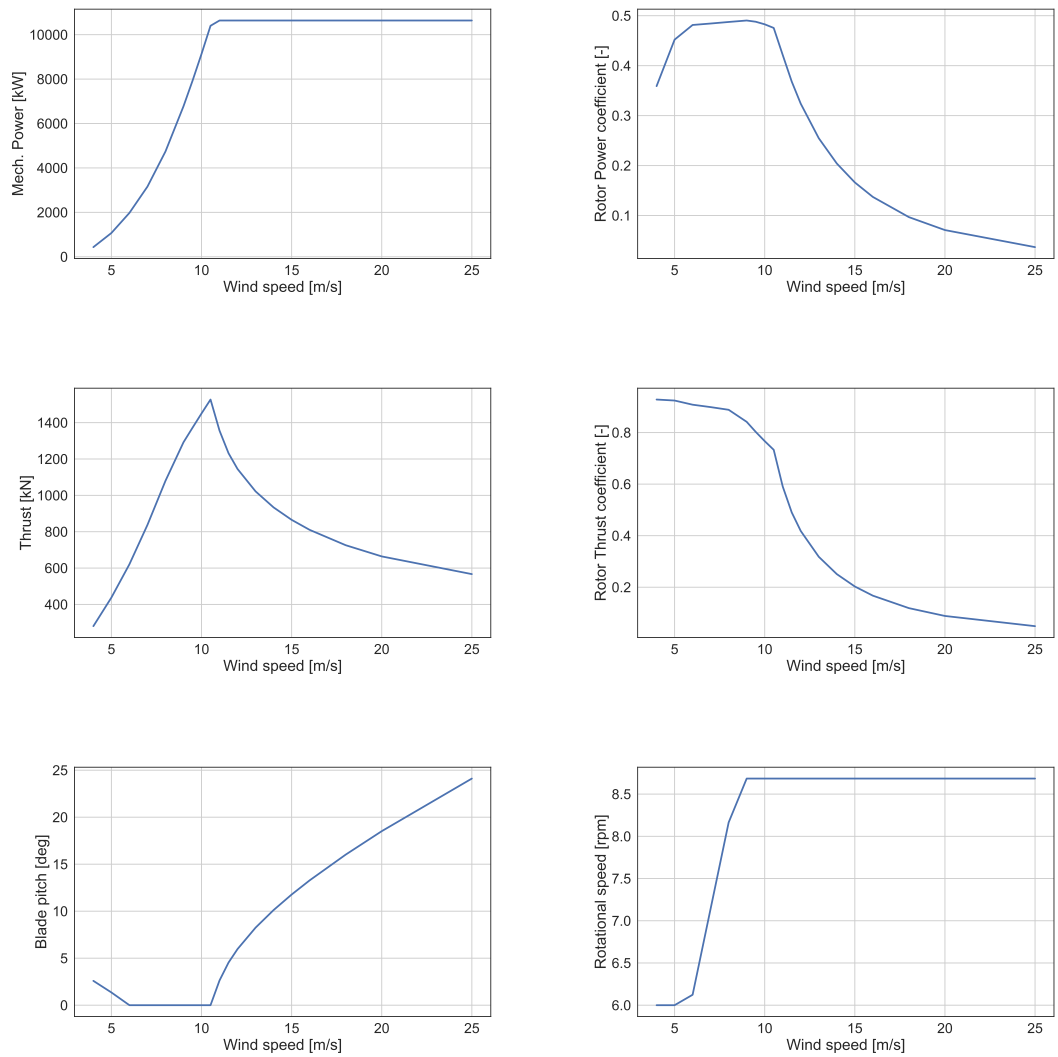

Figure 34: Steady state performance and operation of the 10 MW rotor.

Table 23: Operational data of the 10 MW rotor.

Wind speed [m/s]	Pitch [deg]	RPM [-]
4.00	2.589	6.000
5.00	1.355	6.000
6.00	0.000	6.123
7.00	0.000	7.144
8.00	0.000	8.165
9.00	0.000	8.684
9.50	0.000	8.684
10.00	0.000	8.684
10.50	0.000	8.684
11.00	2.633	8.684
11.50	4.537	8.684
12.00	5.975	8.684
13.00	8.250	8.684
14.00	10.121	8.684
15.00	11.771	8.684
16.00	13.280	8.684
18.00	16.018	8.684
20.00	18.513	8.684
25.00	24.110	8.684

6 Conclusions

This report documented the development of the first two in a series of reference wind turbines from the IEA Wind Task 37 on integrated wind energy research and development. The turbines were designed to align with current commercial wind turbines available in production - a low-wind-speed land-based 3.4 MW turbine and an offshore 10 MW turbine. As technology changes, new turbines will be developed to reflect the state-of-the-art. All the turbine documentation and detailed design data is available on the organization https://github.com/IEAWindTask37 .

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Appendices

A IEA Wind Task 37 onshore reference turbine detailed properties and loads

A.1 Blade aerodynamic shape

Table 24: Aerodynamic shape of the onshore wind turbine blade - Part I.

η	Chord	Twist	Rel. Thick	Abs. Thick.	PreBend	Sweep	Pitch Ax.	Aero. Center Ax.
[-]	[mm]	[deg]	[%]	[mm]	[mm]	[mm]	[%]	[%]
0.000	2600.0	20.00	100.00	2600.0	0.0	0.0	50.00	50.00
0.010	2600.0	19.87	100.00	2600.0	0.0	0.0	49.65	50.00
0.020	2600.0	19.73	100.00	2600.0	0.0	0.0	49.30	50.00
0.030	2620.6	19.56	99.12	2597.6	0.0	0.0	48.57	49.48
0.040	2680.1	19.39	96.68	2591.1	0.0	0.0	47.16	48.06
0.050	2776.7	19.20	92.96	2581.1	0.0	0.0	45.19	45.92
0.060	2910.6	18.99	88.25	2568.6	0.0	0.0	42.80	43.24
0.070	3032.4	18.76	82.84	2512.0	0.0	0.0	40.78	40.22
0.080	3155.4	18.51	77.01	2430.1	0.0	0.0	38.91	37.04
0.100	3400.0	17.94	65.28	2219.4	0.0	0.0	35.57	30.94
0.120	3618.0	17.07	55.34	2002.0	1.3	0.0	32.93	26.44
0.140	3803.9	15.81	49.44	1880.6	5.5	0.0	30.84	25.00
0.160	3958.7	14.37	45.94	1818.7	10.9	0.0	29.18	25.00
0.180	4083.2	12.95	43.11	1760.5	17.5	0.0	27.85	25.00
0.200	4178.5	11.75	40.96	1711.4	25.3	0.0	26.78	25.00
0.220	4245.5	10.73	39.44	1674.3	34.4	0.0	25.93	25.00
0.240	4285.1	9.71	38.23	1638.3	44.9	0.0	25.27	25.00
0.260	4298.4	8.71	37.23	1600.2	56.7	0.0	24.77	25.00
0.280	4286.7	7.74	36.38	1559.4	69.9	0.0	24.42	25.00
0.300	4252.0	6.81	35.64	1515.3	84.6	0.0	24.19	25.00
0.320	4196.1	5.93	34.96	1467.0	100.8	0.0	24.08	25.00
0.340	4121.1	5.12	34.34	1415.2	118.7	0.0	24.08	25.00
0.360	4028.7	4.39	33.79	1361.2	138.1	0.0	24.18	25.00
0.380	3921.1	3.75	33.29	1305.3	159.3	0.0	24.38	25.00
0.400	3800.0	3.21	32.83	1247.5	182.3	0.0	24.68	25.00
0.420	3667.7	2.76	32.39	1188.1	207.0	0.0	25.08	25.00
0.440	3527.8	2.38	31.97	1127.8	233.9	0.0	25.56	25.00
0.460	3384.0	2.05	31.54	1067.4	262.7	0.0	26.11	25.00
0.480	3240.1	1.77	31.10	1007.6	293.7	0.0	26.72	25.00
0.500	3100.0	1.53	30.62	949.3	326.9	0.0	27.34	25.00
0.520	2966.8	1.32	30.10	893.0	362.5	0.0	27.96	25.00
0.540	2841.2	1.13	29.51	838.5	400.6	0.0	28.55	25.00
0.560	2723.1	0.95	28.86	785.9	441.3	0.0	29.13	25.00
0.580	2612.7	0.78	28.16	735.8	484.7	0.0	29.67	25.00
0.600	2509.8	0.60	27.45	688.9	530.9	0.0	30.16	25.00
0.620	2414.5	0.42	26.75	645.8	580.3	0.0	30.60	25.00
0.640	2326.9	0.27	26.08	606.8	632.8	0.0	30.98	25.00
0.660	2246.8	0.13	25.47	572.3	688.8	0.0	31.28	25.00
0.680	2174.3	0.01	24.96	542.6	748.3	0.0	31.49	25.00
0.700	2109.5	-0.11	24.47	516.1	811.8	0.0	31.59	25.00
0.720	2052.3	-0.22	23.97	491.9	879.1	0.0	31.79	25.00
0.740	2002.8	-0.34	23.46	469.9	951.1	0.0	31.73	25.00
0.760	1960.9	-0.47	22.98	450.5	1027.4	0.0	31.57	25.00
0.780	1926.6	-0.60	22.51	433.7	1109.0	0.0	31.26	25.00
0.800	1900.0	-0.75	22.09	419.7	1195.8	0.0	30.80	25.00

Table 25: Aerodynamic shape of the onshore wind turbine blade - Part II.

η [-]	Chord [mm]	Twist [deg]	Rel. Thick [%]	Abs. Thick. [mm]	PreBend [mm]	Sweep [mm]	Pitch Ax. [%]	Aero. Center Ax. [%]
0.820	1879.2	-0.91	21.72	408.1	1288.4	0.0	30.21	25.00
0.840	1854.9	-1.07	21.41	397.1	1387.4	0.0	29.56	25.00
0.860	1816.1	-1.24	21.18	384.6	1493.1	0.0	28.87	25.00
0.880	1751.5	-1.45	21.04	368.5	1606.2	0.0	28.24	25.00
0.900	1650.0	-1.70	21.00	346.5	1727.8	0.0	27.67	25.00
0.920	1500.5	-2.05	21.00	315.1	1858.3	0.0	27.25	25.00
0.940	1291.9	-2.54	21.00	271.3	1998.7	0.0	26.92	25.00
0.960	1013.1	-3.14	21.00	212.7	2150.5	0.0	26.71	25.00
0.980	652.8	-3.84	21.00	137.1	2315.1	0.0	26.44	25.00
1.000	200.0	-4.62	21.00	42.0	2500.0	0.0	25.00	25.00

A.2 Airfoil data

Table 26: Airfoil shape - Root circle

ID	x	y	ID	x	y	ID	x	y
[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]
1	1.0000	0.0000	26	0.2132	0.4096	51	0.2966	-0.4568
2	0.9981	0.0436	27	0.1786	0.3830	52	0.3372	-0.4728
3	0.9924	0.0868	28	0.1464	0.3536	53	0.3790	-0.4851
4	0.9830	0.1294	29	0.1170	0.3214	54	0.4218	-0.4938
5	0.9698	0.1710	30	0.0904	0.2868	55	0.4651	-0.4988
6	0.9532	0.2113	31	0.0670	0.2500	56	0.5087	-0.4999
7	0.9330	0.2500	32	0.0468	0.2113	57	0.5523	-0.4973
8	0.9096	0.2868	33	0.0302	0.1710	58	0.5954	-0.4908
9	0.8830	0.3214	34	0.0170	0.1294	59	0.6378	-0.4806
10	0.8536	0.3536	35	0.0076	0.0868	60	0.6792	-0.4668
11	0.8214	0.3830	36	0.0019	0.0436	61	0.7192	-0.4494
12	0.7868	0.4096	37	0.0000	0.0000	62	0.7575	-0.4286
13	0.7500	0.4330	38	0.0001	-0.0087	63	0.7939	-0.4045
14	0.7113	0.4532	39	0.0027	-0.0523	64	0.8280	-0.3774
15	0.6710	0.4698	40	0.0092	-0.0954	65	0.8597	-0.3473
16	0.6294	0.4830	41	0.0194	-0.1378	66	0.8886	-0.3147
17	0.5868	0.4924	42	0.0332	-0.1792	67	0.9145	-0.2796
18	0.5436	0.4981	43	0.0506	-0.2192	68	0.9373	-0.2424
19	0.5000	0.5000	44	0.0714	-0.2575	69	0.9568	-0.2034
20	0.4564	0.4981	45	0.0955	-0.2939	70	0.9728	-0.1628
21	0.4132	0.4924	46	0.1226	-0.3280	71	0.9851	-0.1210
22	0.3706	0.4830	47	0.1527	-0.3597	72	0.9938	-0.0782
23	0.3290	0.4698	48	0.1853	-0.3886	73	0.9988	-0.0349
24	0.2887	0.4532	49	0.2204	-0.4145	74	1.0000	0.0000
25	0.2500	0.4330	50	0.2576	-0.4373			

Table 27: Airfoil shape - FX77-W-500

ID	x	y	ID	x	y	ID	x	y	ID	x	y
[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]
1	1.0000	-0.0594	18	0.3634	0.2452	35	0.0016	-0.0880	52	0.4486	-0.2466
2	0.9950	-0.0044	19	0.3230	0.2373	36	0.0062	-0.0991	53	0.4931	-0.2499
3	0.9900	0.0556	20	0.2843	0.2256	37	0.0140	-0.1143	54	0.5386	-0.2511
4	0.9820	0.1056	21	0.2476	0.2122	38	0.0248	-0.1257	55	0.5850	-0.2517
5	0.9603	0.1129	22	0.2129	0.1958	39	0.0386	-0.1383	56	0.6319	-0.2496
6	0.9148	0.1282	23	0.1803	0.1784	40	0.0553	-0.1484	57	0.6792	-0.2466
7	0.8685	0.1444	24	0.1502	0.1582	41	0.0749	-0.1602	58	0.7267	-0.2413
8	0.8216	0.1596	25	0.1225	0.1380	42	0.0974	-0.1700	59	0.7743	-0.2351
9	0.7743	0.1755	26	0.0974	0.1155	43	0.1225	-0.1809	60	0.8216	-0.2257
10	0.7267	0.1903	27	0.0749	0.0938	44	0.1502	-0.1902	61	0.8685	-0.2148
11	0.6792	0.2054	28	0.0553	0.0703	45	0.1803	-0.2003	62	0.9148	-0.2002
12	0.6319	0.2189	29	0.0386	0.0489	46	0.2129	-0.2086	63	0.9603	-0.1861
13	0.5850	0.2322	30	0.0248	0.0263	47	0.2476	-0.2174	64	0.9800	-0.1734
14	0.5386	0.2426	31	0.0140	0.0069	48	0.2843	-0.2246	65	0.9900	-0.1244
15	0.4931	0.2498	32	0.0062	-0.0147	49	0.3230	-0.2319	66	1.0000	-0.0844
16	0.4486	0.2517	33	0.0016	-0.0333	50	0.3634	-0.2375			
17	0.4053	0.2506	34	0.0000	-0.0644	51	0.4053	-0.2430			

Table 28: Airfoil shape - FX77-W-400

ID	x	y	ID	x	y	ID	x	y	ID	x	y
[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]
1	1.0000	-0.0466	20	0.3945	0.1998	39	0.0000	-0.0516	58	0.3945	-0.1999
2	0.9950	-0.0016	21	0.3589	0.2014	40	0.0012	-0.0704	59	0.4309	-0.2009
3	0.9800	0.0171	22	0.3243	0.2005	41	0.0050	-0.0793	60	0.4680	-0.2014
4	0.9647	0.0255	23	0.2907	0.1962	42	0.0112	-0.0914	61	0.5055	-0.1997
5	0.9353	0.0344	24	0.2584	0.1898	43	0.0198	-0.1006	62	0.5434	-0.1973
6	0.9044	0.0444	25	0.2275	0.1804	44	0.0308	-0.1106	63	0.5814	-0.1931
7	0.8721	0.0547	26	0.1981	0.1698	45	0.0443	-0.1187	64	0.6194	-0.1881
8	0.8385	0.0662	27	0.1703	0.1566	46	0.0600	-0.1281	65	0.6573	-0.1805
9	0.8039	0.0778	28	0.1443	0.1428	47	0.0779	-0.1360	66	0.6948	-0.1718
10	0.7683	0.0903	29	0.1201	0.1266	48	0.0980	-0.1447	67	0.7319	-0.1602
11	0.7319	0.1026	30	0.0980	0.1104	49	0.1201	-0.1521	68	0.7683	-0.1488
12	0.6948	0.1155	31	0.0779	0.0924	50	0.1443	-0.1602	69	0.8039	-0.1374
13	0.6573	0.1276	32	0.0600	0.0750	51	0.1703	-0.1669	70	0.8385	-0.1273
14	0.6194	0.1404	33	0.0443	0.0562	52	0.1981	-0.1740	71	0.8721	-0.1178
15	0.5814	0.1522	34	0.0308	0.0391	53	0.2275	-0.1797	72	0.9044	-0.1096
16	0.5434	0.1643	35	0.0198	0.0210	54	0.2584	-0.1855	73	0.9353	-0.1022
17	0.5055	0.1751	36	0.0112	0.0056	55	0.2907	-0.1900	74	0.9647	-0.0961
18	0.4680	0.1858	37	0.0050	-0.0118	56	0.3243	-0.1944	75	0.9925	-0.0905
19	0.4309	0.1941	38	0.0012	-0.0267	57	0.3589	-0.1973	76	1.0000	-0.0616

Table 29: Airfoil shape - DU00-W2-350

ID	x	y	ID	x	y	ID	x	y	ID	x	y
[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]
1	1.0000	0.0050	41	0.2252	0.1613	81	0.0045	-0.0272	121	0.4193	-0.1727
2	0.9893	0.0082	42	0.2110	0.1591	82	0.0062	-0.0321	122	0.4338	-0.1700
3	0.9731	0.0130	43	0.1971	0.1566	83	0.0082	-0.0370	123	0.4485	-0.1669
4	0.9526	0.0190	44	0.1836	0.1537	84	0.0106	-0.0420	124	0.4633	-0.1634
5	0.9305	0.0254	45	0.1704	0.1505	85	0.0134	-0.0471	125	0.4781	-0.1594
6	0.9080	0.0320	46	0.1577	0.1469	86	0.0167	-0.0524	126	0.4931	-0.1550
7	0.8854	0.0387	47	0.1453	0.1431	87	0.0203	-0.0577	127	0.5085	-0.1501
8	0.8628	0.0454	48	0.1334	0.1389	88	0.0245	-0.0632	128	0.5241	-0.1447
9	0.8400	0.0522	49	0.1219	0.1345	89	0.0292	-0.0688	129	0.5402	-0.1387
10	0.8169	0.0592	50	0.1109	0.1298	90	0.0347	-0.0747	130	0.5569	-0.1322
11	0.7937	0.0662	51	0.1005	0.1249	91	0.0407	-0.0807	131	0.5744	-0.1250
12	0.7707	0.0731	52	0.0907	0.1199	92	0.0475	-0.0869	132	0.5925	-0.1172
13	0.7479	0.0799	53	0.0815	0.1146	93	0.0549	-0.0932	133	0.6114	-0.1088
14	0.7252	0.0866	54	0.0728	0.1093	94	0.0630	-0.0994	134	0.6314	-0.0997
15	0.7029	0.0932	55	0.0647	0.1038	95	0.0717	-0.1057	135	0.6524	-0.0901
16	0.6809	0.0996	56	0.0571	0.0982	96	0.0811	-0.1118	136	0.6738	-0.0802
17	0.6590	0.1058	57	0.0501	0.0926	97	0.0909	-0.1179	137	0.6948	-0.0705
18	0.6376	0.1118	58	0.0436	0.0869	98	0.1013	-0.1237	138	0.7147	-0.0614
19	0.6165	0.1175	59	0.0376	0.0811	99	0.1122	-0.1293	139	0.7337	-0.0530
20	0.5957	0.1230	60	0.0321	0.0754	100	0.1237	-0.1348	140	0.7517	-0.0453
21	0.5752	0.1282	61	0.0272	0.0697	101	0.1357	-0.1400	141	0.7689	-0.0382
22	0.5549	0.1331	62	0.0228	0.0640	102	0.1482	-0.1450	142	0.7855	-0.0317
23	0.5350	0.1377	63	0.0188	0.0585	103	0.1612	-0.1498	143	0.8013	-0.0258
24	0.5155	0.1420	64	0.0153	0.0531	104	0.1745	-0.1542	144	0.8165	-0.0206
25	0.4963	0.1460	65	0.0123	0.0477	105	0.1882	-0.1583	145	0.8311	-0.0160
26	0.4773	0.1496	66	0.0096	0.0425	106	0.2023	-0.1621	146	0.8452	-0.0120
27	0.4585	0.1529	67	0.0074	0.0375	107	0.2167	-0.1656	147	0.8587	-0.0085
28	0.4400	0.1559	68	0.0055	0.0326	108	0.2313	-0.1687	148	0.8719	-0.0055
29	0.4216	0.1585	69	0.0040	0.0277	109	0.2460	-0.1714	149	0.8847	-0.0031
30	0.4036	0.1608	70	0.0028	0.0226	110	0.2609	-0.1737	150	0.8972	-0.0011
31	0.3858	0.1627	71	0.0018	0.0173	111	0.2758	-0.1757	151	0.9094	0.0004
32	0.3684	0.1642	72	0.0010	0.0122	112	0.2907	-0.1772	152	0.9212	0.0014
33	0.3513	0.1654	73	0.0004	0.0076	113	0.3056	-0.1784	153	0.9325	0.0020
34	0.3345	0.1662	74	0.0001	0.0034	114	0.3204	-0.1791	154	0.9432	0.0022
35	0.3180	0.1666	75	0.0000	-0.0004	115	0.3350	-0.1794	155	0.9533	0.0020
36	0.3017	0.1666	76	0.0001	-0.0042	116	0.3493	-0.1794	156	0.9631	0.0013
37	0.2857	0.1663	77	0.0005	-0.0082	117	0.3633	-0.1789	157	0.9724	0.0003
38	0.2700	0.1656	78	0.0012	-0.0127	118	0.3770	-0.1780	158	0.9818	-0.0011
39	0.2547	0.1645	79	0.0021	-0.0174	119	0.3908	-0.1767	159	0.9911	-0.0029
40	0.2398	0.1631	80	0.0032	-0.0223	120	0.4049	-0.1749	160	1.0000	-0.0050

Table 30: Airfoil shape - DU97-W-300

ID	x	y	ID	x	y	ID	x	y	ID	x	y
[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]
1	1.0000	0.0087	51	0.3035	0.1343	101	0.0032	-0.0161	151	0.4107	-0.1464
2	0.9935	0.0105	52	0.2912	0.1340	102	0.0045	-0.0193	152	0.4232	-0.1428
3	0.9848	0.0129	53	0.2792	0.1336	103	0.0060	-0.0226	153	0.4358	-0.1391
4	0.9739	0.0158	54	0.2674	0.1329	104	0.0079	-0.0261	154	0.4487	-0.1351
5	0.9613	0.0191	55	0.2559	0.1320	105	0.0102	-0.0298	155	0.4618	-0.1309
6	0.9477	0.0226	56	0.2447	0.1310	106	0.0129	-0.0339	156	0.4751	-0.1266
7	0.9332	0.0262	57	0.2337	0.1296	107	0.0162	-0.0383	157	0.4887	-0.1220
8	0.9184	0.0298	58	0.2228	0.1281	108	0.0199	-0.0431	158	0.5025	-0.1172
9	0.9033	0.0335	59	0.2119	0.1263	109	0.0243	-0.0482	159	0.5165	-0.1123
10	0.8882	0.0372	60	0.2010	0.1242	110	0.0292	-0.0536	160	0.5306	-0.1073
11	0.8730	0.0409	61	0.1902	0.1219	111	0.0348	-0.0593	161	0.5449	-0.1022
12	0.8579	0.0446	62	0.1793	0.1194	112	0.0409	-0.0652	162	0.5592	-0.0970
13	0.8427	0.0482	63	0.1686	0.1166	113	0.0475	-0.0712	163	0.5737	-0.0917
14	0.8277	0.0519	64	0.1580	0.1137	114	0.0545	-0.0772	164	0.5883	-0.0864
15	0.8126	0.0554	65	0.1475	0.1105	115	0.0620	-0.0832	165	0.6030	-0.0810
16	0.7976	0.0590	66	0.1372	0.1071	116	0.0698	-0.0891	166	0.6176	-0.0757
17	0.7826	0.0625	67	0.1271	0.1035	117	0.0780	-0.0949	167	0.6321	-0.0704
18	0.7677	0.0660	68	0.1172	0.0997	118	0.0864	-0.1007	168	0.6464	-0.0652
19	0.7528	0.0694	69	0.1076	0.0957	119	0.0952	-0.1063	169	0.6606	-0.0602
20	0.7379	0.0728	70	0.0983	0.0916	120	0.1041	-0.1117	170	0.6747	-0.0552
21	0.7230	0.0761	71	0.0892	0.0873	121	0.1132	-0.1169	171	0.6885	-0.0503
22	0.7082	0.0794	72	0.0805	0.0829	122	0.1224	-0.1219	172	0.7022	-0.0457
23	0.6934	0.0826	73	0.0722	0.0784	123	0.1318	-0.1267	173	0.7158	-0.0411
24	0.6786	0.0858	74	0.0643	0.0738	124	0.1413	-0.1312	174	0.7291	-0.0368
25	0.6639	0.0889	75	0.0568	0.0691	125	0.1508	-0.1355	175	0.7423	-0.0326
26	0.6492	0.0920	76	0.0497	0.0644	126	0.1605	-0.1396	176	0.7552	-0.0287
27	0.6346	0.0949	77	0.0432	0.0597	127	0.1703	-0.1434	177	0.7679	-0.0249
28	0.6200	0.0978	78	0.0371	0.0550	128	0.1800	-0.1469	178	0.7803	-0.0215
29	0.6054	0.1007	79	0.0316	0.0504	129	0.1897	-0.1502	179	0.7926	-0.0182
30	0.5909	0.1034	80	0.0267	0.0460	130	0.1993	-0.1531	180	0.8046	-0.0152
31	0.5765	0.1061	81	0.0223	0.0418	131	0.2089	-0.1558	181	0.8165	-0.0125
32	0.5621	0.1087	82	0.0185	0.0377	132	0.2183	-0.1581	182	0.8282	-0.0100
33	0.5477	0.1111	83	0.0151	0.0339	133	0.2277	-0.1601	183	0.8398	-0.0078
34	0.5334	0.1135	84	0.0122	0.0302	134	0.2369	-0.1618	184	0.8511	-0.0058
35	0.5191	0.1158	85	0.0097	0.0268	135	0.2460	-0.1632	185	0.8623	-0.0041
36	0.5049	0.1180	86	0.0075	0.0236	136	0.2552	-0.1643	186	0.8733	-0.0027
37	0.4908	0.1200	87	0.0057	0.0206	137	0.2644	-0.1652	187	0.8842	-0.0015
38	0.4767	0.1220	88	0.0042	0.0178	138	0.2736	-0.1657	188	0.8950	-0.0006
39	0.4627	0.1238	89	0.0030	0.0150	139	0.2829	-0.1660	189	0.9056	0.0000
40	0.4488	0.1255	90	0.0020	0.0124	140	0.2924	-0.1659	190	0.9161	0.0004
41	0.4350	0.1271	91	0.0012	0.0098	141	0.3019	-0.1656	191	0.9263	0.0005
42	0.4213	0.1286	92	0.0006	0.0073	142	0.3117	-0.1650	192	0.9363	0.0004
43	0.4077	0.1298	93	0.0003	0.0048	143	0.3217	-0.1641	193	0.9458	0.0000
44	0.3942	0.1310	94	0.0001	0.0023	144	0.3319	-0.1629	194	0.9549	-0.0006
45	0.3808	0.1320	95	0.0000	-0.0001	145	0.3424	-0.1614	195	0.9636	-0.0015
46	0.3676	0.1328	96	0.0001	-0.0025	146	0.3531	-0.1597	196	0.9720	-0.0027
47	0.3545	0.1335	97	0.0003	-0.0050	147	0.3640	-0.1576	197	0.9799	-0.0040
48	0.3415	0.1339	98	0.0007	-0.0076	148	0.3753	-0.1552	198	0.9872	-0.0055
49	0.3286	0.1342	99	0.0013	-0.0103	149	0.3868	-0.1526	199	0.9940	-0.0071
50	0.3160	0.1344	100	0.0021	-0.0132	150	0.3986	-0.1496	200	1.0000	-0.0087

Table 31: Airfoil shape - DU91-W2-250

ID	x	y	ID	x	y	ID	x	y	ID	x	y
[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]
1	1.0000	0.0033	53	0.2100	0.1144	105	0.0002	-0.0039	157	0.2500	-0.1207
2	0.9900	0.0061	54	0.2000	0.1122	106	0.0003	-0.0047	158	0.2600	-0.1214
3	0.9800	0.0089	55	0.1900	0.1099	107	0.0004	-0.0055	159	0.2700	-0.1219
4	0.9700	0.0116	56	0.1800	0.1075	108	0.0005	-0.0062	160	0.2800	-0.1223
5	0.9600	0.0142	57	0.1700	0.1049	109	0.0008	-0.0076	161	0.2900	-0.1225
6	0.9500	0.0168	58	0.1600	0.1021	110	0.0010	-0.0088	162	0.3000	-0.1226
7	0.9400	0.0194	59	0.1500	0.0991	111	0.0013	-0.0098	163	0.3100	-0.1225
8	0.9300	0.0219	60	0.1400	0.0959	112	0.0015	-0.0108	164	0.3200	-0.1223
9	0.9200	0.0245	61	0.1300	0.0926	113	0.0017	-0.0117	165	0.3300	-0.1219
10	0.9100	0.0270	62	0.1200	0.0890	114	0.0020	-0.0125	166	0.3400	-0.1214
11	0.9000	0.0295	63	0.1100	0.0852	115	0.0030	-0.0153	167	0.3500	-0.1207
12	0.8750	0.0358	64	0.1000	0.0812	116	0.0040	-0.0177	168	0.3600	-0.1199
13	0.8500	0.0420	65	0.0950	0.0791	117	0.0050	-0.0197	169	0.3700	-0.1189
14	0.8250	0.0482	66	0.0900	0.0769	118	0.0060	-0.0216	170	0.3800	-0.1179
15	0.8000	0.0543	67	0.0850	0.0746	119	0.0070	-0.0233	171	0.3900	-0.1166
16	0.7750	0.0603	68	0.0800	0.0723	120	0.0080	-0.0249	172	0.4000	-0.1153
17	0.7500	0.0662	69	0.0750	0.0699	121	0.0090	-0.0263	173	0.4100	-0.1138
18	0.7250	0.0720	70	0.0700	0.0673	122	0.0100	-0.0278	174	0.4200	-0.1122
19	0.7000	0.0777	71	0.0650	0.0647	123	0.0125	-0.0310	175	0.4300	-0.1105
20	0.6750	0.0833	72	0.0600	0.0620	124	0.0150	-0.0340	176	0.4400	-0.1086
21	0.6500	0.0887	73	0.0550	0.0592	125	0.0175	-0.0368	177	0.4500	-0.1066
22	0.6250	0.0940	74	0.0500	0.0562	126	0.0200	-0.0394	178	0.4750	-0.1010
23	0.6000	0.0990	75	0.0450	0.0531	127	0.0250	-0.0443	179	0.5000	-0.0947
24	0.5750	0.1037	76	0.0400	0.0498	128	0.0300	-0.0486	180	0.5250	-0.0877
25	0.5500	0.1082	77	0.0350	0.0463	129	0.0350	-0.0526	181	0.5500	-0.0801
26	0.5250	0.1124	78	0.0300	0.0426	130	0.0400	-0.0563	182	0.5750	-0.0721
27	0.5000	0.1162	79	0.0250	0.0387	131	0.0450	-0.0597	183	0.6000	-0.0636
28	0.4750	0.1197	80	0.0200	0.0344	132	0.0500	-0.0629	184	0.6250	-0.0549
29	0.4500	0.1227	81	0.0175	0.0320	133	0.0550	-0.0659	185	0.6500	-0.0460
30	0.4400	0.1237	82	0.0150	0.0296	134	0.0600	-0.0688	186	0.6750	-0.0372
31	0.4300	0.1247	83	0.0125	0.0270	135	0.0650	-0.0715	187	0.7000	-0.0287
32	0.4200	0.1256	84	0.0100	0.0241	136	0.0700	-0.0740	188	0.7250	-0.0206
33	0.4100	0.1264	85	0.0090	0.0229	137	0.0750	-0.0765	189	0.7500	-0.0131
34	0.4000	0.1271	86	0.0080	0.0216	138	0.0800	-0.0789	190	0.7750	-0.0065
35	0.3900	0.1277	87	0.0070	0.0203	139	0.0850	-0.0811	191	0.8000	-0.0009
36	0.3800	0.1282	88	0.0060	0.0189	140	0.0900	-0.0833	192	0.8250	0.0035
37	0.3700	0.1285	89	0.0050	0.0174	141	0.0950	-0.0854	193	0.8500	0.0066
38	0.3600	0.1288	90	0.0040	0.0157	142	0.1000	-0.0874	194	0.8750	0.0084
39	0.3500	0.1289	91	0.0030	0.0139	143	0.1100	-0.0913	195	0.9000	0.0088
40	0.3400	0.1288	92	0.0020	0.0116	144	0.1200	-0.0948	196	0.9100	0.0085
41	0.3300	0.1286	93	0.0017	0.0110	145	0.1300	-0.0981	197	0.9200	0.0080
42	0.3200	0.1282	94	0.0015	0.0102	146	0.1400	-0.1011	198	0.9300	0.0073
43	0.3100	0.1277	95	0.0013	0.0094	147	0.1500	-0.1039	199	0.9400	0.0063
44	0.3000	0.1270	96	0.0010	0.0085	148	0.1600	-0.1064	200	0.9500	0.0051
45	0.2900	0.1262	97	0.0008	0.0074	149	0.1700	-0.1088	201	0.9600	0.0036
46	0.2800	0.1252	98	0.0005	0.0060	150	0.1800	-0.1109	202	0.9700	0.0021
47	0.2700	0.1241	99	0.0004	0.0054	151	0.1900	-0.1129	203	0.9800	0.0000
48	0.2600	0.1228	100	0.0003	0.0046	152	0.2000	-0.1146	204	0.9900	-0.0010
49	0.2500	0.1214	101	0.0002	0.0038	153	0.2100	-0.1162	205	1.0000	0.0000
50	0.2400	0.1199	102	0.0001	0.0027	154	0.2200	-0.1176			
51	0.2300	0.1182	103	0.0000	0.0000	155	0.2300	-0.1188			
52	0.2200	0.1164	104	0.0001	-0.0027	156	0.2400	-0.1198			

Table 32: Airfoil shape - DU08-W-210

ID	x	y	ID	x	y	ID	x	y	ID	x	y
[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]
1	1.0000	0.0014	53	0.2100	0.1100	105	0.0002	-0.0028	157	0.2500	-0.0882
2	0.9900	0.0040	54	0.2000	0.1080	106	0.0003	-0.0034	158	0.2600	-0.0885
3	0.9800	0.0066	55	0.1900	0.1058	107	0.0004	-0.0039	159	0.2700	-0.0886
4	0.9700	0.0091	56	0.1800	0.1035	108	0.0005	-0.0044	160	0.2800	-0.0886
5	0.9600	0.0116	57	0.1700	0.1010	109	0.0008	-0.0054	161	0.2900	-0.0885
6	0.9500	0.0140	58	0.1600	0.0983	110	0.0010	-0.0062	162	0.3000	-0.0883
7	0.9400	0.0164	59	0.1500	0.0954	111	0.0013	-0.0070	163	0.3100	-0.0879
8	0.9300	0.0189	60	0.1400	0.0924	112	0.0015	-0.0076	164	0.3200	-0.0874
9	0.9200	0.0213	61	0.1300	0.0892	113	0.0018	-0.0083	165	0.3300	-0.0868
10	0.9100	0.0237	62	0.1200	0.0857	114	0.0020	-0.0088	166	0.3400	-0.0861
11	0.9000	0.0261	63	0.1100	0.0820	115	0.0030	-0.0109	167	0.3500	-0.0853
12	0.8750	0.0321	64	0.1000	0.0781	116	0.0040	-0.0126	168	0.3600	-0.0843
13	0.8500	0.0380	65	0.0950	0.0761	117	0.0050	-0.0141	169	0.3700	-0.0833
14	0.8250	0.0439	66	0.0900	0.0739	118	0.0060	-0.0155	170	0.3800	-0.0822
15	0.8000	0.0497	67	0.0850	0.0717	119	0.0070	-0.0168	171	0.3900	-0.0809
16	0.7750	0.0554	68	0.0800	0.0694	120	0.0080	-0.0180	172	0.4000	-0.0796
17	0.7500	0.0609	69	0.0750	0.0670	121	0.0090	-0.0191	173	0.4100	-0.0782
18	0.7250	0.0664	70	0.0700	0.0646	122	0.0100	-0.0202	174	0.4200	-0.0767
19	0.7000	0.0718	71	0.0650	0.0620	123	0.0125	-0.0227	175	0.4300	-0.0751
20	0.6750	0.0771	72	0.0600	0.0593	124	0.0150	-0.0250	176	0.4400	-0.0734
21	0.6500	0.0823	73	0.0550	0.0565	125	0.0175	-0.0271	177	0.4500	-0.0716
22	0.6250	0.0873	74	0.0500	0.0536	126	0.0200	-0.0291	178	0.4750	-0.0668
23	0.6000	0.0921	75	0.0450	0.0505	127	0.0250	-0.0328	179	0.5000	-0.0615
24	0.5750	0.0967	76	0.0400	0.0472	128	0.0300	-0.0361	180	0.5250	-0.0558
25	0.5500	0.1012	77	0.0350	0.0438	129	0.0350	-0.0392	181	0.5500	-0.0497
26	0.5250	0.1053	78	0.0300	0.0401	130	0.0400	-0.0420	182	0.5750	-0.0434
27	0.5000	0.1091	79	0.0250	0.0361	131	0.0450	-0.0446	183	0.6000	-0.0369
28	0.4750	0.1126	80	0.0200	0.0318	132	0.0500	-0.0471	184	0.6250	-0.0304
29	0.4500	0.1157	81	0.0175	0.0295	133	0.0550	-0.0494	185	0.6500	-0.0239
30	0.4400	0.1168	82	0.0150	0.0271	134	0.0600	-0.0516	186	0.6750	-0.0175
31	0.4300	0.1178	83	0.0125	0.0245	135	0.0650	-0.0536	187	0.7000	-0.0115
32	0.4200	0.1187	84	0.0100	0.0216	136	0.0700	-0.0556	188	0.7250	-0.0060
33	0.4100	0.1196	85	0.0090	0.0204	137	0.0750	-0.0574	189	0.7500	-0.0010
34	0.4000	0.1204	86	0.0080	0.0191	138	0.0800	-0.0592	190	0.7750	0.0031
35	0.3900	0.1210	87	0.0070	0.0178	139	0.0850	-0.0609	191	0.8000	0.0064
36	0.3800	0.1216	88	0.0060	0.0164	140	0.0900	-0.0625	192	0.8250	0.0086
37	0.3700	0.1221	89	0.0050	0.0149	141	0.0950	-0.0641	193	0.8500	0.0097
38	0.3600	0.1225	90	0.0040	0.0133	142	0.1000	-0.0656	194	0.8750	0.0099
39	0.3500	0.1227	91	0.0030	0.0114	143	0.1100	-0.0684	195	0.9000	0.0090
40	0.3400	0.1228	92	0.0020	0.0093	144	0.1200	-0.0709	196	0.9100	0.0084
41	0.3300	0.1227	93	0.0018	0.0087	145	0.1300	-0.0733	197	0.9200	0.0077
42	0.3200	0.1225	94	0.0015	0.0081	146	0.1400	-0.0754	198	0.9300	0.0068
43	0.3100	0.1221	95	0.0013	0.0074	147	0.1500	-0.0774	199	0.9400	0.0058
44	0.3000	0.1215	96	0.0010	0.0066	148	0.1600	-0.0792	200	0.9500	0.0047
45	0.2900	0.1209	97	0.0008	0.0056	149	0.1700	-0.0808	201	0.9600	0.0035
46	0.2800	0.1200	98	0.0005	0.0046	150	0.1800	-0.0823	202	0.9700	0.0022
47	0.2700	0.1190	99	0.0004	0.0041	151	0.1900	-0.0836	203	0.9800	0.0009
48	0.2600	0.1179	100	0.0003	0.0035	152	0.2000	-0.0847	204	0.9900	-0.0003
49	0.2500	0.1166	101	0.0002	0.0028	153	0.2100	-0.0857	205	1.0000	-0.0014
50	0.2400	0.1152	102	0.0001	0.0020	154	0.2200	-0.0865			
51	0.2300	0.1136	103	0.0000	0.0000	155	0.2300	-0.0872			
52	0.2200	0.1119	104	0.0001	-0.0020	156	0.2400	-0.0878			

Table 33: Airfoil aerodynamic coefficients - Root circle

α	C_L	C_D	C_M
[deg]	[-]	[-]	[-]
-180	0.000	0.600	0.000
0	0.000	0.600	0.000
180	0.000	0.600	0.000

Table 34: Airfoil aerodynamic coefficients - FX77-W-500

α [deg]	C_L [-]	C_D [-]	C_M [-]	α [deg]	C_L [-]	C_D [-]	C_M [-]	α [deg]	C_L [-]	C_D [-]	C_M [-]
-180.0	0.000	0.155	0.000	-11.5	-0.427	0.189	-0.011	13.0	1.010	0.183	-0.042
-175.0	0.220	0.173	0.200	-11.0	-0.414	0.183	-0.016	13.5	1.008	0.195	-0.044
-170.0	0.440	0.191	0.400	-10.5	-0.401	0.176	-0.021	14.0	1.007	0.206	-0.046
-165.0	0.547	0.244	0.358	-10.0	-0.388	0.170	-0.026	15.0	1.008	0.227	-0.049
-160.0	0.653	0.296	0.317	-9.5	-0.361	0.164	-0.025	16.0	1.012	0.246	-0.053
-155.0	0.627	0.376	0.300	-9.0	-0.335	0.157	-0.024	17.0	0.994	0.259	-0.063
-150.0	0.602	0.456	0.284	-8.5	-0.309	0.151	-0.023	18.0	0.974	0.271	-0.073
-145.0	0.587	0.554	0.289	-8.0	-0.282	0.144	-0.022	19.0	0.953	0.284	-0.084
-140.0	0.573	0.651	0.294	-7.5	-0.256	0.138	-0.022	20.0	0.933	0.296	-0.094
-135.0	0.547	0.754	0.305	-7.0	-0.230	0.132	-0.021	22.0	0.918	0.328	-0.106
-130.0	0.521	0.856	0.315	-6.5	-0.204	0.125	-0.020	24.0	0.904	0.360	-0.119
-125.0	0.476	0.951	0.326	-6.0	-0.177	0.119	-0.019	26.0	0.889	0.392	-0.131
-120.0	0.432	1.045	0.337	-5.5	-0.151	0.112	-0.019	28.0	0.874	0.424	-0.143
-115.0	0.370	1.118	0.343	-5.0	-0.125	0.106	-0.018	30.0	0.860	0.456	-0.155
-110.0	0.308	1.192	0.350	-4.5	-0.098	0.100	-0.017	32.0	0.852	0.495	-0.164
-105.0	0.233	1.235	0.351	-4.0	-0.072	0.093	-0.016	34.0	0.843	0.534	-0.173
-100.0	0.159	1.278	0.352	-3.5	-0.046	0.087	-0.016	36.0	0.835	0.573	-0.182
-95.0	0.079	1.284	0.345	-3.0	-0.007	0.083	-0.016	38.0	0.827	0.612	-0.191
-90.0	0.000	1.290	0.339	-2.5	0.050	0.084	-0.018	40.0	0.819	0.651	-0.201
-85.0	-0.079	1.284	0.331	-2.0	0.107	0.084	-0.020	45.0	0.781	0.754	-0.221
-80.0	-0.159	1.278	0.324	-1.5	0.164	0.085	-0.022	50.0	0.744	0.856	-0.241
-75.0	-0.233	1.235	0.309	-1.0	0.221	0.085	-0.024	55.0	0.680	0.951	-0.258
-70.0	-0.308	1.192	0.295	-0.5	0.279	0.086	-0.026	60.0	0.617	1.045	-0.276
-65.0	-0.370	1.118	0.276	0.0	0.336	0.086	-0.028	65.0	0.528	1.118	-0.291
-60.0	-0.432	1.045	0.256	0.5	0.393	0.087	-0.030	70.0	0.440	1.192	-0.305
-55.0	-0.476	0.951	0.234	1.0	0.450	0.087	-0.032	75.0	0.333	1.235	-0.316
-50.0	-0.521	0.856	0.212	1.5	0.507	0.088	-0.034	80.0	0.227	1.278	-0.327
-45.0	-0.547	0.754	0.190	2.0	0.570	0.088	-0.037	85.0	0.113	1.284	-0.333
-40.0	-0.573	0.651	0.167	2.5	0.637	0.088	-0.039	90.0	0.000	1.290	-0.339
-38.0	-0.579	0.612	0.158	3.0	0.703	0.087	-0.041	95.0	-0.079	1.284	-0.345
-36.0	-0.585	0.573	0.150	3.5	0.770	0.087	-0.044	100.0	-0.159	1.278	-0.352
-34.0	-0.590	0.534	0.141	4.0	0.837	0.087	-0.046	105.0	-0.233	1.235	-0.351
-32.0	-0.596	0.495	0.132	4.5	0.903	0.087	-0.048	110.0	-0.308	1.192	-0.350
-30.0	-0.602	0.456	0.123	5.0	0.970	0.087	-0.051	115.0	-0.370	1.118	-0.343
-28.0	-0.612	0.424	0.113	5.5	1.037	0.087	-0.053	120.0	-0.432	1.045	-0.337
-26.0	-0.622	0.392	0.103	6.0	1.098	0.086	-0.056	125.0	-0.476	0.951	-0.326
-24.0	-0.633	0.360	0.093	6.5	1.157	0.086	-0.058	130.0	-0.521	0.856	-0.315
-22.0	-0.643	0.328	0.083	7.0	1.217	0.086	-0.061	135.0	-0.547	0.754	-0.305
-20.0	-0.653	0.296	0.073	7.5	1.277	0.086	-0.064	140.0	-0.573	0.651	-0.294
-19.0	-0.627	0.284	0.063	8.0	1.336	0.086	-0.067	145.0	-0.587	0.554	-0.289
-18.0	-0.600	0.271	0.054	8.5	1.396	0.086	-0.069	150.0	-0.602	0.456	-0.284
-17.0	-0.573	0.258	0.044	9.0	1.444	0.086	-0.073	155.0	-0.627	0.376	-0.300
-16.0	-0.547	0.246	0.034	9.5	1.485	0.088	-0.076	160.0	-0.653	0.296	-0.317
-15.0	-0.520	0.233	0.024	10.0	1.526	0.089	-0.080	165.0	-0.547	0.244	-0.408
-14.0	-0.494	0.220	0.014	10.5	1.240	0.105	-0.083	170.0	-0.440	0.191	-0.500
-13.5	-0.481	0.214	0.009	11.0	1.073	0.126	-0.044	175.0	-0.220	0.173	-0.250
-13.0	-0.467	0.208	0.004	11.5	1.045	0.141	-0.037	180.0	0.000	0.155	0.000
-12.5	-0.454	0.201	-0.001	12.0	1.028	0.155	-0.039				
-12.0	-0.441	0.195	-0.006	12.5	1.017	0.169	-0.041				

Table 35: Airfoil aerodynamic coefficients - FX77-W-400

α	C_L	C_D	C_M	α	C_L	C_D	C_M	α	C_L	C_D	C_M
[deg]	[-]	[-]	[-]	[deg]	[-]	[-]	[-]	[deg]	[-]	[-]	[-]
-180.0	0.000	0.010	0.000	-11.5	-0.507	0.043	-0.001	13.0	0.973	0.035	-0.060
-175.0	0.246	0.010	0.200	-11.0	-0.495	0.040	-0.006	13.5	0.985	0.037	-0.062
-170.0	0.493	0.010	0.400	-10.5	-0.483	0.037	-0.011	14.0	0.998	0.038	-0.064
-165.0	0.603	0.052	0.353	-10.0	-0.471	0.034	-0.016	15.0	1.054	0.039	-0.069
-160.0	0.713	0.094	0.306	-9.5	-0.444	0.034	-0.016	16.0	1.127	0.040	-0.074
-155.0	0.675	0.182	0.282	-9.0	-0.417	0.033	-0.016	17.0	1.100	0.054	-0.083
-150.0	0.637	0.270	0.259	-8.5	-0.391	0.033	-0.016	18.0	1.073	0.067	-0.093
-145.0	0.616	0.379	0.261	-8.0	-0.364	0.033	-0.016	19.0	1.046	0.081	-0.102
-140.0	0.594	0.487	0.264	-7.5	-0.338	0.032	-0.016	20.0	1.019	0.094	-0.111
-135.0	0.564	0.603	0.275	-7.0	-0.311	0.032	-0.016	22.0	0.997	0.129	-0.120
-130.0	0.533	0.718	0.285	-6.5	-0.285	0.031	-0.016	24.0	0.975	0.165	-0.130
-125.0	0.486	0.828	0.298	-6.0	-0.258	0.031	-0.016	26.0	0.954	0.200	-0.139
-120.0	0.438	0.937	0.311	-5.5	-0.232	0.030	-0.016	28.0	0.932	0.235	-0.149
-115.0	0.374	1.028	0.322	-5.0	-0.205	0.030	-0.016	30.0	0.910	0.270	-0.158
-110.0	0.311	1.119	0.333	-4.5	-0.179	0.029	-0.016	32.0	0.898	0.314	-0.166
-105.0	0.235	1.180	0.339	-4.0	-0.152	0.029	-0.016	34.0	0.885	0.357	-0.173
-100.0	0.159	1.241	0.344	-3.5	-0.126	0.028	-0.016	36.0	0.873	0.400	-0.180
-95.0	0.080	1.265	0.343	-3.0	-0.099	0.028	-0.016	38.0	0.861	0.443	-0.187
-90.0	0.000	1.290	0.342	-2.5	-0.031	0.028	-0.019	40.0	0.849	0.487	-0.194
-85.0	-0.080	1.265	0.330	-2.0	0.037	0.028	-0.020	45.0	0.805	0.603	-0.212
-80.0	-0.159	1.241	0.319	-1.5	0.105	0.028	-0.022	50.0	0.762	0.718	-0.229
-75.0	-0.235	1.180	0.302	-1.0	0.173	0.028	-0.024	55.0	0.694	0.828	-0.246
-70.0	-0.311	1.119	0.285	-0.5	0.241	0.028	-0.025	60.0	0.626	0.937	-0.263
-65.0	-0.374	1.028	0.264	0.0	0.309	0.028	-0.027	65.0	0.535	1.028	-0.279
-60.0	-0.438	0.937	0.243	0.5	0.377	0.028	-0.029	70.0	0.444	1.119	-0.295
-55.0	-0.486	0.828	0.221	1.0	0.445	0.028	-0.031	75.0	0.336	1.180	-0.308
-50.0	-0.533	0.718	0.200	1.5	0.513	0.028	-0.032	80.0	0.228	1.241	-0.322
-45.0	-0.564	0.603	0.179	2.0	0.580	0.028	-0.034	85.0	0.114	1.265	-0.332
-40.0	-0.594	0.487	0.159	2.5	0.646	0.028	-0.036	90.0	0.000	1.290	-0.342
-38.0	-0.603	0.443	0.152	3.0	0.713	0.028	-0.039	95.0	-0.080	1.265	-0.343
-36.0	-0.611	0.400	0.144	3.5	0.779	0.028	-0.041	100.0	-0.159	1.241	-0.344
-34.0	-0.620	0.357	0.137	4.0	0.845	0.028	-0.043	105.0	-0.235	1.180	-0.339
-32.0	-0.628	0.314	0.130	4.5	0.912	0.028	-0.045	110.0	-0.311	1.119	-0.333
-30.0	-0.637	0.270	0.123	5.0	0.978	0.028	-0.047	115.0	-0.374	1.028	-0.322
-28.0	-0.652	0.235	0.115	5.5	1.045	0.028	-0.049	120.0	-0.438	0.937	-0.311
-26.0	-0.667	0.200	0.107	6.0	1.111	0.028	-0.052	125.0	-0.486	0.828	-0.298
-24.0	-0.683	0.165	0.100	6.5	1.177	0.028	-0.054	130.0	-0.533	0.718	-0.285
-22.0	-0.698	0.129	0.092	7.0	1.244	0.028	-0.056	135.0	-0.564	0.603	-0.275
-20.0	-0.713	0.094	0.084	7.5	1.310	0.028	-0.058	140.0	-0.594	0.487	-0.264
-19.0	-0.689	0.088	0.074	8.0	1.374	0.028	-0.061	145.0	-0.616	0.379	-0.261
-18.0	-0.665	0.082	0.064	8.5	1.434	0.028	-0.064	150.0	-0.637	0.270	-0.259
-17.0	-0.640	0.076	0.054	9.0	1.494	0.029	-0.068	155.0	-0.675	0.182	-0.282
-16.0	-0.616	0.070	0.044	9.5	1.554	0.029	-0.071	160.0	-0.713	0.094	-0.306
-15.0	-0.592	0.064	0.034	10.0	1.614	0.029	-0.074	165.0	-0.603	0.052	-0.403
-14.0	-0.568	0.058	0.024	10.5	1.663	0.029	-0.078	170.0	-0.493	0.010	-0.500
-13.5	-0.555	0.055	0.019	11.0	1.695	0.029	-0.081	175.0	-0.246	0.010	-0.250
-13.0	-0.543	0.052	0.014	11.5	1.728	0.029	-0.084	180.0	0.000	0.010	0.000
-12.5	-0.531	0.049	0.009	12.0	1.760	0.030	-0.088				
-12.0	-0.519	0.046	0.004	12.5	0.986	0.033	-0.059				

Table 36: Airfoil aerodynamic coefficients - DU00-W2-350

α [deg]	C_L [-]	C_D [-]	C_M [-]	α [deg]	C_L [-]	C_D [-]	C_M [-]	α [deg]	C_L [-]	C_D [-]	C_M [-]
-180.0	0.000	0.000	0.000	-11.5	-0.679	0.087	0.086	13.0	1.291	0.059	-0.109
-175.0	0.217	0.054	0.200	-11.0	-0.671	0.080	0.075	13.5	1.270	0.069	-0.109
-170.0	0.433	0.107	0.400	-10.5	-0.664	0.072	0.063	14.0	1.249	0.080	-0.109
-165.0	0.620	0.163	0.212	-10.0	-0.656	0.064	0.051	15.0	1.211	0.103	-0.110
-160.0	0.806	0.219	0.024	-9.5	-0.649	0.056	0.039	16.0	1.188	0.130	-0.119
-155.0	0.763	0.314	0.048	-9.0	-0.641	0.049	0.027	17.0	1.172	0.154	-0.132
-150.0	0.719	0.409	0.072	-8.5	-0.634	0.041	0.015	18.0	1.165	0.179	-0.143
-145.0	0.695	0.525	0.094	-8.0	-0.626	0.033	0.003	19.0	1.176	0.203	-0.148
-140.0	0.670	0.640	0.116	-7.5	-0.584	0.029	-0.001	20.0	1.152	0.219	-0.157
-135.0	0.636	0.763	0.140	-7.0	-0.541	0.026	-0.005	22.0	1.114	0.252	-0.172
-130.0	0.601	0.886	0.163	-6.5	-0.494	0.023	-0.010	24.0	1.084	0.288	-0.184
-125.0	0.548	1.001	0.187	-6.0	-0.447	0.020	-0.014	26.0	1.062	0.326	-0.196
-120.0	0.494	1.116	0.211	-5.5	-0.396	0.018	-0.019	28.0	1.043	0.366	-0.206
-115.0	0.422	1.208	0.234	-5.0	-0.344	0.016	-0.023	30.0	1.027	0.409	-0.215
-110.0	0.350	1.301	0.256	-4.5	-0.289	0.014	-0.028	32.0	1.013	0.452	-0.224
-105.0	0.265	1.360	0.273	-4.0	-0.233	0.013	-0.033	34.0	1.000	0.498	-0.233
-100.0	0.180	1.418	0.291	-3.5	-0.174	0.012	-0.038	36.0	0.986	0.544	-0.242
-95.0	0.090	1.436	0.301	-3.0	-0.115	0.012	-0.043	38.0	0.973	0.592	-0.250
-90.0	0.000	1.453	0.312	-2.5	-0.054	0.011	-0.048	40.0	0.958	0.640	-0.259
-85.0	-0.090	1.436	0.316	-2.0	0.007	0.011	-0.052	45.0	0.914	0.764	-0.279
-80.0	-0.180	1.418	0.320	-1.5	0.070	0.011	-0.056	50.0	0.859	0.886	-0.299
-75.0	-0.265	1.360	0.316	-1.0	0.133	0.010	-0.060	55.0	0.782	1.001	-0.318
-70.0	-0.350	1.301	0.312	-0.5	0.197	0.010	-0.064	60.0	0.706	1.116	-0.337
-65.0	-0.422	1.208	0.302	0.0	0.261	0.010	-0.068	65.0	0.603	1.208	-0.354
-60.0	-0.494	1.116	0.292	0.5	0.326	0.010	-0.072	70.0	0.500	1.301	-0.371
-55.0	-0.548	1.001	0.279	1.0	0.391	0.010	-0.075	75.0	0.378	1.360	-0.384
-50.0	-0.601	0.886	0.267	1.5	0.457	0.010	-0.079	80.0	0.257	1.418	-0.397
-45.0	-0.640	0.764	0.254	2.0	0.522	0.010	-0.082	85.0	0.128	1.436	-0.406
-40.0	-0.670	0.640	0.244	2.5	0.587	0.011	-0.085	90.0	0.000	1.453	-0.415
-38.0	-0.681	0.592	0.240	3.0	0.652	0.011	-0.087	95.0	-0.090	1.436	-0.419
-36.0	-0.691	0.544	0.238	3.5	0.716	0.011	-0.089	100.0	-0.180	1.418	-0.423
-34.0	-0.700	0.498	0.237	4.0	0.779	0.011	-0.091	105.0	-0.265	1.360	-0.419
-32.0	-0.709	0.452	0.237	4.5	0.841	0.012	-0.093	110.0	-0.350	1.301	-0.415
-30.0	-0.719	0.409	0.238	5.0	0.902	0.012	-0.095	115.0	-0.422	1.208	-0.405
-28.0	-0.730	0.366	0.242	5.5	0.961	0.012	-0.097	120.0	-0.494	1.116	-0.395
-26.0	-0.743	0.326	0.247	6.0	1.020	0.013	-0.098	125.0	-0.548	1.001	-0.383
-24.0	-0.759	0.288	0.257	6.5	1.075	0.013	-0.099	130.0	-0.601	0.886	-0.370
-22.0	-0.780	0.252	0.270	7.0	1.129	0.014	-0.100	135.0	-0.636	0.763	-0.358
-20.0	-0.806	0.219	0.289	7.5	1.178	0.015	-0.101	140.0	-0.670	0.640	-0.347
-19.0	-0.791	0.204	0.265	8.0	1.227	0.015	-0.102	145.0	-0.695	0.525	-0.344
-18.0	-0.776	0.188	0.241	8.5	1.268	0.016	-0.103	150.0	-0.719	0.409	-0.341
-17.0	-0.761	0.173	0.218	9.0	1.308	0.017	-0.104	155.0	-0.763	0.314	-0.367
-16.0	-0.746	0.157	0.194	9.5	1.339	0.020	-0.105	160.0	-0.806	0.219	-0.392
-15.0	-0.731	0.142	0.170	10.0	1.369	0.022	-0.106	165.0	-0.605	0.164	-0.446
-14.0	-0.716	0.126	0.146	10.5	1.381	0.026	-0.107	170.0	-0.403	0.110	-0.500
-13.5	-0.709	0.118	0.134	11.0	1.393	0.029	-0.107	175.0	-0.202	0.055	-0.250
-13.0	-0.701	0.111	0.122	11.5	1.368	0.035	-0.108	180.0	0.000	0.000	0.000
-12.5	-0.694	0.103	0.110	12.0	1.342	0.041	-0.108				
-12.0	-0.686	0.095	0.098	12.5	1.317	0.050	-0.109				

Table 37: Airfoil aerodynamic coefficients - DU97-W-300

α [deg]	C_L [-]	C_D [-]	C_M [-]	α [deg]	C_L [-]	C_D [-]	C_M [-]	α [deg]	C_L [-]	C_D [-]	C_M [-]
-180.0	0.000	0.000	0.000	-11.5	-0.975	0.090	-0.019	13.0	1.196	0.059	-0.116
-175.0	0.183	0.047	0.200	-11.0	-0.931	0.083	-0.025	13.5	1.148	0.067	-0.114
-170.0	0.366	0.093	0.400	-10.5	-0.884	0.076	-0.030	14.0	1.100	0.075	-0.113
-165.0	0.549	0.140	0.194	-10.0	-0.838	0.070	-0.035	15.0	1.050	0.089	-0.111
-160.0	0.732	0.187	-0.012	-9.5	-0.801	0.060	-0.041	16.0	1.022	0.103	-0.109
-155.0	0.721	0.279	-0.008	-9.0	-0.765	0.050	-0.047	17.0	1.007	0.117	-0.110
-150.0	0.710	0.371	-0.005	-8.5	-0.751	0.037	-0.052	18.0	1.010	0.133	-0.112
-145.0	0.688	0.489	0.020	-8.0	-0.737	0.024	-0.057	19.0	1.040	0.153	-0.118
-140.0	0.665	0.607	0.045	-7.5	-0.693	0.021	-0.059	20.0	1.065	0.173	-0.125
-135.0	0.632	0.733	0.071	-7.0	-0.649	0.017	-0.060	22.0	1.095	0.212	-0.144
-130.0	0.598	0.858	0.097	-6.5	-0.578	0.016	-0.064	24.0	1.067	0.248	-0.164
-125.0	0.545	0.976	0.124	-6.0	-0.507	0.015	-0.068	26.0	1.046	0.287	-0.180
-120.0	0.492	1.094	0.150	-5.5	-0.438	0.014	-0.072	28.0	1.029	0.328	-0.194
-115.0	0.421	1.190	0.175	-5.0	-0.369	0.013	-0.076	30.0	1.015	0.371	-0.207
-110.0	0.349	1.286	0.201	-4.5	-0.301	0.012	-0.079	32.0	1.002	0.416	-0.220
-105.0	0.264	1.348	0.222	-4.0	-0.233	0.012	-0.082	34.0	0.990	0.462	-0.231
-100.0	0.179	1.411	0.243	-3.5	-0.167	0.011	-0.085	36.0	0.977	0.509	-0.242
-95.0	0.090	1.432	0.257	-3.0	-0.101	0.011	-0.088	38.0	0.964	0.558	-0.252
-90.0	0.000	1.453	0.271	-2.5	-0.036	0.011	-0.090	40.0	0.950	0.607	-0.263
-85.0	-0.090	1.432	0.277	-2.0	0.028	0.011	-0.093	45.0	0.908	0.733	-0.287
-80.0	-0.179	1.411	0.284	-1.5	0.092	0.010	-0.095	50.0	0.854	0.858	-0.311
-75.0	-0.264	1.348	0.282	-1.0	0.156	0.010	-0.098	55.0	0.779	0.976	-0.333
-70.0	-0.349	1.286	0.280	-0.5	0.221	0.010	-0.100	60.0	0.703	1.094	-0.355
-65.0	-0.421	1.190	0.271	0.0	0.287	0.010	-0.103	65.0	0.601	1.190	-0.376
-60.0	-0.492	1.094	0.263	0.5	0.351	0.011	-0.105	70.0	0.499	1.286	-0.396
-55.0	-0.545	0.976	0.251	1.0	0.416	0.011	-0.107	75.0	0.378	1.348	-0.413
-50.0	-0.598	0.858	0.240	1.5	0.480	0.011	-0.109	80.0	0.256	1.411	-0.430
-45.0	-0.636	0.733	0.229	2.0	0.544	0.011	-0.110	85.0	0.128	1.432	-0.442
-40.0	-0.665	0.607	0.221	2.5	0.606	0.011	-0.112	90.0	0.000	1.453	-0.455
-38.0	-0.675	0.558	0.218	3.0	0.668	0.011	-0.114	95.0	-0.090	1.432	-0.461
-36.0	-0.684	0.509	0.217	3.5	0.729	0.011	-0.115	100.0	-0.179	1.411	-0.468
-34.0	-0.693	0.462	0.217	4.0	0.791	0.011	-0.116	105.0	-0.264	1.348	-0.465
-32.0	-0.701	0.416	0.218	4.5	0.852	0.011	-0.118	110.0	-0.349	1.286	-0.463
-30.0	-0.710	0.371	0.222	5.0	0.913	0.011	-0.119	115.0	-0.421	1.190	-0.455
-28.0	-0.720	0.328	0.227	5.5	0.972	0.012	-0.120	120.0	-0.492	1.094	-0.447
-26.0	-0.732	0.287	0.235	6.0	1.031	0.012	-0.120	125.0	-0.545	0.976	-0.435
-24.0	-0.747	0.248	0.248	6.5	1.088	0.012	-0.121	130.0	-0.598	0.858	-0.424
-22.0	-0.766	0.212	0.265	7.0	1.145	0.012	-0.121	135.0	-0.632	0.733	-0.414
-20.0	-0.922	0.197	0.196	7.5	1.200	0.013	-0.122	140.0	-0.665	0.607	-0.405
-19.0	-0.999	0.189	0.162	8.0	1.256	0.013	-0.122	145.0	-0.688	0.489	-0.405
-18.0	-1.077	0.182	0.127	8.5	1.308	0.013	-0.121	150.0	-0.710	0.371	-0.405
-17.0	-1.154	0.174	0.093	9.0	1.359	0.014	-0.121	155.0	-0.703	0.282	-0.432
-16.0	-1.232	0.166	0.058	9.5	1.406	0.014	-0.120	160.0	-0.697	0.193	-0.458
-15.0	-1.259	0.155	0.032	10.0	1.452	0.015	-0.119	165.0	-0.522	0.145	-0.479
-14.0	-1.194	0.137	0.020	10.5	1.489	0.016	-0.117	170.0	-0.348	0.096	-0.500
-13.5	-1.152	0.127	0.012	11.0	1.526	0.017	-0.114	175.0	-0.174	0.048	-0.250
-13.0	-1.110	0.117	0.005	11.5	1.542	0.018	-0.111	180.0	0.000	0.000	0.000
-12.5	-1.065	0.108	-0.004	12.0	1.559	0.020	-0.107				
-12.0	-1.020	0.098	-0.012	12.5	1.377	0.040	-0.111				

Table 38: Airfoil aerodynamic coefficients - DU91-W2-250

α	C_L	C_D	C_M	α	C_L	C_D	C_M	α	C_L	C_D	C_M
[deg]	[-]	[-]	[-]	[deg]	[-]	[-]	[-]	[deg]	[-]	[-]	[-]
-180.0	0.000	0.000	0.000	-11.5	-0.926	0.055	-0.033	13.0	1.097	0.077	-0.106
-175.0	0.181	0.056	0.200	-11.0	-0.903	0.045	-0.035	13.5	1.104	0.085	-0.107
-170.0	0.363	0.112	0.400	-10.5	-0.871	0.038	-0.039	14.0	1.112	0.093	-0.108
-165.0	0.544	0.169	0.198	-10.0	-0.839	0.032	-0.043	15.0	1.126	0.111	-0.112
-160.0	0.726	0.225	-0.003	-9.5	-0.806	0.026	-0.047	16.0	1.129	0.125	-0.113
-155.0	0.731	0.314	-0.019	-9.0	-0.773	0.021	-0.051	17.0	1.122	0.137	-0.112
-150.0	0.737	0.403	-0.035	-8.5	-0.717	0.017	-0.059	18.0	1.127	0.155	-0.115
-145.0	0.709	0.519	-0.008	-8.0	-0.662	0.013	-0.068	19.0	1.134	0.176	-0.121
-140.0	0.681	0.635	0.019	-7.5	-0.595	0.012	-0.074	20.0	1.139	0.196	-0.126
-135.0	0.644	0.759	0.045	-7.0	-0.528	0.010	-0.080	22.0	1.147	0.245	-0.142
-130.0	0.607	0.882	0.072	-6.5	-0.457	0.010	-0.086	24.0	1.119	0.282	-0.165
-125.0	0.552	0.997	0.099	-6.0	-0.387	0.009	-0.092	26.0	1.092	0.320	-0.184
-120.0	0.497	1.113	0.126	-5.5	-0.317	0.009	-0.097	28.0	1.071	0.361	-0.201
-115.0	0.424	1.206	0.152	-5.0	-0.247	0.008	-0.102	30.0	1.052	0.403	-0.216
-110.0	0.351	1.299	0.178	-4.5	-0.179	0.008	-0.105	32.0	1.036	0.447	-0.229
-105.0	0.266	1.358	0.199	-4.0	-0.110	0.008	-0.108	34.0	1.020	0.492	-0.242
-100.0	0.180	1.417	0.221	-3.5	-0.044	0.008	-0.111	36.0	1.005	0.539	-0.254
-95.0	0.090	1.435	0.236	-3.0	0.023	0.008	-0.114	38.0	0.989	0.587	-0.265
-90.0	0.000	1.453	0.250	-2.5	0.089	0.008	-0.116	40.0	0.973	0.635	-0.276
-85.0	-0.090	1.435	0.258	-2.0	0.155	0.008	-0.119	45.0	0.926	0.759	-0.302
-80.0	-0.180	1.417	0.267	-1.5	0.219	0.008	-0.120	50.0	0.868	0.882	-0.327
-75.0	-0.266	1.358	0.267	-1.0	0.283	0.008	-0.122	55.0	0.789	0.997	-0.350
-70.0	-0.351	1.299	0.267	-0.5	0.346	0.008	-0.124	60.0	0.711	1.113	-0.373
-65.0	-0.424	1.206	0.260	0.0	0.408	0.008	-0.126	65.0	0.606	1.206	-0.394
-60.0	-0.497	1.113	0.254	0.5	0.470	0.008	-0.127	70.0	0.502	1.299	-0.415
-55.0	-0.552	0.997	0.244	1.0	0.533	0.008	-0.129	75.0	0.380	1.358	-0.432
-50.0	-0.607	0.882	0.235	1.5	0.595	0.008	-0.130	80.0	0.257	1.417	-0.450
-45.0	-0.648	0.759	0.226	2.0	0.658	0.008	-0.131	85.0	0.129	1.435	-0.463
-40.0	-0.681	0.635	0.220	2.5	0.721	0.008	-0.133	90.0	0.000	1.453	-0.476
-38.0	-0.693	0.587	0.219	3.0	0.782	0.008	-0.134	95.0	-0.090	1.435	-0.484
-36.0	-0.704	0.539	0.219	3.5	0.843	0.008	-0.135	100.0	-0.180	1.417	-0.493
-34.0	-0.714	0.492	0.221	4.0	0.904	0.008	-0.136	105.0	-0.266	1.358	-0.493
-32.0	-0.725	0.447	0.224	4.5	0.964	0.008	-0.136	110.0	-0.351	1.299	-0.492
-30.0	-0.737	0.403	0.229	5.0	1.024	0.009	-0.137	115.0	-0.424	1.206	-0.486
-28.0	-0.749	0.361	0.237	5.5	1.083	0.009	-0.137	120.0	-0.497	1.113	-0.480
-26.0	-0.765	0.320	0.248	6.0	1.141	0.009	-0.138	125.0	-0.552	0.997	-0.470
-24.0	-0.783	0.282	0.264	6.5	1.195	0.009	-0.137	130.0	-0.607	0.882	-0.461
-22.0	-0.812	0.246	0.245	7.0	1.248	0.010	-0.137	135.0	-0.644	0.759	-0.454
-20.0	-0.847	0.210	0.187	7.5	1.289	0.011	-0.134	140.0	-0.681	0.635	-0.446
-19.0	-0.865	0.192	0.158	8.0	1.330	0.011	-0.132	145.0	-0.709	0.519	-0.451
-18.0	-0.883	0.175	0.129	8.5	1.347	0.013	-0.127	150.0	-0.737	0.403	-0.455
-17.0	-0.901	0.157	0.100	9.0	1.365	0.015	-0.123	155.0	-0.714	0.316	-0.478
-16.0	-0.919	0.139	0.070	9.5	1.336	0.025	-0.123	160.0	-0.690	0.230	-0.500
-15.0	-0.936	0.121	0.041	10.0	1.306	0.036	-0.123	165.0	-0.518	0.172	-0.500
-14.0	-0.954	0.103	0.012	10.5	1.231	0.046	-0.122	170.0	-0.345	0.115	-0.500
-13.5	-0.963	0.094	-0.002	11.0	1.156	0.055	-0.121	175.0	-0.173	0.057	-0.250
-13.0	-0.972	0.085	-0.017	11.5	1.133	0.059	-0.117	180.0	0.000	0.000	0.000
-12.5	-0.961	0.075	-0.024	12.0	1.109	0.063	-0.112				
-12.0	-0.949	0.064	-0.031	12.5	1.103	0.070	-0.109				

Table 39: Airfoil aerodynamic coefficients - DU08-W-210

α	C_L	C_D	C_M	α	C_L	C_D	C_M	α	C_L	C_D	C_M
[deg]	[-]	[-]	[-]	[deg]	[-]	[-]	[-]	[deg]	[-]	[-]	[-]
-180.0	0.000	0.000	0.000	-11.5	-0.641	0.055	0.048	13.0	1.510	0.062	-0.127
-175.0	0.250	0.038	0.200	-11.0	-0.626	0.049	0.028	13.5	1.460	0.076	-0.129
-170.0	0.501	0.075	0.400	-10.5	-0.610	0.042	0.008	14.0	1.410	0.089	-0.130
-165.0	0.655	0.124	0.150	-10.0	-0.594	0.036	-0.012	15.0	1.340	0.103	-0.132
-160.0	0.809	0.172	-0.099	-9.5	-0.579	0.029	-0.031	16.0	1.300	0.116	-0.133
-155.0	0.764	0.269	-0.066	-9.0	-0.563	0.022	-0.051	17.0	1.260	0.130	-0.135
-150.0	0.720	0.365	-0.033	-8.5	-0.536	0.017	-0.069	18.0	1.200	0.143	-0.137
-145.0	0.696	0.484	-0.008	-8.0	-0.508	0.012	-0.086	19.0	1.179	0.156	-0.138
-140.0	0.671	0.602	0.018	-7.5	-0.437	0.010	-0.095	20.0	1.155	0.172	-0.148
-135.0	0.636	0.728	0.043	-7.0	-0.366	0.009	-0.103	22.0	1.116	0.206	-0.172
-130.0	0.601	0.854	0.069	-6.5	-0.304	0.008	-0.105	24.0	1.087	0.243	-0.192
-125.0	0.548	0.973	0.095	-6.0	-0.242	0.007	-0.107	26.0	1.064	0.282	-0.208
-120.0	0.494	1.091	0.122	-5.5	-0.180	0.007	-0.109	28.0	1.045	0.322	-0.223
-115.0	0.422	1.188	0.147	-5.0	-0.119	0.007	-0.110	30.0	1.029	0.365	-0.236
-110.0	0.350	1.284	0.172	-4.5	-0.058	0.007	-0.112	32.0	1.015	0.410	-0.248
-105.0	0.265	1.347	0.193	-4.0	0.003	0.006	-0.113	34.0	1.001	0.456	-0.259
-100.0	0.180	1.410	0.215	-3.5	0.064	0.006	-0.114	36.0	0.988	0.504	-0.270
-95.0	0.090	1.431	0.229	-3.0	0.124	0.006	-0.116	38.0	0.974	0.553	-0.280
-90.0	0.000	1.453	0.244	-2.5	0.185	0.006	-0.117	40.0	0.959	0.602	-0.291
-85.0	-0.090	1.431	0.250	-2.0	0.245	0.006	-0.118	45.0	0.915	0.728	-0.315
-80.0	-0.180	1.410	0.256	-1.5	0.305	0.006	-0.119	50.0	0.859	0.854	-0.338
-75.0	-0.265	1.347	0.254	-1.0	0.365	0.006	-0.120	55.0	0.783	0.973	-0.361
-70.0	-0.350	1.284	0.251	-0.5	0.425	0.006	-0.121	60.0	0.706	1.091	-0.383
-65.0	-0.422	1.188	0.243	0.0	0.485	0.006	-0.122	65.0	0.603	1.188	-0.403
-60.0	-0.494	1.091	0.235	0.5	0.545	0.006	-0.124	70.0	0.500	1.284	-0.423
-55.0	-0.548	0.973	0.223	1.0	0.604	0.006	-0.125	75.0	0.378	1.347	-0.440
-50.0	-0.601	0.854	0.212	1.5	0.664	0.007	-0.125	80.0	0.257	1.410	-0.457
-45.0	-0.641	0.728	0.202	2.0	0.723	0.007	-0.126	85.0	0.128	1.431	-0.470
-40.0	-0.671	0.602	0.194	2.5	0.782	0.007	-0.127	90.0	0.000	1.453	-0.483
-38.0	-0.682	0.553	0.192	3.0	0.841	0.007	-0.128	95.0	-0.090	1.431	-0.489
-36.0	-0.691	0.504	0.191	3.5	0.900	0.007	-0.129	100.0	-0.180	1.410	-0.495
-34.0	-0.701	0.456	0.191	4.0	0.959	0.007	-0.130	105.0	-0.265	1.347	-0.493
-32.0	-0.710	0.410	0.193	4.5	1.017	0.007	-0.131	110.0	-0.350	1.284	-0.491
-30.0	-0.720	0.365	0.196	5.0	1.075	0.007	-0.131	115.0	-0.422	1.188	-0.483
-28.0	-0.731	0.322	0.203	5.5	1.132	0.007	-0.132	120.0	-0.494	1.091	-0.474
-26.0	-0.745	0.282	0.212	6.0	1.188	0.008	-0.133	125.0	-0.548	0.973	-0.463
-24.0	-0.761	0.243	0.225	6.5	1.242	0.008	-0.133	130.0	-0.601	0.854	-0.452
-22.0	-0.781	0.206	0.243	7.0	1.291	0.009	-0.132	135.0	-0.636	0.728	-0.442
-20.0	-0.809	0.172	0.269	7.5	1.333	0.011	-0.130	140.0	-0.671	0.602	-0.433
-19.0	-0.825	0.156	0.286	8.0	1.373	0.012	-0.128	145.0	-0.696	0.484	-0.435
-18.0	-0.820	0.141	0.280	8.5	1.412	0.013	-0.126	150.0	-0.720	0.365	-0.436
-17.0	-0.814	0.128	0.266	9.0	1.451	0.015	-0.124	155.0	-0.764	0.269	-0.472
-16.0	-0.782	0.115	0.227	9.5	1.489	0.016	-0.122	160.0	-0.809	0.172	-0.509
-15.0	-0.751	0.102	0.187	10.0	1.516	0.017	-0.122	165.0	-0.639	0.125	-0.504
-14.0	-0.720	0.088	0.147	10.5	1.542	0.018	-0.122	170.0	-0.469	0.078	-0.500
-13.5	-0.704	0.082	0.127	11.0	1.563	0.020	-0.122	175.0	-0.235	0.039	-0.250
-13.0	-0.688	0.075	0.108	11.5	1.580	0.022	-0.122	180.0	0.000	0.000	0.000
-12.5	-0.673	0.069	0.088	12.0	1.587	0.035	-0.124				
-12.0	-0.657	0.062	0.068	12.5	1.549	0.049	-0.125				

A.3 Blade structure

Table 40: Position in respect to blade pitch axis of the structural components of the blade - Part I.

η [-]	First Shear Web [mm]	Second Shear Web [mm]	Spar Caps towards LE [mm]	Spar Caps towards TE [mm]	Extension of the Reinf. at LE [mm]	Extension of the Reinf. at TE [mm]
0.00	[-]	[-]	[-]	[-]	[-]	[-]
0.08	[-]	[-]	[-]	[-]	[-]	[-]
0.10	-257.6	342.4	-357.6	442.4	89.7	474.3
0.12	-252.2	347.8	-352.2	447.8	89.7	459.1
0.14	-246.9	353.1	-346.9	453.1	89.7	436.3
0.16	-241.5	358.5	-341.5	458.5	89.7	403.8
0.18	-236.2	363.8	-336.2	463.8	89.7	366.4
0.20	-233.5	366.5	-333.5	466.5	89.7	357.1
0.22	-228.2	371.8	-328.2	471.8	89.7	347.6
0.24	-222.8	377.2	-322.8	477.2	89.7	338.1
0.26	-217.5	382.5	-317.5	482.5	88.1	328.6
0.28	-212.1	387.9	-312.1	487.9	86.5	319.0
0.30	-209.4	390.6	-309.4	490.6	85.7	314.3
0.32	-204.1	395.9	-304.1	495.9	84.1	304.8
0.34	-198.7	401.3	-298.7	501.3	82.5	295.2
0.36	-193.4	406.6	-293.4	506.6	81.0	285.7
0.38	-188.0	412.0	-288.0	512.0	79.4	276.2
0.40	-185.4	414.6	-285.4	514.6	78.6	271.4
0.42	-180.0	420.0	-280.0	520.0	77.0	261.9
0.44	-174.7	425.3	-274.7	525.3	75.4	252.4
0.46	-169.3	430.7	-269.3	530.7	73.8	242.9
0.48	-164.0	436.0	-264.0	536.0	72.2	233.3
0.50	-161.3	438.7	-261.3	538.7	71.4	228.6
0.52	-155.9	444.1	-255.9	544.1	69.8	219.0
0.54	-150.6	449.4	-250.6	549.4	68.3	209.5
0.56	-145.2	454.8	-245.2	554.8	66.7	200.0
0.58	-139.9	460.1	-239.9	560.1	65.1	190.5
0.60	-137.2	462.8	-237.2	562.8	64.3	185.7

Table 41: Position in respect to blade pitch axis of the structural components of the blade - Part II.

η	First Shear Web	Second Shear Web	Spar Caps towards LE	Spar Caps towards TE	Extension of the Reinf. at LE	Extension of the Reinf. at TE
[-]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]
0.62	-131.8	468.2	-231.8	568.2	62.7	176.2
0.64	-126.5	473.5	-226.5	573.5	61.1	166.7
0.66	-121.1	478.9	-221.1	578.9	59.5	157.1
0.68	-115.8	484.2	-215.8	584.2	57.9	147.6
0.70	-113.1	486.9	-213.1	586.9	57.1	142.9
0.72	-107.8	492.2	-207.8	592.2	54.2	134.7
0.74	-102.4	497.6	-202.4	597.6	49.0	128.8
0.76	-97.1	502.9	-197.1	602.9	43.9	122.8
0.78	-91.7	508.3	-191.7	608.3	39.2	116.3
0.80	-89.0	511.0	-189.0	611.0	37.1	112.9
0.82	-83.7	516.3	-183.7	616.3	[-]	[-]
0.84	-78.3	521.7	-178.3	621.7	[-]	[-]
0.86	-73.0	527.0	-173.0	627.0	[-]	[-]
0.88	-67.6	532.4	-167.6	632.4	[-]	[-]
0.90	-65.0	535.0	-165.0	635.0	[-]	[-]
0.92	-59.6	540.4	-159.6	640.4	[-]	[-]
0.94	-54.3	545.7	-154.3	645.7	[-]	[-]
0.96	[-]	[-]	[-]	[-]	[-]	[-]
1.00	[-]	[-]	[-]	[-]	[-]	[-]

Table 42: Thickness of the structural components of the blade - Part I.

η	Outer Shell Skin	Spar Caps	Shear Webs Skin	Leading Edge Reinforcement	Trailing Edge Reinforcement
[-]	[mm]	[mm]	[mm]	[mm]	[mm]
0.00	65.00	[-]	[-]	[-]	[-]
0.01	60.00	[-]	[-]	[-]	[-]
0.02	55.00	[-]	[-]	[-]	[-]
0.03	50.00	[-]	[-]	[-]	[-]
0.04	45.71	[-]	[-]	[-]	[-]
0.05	41.43	[-]	[-]	[-]	[-]
0.06	37.14	[-]	[-]	[-]	[-]
0.07	32.86	[-]	[-]	[-]	[-]
0.08	28.57	[-]	[-]	[-]	[-]
0.10	20.00	9.93	1.00	3.10	1.18
0.12	16.87	15.95	1.08	3.19	2.24
0.14	13.74	21.96	1.16	3.27	3.30
0.16	10.60	27.97	1.25	3.35	4.37
0.18	7.47	33.99	1.33	3.44	5.43
0.20	4.34	40.00	1.41	3.52	6.49
0.22	3.74	44.76	1.61	3.26	6.69
0.24	3.15	49.52	1.82	2.99	6.88
0.26	2.56	54.28	2.02	2.73	7.07
0.28	1.96	59.04	2.22	2.46	7.26
0.30	1.37	63.80	2.42	2.20	7.45
0.32	1.34	61.22	2.49	2.06	7.32
0.34	1.30	58.64	2.56	1.92	7.19
0.36	1.27	56.05	2.64	1.79	7.05
0.38	1.24	53.47	2.71	1.65	6.92
0.40	1.21	50.89	2.78	1.51	6.79
0.42	1.16	50.46	2.89	1.45	7.20
0.44	1.12	50.03	3.01	1.39	7.61
0.46	1.08	49.59	3.12	1.32	8.02
0.48	1.04	49.16	3.23	1.26	8.43
0.50	1.00	48.73	3.35	1.20	8.84
0.52	1.00	47.23	3.45	1.25	7.67
0.54	1.00	45.74	3.56	1.30	6.50
0.56	1.00	44.24	3.67	1.35	5.33
0.58	1.00	42.74	3.78	1.40	4.16
0.60	1.00	41.24	3.89	1.45	2.99
0.62	1.00	38.84	3.88	1.42	2.59
0.64	1.00	36.44	3.88	1.40	2.20
0.66	1.00	34.03	3.88	1.38	1.80
0.68	1.00	31.63	3.88	1.36	1.40
0.70	1.00	29.22	3.87	1.34	1.00
0.72	1.02	29.39	3.64	1.43	1.15
0.74	1.04	29.56	3.40	1.52	1.29
0.76	1.06	29.73	3.17	1.61	1.44
0.78	1.07	29.89	2.93	1.71	1.59
0.80	1.09	30.06	2.69	1.80	1.73

Table 43: Thickness of the structural components of the blade - Part II.

η Shell Skin	Outer Caps	Spar Webs Skin	Shear Reinforcement	Leading Edge Reinforcement	Trailing Edge
[-]	[mm]	[mm]	[mm]	[mm]	[mm]
0.82	1.07	24.48	2.41	[-]	[-]
0.84	1.06	18.90	2.13	[-]	[-]
0.86	1.04	13.33	1.85	[-]	[-]
0.88	1.02	7.75	1.57	[-]	[-]
0.90	1.00	2.17	1.29	[-]	[-]
0.92	1.00	2.09	1.28	[-]	[-]
0.94	1.00	2.00	1.27	[-]	[-]
0.96	1.00	[-]	[-]	[-]	[-]
0.98	1.00	[-]	[-]	[-]	[-]
1.00	1.00	[-]	[-]	[-]	[-]

Table 44: Thickness of the core in the sandwich panels of the blade. Legend: TE - Trailing Edge, LE - Leading Edge, SS - Suction Side, PS - Pressure Side

η	TE SS	LE SS	LE PS	TE PS	First Shear Web	Second Shear Web
[-]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]
0.00	[-]	[-]	[-]	[-]	[-]	[-]
0.03	[-]	[-]	[-]	[-]	[-]	[-]
0.04	1.29	0.71	0.14	1.29	6.14	7.00
0.05	2.57	1.43	0.29	2.57	12.29	14.00
0.06	3.86	2.14	0.43	3.86	18.43	21.00
0.07	5.14	2.86	0.57	5.14	24.57	28.00
0.08	6.43	3.57	0.71	6.43	30.71	35.00
0.10	9.00	5.00	1.00	9.00	43.00	49.00
0.12	16.20	7.00	3.40	14.60	41.00	47.00
0.14	23.40	9.00	5.80	20.20	39.00	45.00
0.16	30.60	11.00	8.20	25.80	37.00	43.00
0.18	37.80	13.00	10.60	31.40	35.00	41.00
0.20	45.00	15.00	13.00	37.00	33.00	39.00
0.22	48.20	14.20	12.60	43.80	32.20	37.80
0.24	51.40	13.40	12.20	50.60	31.40	36.60
0.26	54.60	12.60	11.80	57.40	30.60	35.40
0.28	57.80	11.80	11.40	64.20	29.80	34.20
0.30	61.00	11.00	11.00	71.00	29.00	33.00
0.32	60.60	10.60	10.60	68.20	28.20	31.80
0.34	60.20	10.20	10.20	65.40	27.40	30.60
0.36	59.80	9.80	9.80	62.60	26.60	29.40
0.38	59.40	9.40	9.40	59.80	25.80	28.20
0.40	59.00	9.00	9.00	57.00	25.00	27.00
0.42	55.40	8.60	9.00	51.80	23.80	25.40
0.44	51.80	8.20	9.00	46.60	22.60	23.80
0.46	48.20	7.80	9.00	41.40	21.40	22.20
0.48	44.60	7.40	9.00	36.20	20.20	20.60
0.50	41.00	7.00	9.00	31.00	19.00	19.00
0.52	39.40	7.00	9.00	29.00	18.20	17.80
0.54	37.80	7.00	9.00	27.00	17.40	16.60
0.56	36.20	7.00	9.00	25.00	16.60	15.40
0.58	34.60	7.00	9.00	23.00	15.80	14.20
0.60	33.00	7.00	9.00	21.00	15.00	13.00
0.62	30.60	7.00	8.60	19.00	14.60	12.20
0.64	28.20	7.00	8.20	17.00	14.20	11.40
0.66	25.80	7.00	7.80	15.00	13.80	10.60
0.68	23.40	7.00	7.40	13.00	13.40	9.80
0.70	21.00	7.00	7.00	11.00	13.00	9.00
0.72	19.40	7.00	7.00	10.20	12.60	8.60
0.74	17.80	7.00	7.00	9.40	12.20	8.20
0.76	16.20	7.00	7.00	8.60	11.80	7.80
0.78	14.60	7.00	7.00	7.80	11.40	7.40
0.80	13.00	7.00	7.00	7.00	11.00	7.00
0.82	13.40	6.60	6.60	7.40	10.60	6.60
0.84	13.80	6.20	6.20	7.80	10.20	6.20
0.86	14.20	5.80	5.80	8.20	9.80	5.80
0.88	14.60	5.40	5.40	8.60	9.40	5.40
0.90	15.00	5.00	5.00	9.00	9.00	5.00
0.92	10.00	4.00	4.00	6.00	7.00	4.00
0.94	5.00	3.00	3.00	3.00	5.00	3.00
0.96	[-]	[-]	[-]	[-]	[-]	[-]
1.00	[-]	[-]	[-]	[-]	[-]	[-]

Table 45: Mass and stiffness properties of the blade - Part I.

η	T_{11}	T_{22}	EA	E_{11}	E_{22}	GJ	Mass
[-]	[N]	[N]	[N]	[Nm^2]	[Nm^2]	[Nm^2]	[kg/m]
0.00	2.44E+09	2.44E+09	1.13E+10	9.05E+09	9.05E+09	7.82E+09	9.64E+02
0.01	2.25E+09	2.25E+09	1.04E+10	8.40E+09	8.40E+09	7.26E+09	8.92E+02
0.02	2.07E+09	2.07E+09	9.58E+09	7.75E+09	7.75E+09	6.69E+09	8.20E+02
0.03	1.90E+09	1.88E+09	8.75E+09	7.10E+09	7.20E+09	6.18E+09	7.50E+02
0.04	1.79E+09	1.70E+09	8.09E+09	6.58E+09	6.94E+09	5.83E+09	7.03E+02
0.05	1.70E+09	1.52E+09	7.46E+09	6.07E+09	6.81E+09	5.54E+09	6.58E+02
0.06	1.62E+09	1.33E+09	6.85E+09	5.58E+09	6.80E+09	5.28E+09	6.15E+02
0.07	1.52E+09	1.12E+09	6.15E+09	4.85E+09	6.55E+09	4.79E+09	5.65E+02
0.08	1.39E+09	9.17E+08	5.41E+09	4.05E+09	6.16E+09	4.18E+09	5.11E+02
0.10	1.10E+09	5.21E+08	5.26E+09	3.33E+09	6.86E+09	2.74E+09	4.83E+02
0.12	1.03E+09	3.96E+08	5.11E+09	2.86E+09	7.03E+09	2.20E+09	4.53E+02
0.14	9.14E+08	3.19E+08	4.84E+09	2.59E+09	6.66E+09	1.83E+09	4.16E+02
0.16	7.49E+08	2.47E+08	4.52E+09	2.36E+09	5.73E+09	1.40E+09	3.78E+02
0.18	5.54E+08	1.79E+08	4.32E+09	2.19E+09	5.15E+09	9.55E+08	3.48E+02
0.20	3.37E+08	1.23E+08	4.12E+09	2.06E+09	4.48E+09	5.51E+08	3.17E+02
0.22	2.96E+08	1.16E+08	4.29E+09	2.10E+09	4.29E+09	4.48E+08	3.24E+02
0.24	2.54E+08	1.09E+08	4.44E+09	2.12E+09	3.85E+09	3.50E+08	3.28E+02
0.26	2.10E+08	1.04E+08	4.61E+09	2.14E+09	3.43E+09	2.64E+08	3.34E+02
0.28	1.64E+08	9.92E+07	4.78E+09	2.15E+09	3.04E+09	1.92E+08	3.40E+02
0.30	1.17E+08	9.45E+07	4.97E+09	2.14E+09	2.69E+09	1.32E+08	3.46E+02
0.32	1.14E+08	9.31E+07	4.77E+09	1.94E+09	2.48E+09	1.18E+08	3.33E+02
0.34	1.11E+08	9.11E+07	4.57E+09	1.73E+09	2.29E+09	1.08E+08	3.19E+02
0.36	1.07E+08	8.89E+07	4.37E+09	1.54E+09	2.09E+09	9.77E+07	3.06E+02
0.38	1.04E+08	8.64E+07	4.16E+09	1.35E+09	1.87E+09	8.81E+07	2.92E+02
0.40	9.99E+07	8.38E+07	3.96E+09	1.18E+09	1.67E+09	7.90E+07	2.79E+02
0.42	9.54E+07	8.18E+07	3.92E+09	1.05E+09	1.54E+09	7.08E+07	2.71E+02
0.44	9.11E+07	7.94E+07	3.87E+09	9.35E+08	1.41E+09	6.31E+07	2.63E+02
0.46	8.69E+07	7.68E+07	3.83E+09	8.23E+08	1.27E+09	5.60E+07	2.55E+02
0.48	8.30E+07	7.40E+07	3.78E+09	7.18E+08	1.14E+09	4.95E+07	2.47E+02
0.50	7.90E+07	7.12E+07	3.74E+09	6.23E+08	1.04E+09	4.38E+07	2.39E+02
0.52	8.33E+07	6.83E+07	3.60E+09	5.25E+08	8.37E+08	3.90E+07	2.29E+02
0.54	9.01E+07	6.55E+07	3.46E+09	4.41E+08	6.76E+08	3.49E+07	2.19E+02
0.56	1.00E+08	6.29E+07	3.32E+09	3.69E+08	5.46E+08	3.13E+07	2.10E+02
0.58	1.15E+08	6.10E+07	3.19E+09	3.07E+08	4.41E+08	2.80E+07	2.01E+02
0.60	1.34E+08	5.99E+07	3.06E+09	2.56E+08	3.61E+08	2.51E+07	1.91E+02
0.62	1.44E+08	5.55E+07	2.88E+09	2.11E+08	3.11E+08	2.22E+07	1.81E+02
0.64	1.54E+08	5.15E+07	2.70E+09	1.74E+08	2.70E+08	1.97E+07	1.70E+02
0.66	1.61E+08	4.78E+07	2.52E+09	1.44E+08	2.35E+08	1.76E+07	1.60E+02
0.68	1.65E+08	4.45E+07	2.34E+09	1.20E+08	2.06E+08	1.57E+07	1.50E+02
0.70	1.63E+08	4.13E+07	2.17E+09	9.97E+07	1.81E+08	1.41E+07	1.39E+02
0.72	1.66E+08	3.67E+07	2.17E+09	8.91E+07	1.78E+08	1.26E+07	1.39E+02
0.74	1.68E+08	3.28E+07	2.18E+09	8.02E+07	1.75E+08	1.14E+07	1.38E+02
0.76	1.69E+08	2.93E+07	2.19E+09	7.28E+07	1.73E+08	1.03E+07	1.37E+02
0.78	1.71E+08	2.63E+07	2.20E+09	6.70E+07	1.72E+08	9.37E+06	1.36E+02
0.80	1.72E+08	2.37E+07	2.21E+09	6.26E+07	1.72E+08	8.64E+06	1.36E+02

Table 46: Mass and stiffness properties of the blade - Part II.

η	T_{11}	T_{22}	EA	E_{11}	E_{22}	GJ	Mass
[-]	[N]	[N]	[N]	[Nm^2]	[Nm^2]	[Nm^2]	[kg/m]
0.82	1.47E+08	2.08E+07	1.79E+09	4.98E+07	1.22E+08	7.42E+06	1.15E+02
0.84	1.20E+08	1.80E+07	1.40E+09	3.78E+07	9.91E+07	6.38E+06	9.67E+01
0.86	9.27E+07	1.51E+07	1.01E+09	2.61E+07	7.58E+07	5.23E+06	7.79E+01
0.88	6.46E+07	1.19E+07	6.24E+08	1.47E+07	5.16E+07	3.89E+06	5.90E+01
0.90	3.55E+07	8.22E+06	2.33E+08	4.44E+06	2.63E+07	2.27E+06	4.00E+01
0.92	3.23E+07	7.00E+06	2.19E+08	3.34E+06	2.15E+07	1.76E+06	3.68E+01
0.94	2.82E+07	5.35E+06	2.03E+08	2.14E+06	1.66E+07	1.18E+06	3.34E+01
0.96	1.59E+07	1.02E+06	4.59E+07	2.38E+05	4.08E+06	3.70E+05	2.51E+01
0.98	1.02E+07	6.54E+05	2.96E+07	6.33E+04	1.09E+06	9.82E+04	2.38E+01
1.00	3.09E+06	1.96E+05	8.96E+06	1.74E+03	3.03E+04	2.70E+03	2.20E+01

Table 47: Mass and stiffness properties of the blade - Part III.

η [-]	Centroid X_s [mm]	Centroid Y_s [mm]	Mass Center x [mm]	Mass Center y [mm]	$\Delta\Theta$ [deg]	J3 [kgm^2/m]	J1 [kgm^2/m]	J2 [kgm^2/m]
0.00	-5.14E-05	2.15E-04	-5.14E-05	2.15E-04	7.97E+01	1.53E+03	7.66E+02	7.66E+02
0.01	-9.10E-03	2.15E-04	-9.10E-03	2.15E-04	7.98E+01	1.42E+03	7.12E+02	7.12E+02
0.02	-1.82E-02	2.16E-04	-1.82E-02	2.16E-04	7.96E+01	1.31E+03	6.56E+02	6.56E+02
0.03	-3.79E-02	-4.81E-04	-3.79E-02	-4.81E-04	-2.91E+00	1.21E+03	6.02E+02	6.10E+02
0.04	-7.80E-02	-2.21E-03	-7.80E-02	-2.21E-03	-2.62E+00	1.14E+03	5.57E+02	5.87E+02
0.05	-1.37E-01	-4.94E-03	-1.37E-01	-4.94E-03	-2.42E+00	1.09E+03	5.14E+02	5.77E+02
0.06	-2.16E-01	-9.13E-03	-2.16E-01	-9.13E-03	-2.10E+00	1.05E+03	4.73E+02	5.76E+02
0.07	-2.90E-01	-1.46E-02	-2.90E-01	-1.46E-02	-1.66E+00	9.65E+02	4.11E+02	5.54E+02
0.08	-3.66E-01	-2.09E-02	-3.66E-01	-2.09E-02	-1.20E+00	8.65E+02	3.43E+02	5.22E+02
0.10	-6.00E-01	-5.68E-02	-6.25E-01	-6.05E-02	2.55E+00	8.03E+02	2.53E+02	5.50E+02
0.12	-6.67E-01	-6.07E-02	-7.03E-01	-6.72E-02	3.21E+00	7.45E+02	2.04E+02	5.41E+02
0.14	-6.48E-01	-4.71E-02	-6.98E-01	-5.58E-02	2.82E+00	6.64E+02	1.74E+02	4.90E+02
0.16	-5.66E-01	-3.00E-02	-6.30E-01	-3.96E-02	2.14E+00	5.53E+02	1.47E+02	4.06E+02
0.18	-5.15E-01	-2.34E-02	-5.88E-01	-3.30E-02	2.66E+00	4.71E+02	1.26E+02	3.45E+02
0.20	-4.49E-01	-1.63E-02	-5.13E-01	-2.41E-02	3.23E+00	3.85E+02	1.09E+02	2.75E+02
0.22	-4.12E-01	-1.28E-02	-4.75E-01	-1.88E-02	3.09E+00	3.69E+02	1.08E+02	2.61E+02
0.24	-3.61E-01	-1.04E-02	-4.20E-01	-1.34E-02	2.39E+00	3.38E+02	1.07E+02	2.31E+02
0.26	-3.19E-01	-1.16E-02	-3.69E-01	-1.25E-02	2.22E+00	3.08E+02	1.06E+02	2.03E+02
0.28	-2.83E-01	-1.47E-02	-3.23E-01	-1.43E-02	3.04E+00	2.79E+02	1.04E+02	1.75E+02
0.30	-2.53E-01	-1.89E-02	-2.80E-01	-1.79E-02	5.82E+00	2.51E+02	1.03E+02	1.48E+02
0.32	-2.54E-01	-2.27E-02	-2.80E-01	-2.12E-02	6.00E+00	2.30E+02	9.31E+01	1.37E+02
0.34	-2.57E-01	-2.80E-02	-2.83E-01	-2.63E-02	6.80E+00	2.10E+02	8.33E+01	1.26E+02
0.36	-2.59E-01	-3.20E-02	-2.83E-01	-3.02E-02	7.45E+00	1.89E+02	7.39E+01	1.15E+02
0.38	-2.60E-01	-3.47E-02	-2.82E-01	-3.29E-02	7.93E+00	1.68E+02	6.50E+01	1.03E+02
0.40	-2.58E-01	-3.62E-02	-2.79E-01	-3.44E-02	7.86E+00	1.48E+02	5.66E+01	9.18E+01
0.42	-2.59E-01	-3.67E-02	-2.77E-01	-3.51E-02	7.61E+00	1.34E+02	5.07E+01	8.37E+01
0.44	-2.59E-01	-3.64E-02	-2.73E-01	-3.49E-02	7.30E+00	1.20E+02	4.49E+01	7.55E+01
0.46	-2.58E-01	-3.53E-02	-2.69E-01	-3.40E-02	6.88E+00	1.07E+02	3.95E+01	6.76E+01
0.48	-2.56E-01	-3.39E-02	-2.65E-01	-3.27E-02	6.32E+00	9.45E+01	3.44E+01	6.01E+01
0.50	-2.54E-01	-3.22E-02	-2.61E-01	-3.12E-02	5.36E+00	8.38E+01	2.97E+01	5.40E+01
0.52	-2.40E-01	-3.06E-02	-2.47E-01	-2.98E-02	6.06E+00	6.91E+01	2.51E+01	4.40E+01
0.54	-2.27E-01	-2.36E-02	-2.33E-01	-2.29E-02	7.34E+00	5.70E+01	2.11E+01	3.59E+01
0.56	-2.16E-01	-1.55E-02	-2.22E-01	-1.50E-02	8.80E+00	4.69E+01	1.76E+01	2.93E+01
0.58	-2.06E-01	-7.92E-03	-2.12E-01	-7.53E-03	1.02E+01	3.87E+01	1.47E+01	2.40E+01
0.60	-1.96E-01	-1.08E-03	-2.02E-01	-8.10E-04	1.13E+01	3.22E+01	1.23E+01	1.99E+01
0.62	-1.95E-01	5.28E-03	-2.01E-01	5.44E-03	9.50E+00	2.73E+01	1.01E+01	1.72E+01
0.64	-1.96E-01	1.07E-02	-2.00E-01	1.08E-02	8.00E+00	2.33E+01	8.33E+00	1.50E+01
0.66	-1.96E-01	1.51E-02	-2.00E-01	1.51E-02	6.68E+00	2.00E+01	6.90E+00	1.31E+01
0.68	-1.97E-01	1.87E-02	-2.01E-01	1.86E-02	5.62E+00	1.73E+01	5.75E+00	1.16E+01
0.70	-1.97E-01	2.22E-02	-2.00E-01	2.21E-02	4.54E+00	1.51E+01	4.78E+00	1.03E+01
0.72	-2.01E-01	2.59E-02	-2.04E-01	2.57E-02	3.42E+00	1.42E+01	4.26E+00	9.96E+00
0.74	-2.06E-01	2.90E-02	-2.09E-01	2.88E-02	2.66E+00	1.35E+01	3.83E+00	9.72E+00
0.76	-2.11E-01	3.19E-02	-2.14E-01	3.16E-02	2.13E+00	1.30E+01	3.47E+00	9.52E+00
0.78	-2.16E-01	3.43E-02	-2.19E-01	3.40E-02	1.76E+00	1.26E+01	3.19E+00	9.37E+00
0.80	-2.19E-01	3.62E-02	-2.22E-01	3.59E-02	1.51E+00	1.23E+01	2.98E+00	9.31E+00

Table 48: Mass and stiffness properties of the blade - Part IV.

η [-]	Centroid X_s [mm]	Centroid Y_s [mm]	Mass Center x [mm]	Mass Center y [mm]	$\Delta\Theta$ [deg]	J3 [kgm^2/m]	J1 [kgm^2/m]	J2 [kgm^2/m]
0.82	-2.20E-01	3.82E-02	-2.23E-01	3.79E-02	1.82E+00	9.24E+00	2.38E+00	6.86E+00
0.84	-2.27E-01	3.93E-02	-2.31E-01	3.89E-02	1.55E+00	7.54E+00	1.82E+00	5.72E+00
0.86	-2.35E-01	3.95E-02	-2.40E-01	3.90E-02	1.13E+00	5.81E+00	1.27E+00	4.55E+00
0.88	-2.44E-01	3.86E-02	-2.51E-01	3.79E-02	4.97E-01	4.02E+00	7.34E-01	3.29E+00
0.90	-2.63E-01	3.54E-02	-2.72E-01	3.43E-02	-5.02E-01	2.19E+00	2.50E-01	1.95E+00
0.92	-2.59E-01	3.27E-02	-2.64E-01	3.16E-02	-7.22E-01	1.74E+00	1.88E-01	1.55E+00
0.94	-2.52E-01	2.89E-02	-2.52E-01	2.77E-02	-9.71E-01	1.26E+00	1.20E-01	1.14E+00
0.96	-2.24E-01	1.90E-02	-2.24E-01	1.90E-02	-1.13E+00	3.66E-01	2.02E-02	3.46E-01
0.98	-1.46E-01	1.23E-02	-1.46E-01	1.23E-02	-1.14E+00	9.75E-02	5.36E-03	9.22E-02
1.00	-4.70E-02	3.78E-03	-4.70E-02	3.78E-03	-1.20E+00	2.72E-03	1.47E-04	2.57E-03

A.4 Tower structure

Table 49: Structure of the tower of the onshore wind turbine.

η [-]	Wall Thickness [mm]	Outer Diameter [m]	Section Area [m^2]
0.00	56.97	5.99	1.06E+00
0.10	56.97	5.93	1.05E+00
0.10	50.47	5.93	9.32E-01
0.20	50.47	5.93	9.32E-01
0.20	46.64	5.93	8.62E-01
0.30	46.64	5.93	8.62E-01
0.30	39.35	5.93	7.28E-01
0.40	39.35	5.93	7.28E-01
0.40	33.54	5.93	6.21E-01
0.50	33.54	5.93	6.21E-01
0.50	28.01	5.93	5.19E-01
0.60	28.01	5.85	5.12E-01
0.60	23.57	5.85	4.31E-01
0.70	23.57	5.12	3.77E-01
0.70	23.74	5.12	3.80E-01
0.80	23.74	4.36	3.23E-01
0.80	22.41	4.36	3.05E-01
0.90	22.41	3.61	2.52E-01
0.90	26.74	3.61	3.01E-01
1.00	26.74	3.00	2.50E-01

Table 50: Elastic properties of the tower of the onshore wind turbine.

η	Mass	Axial Stiffness	Bending Stiffness	Torsional Stiffness	Shear Stiffness	Polar Moment of Inertia
[-]	[kg/m^3]	[N]	[Nm^2]	[Nm^2]	[N]	[m^4]
0.00	9.02E+03	2.23E+11	9.80E+11	7.54E+11	4.29E+10	9.33E+00
0.10	8.93E+03	2.21E+11	9.51E+11	7.31E+11	4.24E+10	9.05E+00
0.10	7.92E+03	1.96E+11	8.45E+11	6.50E+11	3.76E+10	8.05E+00
0.20	7.92E+03	1.96E+11	8.45E+11	6.50E+11	3.76E+10	8.05E+00
0.20	7.33E+03	1.81E+11	7.82E+11	6.02E+11	3.48E+10	7.45E+00
0.30	7.33E+03	1.81E+11	7.82E+11	6.02E+11	3.48E+10	7.45E+00
0.30	6.19E+03	1.53E+11	6.63E+11	5.10E+11	2.94E+10	6.31E+00
0.40	6.19E+03	1.53E+11	6.63E+11	5.10E+11	2.94E+10	6.31E+00
0.40	5.28E+03	1.30E+11	5.66E+11	4.36E+11	2.51E+10	5.39E+00
0.50	5.28E+03	1.30E+11	5.66E+11	4.36E+11	2.51E+10	5.39E+00
0.50	4.41E+03	1.09E+11	4.74E+11	3.65E+11	2.10E+10	4.52E+00
0.60	4.35E+03	1.08E+11	4.56E+11	3.51E+11	2.07E+10	4.34E+00
0.60	3.67E+03	9.06E+10	3.85E+11	2.96E+11	1.74E+10	3.66E+00
0.70	3.21E+03	7.92E+10	2.57E+11	1.97E+11	1.52E+10	2.44E+00
0.70	3.23E+03	7.97E+10	2.59E+11	1.99E+11	1.53E+10	2.46E+00
0.80	2.75E+03	6.79E+10	1.60E+11	1.23E+11	1.31E+10	1.52E+00
0.80	2.60E+03	6.42E+10	1.51E+11	1.16E+11	1.23E+10	1.44E+00
0.90	2.15E+03	5.30E+10	8.52E+10	6.55E+10	1.02E+10	8.11E-01
0.90	2.56E+03	6.32E+10	1.01E+11	7.79E+10	1.21E+10	9.64E-01
1.00	2.12E+03	5.25E+10	5.80E+10	4.46E+10	1.01E+10	5.52E-01

B IEA Wind Task 37 offshore reference turbine detailed properties and loads

B.1 Blade aerodynamic shape

Table 51 contains the aerodynamic planform of the 10 MW offshore blade.

B.2 Airfoil data

B.3 Blade structure

Table 51: Aerodynamic shape of the onshore wind turbine blade - Part I.

η [-]	Chord [mm]	Twist [deg]	Rel. Thick. [%]	Abs. Thick. [mm]	PreBend [mm]	Sweep [mm]	Pitch Ax. [%]
0.0000	4600.000	14.500	100.000	4.600	-0.000	0.000	0.500
0.0176	4601.556	14.037	99.739	4.590	-7.669	0.000	0.500
0.0313	4601.651	13.737	98.192	4.518	-14.693	0.000	0.500
0.0420	4609.049	13.545	95.682	4.410	-20.900	0.000	0.498
0.0507	4636.155	13.413	92.513	4.289	-26.516	0.000	0.489
0.0579	4667.782	13.312	89.240	4.166	-31.484	0.000	0.480
0.0642	4698.278	13.223	86.130	4.047	-35.920	0.000	0.473
0.0700	4729.304	13.139	83.061	3.928	-40.113	0.000	0.465
0.0758	4763.632	13.056	79.871	3.805	-44.343	0.000	0.459
0.0821	4807.427	12.969	76.338	3.670	-48.998	0.000	0.453
0.0893	4869.795	12.874	72.208	3.516	-54.497	0.000	0.445
0.0980	4953.764	12.752	67.393	3.338	-61.250	0.000	0.435
0.1087	5063.527	12.565	61.870	3.133	-69.747	0.000	0.423
0.1224	5218.259	12.223	55.573	2.900	-80.713	0.000	0.408
0.1400	5444.001	11.600	48.640	2.648	-95.183	0.000	0.389
0.1610	5688.237	10.674	42.379	2.411	-112.440	0.000	0.369
0.1841	5937.831	9.329	37.456	2.224	-131.381	0.000	0.351
0.2093	5987.655	7.980	34.759	2.081	-152.316	0.000	0.339
0.2366	5990.629	6.724	33.223	1.990	-175.303	0.000	0.331
0.2660	5896.920	5.879	32.682	1.927	-200.154	0.000	0.331
0.2973	5704.650	5.222	32.580	1.859	-227.286	0.000	0.332
0.3305	5463.845	4.668	32.606	1.782	-257.214	0.000	0.341
0.3653	5176.618	4.131	32.547	1.685	-292.010	0.000	0.353
0.4015	4857.565	3.614	32.367	1.572	-334.013	0.000	0.368
0.4387	4520.899	3.085	32.063	1.450	-385.250	0.000	0.387
0.4766	4179.799	2.496	31.474	1.316	-447.911	0.000	0.407
0.5148	3842.977	1.843	30.700	1.180	-526.833	0.000	0.427
0.5529	3519.719	1.161	29.781	1.048	-625.007	0.000	0.447
0.5905	3217.849	0.472	28.768	0.926	-744.099	0.000	0.465
0.6273	2942.296	-0.197	27.680	0.814	-887.576	0.000	0.481
0.6628	2695.475	-0.821	26.556	0.716	-1057.588	0.000	0.495
0.6969	2477.568	-1.382	25.426	0.630	-1253.153	0.000	0.506
0.7293	2287.113	-1.870	24.340	0.557	-1474.395	0.000	0.515
0.7597	2122.247	-2.277	23.397	0.497	-1720.593	0.000	0.522
0.7882	1980.577	-2.603	22.828	0.452	-1987.436	0.000	0.525
0.8145	1859.108	-2.850	22.755	0.423	-2273.422	0.000	0.526
0.8387	1754.739	-3.024	22.673	0.398	-2573.827	0.000	0.526
0.8608	1665.081	-3.125	22.533	0.375	-2884.584	0.000	0.523
0.8809	1586.370	-3.160	22.351	0.355	-3202.247	0.000	0.519
0.8990	1511.990	-3.130	22.145	0.335	-3522.496	0.000	0.513
0.9153	1434.483	-3.038	21.930	0.315	-3841.371	0.000	0.507
0.9299	1350.941	-2.883	21.722	0.293	-4154.921	0.000	0.499
0.9429	1260.917	-2.669	21.533	0.272	-4460.302	0.000	0.492
0.9544	1166.025	-2.399	21.372	0.249	-4755.279	0.000	0.485
0.9646	1062.491	-2.085	21.241	0.226	-5037.057	0.000	0.477
0.9736	957.120	-1.727	21.143	0.202	-5304.189	0.000	0.470
0.9816	862.535	-1.340	21.073	0.182	-5555.265	0.000	0.464
0.9885	759.755	-0.927	21.030	0.160	-5789.509	0.000	0.457
0.9946	540.567	-0.483	21.007	0.114	-6006.941	0.000	0.452
1.0000	96.200	-0.037	21.000	0.020	-6206.217	0.000	0.446

Table 52: Airfoil shape - FFA-W3-211 21.10% airfoil

ID	x	y	ID	x	y	ID	x	y	ID	x	y
[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]			
0	1.00000	-0.00131	50	0.48071	-0.07319	100	0.00727	0.01970	150	0.50089	0.10054
1	0.98960	-0.00001	51	0.47032	-0.07541	101	0.01380	0.02787	151	0.51109	0.09883
2	0.97919	0.00123	52	0.45992	-0.07751	102	0.02121	0.03525	152	0.52128	0.09707
3	0.96877	0.00240	53	0.44948	-0.07948	103	0.02920	0.04198	153	0.53146	0.09526
4	0.95832	0.00346	54	0.43903	-0.08132	104	0.03759	0.04820	154	0.54163	0.09341
5	0.94786	0.00438	55	0.42855	-0.08302	105	0.04629	0.05398	155	0.55180	0.09152
6	0.93738	0.00514	56	0.41805	-0.08457	106	0.05523	0.05936	156	0.56196	0.08960
7	0.92689	0.00572	57	0.40753	-0.08598	107	0.06436	0.06441	157	0.57212	0.08765
8	0.91638	0.00614	58	0.39699	-0.08726	108	0.07365	0.06915	158	0.58227	0.08566
9	0.90586	0.00639	59	0.38644	-0.08839	109	0.08308	0.07360	159	0.59242	0.08363
10	0.89534	0.00647	60	0.37587	-0.08937	110	0.09263	0.07778	160	0.60255	0.08157
11	0.88481	0.00639	61	0.36530	-0.09021	111	0.10228	0.08171	161	0.61269	0.07948
12	0.87428	0.00616	62	0.35471	-0.09089	112	0.11201	0.08541	162	0.62282	0.07736
13	0.86374	0.00578	63	0.34412	-0.09143	113	0.12182	0.08888	163	0.63294	0.07521
14	0.85321	0.00526	64	0.33352	-0.09182	114	0.13171	0.09214	164	0.64307	0.07305
15	0.84269	0.00459	65	0.32292	-0.09206	115	0.14165	0.09518	165	0.65319	0.07088
16	0.83217	0.00378	66	0.31232	-0.09214	116	0.15165	0.09803	166	0.66331	0.06870
17	0.82165	0.00284	67	0.30172	-0.09207	117	0.16171	0.10068	167	0.67343	0.06650
18	0.81115	0.00177	68	0.29112	-0.09186	118	0.17180	0.10314	168	0.68355	0.06430
19	0.80066	0.00056	69	0.28053	-0.09150	119	0.18194	0.10541	169	0.69368	0.06209
20	0.79017	-0.00078	70	0.26995	-0.09099	120	0.19211	0.10749	170	0.70380	0.05987
21	0.77971	-0.00225	71	0.25938	-0.09034	121	0.20232	0.10940	171	0.71393	0.05766
22	0.76926	-0.00384	72	0.24883	-0.08955	122	0.21255	0.11113	172	0.72406	0.05545
23	0.75882	-0.00554	73	0.23828	-0.08861	123	0.22281	0.11268	173	0.73419	0.05323
24	0.74839	-0.00735	74	0.22776	-0.08753	124	0.23309	0.11406	174	0.74432	0.05103
25	0.73798	-0.00925	75	0.21725	-0.08630	125	0.24339	0.11526	175	0.75446	0.04882
26	0.72759	-0.01126	76	0.20676	-0.08493	126	0.25371	0.11629	176	0.76461	0.04663
27	0.71722	-0.01337	77	0.19630	-0.08340	127	0.26404	0.11713	177	0.77476	0.04445
28	0.70686	-0.01556	78	0.18586	-0.08172	128	0.27438	0.11781	178	0.78491	0.04229
29	0.69651	-0.01785	79	0.17546	-0.07988	129	0.28473	0.11832	179	0.79508	0.04014
30	0.68618	-0.02021	80	0.16509	-0.07789	130	0.29508	0.11866	180	0.80525	0.03800
31	0.67587	-0.02266	81	0.15475	-0.07574	131	0.30544	0.11885	181	0.81542	0.03589
32	0.66558	-0.02518	82	0.14445	-0.07343	132	0.31579	0.11888	182	0.82561	0.03380
33	0.65530	-0.02776	83	0.13419	-0.07096	133	0.32615	0.11877	183	0.83580	0.03172
34	0.64503	-0.03040	84	0.12398	-0.06833	134	0.33650	0.11850	184	0.84600	0.02966
35	0.63477	-0.03308	85	0.11381	-0.06552	135	0.34684	0.11809	185	0.85621	0.02761
36	0.62452	-0.03581	86	0.10371	-0.06253	136	0.35717	0.11756	186	0.86642	0.02557
37	0.61427	-0.03857	87	0.09366	-0.05935	137	0.36750	0.11692	187	0.87664	0.02356
38	0.60403	-0.04135	88	0.08369	-0.05597	138	0.37782	0.11617	188	0.88687	0.02157
39	0.59380	-0.04414	89	0.07380	-0.05237	139	0.38813	0.11531	189	0.89711	0.01960
40	0.58356	-0.04694	90	0.06400	-0.04854	140	0.39843	0.11435	190	0.90735	0.01765
41	0.57332	-0.04973	91	0.05431	-0.04446	141	0.40872	0.11330	191	0.91761	0.01573
42	0.56308	-0.05251	92	0.04476	-0.04006	142	0.41900	0.11217	192	0.92787	0.01383
43	0.55282	-0.05526	93	0.03540	-0.03530	143	0.42927	0.11096	193	0.93815	0.01195
44	0.54256	-0.05799	94	0.02628	-0.03009	144	0.43953	0.10967	194	0.94843	0.01011
45	0.53229	-0.06067	95	0.01753	-0.02430	145	0.44978	0.10831	195	0.95872	0.00830
46	0.52201	-0.06331	96	0.00941	-0.01767	146	0.46002	0.10688	196	0.96903	0.00654
47	0.51171	-0.06590	97	0.00275	-0.00962	147	0.47025	0.10538	197	0.97935	0.00481
48	0.50140	-0.06842	98	-0.00000	0.00037	148	0.48047	0.10382	198	0.98968	0.00308
49	0.49106	-0.07085	99	0.00225	0.01054	149	0.49069	0.10221	199	1.00000	0.00131

Table 53: Airfoil shape - FFA-W3-241 24.10% airfoil

ID	x	y	ID	x	y	ID	x	y	ID	x	y
[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]			
0	1.00000	-0.00360	50	0.47643	-0.09331	100	0.00510	0.02011	150	0.49739	0.10719
1	0.98948	-0.00220	51	0.46591	-0.09584	101	0.01052	0.02920	151	0.50765	0.10552
2	0.97895	-0.00082	52	0.45536	-0.09823	102	0.01705	0.03754	152	0.51792	0.10380
3	0.96841	0.00050	53	0.44478	-0.10048	103	0.02434	0.04519	153	0.52817	0.10204
4	0.95784	0.00172	54	0.43417	-0.10259	104	0.03224	0.05221	154	0.53842	0.10023
5	0.94725	0.00279	55	0.42354	-0.10456	105	0.04056	0.05871	155	0.54866	0.09839
6	0.93664	0.00368	56	0.41288	-0.10638	106	0.04922	0.06474	156	0.55889	0.09650
7	0.92600	0.00438	57	0.40219	-0.10804	107	0.05816	0.07034	157	0.56912	0.09458
8	0.91535	0.00489	58	0.39149	-0.10956	108	0.06731	0.07556	158	0.57934	0.09262
9	0.90468	0.00519	59	0.38076	-0.11091	109	0.07666	0.08043	159	0.58956	0.09063
10	0.89400	0.00528	60	0.37002	-0.11210	110	0.08615	0.08496	160	0.59978	0.08861
11	0.88331	0.00517	61	0.35926	-0.11313	111	0.09579	0.08919	161	0.60999	0.08656
12	0.87263	0.00486	62	0.34849	-0.11398	112	0.10554	0.09312	162	0.62019	0.08448
13	0.86194	0.00437	63	0.33772	-0.11467	113	0.11539	0.09677	163	0.63040	0.08237
14	0.85125	0.00371	64	0.32693	-0.11519	114	0.12533	0.10016	164	0.64060	0.08024
15	0.84057	0.00287	65	0.31614	-0.11554	115	0.13535	0.10330	165	0.65080	0.07810
16	0.82990	0.00187	66	0.30534	-0.11572	116	0.14543	0.10619	166	0.66100	0.07593
17	0.81924	0.00069	67	0.29455	-0.11571	117	0.15558	0.10884	167	0.67120	0.07375
18	0.80859	-0.00065	68	0.28377	-0.11553	118	0.16577	0.11127	168	0.68139	0.07156
19	0.79797	-0.00217	69	0.27299	-0.11516	119	0.17601	0.11348	169	0.69159	0.06935
20	0.78736	-0.00387	70	0.26222	-0.11462	120	0.18629	0.11548	170	0.70179	0.06714
21	0.77678	-0.00575	71	0.25147	-0.11389	121	0.19660	0.11727	171	0.71199	0.06491
22	0.76623	-0.00781	72	0.24074	-0.11298	122	0.20694	0.11886	172	0.72220	0.06268
23	0.75570	-0.01003	73	0.23002	-0.11188	123	0.21731	0.12026	173	0.73240	0.06044
24	0.74521	-0.01241	74	0.21934	-0.11059	124	0.22769	0.12148	174	0.74261	0.05819
25	0.73474	-0.01493	75	0.20868	-0.10909	125	0.23809	0.12252	175	0.75283	0.05595
26	0.72431	-0.01758	76	0.19806	-0.10740	126	0.24850	0.12339	176	0.76304	0.05370
27	0.71390	-0.02034	77	0.18748	-0.10549	127	0.25891	0.12409	177	0.77326	0.05146
28	0.70351	-0.02322	78	0.17694	-0.10338	128	0.26934	0.12464	178	0.78349	0.04922
29	0.69315	-0.02620	79	0.16646	-0.10105	129	0.27977	0.12502	179	0.79372	0.04698
30	0.68281	-0.02928	80	0.15603	-0.09850	130	0.29020	0.12525	180	0.80396	0.04474
31	0.67250	-0.03244	81	0.14566	-0.09572	131	0.30063	0.12534	181	0.81421	0.04252
32	0.66221	-0.03567	82	0.13536	-0.09272	132	0.31105	0.12529	182	0.82446	0.04030
33	0.65193	-0.03897	83	0.12515	-0.08949	133	0.32147	0.12510	183	0.83472	0.03808
34	0.64166	-0.04231	84	0.11501	-0.08601	134	0.33189	0.12479	184	0.84499	0.03588
35	0.63141	-0.04569	85	0.10497	-0.08229	135	0.34230	0.12436	185	0.85526	0.03368
36	0.62116	-0.04909	86	0.09504	-0.07831	136	0.35270	0.12382	186	0.86554	0.03149
37	0.61091	-0.05250	87	0.08522	-0.07408	137	0.36310	0.12316	187	0.87583	0.02931
38	0.60066	-0.05592	88	0.07553	-0.06957	138	0.37348	0.12241	188	0.88613	0.02714
39	0.59040	-0.05933	89	0.06598	-0.06478	139	0.38386	0.12156	189	0.89644	0.02499
40	0.58014	-0.06272	90	0.05661	-0.05968	140	0.39423	0.12062	190	0.90675	0.02284
41	0.56986	-0.06608	91	0.04742	-0.05426	141	0.40459	0.11960	191	0.91708	0.02071
42	0.55957	-0.06939	92	0.03846	-0.04848	142	0.41493	0.11850	192	0.92741	0.01859
43	0.54926	-0.07266	93	0.02980	-0.04228	143	0.42527	0.11732	193	0.93776	0.01648
44	0.53893	-0.07586	94	0.02153	-0.03557	144	0.43560	0.11606	194	0.94811	0.01439
45	0.52858	-0.07900	95	0.01381	-0.02825	145	0.44592	0.11474	195	0.95848	0.01230
46	0.51821	-0.08205	96	0.00708	-0.02004	146	0.45623	0.11335	196	0.96885	0.01021
47	0.50780	-0.08502	97	0.00191	-0.01076	147	0.46653	0.11190	197	0.97922	0.00811
48	0.49738	-0.08790	98	-0.00002	-0.00034	148	0.47683	0.11039	198	0.98961	0.00601
49	0.48692	-0.09066	99	0.00146	0.01016	149	0.48711	0.10882	199	1.00000	0.00391

Table 54: Airfoil shape - FFA-W3-270blend 27.00% airfoil

ID	x	y	ID	x	y	ID	x	y	ID	x	y
[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]			
0	1.00000	-0.00613	50	0.47744	-0.10899	100	0.00113	0.01076	150	0.48932	0.11704
1	0.98941	-0.00440	51	0.46697	-0.11173	101	0.00421	0.02103	151	0.49981	0.11530
2	0.97880	-0.00276	52	0.45645	-0.11433	102	0.00897	0.03063	152	0.51029	0.11351
3	0.96816	-0.00127	53	0.44591	-0.11680	103	0.01489	0.03956	153	0.52076	0.11168
4	0.95749	0.00001	54	0.43533	-0.11913	104	0.02168	0.04785	154	0.53122	0.10980
5	0.94680	0.00107	55	0.42472	-0.12131	105	0.02917	0.05550	155	0.54168	0.10787
6	0.93608	0.00191	56	0.41408	-0.12334	106	0.03701	0.06280	156	0.55213	0.10591
7	0.92534	0.00254	57	0.40341	-0.12521	107	0.04526	0.06961	157	0.56257	0.10390
8	0.91459	0.00293	58	0.39272	-0.12693	108	0.05389	0.07593	158	0.57301	0.10186
9	0.90383	0.00310	59	0.38201	-0.12848	109	0.06282	0.08182	159	0.58344	0.09979
10	0.89306	0.00302	60	0.37127	-0.12987	110	0.07201	0.08729	160	0.59386	0.09768
11	0.88230	0.00271	61	0.36051	-0.13108	111	0.08140	0.09239	161	0.60428	0.09554
12	0.87154	0.00217	62	0.34973	-0.13211	112	0.09098	0.09713	162	0.61469	0.09337
13	0.86079	0.00141	63	0.33894	-0.13297	113	0.10072	0.10153	163	0.62510	0.09117
14	0.85006	0.00045	64	0.32814	-0.13364	114	0.11059	0.10559	164	0.63551	0.08895
15	0.83934	-0.00070	65	0.31733	-0.13413	115	0.12059	0.10935	165	0.64591	0.08670
16	0.82864	-0.00204	66	0.30651	-0.13444	116	0.13069	0.11280	166	0.65631	0.08443
17	0.81796	-0.00357	67	0.29569	-0.13455	117	0.14089	0.11597	167	0.66670	0.08214
18	0.80731	-0.00529	68	0.28488	-0.13447	118	0.15116	0.11885	168	0.67709	0.07983
19	0.79669	-0.00720	69	0.27406	-0.13418	119	0.16150	0.12146	169	0.68748	0.07751
20	0.78610	-0.00930	70	0.26326	-0.13369	120	0.17191	0.12382	170	0.69787	0.07516
21	0.77555	-0.01160	71	0.25247	-0.13300	121	0.18236	0.12592	171	0.70825	0.07280
22	0.76504	-0.01409	72	0.24169	-0.13209	122	0.19286	0.12778	172	0.71863	0.07043
23	0.75457	-0.01674	73	0.23094	-0.13097	123	0.20339	0.12941	173	0.72902	0.06804
24	0.74414	-0.01955	74	0.22022	-0.12962	124	0.21395	0.13082	174	0.73940	0.06565
25	0.73374	-0.02249	75	0.20953	-0.12804	125	0.22454	0.13202	175	0.74978	0.06324
26	0.72338	-0.02556	76	0.19888	-0.12623	126	0.23515	0.13302	176	0.76016	0.06084
27	0.71305	-0.02874	77	0.18828	-0.12417	127	0.24577	0.13384	177	0.77055	0.05842
28	0.70275	-0.03204	78	0.17773	-0.12186	128	0.25640	0.13448	178	0.78093	0.05600
29	0.69248	-0.03543	79	0.16724	-0.11929	129	0.26703	0.13495	179	0.79132	0.05359
30	0.68224	-0.03891	80	0.15682	-0.11646	130	0.27768	0.13525	180	0.80171	0.05117
31	0.67203	-0.04246	81	0.14649	-0.11336	131	0.28832	0.13540	181	0.81211	0.04875
32	0.66183	-0.04608	82	0.13624	-0.10999	132	0.29896	0.13539	182	0.82250	0.04633
33	0.65165	-0.04975	83	0.12609	-0.10635	133	0.30960	0.13525	183	0.83290	0.04391
34	0.64149	-0.05346	84	0.11605	-0.10241	134	0.32024	0.13497	184	0.84330	0.04150
35	0.63133	-0.05719	85	0.10613	-0.09819	135	0.33087	0.13456	185	0.85371	0.03910
36	0.62118	-0.06094	86	0.09634	-0.09367	136	0.34150	0.13404	186	0.86412	0.03670
37	0.61102	-0.06469	87	0.08670	-0.08885	137	0.35212	0.13340	187	0.87454	0.03432
38	0.60086	-0.06844	88	0.07723	-0.08372	138	0.36273	0.13265	188	0.88496	0.03194
39	0.59070	-0.07216	89	0.06794	-0.07827	139	0.37333	0.13180	189	0.89539	0.02958
40	0.58052	-0.07586	90	0.05888	-0.07247	140	0.38392	0.13086	190	0.90582	0.02722
41	0.57033	-0.07952	91	0.05004	-0.06633	141	0.39450	0.12982	191	0.91627	0.02488
42	0.56012	-0.08312	92	0.04141	-0.05990	142	0.40508	0.12870	192	0.92671	0.02256
43	0.54988	-0.08666	93	0.03310	-0.05308	143	0.41564	0.12749	193	0.93717	0.02026
44	0.53963	-0.09013	94	0.02518	-0.04580	144	0.42619	0.12620	194	0.94763	0.01797
45	0.52934	-0.09352	95	0.01779	-0.03800	145	0.43674	0.12485	195	0.95810	0.01569
46	0.51902	-0.09682	96	0.01108	-0.02961	146	0.44727	0.12342	196	0.96857	0.01341
47	0.50868	-0.10003	97	0.00548	-0.02045	147	0.45780	0.12192	197	0.97905	0.01112
48	0.49830	-0.10313	98	0.00141	-0.01052	148	0.46832	0.12035	198	0.98952	0.00882
49	0.48789	-0.10612	99	-0.00002	0.00010	149	0.47882	0.11873	199	1.00000	0.00652

Table 55: Airfoil shape - FFA-W3-301 30.10% airfoil

ID	x	y	ID	x	y	ID	x	y	ID	x	y
[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]			
0	1.00000	-0.00891	50	0.47212	-0.12493	100	0.00087	0.01104	150	0.48498	0.12877
1	0.98934	-0.00673	51	0.46149	-0.12782	101	0.00332	0.02164	151	0.49556	0.12690
2	0.97863	-0.00473	52	0.45083	-0.13058	102	0.00716	0.03181	152	0.50613	0.12496
3	0.96787	-0.00306	53	0.44012	-0.13319	103	0.01213	0.04147	153	0.51669	0.12298
4	0.95705	-0.00172	54	0.42939	-0.13566	104	0.01801	0.05061	154	0.52725	0.12096
5	0.94619	-0.00071	55	0.41861	-0.13797	105	0.02463	0.05921	155	0.53779	0.11889
6	0.93531	0.00003	56	0.40781	-0.14012	106	0.03188	0.06729	156	0.54833	0.11679
7	0.92440	0.00049	57	0.39697	-0.14211	107	0.03963	0.07487	157	0.55887	0.11465
8	0.91348	0.00067	58	0.38611	-0.14392	108	0.04781	0.08199	158	0.56939	0.11247
9	0.90256	0.00059	59	0.37522	-0.14557	109	0.05635	0.08866	159	0.57991	0.11025
10	0.89164	0.00023	60	0.36431	-0.14703	110	0.06521	0.09489	160	0.59043	0.10800
11	0.88072	-0.00040	61	0.35337	-0.14831	111	0.07434	0.10071	161	0.60093	0.10572
12	0.86982	-0.00129	62	0.34241	-0.14940	112	0.08371	0.10614	162	0.61144	0.10341
13	0.85894	-0.00242	63	0.33144	-0.15030	113	0.09328	0.11117	163	0.62193	0.10107
14	0.84808	-0.00378	64	0.32046	-0.15100	114	0.10304	0.11584	164	0.63243	0.09870
15	0.83724	-0.00536	65	0.30946	-0.15150	115	0.11296	0.12013	165	0.64292	0.09631
16	0.82644	-0.00715	66	0.29846	-0.15180	116	0.12303	0.12408	166	0.65340	0.09389
17	0.81566	-0.00914	67	0.28746	-0.15189	117	0.13321	0.12768	167	0.66388	0.09145
18	0.80492	-0.01133	68	0.27646	-0.15176	118	0.14350	0.13096	168	0.67436	0.08898
19	0.79422	-0.01370	69	0.26547	-0.15140	119	0.15389	0.13392	169	0.68483	0.08649
20	0.78355	-0.01627	70	0.25449	-0.15083	120	0.16435	0.13658	170	0.69531	0.08398
21	0.77294	-0.01903	71	0.24352	-0.15002	121	0.17488	0.13894	171	0.70578	0.08146
22	0.76236	-0.02197	72	0.23258	-0.14897	122	0.18547	0.14102	172	0.71624	0.07891
23	0.75183	-0.02506	73	0.22167	-0.14767	123	0.19610	0.14282	173	0.72671	0.07635
24	0.74133	-0.02829	74	0.21079	-0.14612	124	0.20677	0.14437	174	0.73717	0.07377
25	0.73087	-0.03164	75	0.19996	-0.14431	125	0.21747	0.14567	175	0.74764	0.07118
26	0.72045	-0.03511	76	0.18918	-0.14223	126	0.22819	0.14674	176	0.75810	0.06858
27	0.71006	-0.03869	77	0.17845	-0.13987	127	0.23893	0.14760	177	0.76857	0.06597
28	0.69971	-0.04237	78	0.16780	-0.13723	128	0.24969	0.14825	178	0.77904	0.06335
29	0.68938	-0.04613	79	0.15723	-0.13428	129	0.26044	0.14872	179	0.78951	0.06073
30	0.67908	-0.04998	80	0.14676	-0.13104	130	0.27121	0.14900	180	0.79998	0.05811
31	0.66880	-0.05388	81	0.13638	-0.12749	131	0.28197	0.14911	181	0.81045	0.05548
32	0.65854	-0.05784	82	0.12613	-0.12362	132	0.29273	0.14906	182	0.82093	0.05284
33	0.64828	-0.06183	83	0.11600	-0.11943	133	0.30349	0.14885	183	0.83141	0.05021
34	0.63804	-0.06585	84	0.10602	-0.11491	134	0.31425	0.14850	184	0.84189	0.04758
35	0.62780	-0.06988	85	0.09621	-0.11005	135	0.32499	0.14801	185	0.85238	0.04495
36	0.61756	-0.07392	86	0.08657	-0.10485	136	0.33573	0.14741	186	0.86288	0.04233
37	0.60732	-0.07795	87	0.07714	-0.09930	137	0.34646	0.14668	187	0.87338	0.03972
38	0.59707	-0.08195	88	0.06793	-0.09340	138	0.35718	0.14584	188	0.88389	0.03712
39	0.58680	-0.08593	89	0.05898	-0.08713	139	0.36789	0.14489	189	0.89440	0.03453
40	0.57651	-0.08987	90	0.05030	-0.08048	140	0.37859	0.14384	190	0.90493	0.03195
41	0.56621	-0.09375	91	0.04196	-0.07343	141	0.38928	0.14270	191	0.91546	0.02939
42	0.55588	-0.09757	92	0.03399	-0.06596	142	0.39996	0.14146	192	0.92600	0.02685
43	0.54553	-0.10133	93	0.02646	-0.05805	143	0.41062	0.14013	193	0.93655	0.02434
44	0.53514	-0.10500	94	0.01949	-0.04966	144	0.42128	0.13872	194	0.94711	0.02184
45	0.52472	-0.10859	95	0.01321	-0.04074	145	0.43192	0.13724	195	0.95768	0.01936
46	0.51428	-0.11208	96	0.00782	-0.03126	146	0.44255	0.13568	196	0.96826	0.01689
47	0.50379	-0.11546	97	0.00362	-0.02120	147	0.45318	0.13405	197	0.97884	0.01440
48	0.49327	-0.11874	98	0.00091	-0.01066	148	0.46379	0.13236	198	0.98942	0.01190
49	0.48272	-0.12190	99	-0.00001	0.00019	149	0.47439	0.13060	199	1.00000	0.00937

Table 56: Airfoil shape - FFA-W3-330blend 33.00% airfoil

ID	x	y	ID	x	y	ID	x	y	ID	x	y
[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]			
0	1.00000	-0.01163	50	0.46688	-0.13658	100	0.00080	0.01181	150	0.47845	0.14245
1	0.98932	-0.00879	51	0.45612	-0.13961	101	0.00262	0.02270	151	0.48917	0.14032
2	0.97854	-0.00631	52	0.44533	-0.14250	102	0.00513	0.03345	152	0.49988	0.13815
3	0.96765	-0.00435	53	0.43449	-0.14524	103	0.00875	0.04387	153	0.51059	0.13593
4	0.95668	-0.00289	54	0.42361	-0.14782	104	0.01345	0.05385	154	0.52128	0.13366
5	0.94565	-0.00186	55	0.41270	-0.15022	105	0.01893	0.06342	155	0.53196	0.13135
6	0.93459	-0.00118	56	0.40175	-0.15246	106	0.02508	0.07257	156	0.54264	0.12900
7	0.92351	-0.00081	57	0.39076	-0.15452	107	0.03185	0.08126	157	0.55331	0.12661
8	0.91243	-0.00074	58	0.37975	-0.15641	108	0.03918	0.08948	158	0.56397	0.12419
9	0.90134	-0.00098	59	0.36871	-0.15811	109	0.04700	0.09723	159	0.57462	0.12174
10	0.89025	-0.00151	60	0.35764	-0.15963	110	0.05525	0.10451	160	0.58527	0.11925
11	0.87918	-0.00234	61	0.34654	-0.16095	111	0.06389	0.11133	161	0.59591	0.11673
12	0.86814	-0.00346	62	0.33543	-0.16207	112	0.07287	0.11767	162	0.60655	0.11419
13	0.85712	-0.00485	63	0.32430	-0.16300	113	0.08216	0.12355	163	0.61718	0.11162
14	0.84613	-0.00651	64	0.31315	-0.16372	114	0.09172	0.12898	164	0.62781	0.10903
15	0.83518	-0.00840	65	0.30200	-0.16423	115	0.10151	0.13396	165	0.63843	0.10641
16	0.82426	-0.01052	66	0.29084	-0.16452	116	0.11151	0.13852	166	0.64905	0.10377
17	0.81339	-0.01286	67	0.27967	-0.16459	117	0.12167	0.14266	167	0.65967	0.10110
18	0.80255	-0.01539	68	0.26851	-0.16443	118	0.13199	0.14641	168	0.67028	0.09842
19	0.79176	-0.01811	69	0.25736	-0.16403	119	0.14243	0.14979	169	0.68089	0.09572
20	0.78102	-0.02103	70	0.24622	-0.16339	120	0.15298	0.15281	170	0.69149	0.09300
21	0.77032	-0.02413	71	0.23510	-0.16251	121	0.16362	0.15548	171	0.70210	0.09027
22	0.75968	-0.02740	72	0.22401	-0.16137	122	0.17434	0.15780	172	0.71270	0.08752
23	0.74908	-0.03082	73	0.21294	-0.15998	123	0.18512	0.15981	173	0.72331	0.08476
24	0.73852	-0.03439	74	0.20192	-0.15831	124	0.19595	0.16151	174	0.73391	0.08198
25	0.72800	-0.03807	75	0.19094	-0.15638	125	0.20681	0.16293	175	0.74451	0.07920
26	0.71752	-0.04187	76	0.18002	-0.15417	126	0.21771	0.16407	176	0.75511	0.07640
27	0.70707	-0.04577	77	0.16916	-0.15167	127	0.22863	0.16496	177	0.76571	0.07360
28	0.69666	-0.04976	78	0.15839	-0.14886	128	0.23956	0.16563	178	0.77632	0.07079
29	0.68627	-0.05383	79	0.14770	-0.14574	129	0.25050	0.16607	179	0.78692	0.06797
30	0.67590	-0.05796	80	0.13711	-0.14229	130	0.26144	0.16631	180	0.79753	0.06515
31	0.66556	-0.06214	81	0.12665	-0.13851	131	0.27239	0.16636	181	0.80814	0.06233
32	0.65522	-0.06635	82	0.11632	-0.13438	132	0.28333	0.16622	182	0.81875	0.05950
33	0.64489	-0.07059	83	0.10614	-0.12989	133	0.29427	0.16591	183	0.82936	0.05668
34	0.63457	-0.07484	84	0.09614	-0.12502	134	0.30520	0.16545	184	0.83998	0.05385
35	0.62424	-0.07909	85	0.08636	-0.11975	135	0.31612	0.16483	185	0.85060	0.05103
36	0.61391	-0.08333	86	0.07682	-0.11406	136	0.32704	0.16408	186	0.86123	0.04822
37	0.60357	-0.08755	87	0.06756	-0.10792	137	0.33794	0.16320	187	0.87187	0.04541
38	0.59322	-0.09175	88	0.05862	-0.10134	138	0.34883	0.16219	188	0.88251	0.04262
39	0.58285	-0.09592	89	0.05003	-0.09431	139	0.35970	0.16106	189	0.89316	0.03983
40	0.57246	-0.10003	90	0.04185	-0.08681	140	0.37057	0.15981	190	0.90381	0.03705
41	0.56205	-0.10408	91	0.03414	-0.07884	141	0.38141	0.15847	191	0.91447	0.03428
42	0.55161	-0.10807	92	0.02699	-0.07036	142	0.39225	0.15702	192	0.92514	0.03154
43	0.54114	-0.11198	93	0.02048	-0.06139	143	0.40307	0.15548	193	0.93583	0.02883
44	0.53064	-0.11580	94	0.01465	-0.05197	144	0.41388	0.15385	194	0.94652	0.02612
45	0.52010	-0.11953	95	0.00959	-0.04212	145	0.42467	0.15213	195	0.95721	0.02342
46	0.50953	-0.12317	96	0.00557	-0.03181	146	0.43546	0.15034	196	0.96791	0.02071
47	0.49893	-0.12669	97	0.00270	-0.02113	147	0.44622	0.14847	197	0.97861	0.01798
48	0.48828	-0.13011	98	0.00080	-0.01023	148	0.45698	0.14653	198	0.98930	0.01522
49	0.47760	-0.13341	99	-0.00001	0.00079	149	0.46772	0.14452	199	1.00000	0.01245

Table 57: Airfoil shape - FFA-W3-360 36.00% airfoil

ID	x	y	ID	x	y	ID	x	y	ID	x	y
[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]			
0	1.00000	-0.01393	50	0.46236	-0.14904	100	0.00082	0.01320	150	0.47312	0.15863
1	0.98922	-0.01082	51	0.45147	-0.15213	101	0.00229	0.02435	151	0.48398	0.15629
2	0.97834	-0.00809	52	0.44054	-0.15508	102	0.00392	0.03544	152	0.49483	0.15389
3	0.96731	-0.00598	53	0.42957	-0.15785	103	0.00652	0.04630	153	0.50567	0.15144
4	0.95618	-0.00448	54	0.41856	-0.16045	104	0.01032	0.05685	154	0.51650	0.14893
5	0.94499	-0.00351	55	0.40750	-0.16287	105	0.01487	0.06709	155	0.52731	0.14637
6	0.93377	-0.00294	56	0.39640	-0.16510	106	0.02005	0.07700	156	0.53812	0.14377
7	0.92253	-0.00273	57	0.38527	-0.16715	107	0.02593	0.08652	157	0.54891	0.14113
8	0.91128	-0.00287	58	0.37411	-0.16901	108	0.03245	0.09562	158	0.55970	0.13845
9	0.90004	-0.00335	59	0.36292	-0.17067	109	0.03955	0.10426	159	0.57048	0.13573
10	0.88882	-0.00416	60	0.35170	-0.17214	110	0.04717	0.11244	160	0.58125	0.13297
11	0.87762	-0.00530	61	0.34046	-0.17340	111	0.05528	0.12013	161	0.59201	0.13019
12	0.86646	-0.00676	62	0.32919	-0.17446	112	0.06382	0.12733	162	0.60277	0.12738
13	0.85534	-0.00851	63	0.31791	-0.17530	113	0.07277	0.13402	163	0.61352	0.12454
14	0.84426	-0.01055	64	0.30662	-0.17593	114	0.08206	0.14021	164	0.62427	0.12167
15	0.83323	-0.01285	65	0.29532	-0.17633	115	0.09165	0.14593	165	0.63501	0.11878
16	0.82225	-0.01539	66	0.28401	-0.17651	116	0.10151	0.15116	166	0.64574	0.11587
17	0.81132	-0.01815	67	0.27270	-0.17644	117	0.11160	0.15593	167	0.65647	0.11294
18	0.80043	-0.02109	68	0.26140	-0.17613	118	0.12188	0.16027	168	0.66720	0.11000
19	0.78960	-0.02423	69	0.25011	-0.17557	119	0.13232	0.16419	169	0.67793	0.10703
20	0.77882	-0.02754	70	0.23884	-0.17476	120	0.14290	0.16771	170	0.68865	0.10406
21	0.76808	-0.03101	71	0.22759	-0.17368	121	0.15360	0.17083	171	0.69937	0.10106
22	0.75740	-0.03464	72	0.21637	-0.17234	122	0.16440	0.17357	172	0.71009	0.09806
23	0.74676	-0.03842	73	0.20519	-0.17072	123	0.17529	0.17595	173	0.72081	0.09504
24	0.73617	-0.04234	74	0.19406	-0.16883	124	0.18624	0.17799	174	0.73153	0.09201
25	0.72562	-0.04637	75	0.18297	-0.16665	125	0.19725	0.17970	175	0.74224	0.08896
26	0.71512	-0.05051	76	0.17196	-0.16418	126	0.20830	0.18110	176	0.75296	0.08591
27	0.70464	-0.05473	77	0.16101	-0.16142	127	0.21938	0.18221	177	0.76367	0.08286
28	0.69419	-0.05903	78	0.15015	-0.15833	128	0.23048	0.18306	178	0.77439	0.07979
29	0.68377	-0.06339	79	0.13940	-0.15491	129	0.24159	0.18366	179	0.78510	0.07672
30	0.67336	-0.06780	80	0.12877	-0.15115	130	0.25272	0.18403	180	0.79582	0.07364
31	0.66297	-0.07223	81	0.11827	-0.14702	131	0.26384	0.18418	181	0.80654	0.07056
32	0.65258	-0.07669	82	0.10792	-0.14253	132	0.27497	0.18412	182	0.81726	0.06747
33	0.64219	-0.08115	83	0.09776	-0.13765	133	0.28609	0.18386	183	0.82798	0.06439
34	0.63180	-0.08561	84	0.08781	-0.13235	134	0.29720	0.18343	184	0.83871	0.06130
35	0.62140	-0.09005	85	0.07812	-0.12660	135	0.30831	0.18283	185	0.84943	0.05821
36	0.61099	-0.09447	86	0.06873	-0.12038	136	0.31940	0.18207	186	0.86017	0.05513
37	0.60056	-0.09885	87	0.05969	-0.11366	137	0.33048	0.18115	187	0.87090	0.05205
38	0.59011	-0.10318	88	0.05105	-0.10644	138	0.34155	0.18008	188	0.88164	0.04897
39	0.57964	-0.10747	89	0.04286	-0.09872	139	0.35260	0.17888	189	0.89239	0.04589
40	0.56914	-0.11169	90	0.03516	-0.09050	140	0.36364	0.17756	190	0.90314	0.04282
41	0.55862	-0.11585	91	0.02806	-0.08177	141	0.37466	0.17611	191	0.91389	0.03976
42	0.54807	-0.11993	92	0.02166	-0.07252	142	0.38567	0.17455	192	0.92466	0.03672
43	0.53748	-0.12392	93	0.01604	-0.06279	143	0.39665	0.17288	193	0.93543	0.03369
44	0.52686	-0.12783	94	0.01113	-0.05267	144	0.40762	0.17110	194	0.94620	0.03065
45	0.51620	-0.13164	95	0.00700	-0.04221	145	0.41858	0.16923	195	0.95697	0.02760
46	0.50551	-0.13535	96	0.00397	-0.03142	146	0.42952	0.16727	196	0.96774	0.02452
47	0.49478	-0.13895	97	0.00207	-0.02035	147	0.44044	0.16522	197	0.97850	0.02140
48	0.48401	-0.14244	98	0.00069	-0.00916	148	0.45135	0.16310	198	0.98926	0.01823
49	0.47321	-0.14580	99	-0.00001	0.00205	149	0.46224	0.16090	199	1.00000	0.01503

Table 58: Airfoil shape - Interpolated48 48.00% airfoil

ID	x	y	ID	x	y	ID	x	y	ID	x	y
[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]			
0	1.00000	-0.01857	50	0.44979	-0.20346	100	0.00055	0.01465	150	0.45796	0.21569
1	0.98893	-0.01432	51	0.43850	-0.20748	101	0.00169	0.02646	151	0.46926	0.21258
2	0.97767	-0.01060	52	0.42712	-0.21126	102	0.00286	0.03826	152	0.48054	0.20938
3	0.96615	-0.00772	53	0.41567	-0.21480	103	0.00430	0.05000	153	0.49179	0.20610
4	0.95445	-0.00573	54	0.40414	-0.21809	104	0.00649	0.06160	154	0.50301	0.20273
5	0.94263	-0.00448	55	0.39254	-0.22111	105	0.00950	0.07305	155	0.51422	0.19929
6	0.93077	-0.00380	56	0.38087	-0.22387	106	0.01307	0.08433	156	0.52540	0.19577
7	0.91888	-0.00365	57	0.36915	-0.22636	107	0.01711	0.09544	157	0.53657	0.19220
8	0.90699	-0.00402	58	0.35736	-0.22856	108	0.02165	0.10634	158	0.54771	0.18857
9	0.89513	-0.00488	59	0.34553	-0.23048	109	0.02675	0.11699	159	0.55884	0.18488
10	0.88330	-0.00624	60	0.33366	-0.23209	110	0.03238	0.12737	160	0.56996	0.18115
11	0.87154	-0.00808	61	0.32174	-0.23339	111	0.03853	0.13745	161	0.58106	0.17737
12	0.85985	-0.01036	62	0.30980	-0.23437	112	0.04518	0.14719	162	0.59214	0.17354
13	0.84824	-0.01305	63	0.29784	-0.23502	113	0.05232	0.15658	163	0.60322	0.16968
14	0.83673	-0.01613	64	0.28586	-0.23533	114	0.05995	0.16557	164	0.61428	0.16578
15	0.82530	-0.01955	65	0.27389	-0.23528	115	0.06806	0.17413	165	0.62534	0.16185
16	0.81398	-0.02327	66	0.26192	-0.23487	116	0.07662	0.18223	166	0.63638	0.15788
17	0.80274	-0.02727	67	0.24997	-0.23409	117	0.08560	0.18986	167	0.64742	0.15389
18	0.79158	-0.03152	68	0.23805	-0.23292	118	0.09496	0.19700	168	0.65845	0.14987
19	0.78052	-0.03600	69	0.22618	-0.23137	119	0.10469	0.20363	169	0.66947	0.14583
20	0.76955	-0.04070	70	0.21437	-0.22943	120	0.11474	0.20975	170	0.68048	0.14177
21	0.75866	-0.04561	71	0.20264	-0.22709	121	0.12509	0.21536	171	0.69150	0.13768
22	0.74786	-0.05070	72	0.19099	-0.22434	122	0.13568	0.22048	172	0.70250	0.13358
23	0.73713	-0.05597	73	0.17945	-0.22119	123	0.14651	0.22508	173	0.71351	0.12946
24	0.72648	-0.06138	74	0.16804	-0.21764	124	0.15753	0.22917	174	0.72450	0.12532
25	0.71589	-0.06693	75	0.15676	-0.21367	125	0.16873	0.23275	175	0.73550	0.12117
26	0.70536	-0.07259	76	0.14565	-0.20926	126	0.18007	0.23585	176	0.74649	0.11701
27	0.69487	-0.07834	77	0.13473	-0.20441	127	0.19152	0.23847	177	0.75749	0.11283
28	0.68442	-0.08416	78	0.12402	-0.19911	128	0.20307	0.24064	178	0.76848	0.10864
29	0.67400	-0.09003	79	0.11354	-0.19337	129	0.21468	0.24237	179	0.77947	0.10444
30	0.66360	-0.09595	80	0.10333	-0.18718	130	0.22635	0.24370	180	0.79046	0.10024
31	0.65321	-0.10189	81	0.09341	-0.18054	131	0.23805	0.24466	181	0.80146	0.09603
32	0.64282	-0.10784	82	0.08383	-0.17342	132	0.24977	0.24527	182	0.81245	0.09181
33	0.63243	-0.11378	83	0.07463	-0.16582	133	0.26151	0.24555	183	0.82345	0.08759
34	0.62203	-0.11971	84	0.06584	-0.15776	134	0.27324	0.24552	184	0.83445	0.08337
35	0.61161	-0.12561	85	0.05751	-0.14923	135	0.28497	0.24520	185	0.84545	0.07914
36	0.60116	-0.13147	86	0.04966	-0.14025	136	0.29669	0.24461	186	0.85646	0.07492
37	0.59068	-0.13727	87	0.04231	-0.13088	137	0.30838	0.24377	187	0.86748	0.07071
38	0.58016	-0.14300	88	0.03546	-0.12113	138	0.32006	0.24269	188	0.87850	0.06649
39	0.56961	-0.14867	89	0.02919	-0.11100	139	0.33172	0.24138	189	0.88952	0.06228
40	0.55901	-0.15426	90	0.02354	-0.10053	140	0.34334	0.23987	190	0.90056	0.05808
41	0.54836	-0.15975	91	0.01852	-0.08974	141	0.35494	0.23815	191	0.91160	0.05389
42	0.53766	-0.16515	92	0.01411	-0.07870	142	0.36651	0.23625	192	0.92265	0.04971
43	0.52690	-0.17043	93	0.01024	-0.06745	143	0.37805	0.23419	193	0.93372	0.04556
44	0.51608	-0.17558	94	0.00694	-0.05603	144	0.38956	0.23196	194	0.94479	0.04140
45	0.50519	-0.18061	95	0.00440	-0.04443	145	0.40103	0.22957	195	0.95586	0.03722
46	0.49425	-0.18550	96	0.00267	-0.03269	146	0.41248	0.22705	196	0.96692	0.03301
47	0.48324	-0.19024	97	0.00149	-0.02086	147	0.42389	0.22439	197	0.97796	0.02875
48	0.47216	-0.19483	98	0.00044	-0.00901	148	0.43528	0.22160	198	0.98899	0.02442
49	0.46101	-0.19924	99	-0.00001	0.00283	149	0.44663	0.21870	199	1.00000	0.02004

Table 59: Airfoil shape - Interpolated72 72.00% airfoil

ID	x	y	ID	x	y	ID	x	y	ID	x	y
[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]			
0	0.99937	-0.02908	50	0.43360	-0.35508	100	0.00127	0.02867	150	0.47164	0.35905
1	0.98729	-0.03423	51	0.42035	-0.35634	101	0.00237	0.04173	151	0.48446	0.35716
2	0.97522	-0.03944	52	0.40707	-0.35719	102	0.00386	0.05475	152	0.49723	0.35501
3	0.96362	-0.04561	53	0.39378	-0.35762	103	0.00587	0.06770	153	0.50996	0.35259
4	0.95233	-0.05236	54	0.38047	-0.35764	104	0.00845	0.08053	154	0.52264	0.34991
5	0.94125	-0.05946	55	0.36717	-0.35724	105	0.01152	0.09325	155	0.53526	0.34698
6	0.93037	-0.06687	56	0.35389	-0.35645	106	0.01501	0.10586	156	0.54782	0.34381
7	0.91965	-0.07454	57	0.34064	-0.35526	107	0.01892	0.11833	157	0.56032	0.34040
8	0.90910	-0.08243	58	0.32743	-0.35367	108	0.02329	0.13065	158	0.57276	0.33675
9	0.89872	-0.09056	59	0.31428	-0.35166	109	0.02809	0.14280	159	0.58513	0.33287
10	0.88854	-0.09895	60	0.30121	-0.34924	110	0.03334	0.15476	160	0.59742	0.32877
11	0.87845	-0.10745	61	0.28821	-0.34641	111	0.03901	0.16651	161	0.60965	0.32445
12	0.86841	-0.11603	62	0.27532	-0.34316	112	0.04511	0.17804	162	0.62179	0.31991
13	0.85840	-0.12464	63	0.26254	-0.33949	113	0.05163	0.18934	163	0.63386	0.31516
14	0.84839	-0.13327	64	0.24990	-0.33540	114	0.05857	0.20038	164	0.64584	0.31020
15	0.83837	-0.14189	65	0.23739	-0.33090	115	0.06593	0.21113	165	0.65775	0.30504
16	0.82833	-0.15049	66	0.22505	-0.32599	116	0.07369	0.22160	166	0.66956	0.29968
17	0.81825	-0.15906	67	0.21288	-0.32067	117	0.08184	0.23175	167	0.68129	0.29413
18	0.80814	-0.16760	68	0.20089	-0.31494	118	0.09038	0.24158	168	0.69292	0.28838
19	0.79797	-0.17608	69	0.18909	-0.30884	119	0.09929	0.25107	169	0.70447	0.28244
20	0.78775	-0.18450	70	0.17750	-0.30237	120	0.10856	0.26020	170	0.71592	0.27632
21	0.77746	-0.19284	71	0.16614	-0.29551	121	0.11815	0.26898	171	0.72727	0.27002
22	0.76710	-0.20110	72	0.15502	-0.28827	122	0.12807	0.27740	172	0.73853	0.26353
23	0.75666	-0.20926	73	0.14417	-0.28064	123	0.13829	0.28543	173	0.74969	0.25687
24	0.74612	-0.21731	74	0.13359	-0.27264	124	0.14881	0.29306	174	0.76074	0.25004
25	0.73548	-0.22523	75	0.12331	-0.26427	125	0.15960	0.30030	175	0.77169	0.24303
26	0.72475	-0.23302	76	0.11334	-0.25553	126	0.17065	0.30714	176	0.78254	0.23585
27	0.71390	-0.24067	77	0.10369	-0.24645	127	0.18193	0.31357	177	0.79328	0.22851
28	0.70295	-0.24817	78	0.09439	-0.23702	128	0.19344	0.31958	178	0.80391	0.22101
29	0.69188	-0.25550	79	0.08544	-0.22726	129	0.20514	0.32519	179	0.81443	0.21334
30	0.68069	-0.26265	80	0.07688	-0.21716	130	0.21703	0.33040	180	0.82483	0.20552
31	0.66939	-0.26963	81	0.06871	-0.20675	131	0.22908	0.33521	181	0.83513	0.19754
32	0.65796	-0.27641	82	0.06096	-0.19603	132	0.24128	0.33963	182	0.84531	0.18941
33	0.64642	-0.28298	83	0.05365	-0.18502	133	0.25361	0.34367	183	0.85537	0.18113
34	0.63475	-0.28934	84	0.04677	-0.17373	134	0.26605	0.34732	184	0.86532	0.17270
35	0.62296	-0.29548	85	0.04034	-0.16219	135	0.27860	0.35059	185	0.87515	0.16413
36	0.61105	-0.30139	86	0.03435	-0.15042	136	0.29124	0.35351	186	0.88486	0.15541
37	0.59903	-0.30706	87	0.02882	-0.13843	137	0.30395	0.35606	187	0.89445	0.14656
38	0.58688	-0.31248	88	0.02378	-0.12623	138	0.31672	0.35826	188	0.90392	0.13757
39	0.57462	-0.31764	89	0.01923	-0.11385	139	0.32955	0.36011	189	0.91327	0.12844
40	0.56225	-0.32253	90	0.01518	-0.10131	140	0.34242	0.36163	190	0.92249	0.11918
41	0.54977	-0.32713	91	0.01159	-0.08863	141	0.35532	0.36284	191	0.93159	0.10979
42	0.53720	-0.33147	92	0.00843	-0.07584	142	0.36825	0.36369	192	0.94057	0.10028
43	0.52454	-0.33558	93	0.00578	-0.06294	143	0.38120	0.36421	193	0.94942	0.09065
44	0.51180	-0.33941	94	0.00372	-0.04995	144	0.39415	0.36440	194	0.95815	0.08089
45	0.49896	-0.34291	95	0.00220	-0.03688	145	0.40711	0.36426	195	0.96674	0.07099
46	0.48604	-0.34607	96	0.00109	-0.02378	146	0.42006	0.36380	196	0.97517	0.06096
47	0.47303	-0.34888	97	0.00031	-0.01067	147	0.43299	0.36303	197	0.98343	0.05078
48	0.45995	-0.35133	98	0.00002	0.00246	148	0.44590	0.36199	198	0.99150	0.04044
49	0.44680	-0.35340	99	0.00041	0.01558	149	0.45879	0.36066	199	0.99937	0.02993

Table 60: Airfoil aerodynamic coefficients - FFA-W3-211 (Re=1.00e+07)

α	C_L	C_D	C_M	α	C_L	C_D	C_M	α	C_L	C_D	C_M
[deg]	[-]	[-]	[-]	[deg]	[-]	[-]	[-]	[deg]	[-]	[-]	[-]
-180.00	0.00000	0.02464	0.00000	-40.29	-0.70655	0.62488	0.20491	44.43	0.96801	0.73293	-0.25784
-177.71	0.05403	0.02534	0.09143	-36.14	-0.73188	0.51941	0.15416	48.57	0.91904	0.84130	-0.28035
-175.43	0.10805	0.02742	0.18286	-32.00	-0.75635	0.41871	0.10137	52.71	0.86109	0.94773	-0.30163
-173.14	0.16208	0.03088	0.27429	-28.00	-0.85636	0.28691	0.06527	56.86	0.79357	1.05001	-0.32226
-170.86	0.21610	0.03570	0.36571	-24.00	-1.18292	0.13960	0.01647	61.00	0.71651	1.14600	-0.34247
-168.57	0.27013	0.05599	0.39192	-20.00	-1.23596	0.08345	-0.00352	65.14	0.63044	1.23371	-0.36135
-166.29	0.32415	0.08143	0.37898	-18.00	-1.22536	0.06509	-0.00672	69.29	0.53632	1.31129	-0.38024
-164.00	0.37818	0.11112	0.36605	-16.00	-1.20476	0.04888	-0.00881	73.43	0.43546	1.37714	-0.39704
-161.71	0.43220	0.14485	0.35312	-14.00	-1.18332	0.03417	-0.01101	77.57	0.32947	1.42988	-0.41341
-159.43	0.48623	0.18242	0.34768	-12.00	-1.10093	0.02132	-0.02269	81.71	0.22019	1.46842	-0.42844
-157.14	0.54025	0.22359	0.36471	-10.00	-0.88209	0.01386	-0.04397	85.86	0.10965	1.49196	-0.44159
-154.86	0.59428	0.26810	0.38175	-8.00	-0.62981	0.01075	-0.05756	90.00	0.00000	1.50000	-0.45474
-152.57	0.64830	0.31566	0.39878	-6.00	-0.37670	0.00882	-0.06747	94.14	-0.07675	1.49196	-0.46149
-150.29	0.70233	0.36597	0.41581	-4.00	-0.12177	0.00702	-0.07680	98.29	-0.15413	1.46842	-0.46824
-148.00	0.75635	0.41871	0.41955	-2.00	0.12810	0.00663	-0.08283	102.43	-0.23063	1.42988	-0.47101
-143.86	0.73188	0.51941	0.42287	-1.00	0.25192	0.00664	-0.08534	106.57	-0.30482	1.37714	-0.47096
-139.71	0.70655	0.62488	0.42632	0.00	0.37535	0.00670	-0.08777	110.71	-0.37542	1.31129	-0.46998
-135.57	0.67760	0.73293	0.43163	1.00	0.49828	0.00681	-0.09011	114.86	-0.44131	1.23371	-0.46448
-131.43	0.64333	0.84130	0.43694	2.00	0.62052	0.00698	-0.09234	119.00	-0.50156	1.14600	-0.45897
-127.29	0.60277	0.94773	0.44389	3.00	0.74200	0.00720	-0.09447	123.14	-0.55550	1.05001	-0.45171
-123.14	0.55550	1.05001	0.45171	4.00	0.86238	0.00751	-0.09646	127.29	-0.60277	0.94773	-0.44389
-119.00	0.50156	1.14600	0.45897	5.00	0.98114	0.00796	-0.09828	131.43	-0.64333	0.84130	-0.43694
-114.86	0.44131	1.23371	0.46448	6.00	1.09662	0.00872	-0.09977	135.57	-0.67760	0.73293	-0.43163
-110.71	0.37542	1.31129	0.46998	7.00	1.20904	0.00968	-0.10095	139.71	-0.70655	0.62488	-0.42632
-106.57	0.30482	1.37714	0.47096	8.00	1.31680	0.01097	-0.10163	143.86	-0.73188	0.51941	-0.42287
-102.43	0.23063	1.42988	0.47101	9.00	1.42209	0.01227	-0.10207	148.00	-0.75635	0.41871	-0.41955
-98.29	0.15413	1.46842	0.46824	10.00	1.52361	0.01369	-0.10213	150.29	-0.70233	0.36597	-0.41581
-94.14	0.07675	1.49196	0.46149	11.00	1.61988	0.01529	-0.10174	152.57	-0.64830	0.31566	-0.39878
-90.00	0.00000	1.50000	0.45474	12.00	1.70937	0.01717	-0.10087	154.86	-0.59428	0.26810	-0.38175
-85.86	-0.07675	1.49196	0.44026	13.00	1.78681	0.01974	-0.09936	157.14	-0.54025	0.22359	-0.36471
-81.71	-0.15413	1.46842	0.42578	14.00	1.84290	0.02368	-0.09720	159.43	-0.48623	0.18242	-0.34768
-77.57	-0.23063	1.42988	0.40821	15.00	1.85313	0.03094	-0.09410	161.71	-0.43220	0.14485	-0.37026
-73.43	-0.30482	1.37714	0.38846	16.00	1.80951	0.04303	-0.09144	164.00	-0.37818	0.11112	-0.40605
-69.29	-0.37542	1.31129	0.36815	18.00	1.66033	0.07730	-0.09242	166.29	-0.32415	0.08143	-0.44184
-65.14	-0.44131	1.23371	0.34519	20.00	1.56152	0.11202	-0.09871	168.57	-0.27013	0.05599	-0.47763
-61.00	-0.50156	1.14600	0.32223	24.00	1.43327	0.18408	-0.11770	170.86	-0.21610	0.03570	-0.45714
-56.86	-0.55550	1.05001	0.29864	28.00	1.29062	0.27589	-0.14566	173.14	-0.16208	0.03088	-0.34286
-52.71	-0.60277	0.94773	0.27486	32.00	1.08050	0.41871	-0.18266	175.43	-0.10805	0.02742	-0.22857
-48.57	-0.64333	0.84130	0.25128	36.14	1.04554	0.51941	-0.20913	177.71	-0.05403	0.02534	-0.11429
-44.43	-0.67760	0.73293	0.22810	40.29	1.00936	0.62488	-0.23534	180.00	0.00000	0.02464	0.00000

Table 61: Airfoil aerodynamic coefficients - FFA-W3-241 (Re=1.00e+07)

α [deg]	C_L [-]	C_D [-]	C_M [-]	α [deg]	C_L [-]	C_D [-]	C_M [-]	α [deg]	C_L [-]	C_D [-]	C_M [-]
-180.00	0.00000	0.01178	0.00000	-40.29	-0.74511	0.60319	0.20705	44.43	1.01259	0.71263	-0.25992
-177.71	0.05818	0.01248	0.09143	-36.14	-0.77925	0.49645	0.14561	48.57	0.95478	0.82249	-0.28216
-175.43	0.11636	0.01460	0.18286	-32.00	-0.81449	0.39460	0.08131	52.71	0.88932	0.93051	-0.30323
-173.14	0.17453	0.01811	0.27429	-28.00	-1.07781	0.22252	0.04592	56.86	0.81542	1.03447	-0.32368
-170.86	0.23271	0.02300	0.36571	-24.00	-1.12692	0.15159	0.01901	61.00	0.73296	1.13222	-0.34380
-168.57	0.29089	0.02922	0.39568	-20.00	-1.14480	0.09699	0.00063	65.14	0.64236	1.22176	-0.36292
-166.29	0.34907	0.05382	0.38876	-18.00	-1.12797	0.07744	-0.00342	69.29	0.54450	1.30123	-0.38204
-164.00	0.40725	0.08379	0.38184	-16.00	-1.09392	0.06122	-0.00587	73.43	0.44065	1.36903	-0.39944
-161.71	0.46542	0.11786	0.37492	-14.00	-1.05961	0.04667	-0.00652	77.57	0.33237	1.42376	-0.41648
-159.43	0.52360	0.15581	0.37408	-12.00	-1.03121	0.03302	-0.00755	81.71	0.22148	1.46433	-0.43231
-157.14	0.58178	0.19740	0.39148	-10.00	-0.93706	0.02027	-0.02243	85.86	0.10997	1.48990	-0.44643
-154.86	0.63996	0.24237	0.40888	-8.00	-0.67380	0.01168	-0.05583	90.00	0.00000	1.50000	-0.46055
-152.57	0.69814	0.29043	0.42628	-6.00	-0.40391	0.00918	-0.07159	94.14	-0.07698	1.48990	-0.46732
-150.29	0.75631	0.34128	0.44368	-4.00	-0.14226	0.00839	-0.08123	98.29	-0.15503	1.46433	-0.47409
-148.00	0.81449	0.39460	0.44537	-2.00	0.11580	0.00810	-0.08892	102.43	-0.23266	1.42376	-0.47695
-143.86	0.77925	0.49645	0.44436	-1.00	0.24382	0.00808	-0.09235	106.57	-0.30846	1.36903	-0.47705
-139.71	0.74511	0.60319	0.44360	0.00	0.37113	0.00813	-0.09556	110.71	-0.38115	1.30123	-0.47627
-135.57	0.70881	0.71263	0.44609	1.00	0.49766	0.00824	-0.09857	114.86	-0.44965	1.22176	-0.47130
-131.43	0.66835	0.82249	0.44858	2.00	0.62334	0.00842	-0.10139	119.00	-0.51307	1.13222	-0.46633
-127.29	0.62253	0.93051	0.45370	3.00	0.74798	0.00867	-0.10403	123.14	-0.57080	1.03447	-0.46020
-123.14	0.57080	1.03447	0.46020	4.00	0.87137	0.00901	-0.10645	127.29	-0.62253	0.93051	-0.45370
-119.00	0.51307	1.13222	0.46633	5.00	0.99320	0.00945	-0.10863	131.43	-0.66835	0.82249	-0.44858
-114.86	0.44965	1.22176	0.47130	6.00	1.11325	0.00998	-0.11057	135.57	-0.70881	0.71263	-0.44609
-110.71	0.38115	1.30123	0.47627	7.00	1.23037	0.01070	-0.11214	139.71	-0.74511	0.60319	-0.44360
-106.57	0.30846	1.36903	0.47705	8.00	1.34496	0.01153	-0.11337	143.86	-0.77925	0.49645	-0.44436
-102.43	0.23266	1.42376	0.47695	9.00	1.45407	0.01269	-0.11396	148.00	-0.81449	0.39460	-0.44537
-98.29	0.15503	1.46433	0.47409	10.00	1.55911	0.01396	-0.11403	150.29	-0.75631	0.34128	-0.44368
-94.14	0.07698	1.48990	0.46732	11.00	1.65779	0.01545	-0.11336	152.57	-0.69814	0.29043	-0.42628
-90.00	0.00000	1.50000	0.46055	12.00	1.74834	0.01724	-0.11187	154.86	-0.63996	0.24237	-0.40888
-85.86	-0.07698	1.48990	0.44509	13.00	1.82666	0.01961	-0.10935	157.14	-0.58178	0.19740	-0.39148
-81.71	-0.15503	1.46433	0.42964	14.00	1.88831	0.02293	-0.10606	159.43	-0.52360	0.15581	-0.37408
-77.57	-0.23266	1.42376	0.41125	15.00	1.92579	0.02795	-0.10238	161.71	-0.46542	0.11786	-0.39207
-73.43	-0.30846	1.36903	0.39081	16.00	1.92722	0.03609	-0.09887	164.00	-0.40725	0.08379	-0.42184
-69.29	-0.38115	1.30123	0.36988	18.00	1.80055	0.06534	-0.09497	166.29	-0.34907	0.05382	-0.45162
-65.14	-0.44965	1.22176	0.34663	20.00	1.63088	0.10459	-0.09996	168.57	-0.29089	0.02922	-0.48139
-61.00	-0.51307	1.13222	0.32339	24.00	1.43345	0.19148	-0.12589	170.86	-0.23271	0.02300	-0.45714
-56.86	-0.57080	1.03447	0.29984	28.00	1.28805	0.28629	-0.15453	173.14	-0.17453	0.01811	-0.34286
-52.71	-0.62253	0.93051	0.27618	32.00	1.16356	0.39460	-0.18396	175.43	-0.11636	0.01460	-0.22857
-48.57	-0.66835	0.82249	0.25280	36.14	1.11321	0.49645	-0.21099	177.71	-0.05818	0.01248	-0.11429
-44.43	-0.70881	0.71263	0.22992	40.29	1.06444	0.60319	-0.23768	180.00	0.00000	0.01178	0.00000

Table 62: Airfoil aerodynamic coefficients - FFA-W3-270blend (Re=1.00e+07)

α [deg]	C_L [-]	C_D [-]	C_M [-]	α [deg]	C_L [-]	C_D [-]	C_M [-]	α [deg]	C_L [-]	C_D [-]	C_M [-]
-180.00	0.00000	0.01545	0.00000	-40.29	-0.76812	0.56814	0.20447	44.43	1.02914	0.66995	-0.25508
-177.71	0.06213	0.01611	0.09143	-36.14	-0.81660	0.46882	0.13957	48.57	0.95850	0.77214	-0.27485
-175.43	0.12426	0.01807	0.18286	-32.00	-0.86981	0.37404	0.07138	52.71	0.88325	0.87258	-0.29346
-173.14	0.18639	0.02133	0.27429	-28.00	-1.09837	0.21880	0.04400	56.86	0.80225	0.96921	-0.31145
-170.86	0.24852	0.02587	0.36571	-24.00	-1.08339	0.15982	0.02166	61.00	0.71510	1.06002	-0.32925
-168.57	0.31064	0.03289	0.39874	-20.00	-1.06990	0.10744	0.00422	65.14	0.62200	1.14315	-0.34641
-166.29	0.37277	0.05681	0.39672	-18.00	-1.05454	0.08690	-0.00035	69.29	0.52364	1.21688	-0.36357
-164.00	0.43490	0.08471	0.39470	-16.00	-1.03432	0.06844	-0.00334	73.43	0.42107	1.27969	-0.37949
-161.71	0.49703	0.11643	0.39268	-14.00	-1.08360	0.04733	-0.00283	77.57	0.31569	1.33030	-0.39517
-159.43	0.55916	0.15176	0.39544	-12.00	-1.09489	0.03085	-0.00556	81.71	0.20913	1.36768	-0.40983
-157.14	0.62129	0.19048	0.41254	-10.00	-0.92665	0.01984	-0.02952	85.86	0.10324	1.39107	-0.42306
-154.86	0.68342	0.23234	0.42964	-8.00	-0.69676	0.01439	-0.04822	90.00	0.00000	1.40000	-0.43630
-152.57	0.74555	0.27708	0.44674	-6.00	-0.43628	0.01155	-0.06483	94.14	-0.07227	1.39107	-0.44302
-150.29	0.80768	0.32441	0.46384	-4.00	-0.16252	0.01026	-0.07919	98.29	-0.14639	1.36768	-0.44973
-148.00	0.86981	0.37404	0.46186	-2.00	0.10709	0.00976	-0.09041	102.43	-0.22098	1.33030	-0.45298
-143.86	0.81660	0.46882	0.45335	-1.00	0.23993	0.00967	-0.09517	106.57	-0.29475	1.27969	-0.45377
-139.71	0.76812	0.56814	0.44523	0.00	0.37158	0.00968	-0.09953	110.71	-0.36655	1.21688	-0.45387
-135.57	0.72040	0.66995	0.44237	1.00	0.50210	0.00976	-0.10355	114.86	-0.43540	1.14315	-0.45063
-131.43	0.67095	0.77214	0.43951	2.00	0.63139	0.00993	-0.10725	119.00	-0.50057	1.06002	-0.44739
-127.29	0.61828	0.87258	0.44072	3.00	0.75951	0.01016	-0.11068	123.14	-0.56158	0.96921	-0.44407
-123.14	0.56158	0.96921	0.44407	4.00	0.88638	0.01045	-0.11385	127.29	-0.61828	0.87258	-0.44072
-119.00	0.50057	1.06002	0.44739	5.00	1.01172	0.01082	-0.11673	131.43	-0.67095	0.77214	-0.43951
-114.86	0.43540	1.14315	0.45063	6.00	1.13430	0.01140	-0.11923	135.57	-0.72040	0.66995	-0.44237
-110.71	0.36655	1.21688	0.45387	7.00	1.25536	0.01198	-0.12145	139.71	-0.76812	0.56814	-0.44523
-106.57	0.29475	1.27969	0.45377	8.00	1.37379	0.01267	-0.12328	143.86	-0.81660	0.46882	-0.45335
-102.43	0.22098	1.33030	0.45298	9.00	1.48841	0.01353	-0.12460	148.00	-0.86981	0.37404	-0.46186
-98.29	0.14639	1.36768	0.44973	10.00	1.59782	0.01460	-0.12526	150.29	-0.80768	0.32441	-0.46384
-94.14	0.07227	1.39107	0.44302	11.00	1.70005	0.01597	-0.12505	152.57	-0.74555	0.27708	-0.44674
-90.00	0.00000	1.40000	0.43630	12.00	1.79190	0.01777	-0.12370	154.86	-0.68342	0.23234	-0.42964
-85.86	-0.07227	1.39107	0.42180	13.00	1.86782	0.02035	-0.12093	157.14	-0.62129	0.19048	-0.41254
-81.71	-0.14639	1.36768	0.40730	14.00	1.92687	0.02385	-0.11725	159.43	-0.55916	0.15176	-0.39544
-77.57	-0.22098	1.33030	0.39020	15.00	1.90901	0.03236	-0.10931	161.71	-0.49703	0.11643	-0.40982
-73.43	-0.29475	1.27969	0.37125	16.00	1.88548	0.04259	-0.10525	164.00	-0.43490	0.08471	-0.43470
-69.29	-0.36655	1.21688	0.35190	18.00	1.72106	0.07672	-0.10292	166.29	-0.37277	0.05681	-0.45958
-65.14	-0.43540	1.14315	0.33068	20.00	1.54737	0.11914	-0.11017	168.57	-0.31064	0.03289	-0.48445
-61.00	-0.50057	1.06002	0.30945	24.00	1.37176	0.20189	-0.13431	170.86	-0.24852	0.02587	-0.45714
-56.86	-0.56158	0.96921	0.28815	28.00	1.33611	0.27981	-0.15777	173.14	-0.18639	0.02133	-0.34286
-52.71	-0.61828	0.87258	0.26684	32.00	1.24258	0.37404	-0.18432	175.43	-0.12426	0.01807	-0.22857
-48.57	-0.67095	0.77214	0.24576	36.14	1.16657	0.46882	-0.21002	177.71	-0.06213	0.01611	-0.11429
-44.43	-0.72040	0.66995	0.22512	40.29	1.09731	0.56814	-0.23531	180.00	0.00000	0.01545	0.00000

Table 63: Airfoil aerodynamic coefficients - FFA-W3-301 (Re=1.00e+07)

α [deg]	C_L [-]	C_D [-]	C_M [-]	α [deg]	C_L [-]	C_D [-]	C_M [-]	α [deg]	C_L [-]	C_D [-]	C_M [-]
-180.00	0.00000	0.02454	0.00000	-40.29	-0.78187	0.53255	0.20181	44.43	1.03498	0.62677	-0.25011
-177.71	0.06508	0.02514	0.09143	-36.14	-0.84257	0.44061	0.13644	48.57	0.95364	0.72131	-0.26746
-175.43	0.13016	0.02694	0.18286	-32.00	-0.91115	0.35287	0.06760	52.71	0.87040	0.81421	-0.28365
-173.14	0.19525	0.02993	0.27429	-28.00	-1.10349	0.21721	0.04231	56.86	0.78383	0.90355	-0.29923
-170.86	0.26033	0.03408	0.36571	-24.00	-1.10737	0.15629	0.02026	61.00	0.69329	0.98748	-0.31472
-168.57	0.32541	0.03938	0.40085	-20.00	-1.11815	0.10335	0.00407	65.14	0.59878	1.06425	-0.32988
-166.29	0.39049	0.05910	0.40220	-18.00	-1.12332	0.08180	0.00017	69.29	0.50080	1.13227	-0.34505
-164.00	0.45557	0.08495	0.40356	-16.00	-1.11865	0.06331	-0.00167	73.43	0.40024	1.19015	-0.35942
-161.71	0.52066	0.11433	0.40492	-14.00	-1.11620	0.04718	-0.00120	77.57	0.29831	1.23669	-0.37363
-159.43	0.58574	0.14704	0.41010	-12.00	-1.09588	0.03280	-0.00463	81.71	0.19648	1.27093	-0.38702
-157.14	0.65082	0.18290	0.42678	-10.00	-0.91767	0.02351	-0.02494	85.86	0.09644	1.29218	-0.39923
-154.86	0.71590	0.22166	0.44345	-8.00	-0.69311	0.01793	-0.04304	90.00	0.00000	1.30000	-0.41144
-152.57	0.78098	0.26309	0.46013	-6.00	-0.45396	0.01431	-0.05868	94.14	-0.06751	1.29218	-0.41794
-150.29	0.84607	0.30692	0.47680	-4.00	-0.17779	0.01242	-0.07601	98.29	-0.13754	1.27093	-0.42444
-148.00	0.91115	0.35287	0.47162	-2.00	0.10480	0.01160	-0.09121	102.43	-0.20881	1.23669	-0.42788
-143.86	0.84257	0.44061	0.45656	-1.00	0.24383	0.01143	-0.09763	106.57	-0.28017	1.19015	-0.42916
-139.71	0.78187	0.53255	0.44202	0.00	0.38111	0.01138	-0.10341	110.71	-0.35056	1.13227	-0.42992
-135.57	0.72448	0.62677	0.43452	1.00	0.51660	0.01143	-0.10861	114.86	-0.41915	1.06425	-0.42813
-131.43	0.66755	0.72131	0.42701	2.00	0.65044	0.01156	-0.11333	119.00	-0.48530	0.98748	-0.42634
-127.29	0.60928	0.81421	0.42483	3.00	0.78267	0.01177	-0.11762	123.14	-0.54868	0.90355	-0.42544
-123.14	0.54868	0.90355	0.42544	4.00	0.91326	0.01204	-0.12154	127.29	-0.60928	0.81421	-0.42483
-119.00	0.48530	0.98748	0.42634	5.00	1.04207	0.01239	-0.12510	131.43	-0.66755	0.72131	-0.42701
-114.86	0.41915	1.06425	0.42813	6.00	1.16873	0.01283	-0.12828	135.57	-0.72448	0.62677	-0.43452
-110.71	0.35056	1.13227	0.42992	7.00	1.29296	0.01338	-0.13104	139.71	-0.78187	0.53255	-0.44202
-106.57	0.28017	1.19015	0.42916	8.00	1.41390	0.01406	-0.13332	143.86	-0.84257	0.44061	-0.45656
-102.43	0.20881	1.23669	0.42788	9.00	1.53088	0.01488	-0.13503	148.00	-0.91115	0.35287	-0.47162
-98.29	0.13754	1.27093	0.42444	10.00	1.64208	0.01592	-0.13599	150.29	-0.84607	0.30692	-0.47680
-94.14	0.06751	1.29218	0.41794	11.00	1.74568	0.01726	-0.13605	152.57	-0.78098	0.26309	-0.46013
-90.00	0.00000	1.30000	0.41144	12.00	1.83887	0.01908	-0.13514	154.86	-0.71590	0.22166	-0.44345
-85.86	-0.06751	1.29218	0.39804	13.00	1.91764	0.02169	-0.13322	157.14	-0.65082	0.18290	-0.42678
-81.71	-0.13754	1.27093	0.38464	14.00	1.97413	0.02572	-0.13020	159.43	-0.58574	0.14704	-0.41010
-77.57	-0.20881	1.23669	0.36892	15.00	1.99916	0.03222	-0.12641	161.71	-0.52066	0.11433	-0.42206
-73.43	-0.28017	1.19015	0.35157	16.00	1.99377	0.04157	-0.12265	164.00	-0.45557	0.08495	-0.44356
-69.29	-0.35056	1.13227	0.33391	18.00	1.91720	0.06731	-0.11675	166.29	-0.39049	0.05910	-0.46506
-65.14	-0.41915	1.06425	0.31474	20.00	1.73683	0.10526	-0.11652	168.57	-0.32541	0.03938	-0.48656
-61.00	-0.48530	0.98748	0.29557	24.00	1.47321	0.19229	-0.13790	170.86	-0.26033	0.03408	-0.45714
-56.86	-0.54868	0.90355	0.27653	28.00	1.36017	0.27449	-0.16242	173.14	-0.19525	0.02993	-0.34286
-52.71	-0.60928	0.81421	0.25754	32.00	1.30164	0.35287	-0.18463	175.43	-0.13016	0.02694	-0.22857
-48.57	-0.66755	0.72131	0.23873	36.14	1.20367	0.44061	-0.20894	177.71	-0.06508	0.02514	-0.11429
-44.43	-0.72448	0.62677	0.22027	40.29	1.11695	0.53255	-0.23276	180.00	0.00000	0.02454	0.00000

Table 64: Airfoil aerodynamic coefficients - FFA-W3-330blend (Re=1.00e+07)

α [deg]	C_L [-]	C_D [-]	C_M [-]	α [deg]	C_L [-]	C_D [-]	C_M [-]	α [deg]	C_L [-]	C_D [-]	C_M [-]
-180.00	0.00000	0.03169	0.00000	-40.29	-0.82382	0.53115	0.20789	44.43	1.08350	0.62546	-0.25734
-177.71	0.06960	0.03228	0.09143	-36.14	-0.89412	0.43913	0.13731	48.57	0.99253	0.72010	-0.27354
-175.43	0.13920	0.03406	0.18286	-32.00	-0.97442	0.35131	0.06280	52.71	0.90112	0.81310	-0.28862
-173.14	0.20880	0.03702	0.27429	-28.00	-1.16308	0.20648	0.03905	56.86	0.80760	0.90255	-0.30311
-170.86	0.27841	0.04114	0.36571	-24.00	-1.14892	0.15001	0.01853	61.00	0.71119	0.98659	-0.31757
-168.57	0.34801	0.04638	0.40308	-20.00	-1.09451	0.10600	0.00441	65.14	0.61175	1.06348	-0.33194
-166.29	0.41761	0.05732	0.40801	-18.00	-1.05801	0.08732	-0.00061	69.29	0.50971	1.13162	-0.34631
-164.00	0.48721	0.08319	0.41294	-16.00	-1.02281	0.07051	-0.00342	73.43	0.40589	1.18963	-0.36014
-161.71	0.55681	0.11258	0.41788	-14.00	-0.99810	0.05474	-0.00401	77.57	0.30146	1.23629	-0.37385
-159.43	0.62641	0.14533	0.42586	-12.00	-0.98515	0.04052	-0.00272	81.71	0.19788	1.27067	-0.38681
-157.14	0.69601	0.18121	0.44302	-10.00	-0.89583	0.02929	-0.01198	85.86	0.09679	1.29204	-0.39872
-154.86	0.76562	0.22000	0.46017	-8.00	-0.67539	0.02207	-0.03458	90.00	0.00000	1.30000	-0.41063
-152.57	0.83522	0.26146	0.47732	-6.00	-0.43247	0.01735	-0.05466	94.14	-0.06775	1.29204	-0.41683
-150.29	0.90482	0.30532	0.49447	-4.00	-0.15881	0.01473	-0.07425	98.29	-0.13851	1.27067	-0.42303
-148.00	0.97442	0.35131	0.48743	-2.00	0.13456	0.01362	-0.09270	102.43	-0.21103	1.23629	-0.42628
-143.86	0.89412	0.43913	0.46839	-1.00	0.28014	0.01339	-0.10074	106.57	-0.28412	1.18963	-0.42745
-139.71	0.82382	0.53115	0.44996	0.00	0.42386	0.01330	-0.10802	110.71	-0.35680	1.13162	-0.42817
-135.57	0.75845	0.62546	0.43985	1.00	0.56519	0.01333	-0.11450	114.86	-0.42823	1.06348	-0.42673
-131.43	0.69477	0.72010	0.42974	2.00	0.70410	0.01345	-0.12028	119.00	-0.49783	0.98659	-0.42528
-127.29	0.63079	0.81310	0.42589	3.00	0.84071	0.01366	-0.12546	123.14	-0.56532	0.90255	-0.42535
-123.14	0.56532	0.90255	0.42535	4.00	0.97500	0.01397	-0.13011	127.29	-0.63079	0.81310	-0.42589
-119.00	0.49783	0.98659	0.42528	5.00	1.10680	0.01437	-0.13425	131.43	-0.69477	0.72010	-0.42974
-114.86	0.42823	1.06348	0.42673	6.00	1.23603	0.01486	-0.13793	135.57	-0.75845	0.62546	-0.43985
-110.71	0.35680	1.13162	0.42817	7.00	1.36223	0.01547	-0.14108	139.71	-0.82382	0.53115	-0.44996
-106.57	0.28412	1.18963	0.42745	8.00	1.48424	0.01623	-0.14363	143.86	-0.89412	0.43913	-0.46839
-102.43	0.21103	1.23629	0.42628	9.00	1.60097	0.01718	-0.14545	148.00	-0.97442	0.35131	-0.48743
-98.29	0.13851	1.27067	0.42303	10.00	1.71010	0.01841	-0.14636	150.29	-0.90482	0.30532	-0.49447
-94.14	0.06775	1.29204	0.41683	11.00	1.80957	0.02010	-0.14635	152.57	-0.83522	0.26146	-0.47732
-90.00	0.00000	1.30000	0.41063	12.00	1.89473	0.02258	-0.14544	154.86	-0.76562	0.22000	-0.46017
-85.86	-0.06775	1.29204	0.39752	13.00	1.95698	0.02671	-0.14378	157.14	-0.69601	0.18121	-0.44302
-81.71	-0.13851	1.27067	0.38441	14.00	1.98576	0.03380	-0.14185	159.43	-0.62641	0.14533	-0.42586
-77.57	-0.21103	1.23629	0.36905	15.00	1.99260	0.04333	-0.14004	161.71	-0.55681	0.11258	-0.43502
-73.43	-0.28412	1.18963	0.35212	16.00	1.99617	0.05354	-0.13823	164.00	-0.48721	0.08319	-0.45294
-69.29	-0.35680	1.13162	0.33491	18.00	1.96398	0.07706	-0.13351	166.29	-0.41761	0.05732	-0.47087
-65.14	-0.42823	1.06348	0.31634	20.00	1.81179	0.11169	-0.13135	168.57	-0.34801	0.04638	-0.48880
-61.00	-0.49783	0.98659	0.29777	24.00	1.56073	0.19103	-0.14660	170.86	-0.27841	0.04114	-0.45714
-56.86	-0.56532	0.90255	0.27947	28.00	1.46798	0.27199	-0.17242	173.14	-0.20880	0.03702	-0.34286
-52.71	-0.63079	0.81310	0.26125	32.00	1.39203	0.35131	-0.19417	175.43	-0.13920	0.03406	-0.22857
-48.57	-0.69477	0.72010	0.24322	36.14	1.27731	0.43913	-0.21792	177.71	-0.06960	0.03228	-0.11429
-44.43	-0.75845	0.62546	0.22556	40.29	1.17689	0.53115	-0.24115	180.00	0.00000	0.03169	0.00000

Table 65: Airfoil aerodynamic coefficients - FFA-W3-360 (Re=1.00e+07)

α [deg]	C_L [-]	C_D [-]	C_M [-]	α [deg]	C_L [-]	C_D [-]	C_M [-]	α [deg]	C_L [-]	C_D [-]	C_M [-]
-180.00	0.00000	0.03715	0.00000	-40.29	-0.84406	0.53379	0.21097	44.43	1.10690	0.62793	-0.26133
-177.71	0.07178	0.03774	0.09143	-36.14	-0.91898	0.44192	0.13525	48.57	1.01129	0.72238	-0.27648
-175.43	0.14356	0.03951	0.18286	-32.00	-1.00494	0.35424	0.05517	52.71	0.91594	0.81520	-0.29062
-173.14	0.21534	0.04245	0.27429	-28.00	-1.11306	0.20494	0.03211	56.86	0.81907	0.90444	-0.30424
-170.86	0.28713	0.04653	0.36571	-24.00	-1.05425	0.15434	0.01268	61.00	0.71982	0.98826	-0.31787
-168.57	0.35891	0.05174	0.40313	-20.00	-0.98247	0.10967	-0.00282	65.14	0.61801	1.06493	-0.33154
-166.29	0.43069	0.06068	0.40814	-18.00	-0.94173	0.09249	-0.00741	69.29	0.51401	1.13285	-0.34522
-164.00	0.50247	0.08651	0.41315	-16.00	-0.89333	0.07597	-0.01107	73.43	0.40862	1.19061	-0.35846
-161.71	0.57425	0.11586	0.41816	-14.00	-0.85472	0.06054	-0.01250	77.57	0.30299	1.23704	-0.37161
-159.43	0.64603	0.14856	0.42627	-12.00	-0.82348	0.04641	-0.01177	81.71	0.19855	1.27116	-0.38405
-157.14	0.71781	0.18439	0.44370	-10.00	-0.79541	0.03441	-0.01082	85.86	0.09695	1.29229	-0.39547
-154.86	0.78960	0.22313	0.46114	-8.00	-0.63650	0.02548	-0.02769	90.00	0.00000	1.30000	-0.40690
-152.57	0.86138	0.26453	0.47857	-6.00	-0.39095	0.01994	-0.05107	94.14	-0.06787	1.29229	-0.41277
-150.29	0.93316	0.30832	0.49600	-4.00	-0.13071	0.01653	-0.07148	98.29	-0.13899	1.27116	-0.41864
-148.00	1.00494	0.35424	0.48830	-2.00	0.16173	0.01507	-0.09179	102.43	-0.21209	1.23704	-0.42163
-143.86	0.91898	0.44192	0.46784	-1.00	0.31121	0.01477	-0.10119	106.57	-0.28603	1.19061	-0.42258
-139.71	0.84406	0.53379	0.44803	0.00	0.45956	0.01465	-0.10988	110.71	-0.35981	1.13285	-0.42312
-135.57	0.77483	0.62793	0.43697	1.00	0.60566	0.01466	-0.11776	114.86	-0.43261	1.06493	-0.42168
-131.43	0.70790	0.72238	0.42591	2.00	0.74868	0.01481	-0.12477	119.00	-0.50388	0.98826	-0.42024
-127.29	0.64116	0.81520	0.42150	3.00	0.88862	0.01507	-0.13098	123.14	-0.57335	0.90444	-0.42058
-123.14	0.57335	0.90444	0.42058	4.00	1.02544	0.01544	-0.13648	127.29	-0.64116	0.81520	-0.42150
-119.00	0.50388	0.98826	0.42024	5.00	1.15878	0.01593	-0.14130	131.43	-0.70790	0.72238	-0.42591
-114.86	0.43261	1.06493	0.42168	6.00	1.28822	0.01654	-0.14540	135.57	-0.77483	0.62793	-0.43697
-110.71	0.35981	1.13285	0.42312	7.00	1.41282	0.01731	-0.14875	139.71	-0.84406	0.53379	-0.44803
-106.57	0.28603	1.19061	0.42258	8.00	1.53090	0.01831	-0.15118	143.86	-0.91898	0.44192	-0.46784
-102.43	0.21209	1.23704	0.42163	9.00	1.64065	0.01963	-0.15262	148.00	-1.00494	0.35424	-0.48830
-98.29	0.13899	1.27116	0.41864	10.00	1.73926	0.02150	-0.15310	150.29	-0.93316	0.30832	-0.49600
-94.14	0.06787	1.29229	0.41277	11.00	1.81971	0.02445	-0.15254	152.57	-0.86138	0.26453	-0.47857
-90.00	0.00000	1.30000	0.40690	12.00	1.87065	0.02966	-0.15121	154.86	-0.78960	0.22313	-0.46114
-85.86	-0.06787	1.29229	0.39426	13.00	1.89221	0.03770	-0.14969	157.14	-0.71781	0.18439	-0.44370
-81.71	-0.13899	1.27116	0.38162	14.00	1.87910	0.04824	-0.14562	159.43	-0.64603	0.14856	-0.42627
-77.57	-0.21209	1.23704	0.36676	15.00	1.88111	0.05838	-0.14358	161.71	-0.57425	0.11586	-0.43530
-73.43	-0.28603	1.19061	0.35033	16.00	1.86359	0.06992	-0.14095	164.00	-0.50247	0.08651	-0.45315
-69.29	-0.35981	1.13285	0.33362	18.00	1.73324	0.10166	-0.13711	166.29	-0.43069	0.06068	-0.47100
-65.14	-0.43261	1.06493	0.31561	20.00	1.59357	0.13916	-0.14082	168.57	-0.35891	0.05174	-0.48884
-61.00	-0.50388	0.98826	0.29759	24.00	1.46708	0.21002	-0.15693	170.86	-0.28713	0.04653	-0.45714
-56.86	-0.57335	0.90444	0.27989	28.00	1.44834	0.28200	-0.17979	173.14	-0.21534	0.04245	-0.34286
-52.71	-0.64116	0.81520	0.26230	32.00	1.43563	0.35424	-0.20147	175.43	-0.14356	0.03951	-0.22857
-48.57	-0.70790	0.72238	0.24491	36.14	1.31283	0.44192	-0.22409	177.71	-0.07178	0.03774	-0.11429
-44.43	-0.77483	0.62793	0.22794	40.29	1.20580	0.53379	-0.24619	180.00	0.00000	0.03715	0.00000

Table 66: Airfoil aerodynamic coefficients - Cylinder

α	C_L	C_D	C_M	α	C_L	C_D	C_M	α	C_L	C_D	C_M
[deg]	[-]	[-]	[-]	[deg]	[-]	[-]	[-]	[deg]	[-]	[-]	[-]
-180.00	0.00000	0.60000	0.00000	-24.00	0.00000	0.60000	0.00000	60.00	0.00000	0.60000	0.00000
-175.00	0.00000	0.60000	0.00000	-22.00	0.00000	0.60000	0.00000	65.00	0.00000	0.60000	0.00000
-170.00	0.00000	0.60000	0.00000	-20.00	0.00000	0.60000	0.00000	70.00	0.00000	0.60000	0.00000
-165.00	0.00000	0.60000	0.00000	-18.00	0.00000	0.60000	0.00000	75.00	0.00000	0.60000	0.00000
-160.00	0.00000	0.60000	0.00000	-16.00	0.00000	0.60000	0.00000	80.00	0.00000	0.60000	0.00000
-155.00	0.00000	0.60000	0.00000	-14.00	0.00000	0.60000	0.00000	85.00	0.00000	0.60000	0.00000
-150.00	0.00000	0.60000	0.00000	-12.00	0.00000	0.60000	0.00000	90.00	0.00000	0.60000	0.00000
-145.00	0.00000	0.60000	0.00000	-10.00	0.00000	0.60000	0.00000	95.00	0.00000	0.60000	0.00000
-140.00	0.00000	0.60000	0.00000	-8.00	0.00000	0.60000	0.00000	100.00	0.00000	0.60000	0.00000
-135.00	0.00000	0.60000	0.00000	-6.00	0.00000	0.60000	0.00000	105.00	0.00000	0.60000	0.00000
-130.00	0.00000	0.60000	0.00000	-4.00	0.00000	0.60000	0.00000	110.00	0.00000	0.60000	0.00000
-125.00	0.00000	0.60000	0.00000	-2.00	0.00000	0.60000	0.00000	115.00	0.00000	0.60000	0.00000
-120.00	0.00000	0.60000	0.00000	0.00	0.00000	0.60000	0.00000	120.00	0.00000	0.60000	0.00000
-115.00	0.00000	0.60000	0.00000	2.00	0.00000	0.60000	0.00000	125.00	0.00000	0.60000	0.00000
-110.00	0.00000	0.60000	0.00000	4.00	0.00000	0.60000	0.00000	130.00	0.00000	0.60000	0.00000
-105.00	0.00000	0.60000	0.00000	6.00	0.00000	0.60000	0.00000	135.00	0.00000	0.60000	0.00000
-100.00	0.00000	0.60000	0.00000	8.00	0.00000	0.60000	0.00000	140.00	0.00000	0.60000	0.00000
-95.00	0.00000	0.60000	0.00000	10.00	0.00000	0.60000	0.00000	145.00	0.00000	0.60000	0.00000
-90.00	0.00000	0.60000	0.00000	12.00	0.00000	0.60000	0.00000	150.00	0.00000	0.60000	0.00000
-85.00	0.00000	0.60000	0.00000	14.00	0.00000	0.60000	0.00000	155.00	0.00000	0.60000	0.00000
-80.00	0.00000	0.60000	0.00000	16.00	0.00000	0.60000	0.00000	160.00	0.00000	0.60000	0.00000
-75.00	0.00000	0.60000	0.00000	18.00	0.00000	0.60000	0.00000	165.00	0.00000	0.60000	0.00000
-70.00	0.00000	0.60000	0.00000	20.00	0.00000	0.60000	0.00000	170.00	0.00000	0.60000	0.00000
-65.00	0.00000	0.60000	0.00000	22.00	0.00000	0.60000	0.00000	175.00	0.00000	0.60000	0.00000
-60.00	0.00000	0.60000	0.00000	24.00	0.00000	0.60000	0.00000	180.00	0.00000	0.60000	0.00000

Table 67: Position of the structural components wrt the structural reference plane

η	Cap center SS	Cap center PS	Cap width SS	Cap center PS	TE width	LE width	Web1 pos	Web2 pos	Web3 pos
[-]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]
0.000	63.327	-0.670	1445.023	1445.023	800.000	1000.000	-0.000	-0.000	0.000
0.010	62.548	-0.718	1441.352	1441.352	798.656	994.000	-0.000	-0.000	0.000
0.030	60.990	-0.813	1434.011	1434.011	794.555	982.000	-0.000	-442.500	442.500
0.050	59.431	-0.908	1426.670	1426.670	790.012	970.000	-2000.000	-437.500	437.500
0.100	55.536	-1.146	1398.318	1398.318	780.000	940.000	-2000.000	-425.000	425.000
0.150	51.641	-1.384	1349.966	1349.966	770.000	910.000	-2000.000	-412.500	412.500
0.200	47.745	-1.622	1301.613	1301.613	760.000	880.000	-2000.000	-400.000	400.000
0.250	43.850	-1.860	1253.261	1253.261	750.000	850.000	-2000.000	-387.500	387.500
0.325	38.006	-2.217	1180.732	1180.732	735.000	805.000	-2000.000	-368.750	368.750
0.400	32.163	-2.575	1108.203	1108.203	720.000	760.000	-2000.000	-350.000	350.000
0.475	26.320	-2.932	1035.675	1035.675	705.000	715.000	-2000.000	-331.250	331.250
0.550	20.477	-3.289	963.146	963.146	690.000	670.000	-0.000	-312.500	312.500
0.625	14.634	-3.646	890.617	890.617	675.000	625.000	-0.000	-293.750	293.750
0.700	8.791	-4.003	818.089	818.089	660.000	580.000	-0.000	-275.000	275.000
0.775	2.947	-4.360	745.560	745.560	644.994	535.000	-0.000	-256.250	256.250
0.850	-2.896	-4.717	673.031	673.031	632.174	490.000	-0.000	-237.500	237.500
0.925	-8.739	-5.074	600.503	600.503	557.829	445.000	-0.000	-218.750	218.750
0.980	-13.024	-5.336	547.315	547.315	232.367	412.000	-0.000	-0.000	0.000
1.000	0.000	0.000	527.974	527.974	50.000	400.000	-0.000	-0.000	0.000

Table 68: Material thicknesses in the Trailing edge reinforcement region

η [-]	triax00 [mm]	uniax00 [mm]	triax01 [mm]
0.00000	8.00000	70.00000	8.00000
0.01000	7.86753	69.85357	7.86753
0.03000	7.62134	31.46486	7.62134
0.05000	7.38447	31.07635	7.38447
0.10000	5.67751	26.18724	5.67751
0.15000	4.03534	22.23692	4.03534
0.20000	2.73966	20.28272	2.73966
0.25000	1.65892	19.22599	1.65892
0.32500	0.82252	17.23762	0.82252
0.40000	0.56426	15.18824	0.56426
0.47500	0.40011	13.11602	0.40011
0.55000	0.33868	11.13263	0.33868
0.62500	0.35833	9.32695	0.35833
0.70000	0.39453	7.63334	0.39453
0.77500	0.56737	5.97388	0.56737
0.85000	0.81173	4.10204	0.81173
0.92500	1.19772	2.16123	1.19772
0.98000	1.63914	1.00611	1.63914
1.00000	1.83414	0.92178	1.83414

Table 69: Material thicknesses in the Main panel region

η [-]	triax00 [mm]	uniax00 [mm]	balsa00 [mm]	uniax01 [mm]	triax01 [mm]
0.00000	8.00000	35.00000	0.00000	35.00000	8.00000
0.01000	7.85562	35.00000	0.00000	35.00000	7.85562
0.03000	7.59567	7.94313	13.72647	7.94313	7.59567
0.05000	7.35630	7.87383	17.48073	7.87383	7.35630
0.10000	5.68137	5.82487	37.85444	5.82487	5.68137
0.15000	4.11245	3.80106	59.19593	3.80106	4.11245
0.20000	2.92062	2.13546	69.49772	2.13546	2.92062
0.25000	1.96765	0.77203	70.00000	0.77203	1.96765
0.32500	1.35832	0.00000	70.00000	0.00000	1.35832
0.40000	1.36100	0.00000	66.76000	0.00000	1.36100
0.47500	1.48657	0.00000	64.33235	0.00000	1.48657
0.55000	1.71923	0.00000	58.52124	0.00000	1.71923
0.62500	2.06310	0.00000	48.48791	0.00000	2.06310
0.70000	2.47522	0.00000	38.12001	0.00000	2.47522
0.77500	2.95092	0.00000	29.53813	0.00000	2.95092
0.85000	3.53859	0.00000	20.71924	0.00000	3.53859
0.92500	4.26982	0.00000	14.10794	0.00000	4.26982
0.98000	4.94388	0.00000	11.36986	0.00000	4.94388
1.00000	5.24559	0.00000	10.00000	0.00000	5.24559

Table 70: Material thicknesses in the Spar cap region

η [-]	triax00 [mm]	uniax00 [mm]	triax01 [mm]
0.00000	8.00000	70.00000	8.00000
0.01000	7.85158	70.00000	7.85158
0.03000	7.45871	70.00000	7.45871
0.05000	6.90438	70.00000	6.90438
0.10000	3.58516	73.39493	3.58516
0.15000	0.51223	78.03234	0.51223
0.20000	0.40000	73.47955	0.40000
0.25000	0.40000	68.83992	0.40000
0.32500	0.40000	64.50527	0.40000
0.40000	0.40000	61.72287	0.40000
0.47500	0.40000	59.20501	0.40000
0.55000	0.40000	56.45319	0.40000
0.62500	0.40000	53.69106	0.40000
0.70000	0.40000	49.98219	0.40000
0.77500	0.40000	43.16906	0.40000
0.85000	0.40000	33.72269	0.40000
0.92500	0.40000	20.92222	0.40000
0.98000	0.40000	8.28438	0.40000
1.00000	0.40000	3.00000	0.40000

Table 71: Material thicknesses in the Leading panel region

η [-]	triax00 [mm]	uniax00 [mm]	balsa00 [mm]	uniax01 [mm]	triax01 [mm]
0.00000	8.00000	35.00000	0.00000	35.00000	8.00000
0.01000	7.94414	34.76058	0.00000	34.76058	7.94414
0.03000	7.83267	7.33220	11.34417	7.33220	7.83267
0.05000	7.70242	7.00924	12.71701	7.00924	7.70242
0.10000	6.18170	4.71368	20.70374	4.71368	6.18170
0.15000	4.63933	2.83823	30.12736	2.83823	4.63933
0.20000	3.42364	1.58890	34.77312	1.58890	3.42364
0.25000	2.40084	0.82757	35.00000	0.82757	2.40084
0.32500	1.58624	1.18382	33.45733	1.18382	1.58624
0.40000	1.31986	2.45801	30.00000	2.45801	1.31986
0.47500	1.22613	3.76610	28.69302	3.76610	1.22613
0.55000	1.25023	5.00729	25.10338	5.00729	1.25023
0.62500	1.32690	6.07684	22.09250	6.07684	1.32690
0.70000	1.42396	6.84971	18.72395	6.84971	1.42396
0.77500	1.69446	7.15523	15.56165	7.15523	1.69446
0.85000	2.04462	6.72488	12.26978	6.72488	2.04462
0.92500	2.59408	5.05297	8.11572	5.05297	2.59408
0.98000	3.20397	2.37364	5.00000	2.37364	3.20397
1.00000	3.49012	0.85136	5.00000	0.85136	3.49012

Table 72: Material thicknesses in the Leading edge reinforcement region

η [-]	triax00 [mm]	uniax00 [mm]	balsa00 [mm]	uniax01 [mm]	triax01 [mm]
0.00000	8.00000	35.00000	0.00000	35.00000	8.00000
0.01000	7.94414	34.97471	0.00000	34.97471	7.94414
0.03000	7.83267	7.90588	11.34417	7.90588	7.83267
0.05000	7.70242	7.84107	12.71701	7.84107	7.70242
0.10000	6.18170	6.90597	20.70374	6.90597	6.18170
0.15000	4.63933	5.59489	30.12736	5.59489	4.63933
0.20000	3.42364	3.74732	34.77312	3.74732	3.42364
0.25000	2.40084	1.74157	35.00000	1.74157	2.40084
0.32500	1.58624	0.48885	33.45733	0.48885	1.58624
0.40000	1.31986	0.54644	30.00000	0.54644	1.31986
0.47500	1.22613	0.65148	28.69302	0.65148	1.22613
0.55000	1.25023	0.75084	25.10338	0.75084	1.25023
0.62500	1.32690	0.77836	22.09250	0.77836	1.32690
0.70000	1.42396	0.61785	18.72395	0.61785	1.42396
0.77500	1.69446	0.59653	15.56165	0.59653	1.69446
0.85000	2.04462	0.65853	12.26978	0.65853	2.04462
0.92500	2.59408	0.68755	8.11572	0.68755	2.59408
0.98000	3.20397	0.65337	5.00000	0.65337	3.20397
1.00000	3.49012	0.61943	5.00000	0.61943	3.49012

B.4 Controller inputs

Below, the settings used to evaluate the 10 MW offshore turbine using the Basic DTU Wind Energy Controller is listed:

```
\small
      constant   1 10000.0      ; Rated power [kW]
      constant   2   0.628318       ; Minimum rotor (LSS) speed [rad/s]
      constant   3   0.909389       ; Rated rotor (LSS) speed [rad/s]
      constant   4  15.6E+06    ; Maximum allowable generator torque [Nm]
      constant   5  100.0       ; Minimum pitch angle, theta_min [deg],
                                ; if |theta_min|>90, then a table of <wsp,theta_min> is read ;
                                ; from a file named 'wptable.n', where n=int(theta_min)
      constant   6  90.0        ; Maximum pitch angle [deg]
      constant   7  10.0        ; Maximum pitch velocity operation [deg/s]
      constant   8   0.4        ; Frequency of generator speed filter [Hz]
      constant   9   0.7        ; Damping ratio of speed filter [-]
      constant  10   3.43       ; Frequency of free-free DT torsion mode [Hz],
          ; if zero no notch filter used
      ; Partial load control parameters
      constant  11   0.0 ; Optimal Cp tracking K factor [Nm/(rad/s)^2], ;
                                ; Qg=K*Omega^2, K=eta*0.5*rho*A*Cp_opt*R^3/lambda_opt^3
      constant  12   0.708402e8 ; Proportional gain of torque controller [Nm/(rad/s)]
      constant  13   0.158965e8 ; Integral gain of torque controller [Nm/rad]
      constant  14   0.0        ; Differential gain of torque controller [Nm/(rad/s^2)]
;     Full load control parameters
      constant  15   2          ; Generator control switch [1=constant power, 0=constant torque]
      constant  16   1.193240    ; Proportional gain of pitch controller [rad/(rad/s)]
      constant  17   0.366725   ; Integral gain of pitch controller [rad/rad]
      constant  18   0.0        ; Differential gain of pitch controller [rad/(rad/s^2)]
      constant  19   0.4e-9     ; Proportional power error gain [rad/W]
      constant  20   0.4e-9     ; Integral power error gain [rad/(Ws)]
      constant  21   9.935269   ; Coefficient of linear term in aerodynamic gain scheduling, KK1 [deg]
      constant  22   440.019113 ; Coefficient of quadratic term in aerodynamic gain scheduling,
                                ; KK2 [deg^2] & (if zero, KK1 = pitch angle at double gain)
      constant  23   1.3        ; Relative speed for double nonlinear gain [-]
;     Cut-in simulation parameters
      constant  24  -1    ; Cut-in time [s], no cut-in is simulated if zero or negative
      constant  25  1.0   ; Time delay for soft start of torque [1/1P]
;     Cut-out simulation parameters
      constant  26  -1    ; Shut-down time [s], no shut-down is simulated if zero or negative
      constant  27   5.0  ; Time of linear torque cut-out during a generator assisted stop [s]
      constant  28  1     ; Stop type [1=normal, 2=emergency]
      constant  29  1.0   ; Time delay for pitch stop after shut-down signal [s]
      constant  30  3     ; Maximum pitch velocity during initial period of stop [deg/s]
      constant  31  3.0   ; Time period of initial pitch stop phase [s]
         ; (maintains pitch speed specified in constant 30)
      constant  32  4     ; Maximum pitch velocity during final phase of stop [deg/s]
;     Expert parameters (keep default values unless otherwise given)
      constant  33   2.0  ; Time for the maximum torque rate = Maximum allowable
         ;generator torque/(constant 33 + 0.01s) [s]
      constant  34   2.0   ; Upper angle above lowest minimum pitch angle for switch [deg],
```

```
        ;if equal then hard switch
    constant  35  300.0   ; Percentage of the rated speed when the
         ;torque limits are fully opened [%]
    constant  36   2.0    ; Time constant of 1st order filter on wind speed
         ;used for minimum pitch [1/1P]
    constant  37   1.0    ; Time constant of 1st order filter on pitch angle
        ;used for gain scheduling [1/1P]
;     Drivetrain damper
    constant  38   0.0    ; Proportional gain of active DT damper [Nm/(rad/s)],
     ;requires frequency in input 10
;     Over speed
    constant  39  50.0    ; Overspeed percentage before initiating
         ;turbine controller alarm (shut-down) [%]
;     Additional non-linear pitch control term (not used when all zero)
    constant  40   0.0    ; Rotor speed error scaling factor [rad/s]
    constant  41   0.0    ; Rotor acceleration error scaling factor [rad/s^2]
    constant  42   0.0    ; Pitch rate gain [rad/s]
;     Storm control command
    constant 43   28.0    ; Wind speed 'Vstorm' above which derating of rotor speed is used [m/s]
    constant 44   28.0    ; Cut-out wind speed (only
         ; used for derating of rotor speed in storm) [m/s]
;     Safety system parameters
    constant 45   50.0  ; Overspeed percentage before initiating
       ; safety system alarm (shut-down) [%]
    constant 46    4.5  ; Max low-pass filtered tower top acceleration level [m/s^2]
;     Turbine parameter
    constant 47  198.0  ; Nominal rotor diameter [m]
;     Parameters for rotor inertia reduction in variable speed region
    constant 48    0.0  ; Proportional gain on rotor acceleration
                        ; in variable speed region [Nm/(rad/s^2)] (not used when zero)
;     Parameters for alternative partial load controller with PI regulated TSR tracking
    constant 49    10.577072  ; Optimal tip speed ratio [-]
                              ; (only used when K=constant 11 = 0 otherwise  Qg=K*Omega^2 is used)
```

B.5 Tower structure

height m	outer diameter m	wall thickness mm
0.000	8.3000	38
11.500	8.0215	38
11.501	8.0215	36
23.000	7.7431	36
23.001	7.7430	34
34.500	7.4646	34
34.501	7.4646	32
46.000	7.1861	32
46.001	7.1861	30
57.500	6.9076	30
57.501	6.9076	28
69.000	6.6292	28
69.001	6.6291	26
80.500	6.3507	26
80.501	6.3507	24
92.000	6.0722	24
92.001	6.0722	22
103.500	5.7937	22
103.501	5.7937	20
115.630	5.5000	20

Table 73: Wall thickness distribution of the tower. Reproduced from [43].

height	cross section area	mass per length	radius of gyration	second moment of area	torsional stiffness constant
m	m^2	kg/m	m^4	m^4	
0.000	0.98632	8383.74	2.921	8.41605	16.83210
11.500	0.95308	8101.16	2.823	7.59342	15.18684
11.501	0.90314	7676.68	2.823	7.19909	14.39819
23.000	0.87165	7409.00	2.725	6.47197	12.94394
23.001	0.82343	6999.18	2.726	6.11710	12.23421
34.500	0.79369	6746.37	2.627	5.47792	10.95583
34.501	0.74720	6351.21	2.628	5.15979	10.31958
46.000	0.71921	6113.27	2.529	4.60134	9.20267
46.001	0.67444	5732.78	2.530	4.31732	8.63463
57.500	0.64820	5509.71	2.432	3.83271	7.66541
57.501	0.60516	5143.87	2.432	3.58027	7.16053
69.000	0.58067	4935.68	2.334	3.16290	6.32580
69.001	0.53935	4584.50	2.335	2.93961	5.87921
80.500	0.51661	4391.17	2.236	2.58319	5.16638
80.501	0.47702	4054.66	2.237	2.38671	4.77342
92.000	0.45602	3876.20	2.138	2.08525	4.17049
92.001	0.41816	3554.35	2.139	1.91334	3.82669
103.500	0.39891	3390.76	2.041	1.66114	3.32229
103.501	0.36277	3083.57	2.041	1.51168	3.02335
115.630	0.34432	2926.71	1.937	1.29252	2.58504

Table 74: Cross section stiffness and mass properties of the tower. Reproduced from [43].