Project funded by the European Commission under the 6th (EC) RTD Framework Programme (2002- 2006) within the framework of the specific research and technological development programme “Integrating and strengthening the European Research Area”

Project UpWind

Contract No.:
019945 (SES6)

“Integrated Wind Turbine Design”

AUTHOR:	Ervin Bossanyi
AFFILIATION:	Garrad Hassan and Partners Limited
ADDRESS:	St Vincent’s Works, Silverthorne Lane, BRISTOL BS2 0QD, England
TEL.:	+44 (0) 117 972 9900
EMAIL:	Ervin.bossanyi@garradhassan.com
FURTHER AUTHORS:	Alan Wright, Paul Fleming
REVIEWER:	
APPROVER:	

Document Information

DOCUMENT TYPE	Report
DOCUMENT NAME:	Controller field tests on the NREL CART3 turbine
DOCUMENT NUMBER:	11593/BR/09
REVISION:	A
REV.DATE:	
CLASSIFICATION:	R0: General public
STATUS:	

Abstract: This document describes the programme of field tests designed to validate individual pitch control and active tower damping on the CART3 turbine at NREL.

Contents

1. Introduction 3
2. The CART3 turbine 4
3. Controller design 5
4. Simulation results 7
5. Field tests 11
6. Conclusions 13
7. References 13
Appendix A 14

STATUS, CONFIDENTIALITY AND ACCESSIBILITY									
Status				**Confidentiality**				**Accessibility**	
S0	Approved/Released	●		**R0**	General public	●		Private web site	
S1	Reviewed			**R1**	Restricted to project members			Public web site	●
S2	Pending for review			**R2**	Restricted to European. Commission			Paper copy	
S3	Draft for comments			**R3**	Restricted to WP members + PL				
S4	Under preparation			**R4**	Restricted to Task members +WPL+PL				

PL: *Project leader* **WPL:** *Work package leader* **TL:** *Task leader*

1. Introduction

An important task of the UPWIND control systems work package is to use field tests to demonstrate that the very significant load reductions predicted with **individual pitch control** (IPC) can really be achieved in practice. Previously, the only published results came from simulation models [1], so field test results are vital for increasing confidence of turbine designers to use IPC in their new designs, to improve cost-effectiveness.

These field tests were originally intended for a commercial European turbine, but commercial considerations prevented this from going ahead. A new programme was therefore conceived in 2008, making use of two 600 kW research turbines at the NREL test site in Colorado, USA. Both turbines are 42m in diameter but one (CART2) is two bladed and one (CART3) is three-bladed, this provided an excellent opportunity to test IPC for both cases. Although these turbines may be a bit small and commercially unrepresentative, they are quite adequate for the required proof of principle, and have the advantage of being very accessible and free of commercial problems to prevent publication of results. As well as verifying the IPC, the opportunity was also taken to validate an algorithm for **fore-aft tower damping** (FATD) using the collective part of the pitch controller, for which only very limited field test results had previously been published [2].

The CART3 turbine was originally the same as the CART2, but the two-bladed teetered rotor was replaced by a three-bladed fixed hub rotor. The nominal speed and rating were not changed but the blade design is different. When the test programme was set up the CART2 was available to run, but the CART3 control system was not yet complete and the turbine had not yet been commissioned. Therefore the field testing on the CART2 was carried out first. The teetered rotor was locked with a teeter brake, providing the opportunity to show that IPC could be used instead of a mechanical teeter hinge to control the asymmetrical out of plane loading [3].

After some initial delays the CART2 field tests were successfully completed in the first few months of 2010, and provided very conclusive validation of both IPC and FATD. Some of the field test results were published in [4],[5] and a full account of the test programme is in the UPWIND report on these tests, [6].

The advanced control principles to be tested (both IPC and tower damping) are basically the same for two and three bladed turbines. The IPC control is calculated in the non-rotating frame in two orthogonal axes, and this is equally valid for any number of blades. Repeating the tests on the CART3 turbine is valuable for two main reasons:

- Most commercial turbines are three-bladed, so validation of the technique for a three-bladed turbine will clearly provide more confidence where it is needed, and
- This provides the opportunity to validate second-harmonic or 2P IPC. The basic 1P IPC reduces the 1P rotating loads, and it also reduces the 2P non-rotating loads. While these drive the fatigue on the non-rotating components of a two-bladed turbine, they are not important on a three-bladed turbine where the fatigue-driving non-rotating loads are at 3P. Second-harmonic or 2P IPC can then be introduced, since this does have the capability to reduce the 3P non-rotating loads, which provides a significant further enhancement to the benefit of IPC [3].

2. The CART3 turbine

The CART3 turbine is a modified CART2, fitted with a new hub and three blades of a different design. The generator and power converter are also different. The turbine was intended to run at the same rated power and rotational speed as the CART2 (about 600 kW at 42 rpm). The turbine was first run in this configuration in early 2010, but significant dynamic problems were encountered. Significant efforts were made by NREL to understand these problems [7], and eventually the most likely cause was thought to be in the power electronics. Pending a final solution, the problems could be avoided by running at reduced speed and power (about 550 kW at 37 rpm), and these settings were therefore used for the field tests reported here.

A *Bladed* model of the CART3 turbine was built from information supplied by NREL, and used for an initial controller design incorporating IPC and FATD. The model was subsequently changed as a result of new parameter estimations resulting from data collected during the commissioning of the machine, and used to re-rune the controller before the tests started. Details of the turbine model are provided in Appendix A.

Linearised models were derived from this at a number of operating points, and used as the starting point for control tuning. A Campbell diagram showing the coupled system modes is shown in Figure 2.1, with labels to indicate the dominant contributions to the coupled modes.

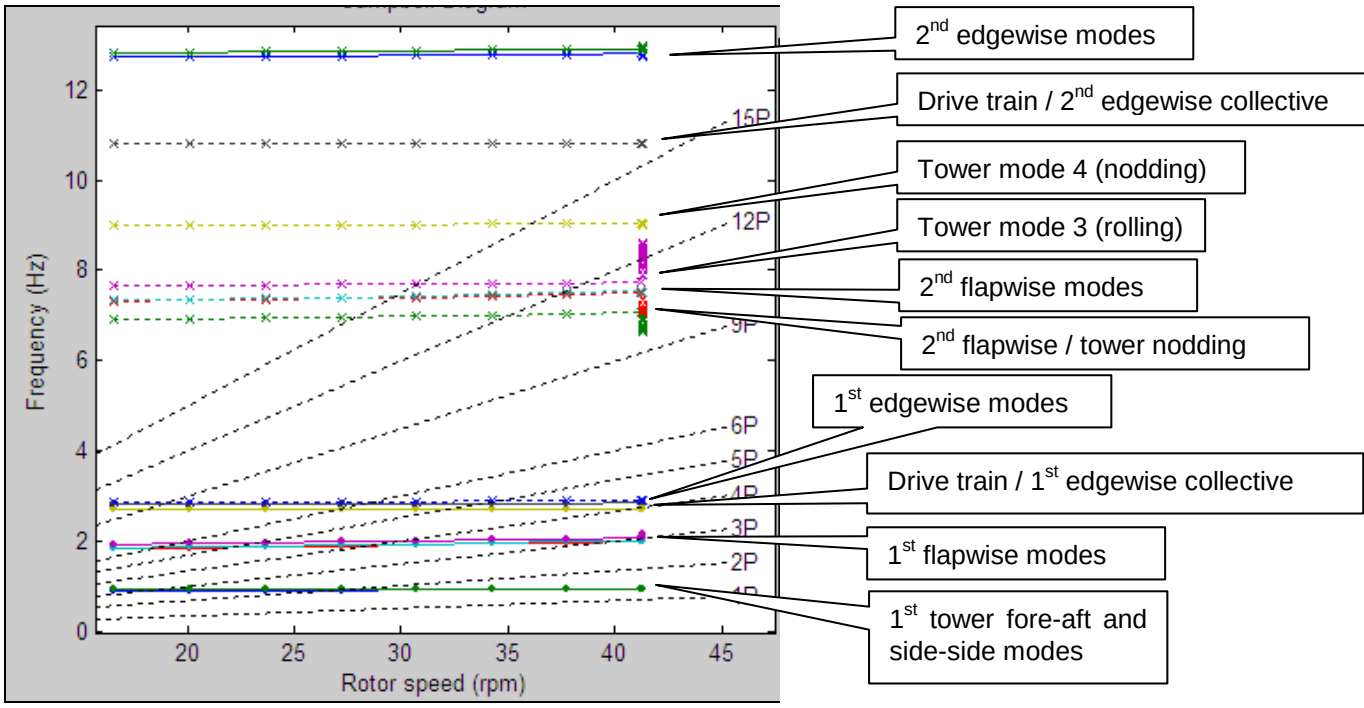

Figure 2.1: CART3 Campbell diagram

Figure 2.1 plots the frequencies for rotor speeds up to 42 rpm. For this work the rated rotor speed was reduced to 37 rpm, at which point the main forcing frequencies and the first few modal frequencies are as shown in Table 2.1.

Rated rotational frequency (1P)	0.617	Hz
1st tower fore-aft and side-side modes	0.92	Hz
Blade passing frequency (3P)	1.85	Hz
1st flapwise modes	1.98-2.05	Hz
Drive train / 1st edgewise collective	2.7	Hz
1st edgewise modes	2.83 – 2.88	Hz

Table 2.1: Principal frequencies at 37 rpm

3. Controller design

As in the case of the CART2, a power production control algorithm was designed for the CART3 based on up-to-date principles regularly used by GH for commercial controller design work [1],[9]. The application of these techniques to the UPWIND 5MW reference turbine is documented in [10],[11]. The application of these techniques to the CART3 is similar and therefore not elaborated here in detail.

The controller includes the following features:

- Optimal power production, maintaining peak Cp over the whole nominal operating speed range
- Speed regulation by interacting PI-based torque and collective pitch control loops
- Drive train damping filter in torque controller
- Damping of fore-aft tower vibration by collective pitch control
- PI-based 1P and 2P individual pitch control loops to reduce rotating and non-rotating loads

The tuning of the control loops has been carried out using classical design techniques. Although the controller as a whole has several measured input signals and several output demands, it can easily be divided into a series of largely decoupled single-input, single-output loops for which classical methods are well suited. Where the loops are not fully decoupled, for example the collective pitch control loops for rotor speed and tower vibration, a good coupled solution can be reached after only a very small number of iterations with each loop in turn. In many ways this is more practical than using multivariable methods.

Of particular relevance to this work, the IPC control is decoupled into two orthogonal PI control loops, tuned identically, thus ignoring the azimuthal asymmetry in the turbine dynamics due to the tower. The tower damper was tuned in parallel with the pitch PI controller using an iterative approach, but a single iteration was sufficient.

The main controller parameters are listed in Table 3.1.

For the field testing, the IPC and FATD action can be switched on and off during operation without affecting speed regulation, so by comparing test data with and without the advanced features, the load reduction can be quantified across a variety of wind conditions.

Parameter	Value	Units
Minimum generator speed	862	rpm
Optimal mode quadratic speed-torque gain	0.088425	Nms²/rad²
Rated generator speed	1600	rpm
Generator torque set point	3524.36	Nm
Fine pitch angle	3.7	deg
Dead-band	0.1	deg
Maximum negative pitch rate	-18	deg/s
Maximum positive pitch rate	18	deg/s
Pitch position error adjustment gain	1	s^{-1}
Nominal pitch controller proportional gain	0.0336	s
Nominal pitch controller integral gain	0.0286	-
Gain schedule	Inverse linear on pitch angle	
Gain divisor below 5º	1	-
Gain divisor above 40º	9	-
Fraction of max torque for full pitch bias	0.7	-
Speed set-point increase at full pitch bias	5%	-
Time constant for set-point increase	5	s
Time constant for set-point decrease	2	s
Pitch difference above fine for full torque bias	5	deg
Speed set-point decrease at full torque bias	5%	-
Time constant for set-point decrease	10	s
Time constant for set-point increase	5	s
Pitch controller notch filter	13.8057, 0.177448, 11.36, 0.737909	*Note 1*
Pitch controller notch filter	23.4713, 0.351997, 23.0864, 0.414074	*Note 1*
Pitch controller notch filter	47.86, 0, 47.74, 0.0404	*Note 1*
Pitch controller notch filter	17.3, 0, 17.3, 1	*Note 1*
Pitch controller roll-off filter frequency	62.8319	rad/s
Pitch controller roll-off filter damping factor	0.7071	-
Tower damping gain	0.0225	rad/m
Tower damping high-pass filter frequency	0.628	rad/s
Tower damping high-pass filter damping factor	0.7071	-
Tower damping notch filter	12.97, 0, 12.97, 0.7	*Note 1*
Tower damping lead time constant	1.126	s
Tower damping lag time constant	0.1379	s
Tower damping roll-off filter frequency	40	rad/s
Tower damping roll-off filter damping factor	0.7071	-
IPC maximum amplitude	3	deg
IPC proportional gain	6.676e-8	deg/Nm
IPC integral gain	6.491e-7	deg/Nms
IPC variable notch filter (*Note 2*)	12.97, 0, 16.1064, 0.39363	*Note 1*
IPC notch filter	22, 0, 22, 0.3	*Note 1*
IPC low pass filter frequency	15	rad/s
IPC low pass filter damping factor	0.7071	-
IPC azimuthal compensation time shift	0.0025	s
2P-IPC maximum amplitude	1	deg
2P-IPC proportional gain	1.669e-8	deg/Nm
2P-IPC integral gain	1.623e-7	deg/Nms
2P-IPC filters	Same as 1P-IPC	
Torque controller proportional gain	195.4	Nms/rad
Torque controller integral gain	61.4	Nm/rad
Torque controller notch filter	5.75, 0, 5.67842, 0.9944	*Note 1*
Torque controller 2nd order filter frequency	1.91	rad/s
Torque controller 2nd order filter damping factor	0.55	-

Note 1: Numerator frequency (rad/s), numerator damping factor, denominator frequency (rad/s), denominator damping factor.

Note 2: At 1600 rpm; filter frequency changes in proportion to rpm

Table 3.1: Controller parameters

4. Simulation results

To verify the controller design, a series of turbulent wind simulations were carried out using Bladed 4.0, with and without IPC and FATD, at 6, 9, 12, 15, 18, 21 and 24 m/s mean wind speeds, with turbulence intensities of 20% (longitudinal), 15% (lateral) and 10% (vertical). A few example plots from these runs are presented here, to illustrate the key features of the control action.

Figure 4.1 shows the simulated rotor speed at five different wind speeds. IPC and FATD are enabled throughout these runs, but the results are very similar if they are disabled. The same is true for the power output (Figure 4.2) and collective pitch angle (Figure 4.3).

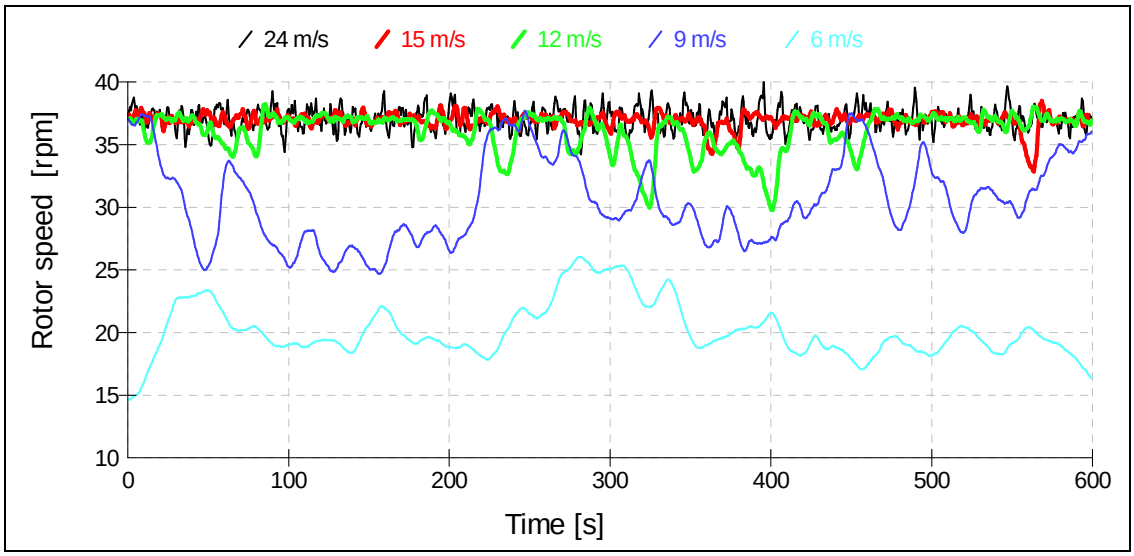

Figure 4.1: Simulated rotor speed at five wind speeds

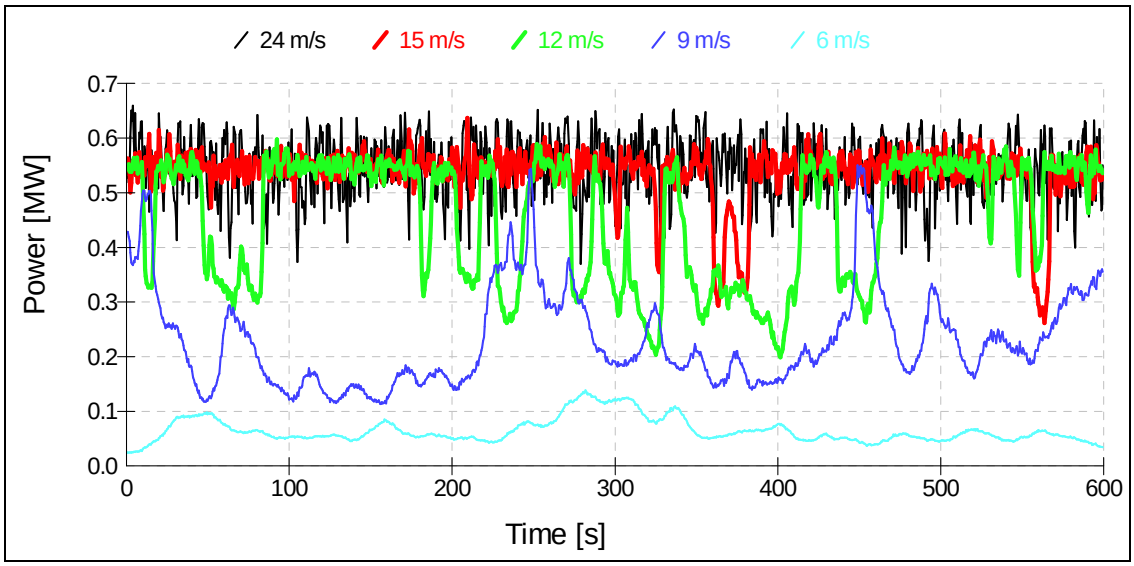

Figure 4.2: Simulated power output at five wind speeds

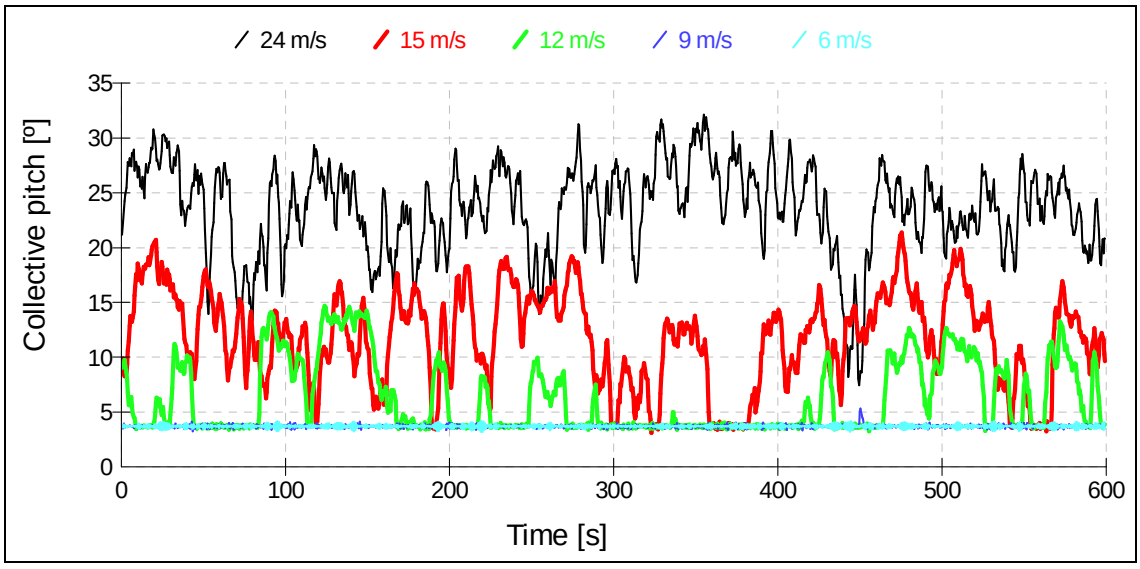

Figure 4.3: Simulated collective pitch angle at five wind speeds
(mean of the three pitch angles)

Figure 4.4 compares the mean power for each simulation with and without the IPC and FATD features, and shows that there is very slight reduction in power when these features are used below rated. This is because the pitch angles are constantly moving around the optimum setting. However the IPC and FATD would normally be phased out below rated anyway, as the load reduction in this region would not be worth the additional pitch activity.

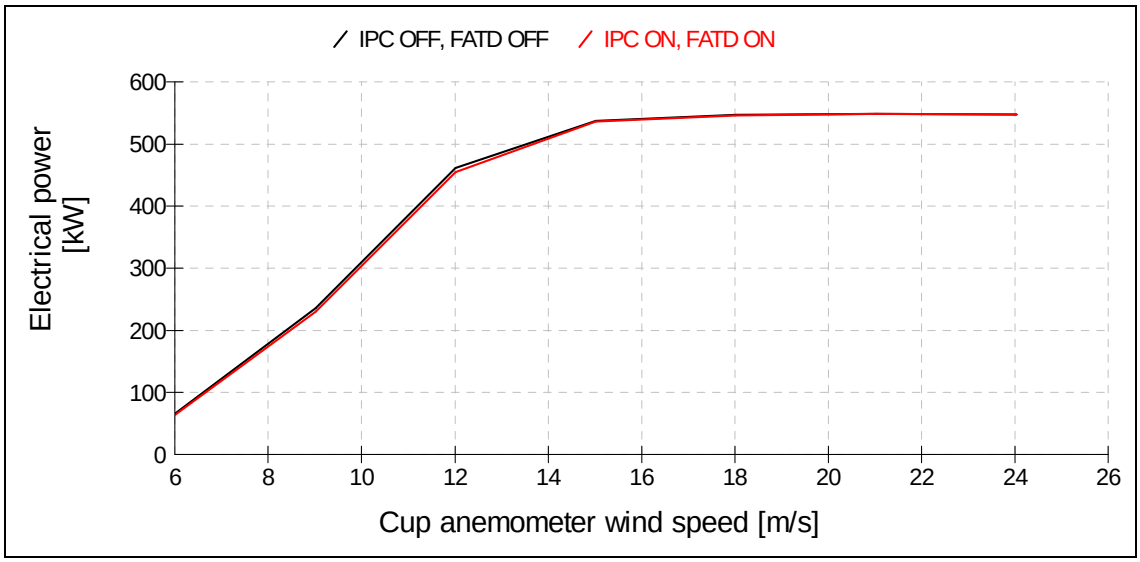

Figure 4.4: Dynamic power curves with and without load reducing control features

Figure 4.5 shows spectra of the simulated shaft bending moment at 9 m/s. Normally IPC would not be used at this low wind speed since the additional pitch action is unlikely to be worth while, but this clearly shows that IPC continues to work at this wind speed. The 1P and 2P peaks in the spectrum are substantially removed, as a result of the 1P IPC and 2P IPC respectively. Note that the peaks are spread out due to the varying speed of operation (see Figure 4.1).

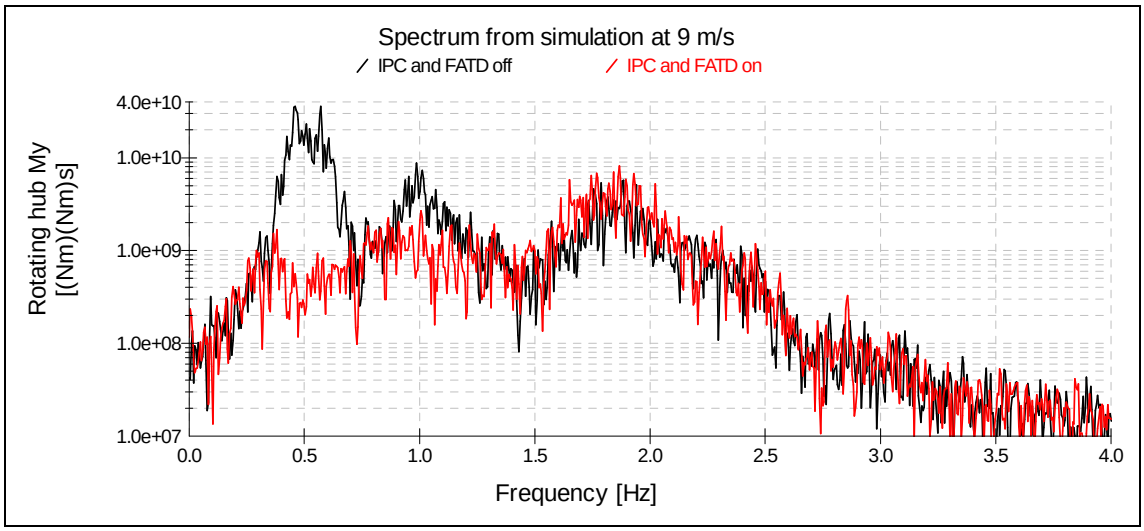

Figure 4.5: Shaft moment spectra at 9 m/s

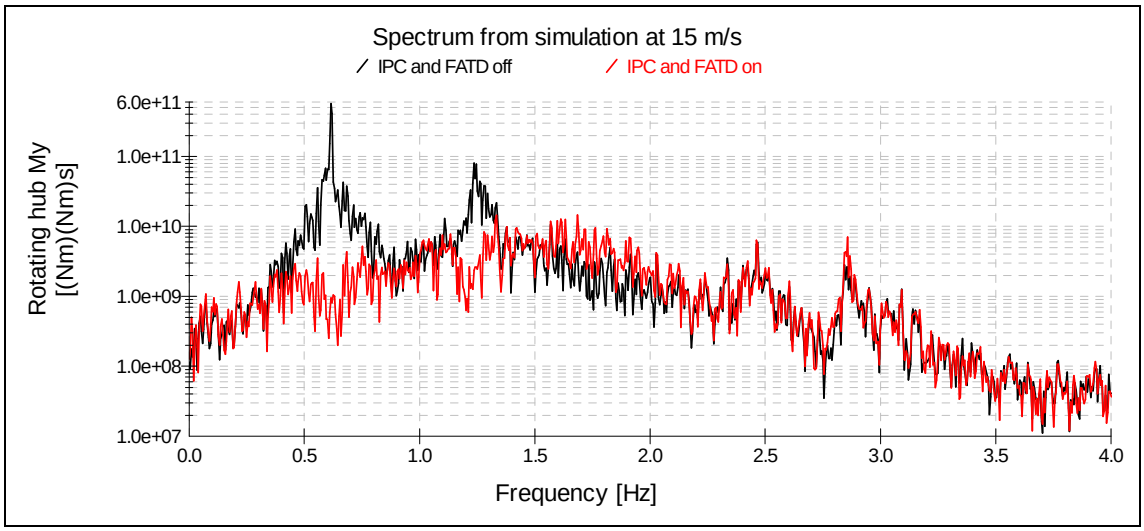

Figure 4.6: Shaft moment spectra at 15 m/s

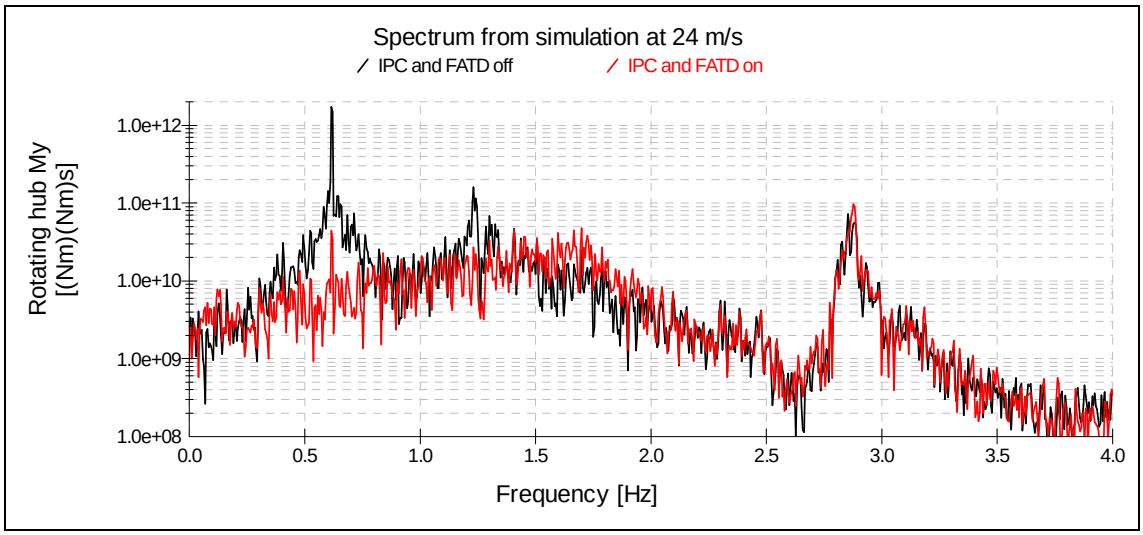

Figure 4.7: Shaft moment spectra at 24 m/s

Figure 4.6 and Figure 4.7 show the same comparison at 15 and 24 m/s respectively. The 1P and 2P peaks are now much sharper as the rotor speed is nearly constant above rated, but again it is clear that both peaks are being substantially removed by the 1P and 2P IPC action, which therefore appears to work equally well at all wind speeds.

A few more spectra are now shown for the 15 m/s case. Figure 4.8 shows the out of plane blade root spectra, and once again the 1P and 2P peaks are removed. There is actually a significant 3P too, indicating that it might be worth also adding a 3P IPC loop, but this has not been done due to lack of time. (In any case the other graphs show that there would not be any benefit for the other loads: there is no significant 3P peak in the shaft loading, nor any significant 2P or 4P peaks in the non-rotating loads.)

Figure 4.9 shows the non-rotating yaw moment at the tower top. Now the 1P IPC removes the low frequency (0P) loading (it would also remove any peak at 2P if it existed). Also the 2P IPC removes the 3P peak (it would also remove any peak at 1P if it existed).

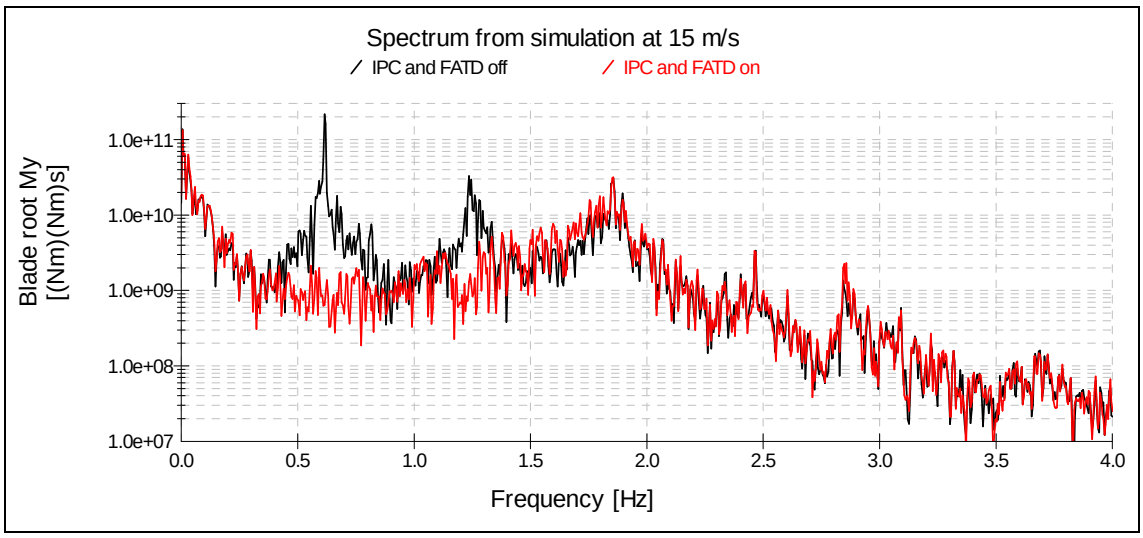

Figure 4.8: Blade root My spectra at 15 m/s

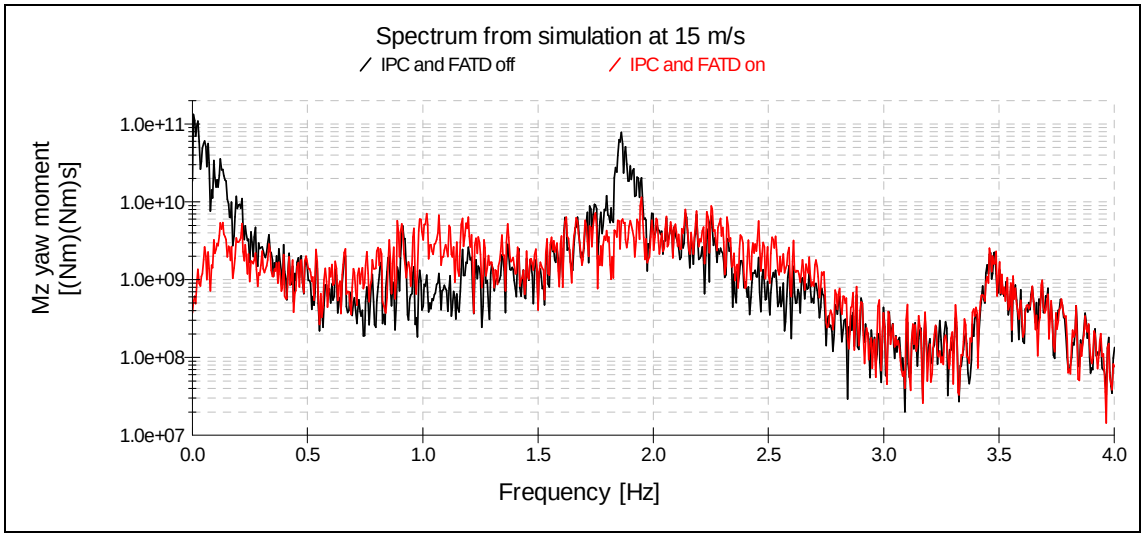

Figure 4.9: Yaw moment spectra at 15 m/s

The effect of the FATD can be clearly seen in Figure 4.10, where the peak at the first tower mode frequency is removed from the tower base fore-aft bending moment.

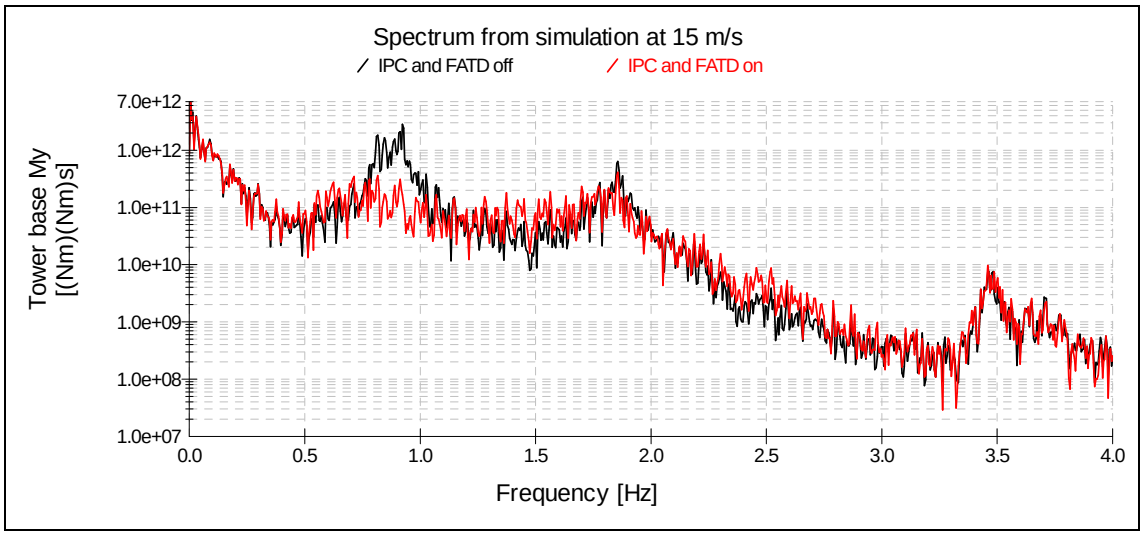

Figure 4.10: Tower base fore-aft bending moment spectra at 15 m/s

Finally Figure 4.11 shows the increase in pitch rate activity at 1P and 2P due to the IPC. There is no discernible increase due to FATD at the tower frequency. However both IPC and FATD contribute to a small increase at the higher frequencies.

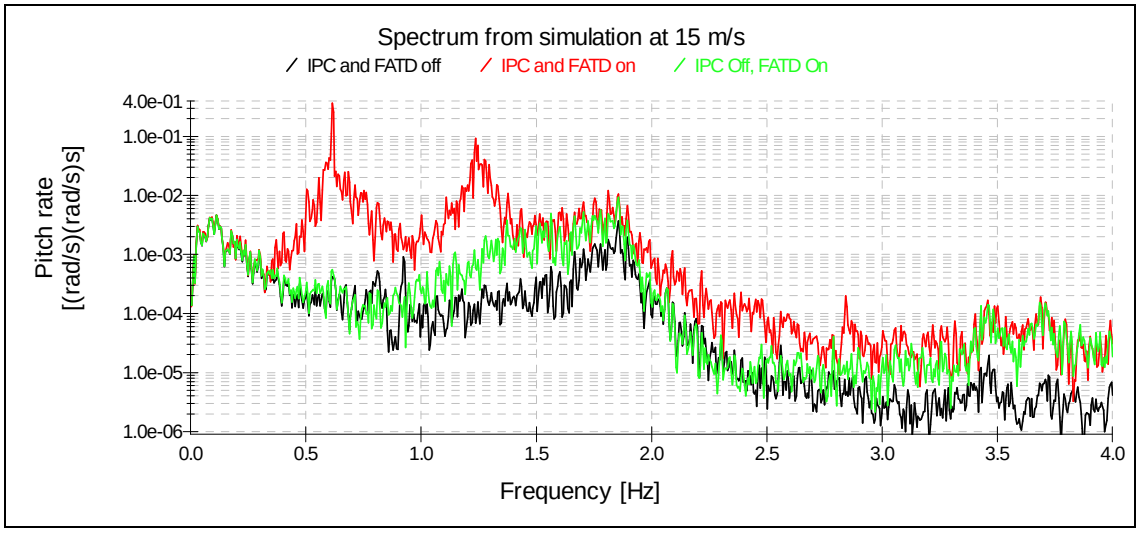

Figure 4.11: Pitch rate spectra at 15 m/s

5. Field tests

The CART3 control system is written using the proprietary LabView software. The GH controller was compiled as a Windows DLL and linked in to the existing controller in such a way as to preserve all the supervisory control, alarm handling etc. and only replace the power production control action. The interface was put together in January 2010 and tested as far as possible without actually running the turbine. As mentioned above, testing could not begin until the turbine was fully commissioned, and problems with vibrational dynamics meant that the turbine was not commissioned fully until November 2010. Parameters of the turbine model were then

adjusted in the light of measured behaviour, and the controller re-tuned and tested in simulation as described in Section 4.

Once the turbine was finally commissioned and ready for testing, some initial running revealed various minor problems which had to be rectified before allowing extended operation with the new controller. This included a memory overrun caused by the DLL, a timestep overrun on the first DLL call, incorrect initialisation of the tower acceleration feedback integrator, and the need for two additional filters: a low-pass filter to prevent pitch actuator problems arising from high-frequency noise on the pitch demands, and a notch at the drive train frequency to prevent excitation by the collective pitch control. From mid-January 2011 a lack of wind prevented significant further data collection, so only some very preliminary indications are available at the time of writing. For example, Figure 5.1 shows two brief samples of IPC operation for a little over 100 seconds each, indicating a distinct reduction in shaft bending moment when IPC is switched on (red line at 100%). This is however at a low wind speed (8 m/s) when IPC would not normally be active. Further progress on testing is awaiting some higher wind speeds.

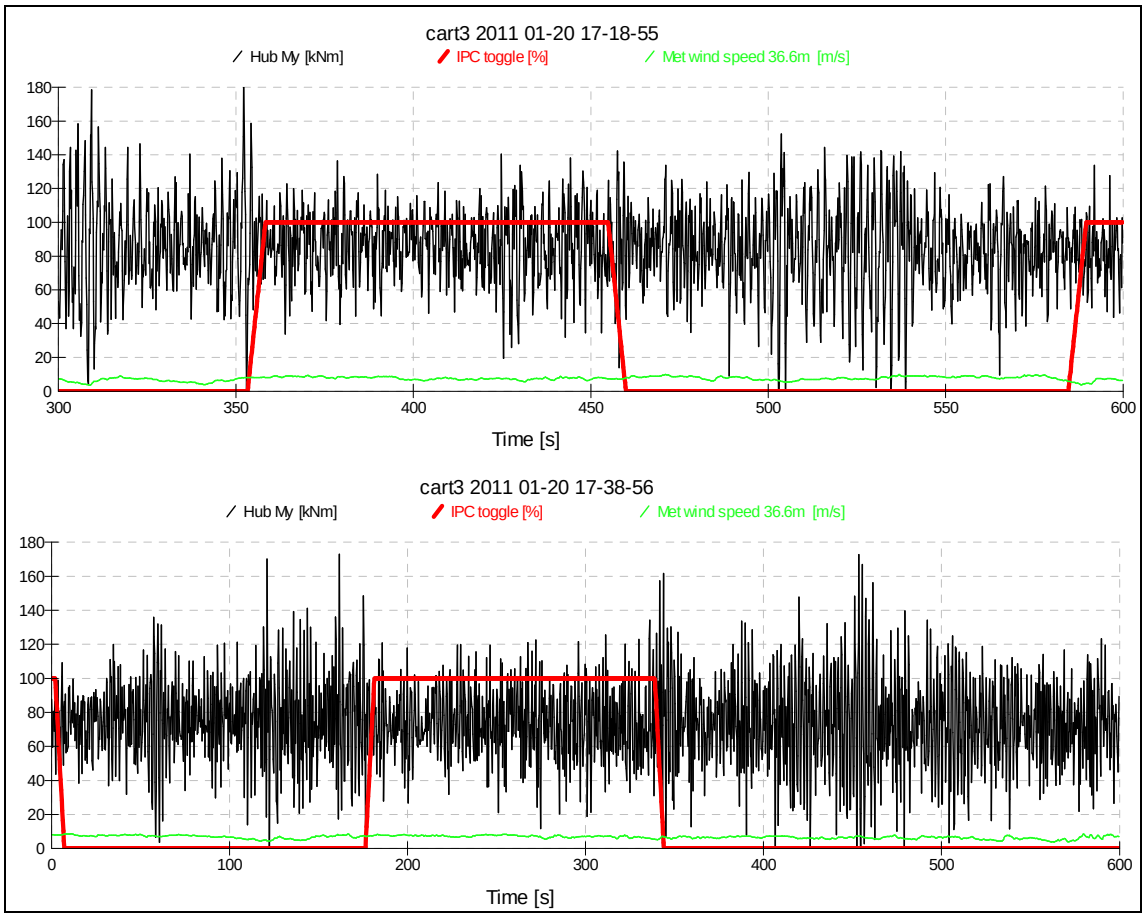

Figure 5.1: Brief data samples showing effect of IPC operation on shaft moment

6. Conclusions

Commissioning problems with the CART3 delayed the programme of testing and only some very preliminary results have been obtained so far, although these appear to be promising. GH and NREL have agreed to continue the programme of work so that a sufficient amount of data for detailed analysis can be obtained covering a range of wind speeds above rated.

7. References

[1] Developments in Individual Blade Pitch Control, E Bossanyi, "The Science of making Torque from Wind" Delft University of Technology, The Netherlands, April 19-21 2004.

[2] Damping of tower motions via pitch control – theory and practice, M. Rossetti, E. Bossanyi, proc. European Wind Energy Conference 2004.

[3] Field testing of individual pitch control on the NREL CART-2 wind turbine, E. Bossanyi, A. Wright, proc. European Wind Energy Conference 2009.

[4] Further progress with field testing of individual pitch control, E. Bossanyi, A. Wright and P. Fleming, proc. European Wind Energy Conference 2010.

[5] Progress with field testing of individual pitch control, E. Bossanyi, A. Wright and P. Fleming, proc. Conference on the science of making torque from wind, The European Academy of Wind Energy, June 2010.

[6] Controller field tests on the NREL CART2 turbine, E. Bossanyi, A. Wright and P. Fleming, Upwind Work Package 5 deliverable report 11593/BR/08, 22/06/2010, http://www.upwind.eu/Shared%20Documents/WP5%20-%20Publications/D%205.6.1.pdf

[7] Resonant vibrations resulting from the re-engineering of a constant-speed 2-bladed turbine to a variable-speed 3-bladed turbine, P A Fleming, A D Wright, L J Fingersh and J-W van Wingerden, 49th AIAA Aerospace Sciences Meeting, 2011.

[8] Geometry and Structural Properties for the Controls Advanced Research Turbine (CART) from Model Tuning, August 25, 2003–November 30, 2003, K A Stol, NREL/SR-500-32087, http://www.nrel.gov/docs/fy04osti/32087.pdf

[9] Wind Turbine Control for Load Reduction, E Bossanyi, Wind Energy 2003 vol 6 pp 229-244.

[10] A state-of-the-art controller for the 5MW UPWIND reference wind turbine, E. Bossanyi and D Witcher, Proceedings of European Wind Energy Conference 2009.

[11] Controller for 5MW reference turbine, E Bossanyi and D Witcher, Upwind Work Package 5 deliverable report 11593/BR/04, 10th July 2009, http://www.upwind.eu/Shared%20Documents/WP5%20-%20Publications/D%205.1.1.%20Controller%20for%205MW%20reference%20turbine.pdf

Appendix A

Bladed model parameters for CART3

GENERAL CHARACTERISTICS OF ROTOR AND TURBINE

Rotor diameter	40.0003	m
Number of blades	3	
Teeter hinge	No	
Hub height	36.596	m
Offset of hub to side of tower centre	0	m
Tower height	34.862	m
Tilt angle of rotor to horizontal	0	deg
Cone angle of rotor	0	deg
Blade set angle	0	deg
Rotor overhang	4.25704	m
Rotational sense of rotor, viewed from upwind	Clockwise	
Position of rotor relative to tower	Upwind	
Transmission	Gearbox	
Aerodynamic control surfaces	Pitch	
Fixed / Variable speed	Variable	
Diameter of spinner	1.6383	m
Radial position of root station	0.81915	m
Extension piece diameter	0	m
Extension piece drag coefficient	0	
Cut in windspeed	4	m/s
Cut out windspeed	25	m/s

BLADE GEOMETRY

Blade length	19.181	m
Pre-bend at tip	0	m
Pitch control	Full span	

Distance along blade (m)	Distance along pitch axis (m)	Chord (m)	Aerodynamic Twist (deg)	Thickness (%)	Neutral axis (x) (m)	Neutral axis (y) (m)	Neutral axis, local (x) (%)	Neutral axis, local (y) (%)
0	0	1.359	19.19	100	0	0	0	50
0.38362	0.38362	1.359	19.19	100	0	0	0	50
0.76724	0.76724	1.359	19.19	100	0	0	0	49
1.15086	1.15086	1.35517	19.002	100	0	0	0	47.5
1.53448	1.53448	1.34749	18.626	100	0	0	0	45
1.9181	1.9181	1.33982	18.25	100	0	0	0	44
2.30172	2.30172	1.41217	17.446	96.274	0	0	0	42.5
2.68534	2.68534	1.48451	16.642	91.3688	0	0	0	40
3.06896	3.06896	1.57842	15.878	83.9125	0	0	0	39.5
3.45258	3.45258	1.6939	15.154	74.6143	0	0	0	38.5
3.8362	3.8362	1.80938	14.43	66.5029	0	0	0	37.5
4.21982	4.21982	1.92812	13.722	52.9738	0	0	0	37.5
4.60344	4.60344	2.04687	13.014	41.0144	0	0	0	37.5
4.98706	4.98706	2.1362	12.194	33.0838	0	0	0	37.5
5.37068	5.37068	2.19614	11.262	28.3716	0	0	0	37.5
5.7543	5.7543	2.25607	10.33	23.9098	0	0	0	37.5
6.13792	6.13792	2.24075	9.51	23.6302	0	0	0	37.5
6.52154	6.52154	2.22542	8.69	23.3467	0	0	0	37.5
6.90516	6.90516	2.20785	7.95	23.0986	0	0	0	37.5
7.28878	7.28878	2.18804	7.29	22.8859	0	0	0	37.5
7.6724	7.6724	2.16823	6.63	22.6693	0	0	0	37.5
8.05602	8.05602	2.14458	6.086	22.5123	0	0	0	37.5
8.43964	8.43964	2.12094	5.542	22.3519	0	0	0	37.5
8.82326	8.82326	2.09563	5.04	22.2189	0	0	0	37.5
9.20688	9.20688	2.06864	4.58	22.1141	0	0	0	37.5
9.5905	9.5905	2.04166	4.12	22.0066	0	0	0	37.5
9.97412	9.97412	2.01236	3.736	21.931	0	0	0	37.5
10.3577	10.3577	1.98305	3.352	21.8533	0	0	0	37.5
10.7414	10.7414	1.95241	2.998	21.7807	0	0	0	37.5
11.125	11.125	1.92043	2.674	21.7135	0	0	0	37.5
11.5086	11.5086	1.88845	2.35	21.644	0	0	0	37.5
11.8922	11.8922	1.85373	2.074	21.5463	0	0	0	37.5
12.2758	12.2758	1.81901	1.798	21.4449	0	0	0	37.5
12.6595	12.6595	1.78319	1.536	21.2934	0	0	0	37.5
13.0431	13.0431	1.74627	1.288	21.0884	0	0	0	37.5
13.4267	13.4267	1.70934	1.04	20.8745	0	0	0	37.5
13.8103	13.8103	1.67013	0.82	20.5103	0	0	0	37.5
14.1939	14.1939	1.63092	0.6	20.1285	0	0	0	37.5
14.5776	14.5776	1.59095	0.398	19.6956	0	0	0	37.5
14.9612	14.9612	1.55022	0.214	19.207	0	0	0	37.5
15.3448	15.3448	1.5095	0.03	18.692	0	0	0	37.5
15.7284	15.7284	1.46729	-0.142	18.1839	0	0	0	37.5
16.112	16.112	1.42508	-0.314	17.6456	0	0	0	37.5
16.4957	16.4957	1.38156	-0.476	17.1674	0	0	0	37.5
16.8793	16.8793	1.33671	-0.628	16.7535	0	0	0	37.5
17.2629	17.2629	1.29187	-0.78	16.311	0	0	0	37.5
17.6465	17.6465	1.24559	-0.916	16.0774	0	0	0	37.5
18.0301	18.0301	1.19932	-1.052	15.8257	0	0	0	37.5
18.4138	18.4138	1.15222	-1.184	15.649	0	0	0	37.5
18.7974	18.7974	1.1043	-1.312	15.5564	0	0	0	37.5
19.181	19.181	1.1043	-1.312	15.5564	0	0	0	37.5

Distance along blade (m)	Aerofoil section	Aerodynamic control
0	1	Moving
0.38362	1	Moving
0.76724	1	Moving
1.15086	1	Moving
1.53448	1	Moving
1.9181	1	Moving
2.30172	1	Moving
2.68534	1	Moving
3.06896	2	Moving
3.45258	2	Moving
3.8362	2	Moving
4.21982	3	Moving
4.60344	3	Moving
4.98706	3	Moving
5.37068	4	Moving
5.7543	4	Moving
6.13792	4	Moving
6.52154	5	Moving
6.90516	5	Moving
7.28878	5	Moving
7.6724	6	Moving
8.05602	6	Moving
8.43964	6	Moving
8.82326	7	Moving
9.20688	7	Moving
9.5905	7	Moving
9.97412	8	Moving
10.3577	8	Moving
10.7414	8	Moving
11.125	9	Moving
11.5086	9	Moving
11.8922	9	Moving
12.2758	10	Moving
12.6595	10	Moving
13.0431	10	Moving
713.4267	11	Moving
13.8103	11	Moving
14.1939	11	Moving
14.5776	11	Moving
14.9612	11	Moving
15.3448	11	Moving
15.7284	12	Moving
16.112	12	Moving
16.4957	12	Moving
16.8793	13	Moving
17.2629	13	Moving
17.6465	13	Moving
18.0301	14	Moving
18.4138	14	Moving
18.7974	14	Moving
19.181	14	Moving

AEROFOIL DATA

Aerofoil Section reference 1: Aerofoil datasets used for interpolation

c3_01-02_circle_AD12R1.5	c3_01-02_circle_AD12R2.5	c3_01-02_circle_AD12R4

Aerofoil Section reference 2: Aerofoil datasets used for interpolation

c3_03_2cir+1s818_AD12R1	c3_03_2cir+1s818_AD12R1.5	c3_03_2cir+1s818_AD12R2
c3_01-02_circle_AD12R1.5	c3_01-02_circle_AD12R2.5	c3_01-02_circle_AD12R4

Aerofoil Section reference 3: Aerofoil datasets used for interpolation

c3_04_1cir+2s818_AD12R2	c3_04_1cir+2s818_AD12R3	c3_04_1cir+2s818_AD12R4

Aerofoil Section reference 4: Aerofoil datasets used for interpolation

c3_05_s818_AD12R2	c3_05_s818_AD12R3	c3_05_s818_AD12R3.5

Aerofoil Section reference 5: Aerofoil datasets used for interpolation

c3_06_6s818+1s816_AD12R2	c3_06_6s818+1s816_AD12R3	c3_06_6s818+1s816_AD12R4

Aerofoil Section reference 6: Aerofoil datasets used for interpolation

c3_07_5s818+2s816_AD12R2	c3_07_5s818+2s816_AD12R3	c3_07_5s818+2s816_AD12R4

Aerofoil Section reference 7: Aerofoil datasets used for interpolation

c3_08_4s818+3s816_AD12R2	c3_08_4s818+3s816_AD12R3	c3_08_4s818+3s816_AD12R4

Aerofoil Section reference 8: Aerofoil datasets used for interpolation

c3_08_4s818+3s816_AD12R2	c3_08_4s818+3s816_AD12R3	c3_08_4s818+3s816_AD12R4

Aerofoil Section reference 9: Aerofoil datasets used for interpolation

c3_10_2s818+5s816_AD12R2	c3_10_2s818+5s816_AD12R3	c3_10_2s818+5s816_AD12R4

Aerofoil Section reference 10: Aerofoil datasets used for interpolation

c3_11_1s818+6s816_AD12R2	c3_11_1s818+6s816_AD12R3	c3_10_2s818+5s816_AD12R4

Aerofoil Section reference 11: Aerofoil datasets used for interpolation

c3_12-13_s816_AD12R2	c3_12-13_s816_AD12R3	c3_12-13_s816_AD12R4

Aerofoil Section reference 12: Aerofoil datasets used for interpolation

c3_14_2s816+1s817_AD12R2	c3_14_2s816+1s817_AD12R3	c3_14_2s816+1s817_AD12R4

Aerofoil Section reference 13: Aerofoil datasets used for interpolation

c3_15_1s816+2s817_AD12R2	c3_15_1s816+2s817_AD12R3	c3_15_1s816+2s817_AD12R4

Aerofoil Section reference 14: Aerofoil datasets used for interpolation

c3_16-20_s817_AD12R2	c3_16-20_s817_AD12R3	c3_16-20_s817_AD12R4

Aerofoil dataset: c3_01-02_circle_AD12R1.5

Description	CART3 set 1
Last changed	01-19-2010@23:59:14

Percentage thickness	100	%
Reynolds number	1.5E+06	
Chordwise origin for pitch moments	25	%
Aileron deployment angle	0	deg

Angle of Attack (deg)	Lift coefficient	Drag coefficient
-180	0	0.46
180	0	0.46

Aerofoil dataset: c3_01-02_circle_AD12R2.5

Description	CART3 set 1
Last changed	01-19-2010@23:59:23

Percentage thickness	100	%
Reynolds number	2.5E+06	
Chordwise origin for pitch moments	25	%
Aileron deployment angle	0	deg

Angle of Attack (deg)	Lift coefficient	Drag coefficient
-180	0	0.57
180	0	0.57

Aerofoil dataset: c3_01-02_circle_AD12R4

Description	CART3 set 1
Last changed	01-19-2010@23:59:35

Percentage thickness	100	%
Reynolds number	4.E+06	
Chordwise origin for pitch moments	25	%
Aileron deployment angle	0	deg

Angle of Attack (deg)	Lift coefficient	Drag coefficient
-180	0	0.67
180	0	0.67

Aerofoil dataset: c3_03_2cir+1s818_AD12R1

Description	CART3 set 2
Last changed	01-20-2010@16:41:46

Percentage thickness	70	%
Reynolds number	1.E+06	
Chordwise origin for pitch moments	25	%
Aileron deployment angle	0	deg

Angle of Attack (deg)	Lift coefficient	Drag coefficient
-180	0	0.3689
-170	0.114	0.375
-160	0.095	0.3925
-150	0.09	0.4193
-140	0.086	0.4522
-130	0.079	0.4873
-120	0.066	0.5204
-110	0.047	0.5475
-100	0.024	0.5655
-90	0	0.5723
-80	-0.024	0.5655
-70	-0.047	0.5475
-60	-0.066	0.5204
-50	-0.079	0.4873
-40	-0.086	0.4522
-30	-0.09	0.4193
-20	-0.095	0.3925
-10	-0.102	0.3759
-6	-0.01	0.3744
-5	0.002	0.3744
-4	0.014	0.3744
-3	0.026	0.3744
-2	0.037	0.3744
-1	0.049	0.3744
0	0.061	0.3745
1	0.073	0.3745
2	0.085	0.3745
3	0.097	0.3745
4	0.109	0.3746
5	0.12	0.3746
6	0.132	0.3746
7	0.143	0.3747
8	0.155	0.3748
9	0.166	0.3748
10	0.171	0.3759
11	0.179	0.3762
12	0.136	0.3925
13	0.136	0.394
20	0.132	0.4059
30	0.128	0.4193
40	0.124	0.4522
50	0.113	0.4873
60	0.094	0.5204
70	0.067	0.5475
80	0.035	0.5655
90	0	0.5723
100	-0.024	0.5655
110	-0.047	0.5475
120	-0.066	0.5204
130	-0.079	0.4873
140	-0.086	0.4522
150	-0.09	0.4193
160	-0.095	0.3925
170	-0.114	0.375
180	0	0.3689

Aerofoil dataset: c3_03_2cir+1s818_AD12R1.5

Description	CART3 set 2
Last changed	01-20-2010@16:41:56

Percentage thickness	70	%
Reynolds number	1.5E+06	
Chordwise origin for pitch moments	25	%
Aileron deployment angle	0	deg

Angle of Attack (deg)	Lift coefficient	Drag coefficient
-180	0	0.4223
-170	0.114	0.4283
-160	0.095	0.4458
-150	0.09	0.4726
-140	0.086	0.5055
-130	0.079	0.5406
-120	0.066	0.5737
-110	0.047	0.6009
-100	0.024	0.6189
-90	0	0.6256
-80	-0.024	0.6189
-70	-0.047	0.6009
-60	-0.066	0.5737
-50	-0.079	0.5406
-40	-0.086	0.5055
-30	-0.09	0.4726
-20	-0.095	0.4458
-10	-0.102	0.4292
-6	-0.01	0.4277
-5	0.002	0.4277
-4	0.014	0.4277
-3	0.026	0.4277
-2	0.037	0.4278
-1	0.049	0.4278
0	0.061	0.4278
1	0.073	0.4278
2	0.085	0.4278
3	0.097	0.4279
4	0.109	0.4279
5	0.12	0.4279
6	0.132	0.428
7	0.143	0.428
8	0.155	0.4281
9	0.166	0.4282
10	0.171	0.4293
11	0.179	0.4296
12	0.136	0.4458
13	0.136	0.4473
20	0.132	0.4592
30	0.128	0.4726
40	0.124	0.5055
50	0.113	0.5406
60	0.094	0.5737
70	0.067	0.6009
80	0.035	0.6189
90	0	0.6256
100	-0.024	0.6189
110	-0.047	0.6009

120	-0.066	0.5737
130	-0.079	0.5406
140	-0.086	0.5055
150	-0.09	0.4726
160	-0.095	0.4458
170	-0.114	0.4283
180	0	0.4223

Aerofoil dataset: c3_03_2cir+1s818_AD12R2

Description	CART3 set 2
Last changed	01-20-2010@16:42:08

Percentage thickness	70	%
Reynolds number	2.E+06	
Chordwise origin for pitch moments	25	%
Aileron deployment angle	0	deg

Angle of Attack (deg)	Lift coefficient	Drag coefficient
-180	0	0.3567
-170	0.328	0.3545
-160	0.307	0.4071
-150	0.281	0.4878
-140	0.267	0.5869
-130	0.242	0.6926
-120	0.2	0.7925
-110	0.143	0.8746
-100	0.074	0.9293
-90	0	0.9503
-80	-0.074	0.9293
-70	-0.143	0.8746
-60	-0.2	0.7925
-50	-0.242	0.6926
-40	-0.267	0.5869
-30	-0.281	0.4878
-20	-0.307	0.4071
-10	-0.269	0.3604
-6	-0.031	0.3563
-5	0.005	0.3563
-4	0.041	0.3563
-3	0.077	0.3564
-2	0.113	0.3564
-1	0.149	0.3565
0	0.185	0.3565
1	0.22	0.3566
2	0.256	0.3566
3	0.291	0.3567
4	0.327	0.3568
5	0.362	0.3569
6	0.397	0.3571
7	0.431	0.3572
8	0.466	0.3574
9	0.5	0.3576
10	0.516	0.3608
11	0.542	0.3616
12	0.562	0.3624

13	0.546	0.368
20	0.439	0.4071
30	0.402	0.4878
40	0.381	0.5869
50	0.346	0.6926
60	0.286	0.7925
70	0.204	0.8746
80	0.105	0.9293
90	0	0.9503
100	-0.074	0.9293
110	-0.143	0.8746
120	-0.2	0.7925
130	-0.242	0.6926
140	-0.267	0.5869
150	-0.281	0.4878
160	-0.307	0.4071
170	-0.328	0.3545
180	0	0.3567

Aerofoil dataset: c3_04_1cir+2s818_AD12R2

Description	CART3 set 3
Last changed	01-20-2010@00:13:51

Percentage thickness	0	%
Reynolds number	2.E+06	
Chordwise origin for pitch moments	25	%
Aileron deployment angle	0	deg

Angle of Attack (deg)	Lift coefficient	Drag coefficient
-180	0	0.1833
-170	0.655	0.179
-160	0.614	0.2842
-150	0.563	0.4455
-140	0.534	0.6437
-130	0.484	0.8553
-120	0.401	1.055
-110	0.285	1.2192
-100	0.147	1.3286
-90	0	1.3706
-80	-0.147	1.3286
-70	-0.285	1.2192
-60	-0.401	1.055
-50	-0.484	0.8553
-40	-0.534	0.6437
-30	-0.563	0.4455
-20	-0.614	0.2842
-10	-0.539	0.1907
-6	-0.062	0.1826
-5	0.01	0.1827
-4	0.082	0.1827
-3	0.154	0.1827
-2	0.226	0.1829
-1	0.297	0.1829
0	0.369	0.183

1	0.441	0.1831
2	0.511	0.1833
3	0.583	0.1834
4	0.653	0.1836
5	0.723	0.1839
6	0.793	0.1841
7	0.863	0.1845
8	0.932	0.1849
9	1	0.1853
10	1.031	0.1915
11	1.085	0.1933
12	1.123	0.1948
13	1.093	0.206
20	0.878	0.2842
30	0.804	0.4455
40	0.763	0.6437
50	0.691	0.8553
60	0.572	1.055
70	0.408	1.2192
80	0.21	1.3286
90	0	1.3706
100	-0.147	1.3286
110	-0.285	1.2192
120	-0.401	1.055
130	-0.484	0.8553
140	-0.534	0.6437
150	-0.563	0.4455
160	-0.614	0.2842
170	-0.655	0.179
180	0	0.1833

Aerofoil dataset: c3_04_1cir+2s818_AD12R3

Description	CART3 set 3
Last changed	01-20-2010@00:14:03

Percentage thickness	0	%
Reynolds number	3.E+06	
Chordwise origin for pitch moments	25	%
Aileron deployment angle	0	deg

Angle of Attack (deg)	Lift coefficient	Drag coefficient
-180	0	0.1833
-170	0.666	0.1777
-160	0.622	0.2829
-150	0.567	0.4444
-140	0.536	0.6427
-130	0.485	0.8544
-120	0.401	1.0543
-110	0.286	1.2188
-100	0.147	1.3284
-90	0	1.3706
-80	-0.147	1.3284
-70	-0.286	1.2188
-60	-0.401	1.0543

-50	-0.485	0.8544
-40	-0.536	0.6427
-30	-0.567	0.4444
-20	-0.622	0.2829
-10	-0.547	0.1898
-6	-0.06	0.1823
-5	0.012	0.1823
-4	0.084	0.1823
-3	0.156	0.1824
-2	0.228	0.1824
-1	0.299	0.1825
0	0.371	0.1825
1	0.443	0.1827
2	0.514	0.1828
3	0.585	0.1829
4	0.655	0.1831
5	0.726	0.1834
6	0.796	0.1837
7	0.866	0.1839
8	0.935	0.1843
9	0.983	0.1885
10	1.039	0.1905
11	1.095	0.1921
12	1.142	0.1935
13	1.11	0.2047
20	0.888	0.2829
30	0.81	0.4444
40	0.766	0.6427
50	0.693	0.8544
60	0.573	1.0543
70	0.408	1.2188
80	0.21	1.3284
90	0	1.3706
100	-0.147	1.3284
110	-0.286	1.2188
120	-0.401	1.0543
130	-0.485	0.8544
140	-0.536	0.6427
150	-0.567	0.4444
160	-0.622	0.2829
170	-0.666	0.1777
180	0	0.1833

Aerofoil dataset: c3_04_1cir+2s818_AD12R4

Description	CART3 set 3
Last changed	01-20-2010@00:14:12

Percentage thickness	0	%
Reynolds number	4.E+06	
Chordwise origin for pitch moments	25	%
Aileron deployment angle	0	deg

Angle of Attack (deg)	Lift coefficient	Drag coefficient
-180	0	0.1833
-170	0.635	0.1833
-160	0.662	0.2754
-150	0.59	0.4374
-140	0.551	0.6366
-130	0.494	0.8493
-120	0.406	1.0503
-110	0.288	1.216
-100	0.148	1.327
-90	0	1.3706
-80	-0.148	1.327
-70	-0.288	1.216
-60	-0.406	1.0503
-50	-0.494	0.8493
-40	-0.551	0.6366
-30	-0.59	0.4374
-20	-0.662	0.2754
-10	-0.49	0.1893
-6	-0.06	0.1821
-5	0.013	0.1822
-4	0.085	0.1822
-3	0.157	0.1823
-2	0.229	0.1823
-1	0.3	0.1823
0	0.372	0.1824
1	0.443	0.1825
2	0.515	0.1827
3	0.586	0.1828
4	0.657	0.183
5	0.727	0.1833
6	0.797	0.1835
7	0.867	0.1837
8	0.936	0.1841
9	0.983	0.1884
10	1.041	0.1901
11	1.097	0.1917
12	1.149	0.1931
13	1.18	0.1947
20	0.945	0.2754
30	0.843	0.4374
40	0.787	0.6366
50	0.705	0.8493
60	0.58	1.0503
70	0.411	1.216
80	0.211	1.327
90	0	1.3706
100	-0.148	1.327
110	-0.288	1.216
120	-0.406	1.0503
130	-0.494	0.8493
140	-0.551	0.6366
150	-0.59	0.4374
160	-0.662	0.2754

170	-0.635	0.1833
180	0	0.1833

Aerofoil dataset: c3_05_s818_AD12R2

Description	CART3 set 4
Last changed	01-20-2010@00:14:24

Percentage thickness	0	%
Reynolds number	2.E+06	
Chordwise origin for pitch moments	25	%
Aileron deployment angle	0	deg

Angle of Attack (deg)	Lift coefficient	Drag coefficient
-180	0	0.01
-170	0.983	0.0034
-160	0.922	0.1612
-150	0.844	0.4033
-140	0.801	0.7006
-130	0.726	1.0179
-120	0.601	1.3175
-110	0.428	1.5638
-100	0.221	1.7279
-90	0	1.7908
-80	-0.221	1.7279
-70	-0.428	1.5638
-60	-0.601	1.3175
-50	-0.726	1.0179
-40	-0.801	0.7006
-30	-0.844	0.4033
-20	-0.922	0.1612
-10	-0.808	0.0211
-6	-0.093	0.0089
-5	0.015	0.009
-4	0.123	0.009
-3	0.231	0.0091
-2	0.339	0.0093
-1	0.446	0.0094
0	0.554	0.0095
1	0.661	0.0097
2	0.767	0.0099
3	0.874	0.0101
4	0.98	0.0104
5	1.085	0.0108
6	1.19	0.0112
7	1.294	0.0117
8	1.398	0.0123
9	1.5	0.0129
10	1.547	0.0223
11	1.627	0.0249
12	1.685	0.0272
13	1.639	0.044
20	1.317	0.1612
30	1.206	0.4033
40	1.144	0.7006

50	1.037	1.0179
60	0.858	1.3175
70	0.611	1.5638
80	0.315	1.7279
90	0	1.7908
100	-0.221	1.7279
110	-0.428	1.5638
120	-0.601	1.3175
130	-0.726	1.0179
140	-0.801	0.7006
150	-0.844	0.4033
160	-0.922	0.1612
170	-0.983	0.0034
180	0	0.01

Aerofoil dataset: c3_05_s818_AD12R3

Description	CART3 set 4
Last changed	01-20-2010@00:14:32

Percentage thickness	0	%
Reynolds number	3.E+06	
Chordwise origin for pitch moments	25	%
Aileron deployment angle	0	deg

Angle of Attack (deg)	Lift coefficient	Drag coefficient
-180	0	0.01
-170	0.999	0.0015
-160	0.933	0.1594
-150	0.851	0.4016
-140	0.805	0.6991
-130	0.728	1.0167
-120	0.602	1.3165
-110	0.428	1.5631
-100	0.221	1.7276
-90	0	1.7908
-80	-0.221	1.7276
-70	-0.428	1.5631
-60	-0.602	1.3165
-50	-0.728	1.0167
-40	-0.805	0.6991
-30	-0.851	0.4016
-20	-0.933	0.1594
-10	-0.82	0.0197
-6	-0.09	0.0084
-5	0.018	0.0085
-4	0.126	0.0085
-3	0.234	0.0086
-2	0.342	0.0086
-1	0.449	0.0087
0	0.557	0.0088
1	0.664	0.009
2	0.771	0.0092
3	0.877	0.0094
4	0.983	0.0097

5	1.089	0.0101
6	1.194	0.0105
7	1.299	0.0109
8	1.403	0.0114
9	1.474	0.0178
10	1.558	0.0207
11	1.642	0.0231
12	1.713	0.0253
13	1.665	0.0421
20	1.332	0.1594
30	1.215	0.4016
40	1.149	0.6991
50	1.04	1.0167
60	0.86	1.3165
70	0.612	1.5631
80	0.315	1.7276
90	0	1.7908
100	-0.221	1.7276
110	-0.428	1.5631
120	-0.602	1.3165
130	-0.728	1.0167
140	-0.805	0.6991
150	-0.851	0.4016
160	-0.933	0.1594
170	-0.999	0.0015
180	0	0.01

Aerofoil dataset: c3_05_s818_AD12R3.5

Description	CART3 set 4
Last changed	01-20-2010@00:14:39

Percentage thickness	0	%
Reynolds number	3.5E+06	
Chordwise origin for pitch moments	25	%
Aileron deployment angle	0	deg

Angle of Attack (deg)	Lift coefficient	Drag coefficient
-180	0	0.01
-170	0.953	0.01
-160	0.993	0.1481
-150	0.886	0.3912
-140	0.826	0.6899
-130	0.74	1.0089
-120	0.609	1.3105
-110	0.431	1.559
-100	0.221	1.7255
-90	0	1.7908
-80	-0.221	1.7255
-70	-0.431	1.559
-60	-0.609	1.3105
-50	-0.74	1.0089
-40	-0.826	0.6899
-30	-0.886	0.3912
-20	-0.993	0.1481

-10	-0.735	0.0189
-6	-0.09	0.0082
-5	0.019	0.0083
-4	0.127	0.0083
-3	0.235	0.0084
-2	0.343	0.0084
-1	0.45	0.0085
0	0.558	0.0086
1	0.665	0.0088
2	0.772	0.009
3	0.879	0.0092
4	0.985	0.0095
5	1.09	0.0099
6	1.196	0.0102
7	1.3	0.0106
8	1.404	0.0111
9	1.475	0.0176
10	1.562	0.0202
11	1.646	0.0225
12	1.724	0.0246
13	1.77	0.027
20	1.418	0.1481
30	1.265	0.3912
40	1.18	0.6899
50	1.058	1.0089
60	0.87	1.3105
70	0.616	1.559
80	0.316	1.7255
90	0	1.7908
100	-0.221	1.7255
110	-0.431	1.559
120	-0.609	1.3105
130	-0.74	1.0089
140	-0.826	0.6899
150	-0.886	0.3912
160	-0.993	0.1481
170	-0.953	0.01
180	0	0.01

Aerofoil dataset: c3_06_6s818+1s816_AD12R2

Description	CART3 set 5
Last changed	01-20-2010@00:14:50

Percentage thickness	0	%
Reynolds number	2.E+06	
Chordwise origin for pitch moments	25	%
Aileron deployment angle	0	deg

Angle of Attack (deg)	Lift coefficient	Drag coefficient
-180	0	0.01
-170	0.954	0.007
-160	0.886	0.1652
-150	0.825	0.408
-140	0.79	0.7061

-130	0.72	1.0243
-120	0.599	1.3245
-110	0.428	1.5713
-100	0.221	1.7354
-90	0	1.798
-80	-0.221	1.7354
-70	-0.428	1.5713
-60	-0.599	1.3245
-50	-0.72	1.0243
-40	-0.79	0.7061
-30	-0.825	0.408
-20	-0.886	0.1652
-10	-0.804	0.0221
-6	-0.123	0.0098
-5	-0.014	0.0095
-4	0.096	0.009
-3	0.199	0.0087
-2	0.307	0.0089
-1	0.415	0.009
0	0.523	0.0091
1	0.63	0.0093
2	0.736	0.0094
3	0.843	0.0096
4	0.949	0.0099
5	1.054	0.0103
6	1.159	0.0106
7	1.255	0.012
8	1.356	0.0128
9	1.455	0.0136
10	1.486	0.0231
11	1.552	0.0277
12	1.6	0.0319
13	1.558	0.0486
20	1.266	0.1652
30	1.178	0.408
40	1.129	0.7061
50	1.029	1.0243
60	0.856	1.3245
70	0.611	1.5713
80	0.316	1.7354
90	0	1.798
100	-0.221	1.7354
110	-0.428	1.5713
120	-0.599	1.3245
130	-0.72	1.0243
140	-0.79	0.7061
150	-0.825	0.408
160	-0.886	0.1652
170	-0.954	0.007
180	0	0.01

Aerofoil dataset: c3_06_6s818+1s816_AD12R3

Description	CART3 set 5
Last changed	01-20-2010@00:15:15

Percentage thickness	0	%
Reynolds number	3.E+06	
Chordwise origin for pitch moments	25	%
Aileron deployment angle	0	deg

Angle of Attack (deg)	Lift coefficient	Drag coefficient
-180	0	0.01
-170	0.968	0.0053
-160	0.896	0.1637
-150	0.83	0.4065
-140	0.793	0.7049
-130	0.722	1.0232
-120	0.6	1.3237
-110	0.428	1.5707
-100	0.221	1.7351
-90	0	1.798
-80	-0.221	1.7351
-70	-0.428	1.5707
-60	-0.6	1.3237
-50	-0.722	1.0232
-40	-0.793	0.7049
-30	-0.83	0.4065
-20	-0.896	0.1637
-10	-0.815	0.0209
-6	-0.121	0.0094
-5	-0.011	0.009
-4	0.098	0.0086
-3	0.201	0.0083
-2	0.31	0.0083
-1	0.417	0.0084
0	0.525	0.0085
1	0.633	0.0087
2	0.74	0.0088
3	0.846	0.009
4	0.952	0.0093
5	1.058	0.0097
6	1.163	0.01
7	1.259	0.0113
8	1.36	0.0121
9	1.432	0.0178
10	1.495	0.0218
11	1.565	0.0261
12	1.624	0.0303
13	1.581	0.047
20	1.28	0.1637
30	1.186	0.4065
40	1.133	0.7049
50	1.032	1.0232
60	0.857	1.3237
70	0.612	1.5707
80	0.316	1.7351

90	0	1.798
100	-0.221	1.7351
110	-0.428	1.5707
120	-0.6	1.3237
130	-0.722	1.0232
140	-0.793	0.7049
150	-0.83	0.4065
160	-0.896	0.1637
170	-0.968	0.0053
180	0	0.01

Aerofoil dataset: c3_06_6s818+1s816_AD12R4

Description	CART3 set 5
Last changed	01-20-2010@00:15:24

Percentage thickness	0	%
Reynolds number	4.E+06	
Chordwise origin for pitch moments	25	%
Aileron deployment angle	0	deg

Angle of Attack (deg)	Lift coefficient	Drag coefficient
-180	0	0.01
-170	0.944	0.0112
-160	0.954	0.1527
-150	0.864	0.3964
-140	0.814	0.6959
-130	0.735	1.0157
-120	0.606	1.3178
-110	0.431	1.5667
-100	0.222	1.7331
-90	0	1.798
-80	-0.222	1.7331
-70	-0.431	1.5667
-60	-0.606	1.3178
-50	-0.735	1.0157
-40	-0.814	0.6959
-30	-0.864	0.3964
-20	-0.954	0.1527
-10	-0.757	0.0189
-6	-0.126	0.0087
-5	-0.013	0.0086
-4	0.099	0.0084
-3	0.202	0.0081
-2	0.311	0.0081
-1	0.418	0.0082
0	0.526	0.0083
1	0.634	0.0084
2	0.741	0.0086
3	0.848	0.0088
4	0.954	0.0091
5	1.059	0.0094
6	1.165	0.0097
7	1.261	0.011
8	1.363	0.0117

9	1.435	0.0175
10	1.52	0.02
11	1.589	0.0242
12	1.652	0.0283
13	1.688	0.0327
20	1.363	0.1527
30	1.235	0.3964
40	1.163	0.6959
50	1.049	1.0157
60	0.866	1.3178
70	0.616	1.5667
80	0.317	1.7331
90	0	1.798
100	-0.222	1.7331
110	-0.431	1.5667
120	-0.606	1.3178
130	-0.735	1.0157
140	-0.814	0.6959
150	-0.864	0.3964
160	-0.954	0.1527
170	-0.944	0.0112
180	0	0.01

Aerofoil dataset: c3_07_5s818+2s816_AD12R2

Description	CART3 set 6
Last changed	01-20-2010@15:12:22

Percentage thickness	40	%
Reynolds number	2.E+06	
Chordwise origin for pitch moments	25	%
Aileron deployment angle	0	deg

Angle of Attack (deg)	Lift coefficient	Drag coefficient
-180	0	0.01
-170	0.926	0.0105
-160	0.851	0.1692
-150	0.806	0.4126
-140	0.779	0.7117
-130	0.715	1.0306
-120	0.597	1.3315
-110	0.428	1.5787
-100	0.221	1.7429
-90	0	1.8051
-80	-0.221	1.7429
-70	-0.428	1.5787
-60	-0.597	1.3315
-50	-0.715	1.0306
-40	-0.779	0.7117
-30	-0.806	0.4126
-20	-0.851	0.1692
-10	-0.801	0.0231
-6	-0.154	0.0108
-5	-0.043	0.0099
-4	0.068	0.009

-3	0.167	0.0084
-2	0.275	0.0085
-1	0.383	0.0086
0	0.492	0.0086
1	0.599	0.0088
2	0.705	0.009
3	0.812	0.0091
4	0.918	0.0094
5	1.023	0.0097
6	1.128	0.0101
7	1.216	0.0123
8	1.314	0.0134
9	1.409	0.0142
10	1.425	0.024
11	1.477	0.0304
12	1.514	0.0367
13	1.477	0.0532
20	1.216	0.1692
30	1.151	0.4126
40	1.114	0.7117
50	1.022	1.0306
60	0.853	1.3315
70	0.611	1.5787
80	0.316	1.7429
90	0	1.8051
100	-0.221	1.7429
110	-0.428	1.5787
120	-0.597	1.3315
130	-0.715	1.0306
140	-0.779	0.7117
150	-0.806	0.4126
160	-0.851	0.1692
170	-0.926	0.0105
180	0	0.01

Aerofoil dataset: c3_07_5s818+2s816_AD12R3

Description	CART3 set 6
Last changed	01-20-2010@15:12:32

Percentage thickness	40	%
Reynolds number	3.E+06	
Chordwise origin for pitch moments	25	%
Aileron deployment angle	0	deg

Angle of Attack (deg)	Lift coefficient	Drag coefficient
-180	0	0.01
-170	0.937	0.0091
-160	0.859	0.1679
-150	0.81	0.4114
-140	0.782	0.7106
-130	0.717	1.0297
-120	0.598	1.3308
-110	0.428	1.5782
-100	0.221	1.7427

-90	0	1.8051
-80	-0.221	1.7427
-70	-0.428	1.5782
-60	-0.598	1.3308
-50	-0.717	1.0297
-40	-0.782	0.7106
-30	-0.81	0.4114
-20	-0.859	0.1679
-10	-0.81	0.0221
-6	-0.152	0.0104
-5	-0.041	0.0096
-4	0.071	0.0087
-3	0.169	0.008
-2	0.277	0.008
-1	0.385	0.0081
0	0.494	0.0081
1	0.601	0.0083
2	0.708	0.0085
3	0.814	0.0086
4	0.92	0.0089
5	1.026	0.0092
6	1.131	0.0096
7	1.22	0.0117
8	1.318	0.0127
9	1.391	0.0177
10	1.432	0.0228
11	1.488	0.0291
12	1.534	0.0353
13	1.496	0.0519
20	1.227	0.1679
30	1.157	0.4114
40	1.118	0.7106
50	1.024	1.0297
60	0.854	1.3308
70	0.611	1.5782
80	0.316	1.7427
90	0	1.8051
100	-0.221	1.7427
110	-0.428	1.5782
120	-0.598	1.3308
130	-0.717	1.0297
140	-0.782	0.7106
150	-0.81	0.4114
160	-0.859	0.1679
170	-0.937	0.0091
180	0	0.01

Aerofoil dataset: c3_07_5s818+2s816_AD12R4

Description	CART3 set 6
Last changed	01-20-2010@15:12:40

Percentage thickness	40	%
Reynolds number	4.E+06	
Chordwise origin for pitch moments	25	%
Aileron deployment angle	0	deg

Angle of Attack (deg)	Lift coefficient	Drag coefficient
-180	0	0.01
-170	0.935	0.0124
-160	0.916	0.1572
-150	0.843	0.4016
-140	0.802	0.7019
-130	0.729	1.0224
-120	0.604	1.3252
-110	0.431	1.5743
-100	0.222	1.7407
-90	0	1.8051
-80	-0.222	1.7407
-70	-0.431	1.5743
-60	-0.604	1.3252
-50	-0.729	1.0224
-40	-0.802	0.7019
-30	-0.843	0.4016
-20	-0.916	0.1572
-10	-0.779	0.0188
-6	-0.162	0.0093
-5	-0.045	0.0089
-4	0.071	0.0084
-3	0.17	0.0078
-2	0.278	0.0078
-1	0.386	0.0078
0	0.495	0.0079
1	0.602	0.0081
2	0.71	0.0083
3	0.816	0.0084
4	0.922	0.0086
5	1.028	0.009
6	1.134	0.0092
7	1.222	0.0114
8	1.321	0.0123
9	1.395	0.0174
10	1.478	0.0197
11	1.532	0.026
12	1.58	0.0321
13	1.607	0.0384
20	1.308	0.1572
30	1.205	0.4016
40	1.146	0.7019
50	1.041	1.0224
60	0.863	1.3252
70	0.615	1.5743
80	0.317	1.7407

90	0	1.8051
100	-0.222	1.7407
110	-0.431	1.5743
120	-0.604	1.3252
130	-0.729	1.0224
140	-0.802	0.7019
150	-0.843	0.4016
160	-0.916	0.1572
170	-0.935	0.0124
180	0	0.01

Aerofoil dataset: c3_11_1s818+6s816_AD12R2

Description

Last changed 01-20-2010@15:27:09

Percentage thickness	0	%
Reynolds number	2.E+06	
Chordwise origin for pitch moments	25	%
Aileron deployment angle	0	deg

Angle of Attack (deg)	Lift coefficient	Drag coefficient
-180	0	0.01
-170	0.812	0.0246
-160	0.71	0.1852
-150	0.728	0.4314
-140	0.737	0.7338
-130	0.694	1.056
-120	0.589	1.3597
-110	0.427	1.6085
-100	0.223	1.773
-90	0	1.8337
-80	-0.223	1.773
-70	-0.427	1.6085
-60	-0.589	1.3597
-50	-0.694	1.056
-40	-0.737	0.7338
-30	-0.728	0.4314
-20	-0.71	0.1852
-10	-0.787	0.0271
-6	-0.276	0.0145
-5	-0.158	0.0118
-4	-0.041	0.0091
-3	0.038	0.007
-2	0.148	0.0069
-1	0.257	0.0069
0	0.367	0.0069
1	0.475	0.007
2	0.582	0.0072
3	0.689	0.0072
4	0.795	0.0074
5	0.9	0.0075
6	1.005	0.0078
7	1.06	0.0135
8	1.147	0.0155

9	1.227	0.0169
10	1.18	0.0273
11	1.178	0.0415
12	1.173	0.0556
13	1.153	0.0718
20	1.014	0.1852
30	1.041	0.4314
40	1.053	0.7338
50	0.992	1.056
60	0.841	1.3597
70	0.61	1.6085
80	0.319	1.773
90	0	1.8337
100	-0.223	1.773
110	-0.427	1.6085
120	-0.589	1.3597
130	-0.694	1.056
140	-0.737	0.7338
150	-0.728	0.4314
160	-0.71	0.1852
170	-0.812	0.0246
180	0	0.01

Aerofoil dataset: c3_12-13_s816_AD12R2

Description

Last changed 01-20-2010@15:30:28

Percentage thickness	24	%
Reynolds number	2.E+06	
Chordwise origin for pitch moments	25	%
Aileron deployment angle	0	deg

Angle of Attack (deg)	Lift coefficient	Drag coefficient
-180	0	0.01
-170	0.788	0.0276
-160	0.677	0.1887
-150	0.71	0.4357
-140	0.727	0.7389
-130	0.689	1.0621
-120	0.587	1.3665
-110	0.427	1.6158
-100	0.223	1.7804
-90	0	1.8408
-80	-0.223	1.7804
-70	-0.427	1.6158
-60	-0.587	1.3665
-50	-0.689	1.0621
-40	-0.727	0.7389
-30	-0.71	0.4357
-20	-0.677	0.1887
-10	-0.788	0.0276
-4	-0.069	0.0088
-3	0.006	0.0064
-2	0.116	0.0064

-1	0.226	0.0063
0	0.336	0.0063
1	0.446	0.0064
2	0.552	0.0065
3	0.659	0.0066
4	0.765	0.0067
5	0.871	0.0068
6	0.976	0.007
7	1.024	0.0136
8	1.111	0.0156
9	1.19	0.0171
10	1.126	0.0276
20	0.967	0.1887
30	1.015	0.4357
40	1.039	0.7389
50	0.985	1.0621
60	0.839	1.3665
70	0.61	1.6158
80	0.319	1.7804
90	0	1.8408
100	-0.223	1.7804
110	-0.427	1.6158
120	-0.587	1.3665
130	-0.689	1.0621
140	-0.727	0.7389
150	-0.71	0.4357
160	-0.677	0.1887
170	-0.788	0.0276
180	0	0.01

Aerofoil dataset: c3_14_2s816+1s817_AD12R2

Description

Last changed 01-20-2010@15:31:00

Percentage thickness	21	%
Reynolds number	2.E+06	
Chordwise origin for pitch moments	25	%
Aileron deployment angle	0	deg

Angle of Attack (deg)	Lift coefficient	Drag coefficient
-180	0	0.01
-170	0.726	0.0336
-160	0.653	0.1972
-150	0.702	0.4481
-140	0.727	0.756
-130	0.694	1.084
-120	0.594	1.3929
-110	0.432	1.6457
-100	0.227	1.8122
-90	0	1.8727
-80	-0.227	1.8122
-70	-0.432	1.6457
-60	-0.594	1.3929
-50	-0.694	1.084

-40	-0.727	0.756
-30	-0.702	0.4481
-20	-0.653	0.1972
-10	-0.726	0.0336
-4	-0.067	0.009
-3	0.016	0.0071
-2	0.126	0.0069
-1	0.236	0.006
0	0.345	0.0061
1	0.453	0.0062
2	0.559	0.0062
3	0.666	0.0063
4	0.771	0.0065
5	0.875	0.0066
6	0.979	0.0069
7	1.02	0.0141
8	1.06	0.0189
9	1.095	0.0233
10	1.037	0.0336
20	0.933	0.1972
30	1.003	0.4481
40	1.039	0.756
50	0.991	1.084
60	0.848	1.3929
70	0.618	1.6457
80	0.324	1.8122
90	0	1.8727
100	-0.227	1.8122
110	-0.432	1.6457
120	-0.594	1.3929
130	-0.694	1.084
140	-0.727	0.756
150	-0.702	0.4481
160	-0.653	0.1972
170	-0.726	0.0336
180	0	0.01

Aerofoil dataset: c3_15_1s816+2s817_AD12R2

Description

Last changed 01-20-2010@15:31:45

Percentage thickness	19	%
Reynolds number	2.E+06	
Chordwise origin for pitch moments	25	%
Aileron deployment angle	0	deg

Angle of Attack (deg)	Lift coefficient	Drag coefficient
-180	0	0.01
-170	0.669	0.0391
-160	0.632	0.2053
-150	0.696	0.46
-140	0.728	0.7726
-130	0.699	1.1057
-120	0.6	1.4191

-110	0.438	1.6754
-100	0.23	1.8439
-90	0	1.9046
-80	-0.23	1.8439
-70	-0.438	1.6754
-60	-0.6	1.4191
-50	-0.699	1.1057
-40	-0.728	0.7726
-30	-0.696	0.46
-20	-0.632	0.2053
-10	-0.669	0.0391
-4	-0.067	0.0088
-3	0.027	0.0077
-2	0.135	0.0073
-1	0.245	0.0056
0	0.354	0.0056
1	0.461	0.0057
2	0.568	0.0058
3	0.673	0.0059
4	0.778	0.0061
5	0.882	0.0063
6	0.985	0.0065
7	1.02	0.0145
8	1.015	0.0218
9	1.009	0.029
10	0.955	0.0391
20	0.903	0.2053
30	0.994	0.46
40	1.041	0.7726
50	0.999	1.1057
60	0.857	1.4191
70	0.626	1.6754
80	0.329	1.8439
90	0	1.9046
100	-0.23	1.8439
110	-0.438	1.6754
120	-0.6	1.4191
130	-0.699	1.1057
140	-0.728	0.7726
150	-0.696	0.46
160	-0.632	0.2053
170	-0.669	0.0391
180	0	0.01

Aerofoil dataset: c3_16-20_s817_AD12R2

Description

Last changed 01-20-2010@15:32:09

Percentage thickness	18	%
Reynolds number	2.E+06	
Chordwise origin for pitch moments	25	%
Aileron deployment angle	0	deg

Angle of Attack (deg)	Lift coefficient	Drag coefficient
-180	0	0.01
-170	0.611	0.0445
-160	0.611	0.2133
-150	0.689	0.4719
-140	0.729	0.7893
-130	0.704	1.1273
-120	0.607	1.4453
-110	0.444	1.7051
-100	0.234	1.8756
-90	0	1.9364
-80	-0.234	1.8756
-70	-0.444	1.7051
-60	-0.607	1.4453
-50	-0.704	1.1273
-40	-0.729	0.7893
-30	-0.689	0.4719
-20	-0.611	0.2133
-10	-0.611	0.0445
-4	-0.066	0.0087
-3	0.037	0.0082
-2	0.145	0.0077
-1	0.255	0.0051
0	0.363	0.0052
1	0.47	0.0053
2	0.576	0.0053
3	0.681	0.0055
4	0.785	0.0057
5	0.888	0.0059
6	0.99	0.0062
7	1.019	0.0148
8	0.97	0.0247
9	0.922	0.0346
10	0.873	0.0445
20	0.873	0.2133
30	0.984	0.4719
40	1.042	0.7893
50	1.006	1.1273
60	0.867	1.4453
70	0.634	1.7051
80	0.334	1.8756
90	0	1.9364
100	-0.234	1.8756
110	-0.444	1.7051
120	-0.607	1.4453
130	-0.704	1.1273
140	-0.729	0.7893
150	-0.689	0.4719
160	-0.611	0.2133
170	-0.611	0.0445
180	0	0.01

Aerofoil dataset: c3_15_1s816+2s817_AD12R4

Description

Last changed 01-20-2010@15:31:59

Percentage thickness	19	%
Reynolds number	4.E+06	
Chordwise origin for pitch moments	25	%
Aileron deployment angle	0	deg

Angle of Attack (deg)	Lift coefficient	Drag coefficient
-180	0	0.01
-170	0.835	0.0242
-160	0.709	0.191
-150	0.74	0.4469
-140	0.756	0.761
-130	0.715	1.0959
-120	0.609	1.4115
-110	0.442	1.6702
-100	0.231	1.8413
-90	0	1.9046
-80	-0.231	1.8413
-70	-0.442	1.6702
-60	-0.609	1.4115
-50	-0.715	1.0959
-40	-0.756	0.761
-30	-0.74	0.4469
-20	-0.709	0.191
-10	-0.835	0.0242
-4	-0.073	0.0081
-3	0.025	0.007
-2	0.135	0.0068
-1	0.245	0.0051
0	0.355	0.0051
1	0.465	0.0051
2	0.574	0.0053
3	0.679	0.0054
4	0.785	0.0055
5	0.89	0.0057
6	0.958	0.0101
7	1.037	0.0133
8	1.127	0.0147
9	1.212	0.0162
10	1.194	0.0242
20	1.013	0.191
30	1.058	0.4469
40	1.08	0.761
50	1.022	1.0959
60	0.87	1.4115
70	0.631	1.6702
80	0.33	1.8413
90	0	1.9046
100	-0.231	1.8413
110	-0.442	1.6702
120	-0.609	1.4115
130	-0.715	1.0959

140	-0.756	0.761
150	-0.74	0.4469
160	-0.709	0.191
170	-0.835	0.0242
180	0	0.01

Aerofoil dataset: c3_14_2s816+1s817_AD12R4

Description

Last changed 01-20-2010@15:31:12

Percentage thickness	21	%
Reynolds number	4.E+06	
Chordwise origin for pitch moments	25	%
Aileron deployment angle	0	deg

Angle of Attack (deg)	Lift coefficient	Drag coefficient
-180	0	0.01
-170	0.862	0.0213
-160	0.716	0.1855
-150	0.739	0.4373
-140	0.75	0.7464
-130	0.707	1.076
-120	0.601	1.3867
-110	0.436	1.6414
-100	0.228	1.81
-90	0	1.8727
-80	-0.228	1.81
-70	-0.436	1.6414
-60	-0.601	1.3867
-50	-0.707	1.076
-40	-0.75	0.7464
-30	-0.739	0.4373
-20	-0.716	0.1855
-10	-0.862	0.0213
-4	-0.072	0.0084
-3	0.016	0.0066
-2	0.126	0.0065
-1	0.236	0.0056
0	0.346	0.0056
1	0.456	0.0057
2	0.564	0.0058
3	0.67	0.0059
4	0.775	0.006
5	0.881	0.0062
6	0.968	0.0085
7	1.032	0.0133
8	1.121	0.0149
9	1.204	0.0165
10	1.231	0.0213
20	1.023	0.1855
30	1.056	0.4373
40	1.071	0.7464
50	1.01	1.076
60	0.858	1.3867

70	0.622	1.6414
80	0.325	1.81
90	0	1.8727
100	-0.228	1.81
110	-0.436	1.6414
120	-0.601	1.3867
130	-0.707	1.076
140	-0.75	0.7464
150	-0.739	0.4373
160	-0.716	0.1855
170	-0.862	0.0213
180	0	0.01

Aerofoil dataset: c3_12-13_s816_AD12R4

Description

Last changed 01-20-2010@15:30:42

Percentage thickness	24	%
Reynolds number	4.E+06	
Chordwise origin for pitch moments	25	%
Aileron deployment angle	0	deg

Angle of Attack (deg)	Lift coefficient	Drag coefficient
-180	0	0.01
-170	0.895	0.0182
-160	0.726	0.1797
-150	0.739	0.4274
-140	0.745	0.7316
-130	0.7	1.0559
-120	0.593	1.3617
-110	0.429	1.6125
-100	0.224	1.7787
-90	0	1.8408
-80	-0.224	1.7787
-70	-0.429	1.6125
-60	-0.593	1.3617
-50	-0.7	1.0559
-40	-0.745	0.7316
-30	-0.739	0.4274
-20	-0.726	0.1797
-10	-0.895	0.0182
-4	-0.072	0.0085
-3	0.006	0.0062
-2	0.116	0.0061
-1	0.226	0.0061
0	0.336	0.0061
1	0.446	0.0061
2	0.555	0.0062
3	0.661	0.0063
4	0.768	0.0064
5	0.874	0.0065
6	0.979	0.0067
7	1.028	0.0133
8	1.118	0.0149

9	1.202	0.0164
10	1.278	0.0182
20	1.037	0.1797
30	1.056	0.4274
40	1.064	0.7316
50	0.999	1.0559
60	0.847	1.3617
70	0.613	1.6125
80	0.32	1.7787
90	0	1.8408
100	-0.224	1.7787
110	-0.429	1.6125
120	-0.593	1.3617
130	-0.7	1.0559
140	-0.745	0.7316
150	-0.739	0.4274
160	-0.726	0.1797
170	-0.895	0.0182
180	0	0.01

Aerofoil dataset: c3_08_4s818+3s816_AD12R2

Description

Last changed 01-20-2010@15:13:01

Percentage thickness	30	%
Reynolds number	2.E+06	
Chordwise origin for pitch moments	25	%
Aileron deployment angle	0	deg

Angle of Attack (deg)	Lift coefficient	Drag coefficient
-180	0	0.01
-170	0.897	0.014
-160	0.816	0.1732
-150	0.786	0.4173
-140	0.769	0.7172
-130	0.71	1.037
-120	0.595	1.3386
-110	0.427	1.5862
-100	0.222	1.7505
-90	0	1.8123
-80	-0.222	1.7505
-70	-0.427	1.5862
-60	-0.595	1.3386
-50	-0.71	1.037
-40	-0.769	0.7172
-30	-0.786	0.4173
-20	-0.816	0.1732
-10	-0.797	0.0241
-6	-0.184	0.0117
-5	-0.072	0.0104
-4	0.041	0.009
-3	0.135	0.008
-2	0.243	0.0081
-1	0.352	0.0082

0	0.461	0.0082
1	0.568	0.0084
2	0.674	0.0085
3	0.781	0.0086
4	0.887	0.0089
5	0.992	0.0092
6	1.097	0.0095
7	1.177	0.0126
8	1.272	0.0139
9	1.364	0.0149
10	1.363	0.0248
11	1.402	0.0332
12	1.429	0.0414
13	1.396	0.0579
20	1.165	0.1732
30	1.123	0.4173
40	1.098	0.7172
50	1.014	1.037
60	0.85	1.3386
70	0.611	1.5862
80	0.317	1.7505
90	0	1.8123
100	-0.222	1.7505
110	-0.427	1.5862
120	-0.595	1.3386
130	-0.71	1.037
140	-0.769	0.7172
150	-0.786	0.4173
160	-0.816	0.1732
170	-0.897	0.014
180	0	0.01

Aerofoil dataset: c3_08_4s818+3s816_AD12R3

Description

Last changed 01-20-2010@15:13:10

Percentage thickness	30	%
Reynolds number	3.E+06	
Chordwise origin for pitch moments	25	%
Aileron deployment angle	0	deg

Angle of Attack (deg)	Lift coefficient	Drag coefficient
-180	0	0.01
-170	0.907	0.0129
-160	0.822	0.1722
-150	0.79	0.4164
-140	0.771	0.7163
-130	0.711	1.0363
-120	0.596	1.338
-110	0.428	1.5858
-100	0.222	1.7503
-90	0	1.8123
-80	-0.222	1.7503
-70	-0.428	1.5858

-60	-0.596	1.338
-50	-0.711	1.0363
-40	-0.771	0.7163
-30	-0.79	0.4164
-20	-0.822	0.1722
-10	-0.804	0.0233
-6	-0.183	0.0114
-5	-0.07	0.0101
-4	0.043	0.0088
-3	0.136	0.0077
-2	0.245	0.0077
-1	0.353	0.0078
0	0.462	0.0078
1	0.57	0.008
2	0.677	0.0081
3	0.783	0.0082
4	0.889	0.0085
5	0.995	0.0088
6	1.1	0.0091
7	1.18	0.0121
8	1.275	0.0134
9	1.349	0.0177
10	1.37	0.0239
11	1.411	0.0322
12	1.445	0.0403
13	1.411	0.0568
20	1.174	0.1722
30	1.128	0.4164
40	1.102	0.7163
50	1.016	1.0363
60	0.851	1.338
70	0.611	1.5858
80	0.317	1.7503
90	0	1.8123
100	-0.222	1.7503
110	-0.428	1.5858
120	-0.596	1.338
130	-0.711	1.0363
140	-0.771	0.7163
150	-0.79	0.4164
160	-0.822	0.1722
170	-0.907	0.0129
180	0	0.01

Aerofoil dataset: c3_08_4s818+3s816_AD12R4

Description

Last changed 01-20-2010@15:13:20

Percentage thickness	30	%
Reynolds number	4.E+06	
Chordwise origin for pitch moments	25	%
Aileron deployment angle	0	deg

Angle of Attack (deg)	Lift coefficient	Drag coefficient
-180	0	0.01
-170	0.925	0.0136
-160	0.877	0.1618
-150	0.822	0.4068
-140	0.791	0.7079
-130	0.723	1.0291
-120	0.602	1.3325
-110	0.43	1.582
-100	0.223	1.7483
-90	0	1.8123
-80	-0.223	1.7483
-70	-0.43	1.582
-60	-0.602	1.3325
-50	-0.723	1.0291
-40	-0.791	0.7079
-30	-0.822	0.4068
-20	-0.877	0.1618
-10	-0.801	0.0188
-6	-0.198	0.0098
-5	-0.078	0.0092
-4	0.043	0.0085
-3	0.137	0.0075
-2	0.246	0.0075
-1	0.354	0.0075
0	0.463	0.0076
1	0.571	0.0077
2	0.679	0.0079
3	0.785	0.008
4	0.891	0.0082
5	0.997	0.0085
6	1.103	0.0087
7	1.183	0.0118
8	1.28	0.0129
9	1.355	0.0173
10	1.436	0.0195
11	1.474	0.0277
12	1.509	0.0358
13	1.525	0.0441
20	1.253	0.1618
30	1.174	0.4068
40	1.129	0.7079
50	1.032	1.0291
60	0.86	1.3325
70	0.615	1.582
80	0.318	1.7483
90	0	1.8123
100	-0.223	1.7483
110	-0.43	1.582
120	-0.602	1.3325
130	-0.723	1.0291
140	-0.791	0.7079
150	-0.822	0.4068
160	-0.877	0.1618
170	-0.925	0.0136
180	0	0.01

Aerofoil dataset: c3_10_2s818+5s816_AD12R2

Description

Last changed 01-20-2010@00:21:14

Percentage thickness	0	%
Reynolds number	2.E+06	
Chordwise origin for pitch moments	25	%
Aileron deployment angle	0	deg

Angle of Attack (deg)	Lift coefficient	Drag coefficient
-180	0	0.01
-170	0.84	0.0211
-160	0.745	0.1812
-150	0.748	0.4267
-140	0.748	0.7282
-130	0.699	1.0497
-120	0.591	1.3526
-110	0.427	1.6011
-100	0.223	1.7655
-90	0	1.8265
-80	-0.223	1.7655
-70	-0.427	1.6011
-60	-0.591	1.3526
-50	-0.699	1.0497
-40	-0.748	0.7282
-30	-0.748	0.4267
-20	-0.745	0.1812
-10	-0.79	0.0261
-6	-0.245	0.0136
-5	-0.129	0.0113
-4	-0.013	0.0091
-3	0.07	0.0073
-2	0.18	0.0073
-1	0.289	0.0073
0	0.398	0.0074
1	0.506	0.0075
2	0.613	0.0076
3	0.72	0.0077
4	0.826	0.0079
5	0.931	0.0081
6	1.036	0.0083
7	1.099	0.0132
8	1.189	0.0149
9	1.273	0.0163
10	1.241	0.0265
11	1.253	0.0387
12	1.258	0.0509
13	1.234	0.0672
20	1.064	0.1812
30	1.068	0.4267
40	1.068	0.7282
50	0.999	1.0497
60	0.844	1.3526
70	0.61	1.6011
80	0.318	1.7655

90	0	1.8265
100	-0.223	1.7655
110	-0.427	1.6011
120	-0.591	1.3526
130	-0.699	1.0497
140	-0.748	0.7282
150	-0.748	0.4267
160	-0.745	0.1812
170	-0.84	0.0211
180	0	0.01

Aerofoil dataset: c3_10_2s818+5s816_AD12R3

Description

Last changed 01-20-2010@00:21:37

Percentage thickness	0	%
Reynolds number	3.E+06	
Chordwise origin for pitch moments	25	%
Aileron deployment angle	0	deg

Angle of Attack (deg)	Lift coefficient	Drag coefficient
-180	0	0.01
-170	0.845	0.0205
-160	0.748	0.1807
-150	0.75	0.4263
-140	0.749	0.7278
-130	0.7	1.0493
-120	0.591	1.3524
-110	0.427	1.6009
-100	0.223	1.7654
-90	0	1.8265
-80	-0.223	1.7654
-70	-0.427	1.6009
-60	-0.591	1.3524
-50	-0.7	1.0493
-40	-0.749	0.7278
-30	-0.75	0.4263
-20	-0.748	0.1807
-10	-0.794	0.0257
-6	-0.245	0.0134
-5	-0.129	0.0112
-4	-0.013	0.0089
-3	0.071	0.0072
-2	0.181	0.0071
-1	0.29	0.0071
0	0.399	0.0072
1	0.507	0.0073
2	0.614	0.0074
3	0.721	0.0075
4	0.827	0.0077
5	0.932	0.0079
6	1.037	0.0081
7	1.1	0.013
8	1.19	0.0147

9	1.265	0.0177
10	1.244	0.026
11	1.257	0.0382
12	1.266	0.0503
13	1.242	0.0666
20	1.069	0.1807
30	1.071	0.4263
40	1.07	0.7278
50	1	1.0493
60	0.845	1.3524
70	0.61	1.6009
80	0.318	1.7654
90	0	1.8265
100	-0.223	1.7654
110	-0.427	1.6009
120	-0.591	1.3524
130	-0.7	1.0493
140	-0.749	0.7278
150	-0.75	0.4263
160	-0.748	0.1807
170	-0.845	0.0205
180	0	0.01

Aerofoil dataset: c3_10_2s818+5s816_AD12R4

Description

Last changed 01-20-2010@00:21:59

Percentage thickness	0	%
Reynolds number	4.E+06	
Chordwise origin for pitch moments	25	%
Aileron deployment angle	0	deg

Angle of Attack (deg)	Lift coefficient	Drag coefficient
-180	0	0.01
-170	0.907	0.0161
-160	0.8	0.1709
-150	0.78	0.4172
-140	0.767	0.7198
-130	0.711	1.0426
-120	0.597	1.3472
-110	0.43	1.5973
-100	0.223	1.7636
-90	0	1.8265
-80	-0.223	1.7636
-70	-0.43	1.5973
-60	-0.597	1.3472
-50	-0.711	1.0426
-40	-0.767	0.7198
-30	-0.78	0.4172
-20	-0.8	0.1709
-10	-0.845	0.0186
-6	-0.271	0.0109
-5	-0.142	0.0098
-4	-0.014	0.0086

-3	0.071	0.0069
-2	0.181	0.0069
-1	0.29	0.0069
0	0.399	0.0069
1	0.509	0.007
2	0.616	0.0071
3	0.723	0.0072
4	0.829	0.0074
5	0.934	0.0076
6	1.04	0.0078
7	1.105	0.0126
8	1.198	0.014
9	1.276	0.017
10	1.353	0.019
11	1.36	0.0312
12	1.365	0.0433
13	1.362	0.0555
20	1.143	0.1709
30	1.114	0.4172
40	1.096	0.7198
50	1.016	1.0426
60	0.853	1.3472
70	0.614	1.5973
80	0.319	1.7636
90	0	1.8265
100	-0.223	1.7636
110	-0.43	1.5973
120	-0.597	1.3472
130	-0.711	1.0426
140	-0.767	0.7198
150	-0.78	0.4172
160	-0.8	0.1709
170	-0.907	0.0161
180	0	0.01

Aerofoil dataset: c3_11_1s818+6s816_AD12R3

Description

Last changed 01-20-2010@15:27:01

Percentage thickness	0	%
Reynolds number	3.E+06	
Chordwise origin for pitch moments	25	%
Aileron deployment angle	0	deg

Angle of Attack (deg)	Lift coefficient	Drag coefficient
-180	0	0.01
-170	0.814	0.0243
-160	0.711	0.185
-150	0.729	0.4312
-140	0.738	0.7336
-130	0.694	1.0558
-120	0.589	1.3595
-110	0.427	1.6084
-100	0.223	1.7729

-90	0	1.8337
-80	-0.223	1.7729
-70	-0.427	1.6084
-60	-0.589	1.3595
-50	-0.694	1.0558
-40	-0.738	0.7336
-30	-0.729	0.4312
-20	-0.711	0.185
-10	-0.788	0.0269
-6	-0.275	0.0144
-5	-0.158	0.0117
-4	-0.04	0.009
-3	0.039	0.0069
-2	0.148	0.0068
-1	0.258	0.0068
0	0.368	0.0068
1	0.475	0.0069
2	0.582	0.0071
3	0.689	0.0071
4	0.795	0.0073
5	0.9	0.0074
6	1.005	0.0077
7	1.061	0.0134
8	1.148	0.0153
9	1.224	0.0176
10	1.181	0.0271
11	1.18	0.0412
12	1.177	0.0553
13	1.157	0.0715
20	1.016	0.185
30	1.042	0.4312
40	1.054	0.7336
50	0.992	1.0558
60	0.842	1.3595
70	0.61	1.6084
80	0.319	1.7729
90	0	1.8337
100	-0.223	1.7729
110	-0.427	1.6084
120	-0.589	1.3595
130	-0.694	1.0558
140	-0.738	0.7336
150	-0.729	0.4312
160	-0.711	0.185
170	-0.814	0.0243
180	0	0.01

Aerofoil dataset: c3_12-13_s816_AD12R3

Description

Last changed 01-20-2010@15:30:35

Percentage thickness	24	%
Reynolds number	3.E+06	
Chordwise origin for pitch moments	25	%
Aileron deployment angle	0	deg

Angle of Attack (deg)	Lift coefficient	Drag coefficient
-180	0	0.01
-170	0.888	0.0185
-160	0.723	0.18
-150	0.737	0.4277
-140	0.744	0.7318
-130	0.699	1.0561
-120	0.592	1.3618
-110	0.429	1.6126
-100	0.224	1.7788
-90	0	1.8408
-80	-0.224	1.7788
-70	-0.429	1.6126
-60	-0.592	1.3618
-50	-0.699	1.0561
-40	-0.744	0.7318
-30	-0.737	0.4277
-20	-0.723	0.18
-10	-0.888	0.0185
-4	-0.07	0.0087
-3	0.006	0.0063
-2	0.116	0.0063
-1	0.226	0.0062
0	0.336	0.0062
1	0.446	0.0063
2	0.554	0.0064
3	0.66	0.0064
4	0.766	0.0065
5	0.872	0.0067
6	0.978	0.0068
7	1.027	0.0134
8	1.115	0.0152
9	1.196	0.0168
10	1.269	0.0185
20	1.033	0.18
30	1.053	0.4277
40	1.062	0.7318
50	0.999	1.0561
60	0.846	1.3618
70	0.613	1.6126
80	0.32	1.7788
90	0	1.8408
100	-0.224	1.7788
110	-0.429	1.6126
120	-0.592	1.3618
130	-0.699	1.0561

140	-0.744	0.7318
150	-0.737	0.4277
160	-0.723	0.18
170	-0.888	0.0185
180	0	0.01

Aerofoil dataset: c3_14_2s816+1s817_AD12R3

Description

Last changed 01-20-2010@16:40:18

Percentage thickness	21	%
Reynolds number	3.E+06	
Chordwise origin for pitch moments	25	%
Aileron deployment angle	0	deg

Angle of Attack (deg)	Lift coefficient	Drag coefficient
-180	0	0.01
-170	0.757	0.0308
-160	0.668	0.1946
-150	0.711	0.4456
-140	0.733	0.7538
-130	0.697	1.0822
-120	0.595	1.3915
-110	0.433	1.6447
-100	0.227	1.8117
-90	0	1.8727
-80	-0.227	1.8117
-70	-0.433	1.6447
-60	-0.595	1.3915
-50	-0.697	1.0822
-40	-0.733	0.7538
-30	-0.711	0.4456
-20	-0.668	0.1946
-10	-0.757	0.0308
-4	-0.069	0.0088
-3	0.016	0.0069
-2	0.126	0.0068
-1	0.236	0.0059
0	0.346	0.0059
1	0.454	0.006
2	0.561	0.0061
3	0.667	0.0062
4	0.773	0.0064
5	0.878	0.0065
6	0.963	0.0088
7	1.025	0.0138
8	1.111	0.0157
9	1.143	0.0203
10	1.082	0.0308
20	0.954	0.1946
30	1.016	0.4456
40	1.047	0.7538
50	0.996	1.0822
60	0.85	1.3915

70	0.619	1.6447
80	0.324	1.8117
90	0	1.8727
100	-0.227	1.8117
110	-0.433	1.6447
120	-0.595	1.3915
130	-0.697	1.0822
140	-0.733	0.7538
150	-0.711	0.4456
160	-0.668	0.1946
170	-0.757	0.0308
180	0	0.01

Aerofoil dataset: c3_15_1s816+2s817_AD12R3

Description

Last changed 01-20-2010@15:31:52

Percentage thickness	19	%
Reynolds number	3.E+06	
Chordwise origin for pitch moments	25	%
Aileron deployment angle	0	deg

Angle of Attack (deg)	Lift coefficient	Drag coefficient
-180	0	0.01
-170	0.732	0.0335
-160	0.661	0.2
-150	0.713	0.4551
-140	0.739	0.7683
-130	0.705	1.102
-120	0.603	1.4163
-110	0.44	1.6735
-100	0.231	1.8429
-90	0	1.9046
-80	-0.231	1.8429
-70	-0.44	1.6735
-60	-0.603	1.4163
-50	-0.705	1.102
-40	-0.739	0.7683
-30	-0.713	0.4551
-20	-0.661	0.2
-10	-0.732	0.0335
-4	-0.07	0.0084
-3	0.025	0.0073
-2	0.135	0.007
-1	0.245	0.0053
0	0.355	0.0053
1	0.465	0.0054
2	0.571	0.0055
3	0.677	0.0056
4	0.782	0.0058
5	0.886	0.006
6	0.953	0.0105
7	1.03	0.0138
8	1.116	0.0155

9	1.104	0.023
10	1.046	0.0335
20	0.945	0.2
30	1.018	0.4551
40	1.055	0.7683
50	1.007	1.102
60	0.862	1.4163
70	0.628	1.6735
80	0.33	1.8429
90	0	1.9046
100	-0.231	1.8429
110	-0.44	1.6735
120	-0.603	1.4163
130	-0.705	1.102
140	-0.739	0.7683
150	-0.713	0.4551
160	-0.661	0.2
170	-0.732	0.0335
180	0	0.01

Aerofoil dataset: c3_16-20_s817_AD12R3

Description

Last changed 01-20-2010@15:32:17

Percentage thickness	18	%
Reynolds number	3.E+06	
Chordwise origin for pitch moments	25	%
Aileron deployment angle	0	deg

Angle of Attack (deg)	Lift coefficient	Drag coefficient
-180	0	0.01
-170	0.706	0.0362
-160	0.655	0.2054
-150	0.714	0.4646
-140	0.745	0.7828
-130	0.713	1.1219
-120	0.611	1.4411
-110	0.446	1.7022
-100	0.234	1.8741
-90	0	1.9364
-80	-0.234	1.8741
-70	-0.446	1.7022
-60	-0.611	1.4411
-50	-0.713	1.1219
-40	-0.745	0.7828
-30	-0.714	0.4646
-20	-0.655	0.2054
-10	-0.706	0.0362
-4	-0.071	0.0081
-3	0.035	0.0076
-2	0.145	0.0073
-1	0.255	0.0047
0	0.365	0.0047
1	0.475	0.0048

2	0.581	0.0049
3	0.686	0.0051
4	0.791	0.0053
5	0.895	0.0055
6	0.942	0.0121
7	1.034	0.0138
8	1.122	0.0152
9	1.065	0.0257
10	1.009	0.0362
20	0.936	0.2054
30	1.021	0.4646
40	1.064	0.7828
50	1.019	1.1219
60	0.874	1.4411
70	0.637	1.7022
80	0.335	1.8741
90	0	1.9364
100	-0.234	1.8741
110	-0.446	1.7022
120	-0.611	1.4411
130	-0.713	1.1219
140	-0.745	0.7828
150	-0.714	0.4646
160	-0.655	0.2054
170	-0.706	0.0362
180	0	0.01

Aerofoil dataset: c3_16-20_s817_AD12R4

Description

Last changed 01-20-2010@15:32:27

Percentage thickness	18	%
Reynolds number	4.E+06	
Chordwise origin for pitch moments	25	%
Aileron deployment angle	0	deg

Angle of Attack (deg)	Lift coefficient	Drag coefficient
-180	0	0.01
-170	0.809	0.027
-160	0.703	0.1966
-150	0.742	0.4565
-140	0.762	0.7757
-130	0.723	1.1158
-120	0.617	1.4364
-110	0.449	1.699
-100	0.235	1.8725
-90	0	1.9364
-80	-0.235	1.8725
-70	-0.449	1.699
-60	-0.617	1.4364
-50	-0.723	1.1158
-40	-0.762	0.7757
-30	-0.742	0.4565
-20	-0.703	0.1966
-10	-0.809	0.027

-4	-0.075	0.0078
-3	0.035	0.0073
-2	0.145	0.007
-1	0.255	0.0045
0	0.365	0.0045
1	0.475	0.0045
2	0.584	0.0047
3	0.689	0.0049
4	0.794	0.005
5	0.899	0.0052
6	0.948	0.0118
7	1.042	0.0132
8	1.133	0.0144
9	1.22	0.0159
10	1.156	0.027
20	1.004	0.1966
30	1.06	0.4565
40	1.088	0.7757
50	1.033	1.1158
60	0.881	1.4364
70	0.641	1.699
80	0.336	1.8725
90	0	1.9364
100	-0.235	1.8725
110	-0.449	1.699
120	-0.617	1.4364
130	-0.723	1.1158
140	-0.762	0.7757
150	-0.742	0.4565
160	-0.703	0.1966
170	-0.809	0.027
180	0	0.01

BLADE MASS DISTRIBUTION

Centre of mass (x) (%)	Centre of mass (y) (%)	Mass/unit length (kg/m)	Moment of intertia/unit length (kgm)	Radii of gyration ratio	Mass axis orientation (deg)
0	50	175.402	0	1	19.19
0	50	175.402	0	1	19.19
0	49	172.04	0	1	19.19
0	47.5	166.896	0	1	19.002
0	45	161.752	0	1	18.626
0	44	156.608	0	1	18.25
0	42.5	151.464	0	0.96274	17.446
0	40	146.32	0	0.913688	16.642
0	39.5	140.86	0	0.839125	15.878
0	38.5	134.813	0	0.746143	15.154
0	37.5	128.766	0	0.665029	14.43
0	37.5	122.719	0	0.529738	13.722
0	37.5	116.673	0	0.410144	13.014
0	37.5	110.626	0	0.330838	12.194
0	37.5	104.579	0	0.283716	11.262
0	37.5	102.266	0	0.239098	10.33
0	37.5	100.393	0	0.236302	9.51
0	37.5	98.5192	0	0.233467	8.69
0	37.5	96.6458	0	0.230986	7.95
0	37.5	94.8676	0	0.228859	7.29
0	37.5	93.2324	0	0.226693	6.63
0	37.5	91.5972	0	0.225123	6.086
0	37.6	89.962	0	0.223519	5.542
0	37.7	88.3268	0	0.222189	5.04
0	37.8	86.6916	0	0.221141	4.58
0	37.9	85.0109	0	0.220066	4.12
0	37.1	83.263	0	0.21931	3.736
0	37.11	81.5151	0	0.218533	3.352
0	37.12	79.7673	0	0.217807	2.998
0	37.13	78.0194	0	0.217135	2.674
0	37.14	76.2715	0	0.21644	2.35
0	37.15	74.3918	0	0.215463	2.074
0	37.16	72.3221	0	0.214449	1.798
0	37.17	70.2524	0	0.212934	1.536
0	37.18	68.1827	0	0.210884	1.288
0	37.19	66.1131	0	0.208745	1.04
0	37.2	64.0434	0	0.205103	0.82
0	37.21	61.6197	0	0.201285	0.6
0	37.22	58.6924	0	0.196956	0.398
0	37.23	55.765	0	0.19207	0.214
0	37.24	52.8377	0	0.18692	0.03
0	37.25	49.9104	0	0.181839	-0.142
0	37.26	53.5451	0	0.176456	-0.314
0	37.27	65.2352	0	0.171674	-0.476
0	37.28	76.9253	0	0.167535	-0.628
0	37.29	75.8437	0	0.16311	-0.78
0	37.3	67.1579	0	0.160774	-0.916
0	37.31	55.8491	0	0.158257	-1.052
0	37.32	55.8491	0	0.15649	-1.184
0	37.33	55.8491	0	0.155564	-1.312
0	37.34	55.8491	0	0.155564	-1.312

BLADE STIFFNESS DISTRIBUTION

Flapwise stiffness (Nm²)	Edgewise stiffness (Nm²)	Structural twist (deg)
4.47E+08	4.47E+08	19.19
4.47E+08	4.47E+08	19.19
4.268E+08	4.319E+08	19.19
3.959E+08	4.087E+08	19.002
3.649E+08	3.855E+08	18.626
3.34E+08	3.624E+08	18.25
3.031E+08	3.392E+08	17.446
2.721E+08	3.161E+08	16.642
2.412E+08	2.928E+08	15.878
2.103E+08	2.692E+08	15.154
1.794E+08	2.457E+08	14.43
1.485E+08	2.221E+08	13.722
1.176E+08	1.986E+08	13.014
8.674E+07	1.75E+08	12.194
5.585E+07	1.515E+08	11.262
5.025E+07	1.456E+08	10.33
4.763E+07	1.418E+08	9.51
4.5E+07	1.381E+08	8.69
4.238E+07	1.343E+08	7.95
3.997E+07	1.305E+08	7.29
3.788E+07	1.266E+08	6.63
3.58E+07	1.228E+08	6.086
3.371E+07	1.19E+08	5.542
3.163E+07	1.151E+08	5.04
2.954E+07	1.113E+08	4.58
2.763E+07	1.074E+08	4.12
2.596E+07	1.035E+08	3.736
2.429E+07	9.954E+07	3.352
2.262E+07	9.56E+07	2.998
2.095E+07	9.166E+07	2.674
1.928E+07	8.772E+07	2.35
1.776E+07	8.362E+07	2.074
1.644E+07	7.929E+07	1.798
1.513E+07	7.495E+07	1.536
1.381E+07	7.062E+07	1.288
1.249E+07	6.628E+07	1.04
1.117E+07	6.195E+07	0.82
9.923E+06	5.709E+07	0.6
8.766E+06	5.149E+07	0.398
7.61E+06	4.589E+07	0.214
6.454E+06	4.029E+07	0.03
5.297E+06	3.469E+07	-0.142
4.66E+06	3.16E+07	-0.314
4.66E+06	3.16E+07	-0.476
4.66E+06	3.16E+07	-0.628
3.427E+06	2.506E+07	-0.78
2.575E+06	2.054E+07	-0.916
1.952E+06	1.724E+07	-1.052
1.952E+06	1.724E+07	-1.184
1.952E+06	1.724E+07	-1.312
1.952E+06	1.724E+07	-1.312

Blade 1 Mass Integrals (No ice)

Blade Mass	1815.24	kg
First Mass Moment	13877	kgm
Second Mass Moment	161131	kgm²
Blade inertia about shaft	185084	kgm²

HUB MASS AND INERTIA

Mass of hub	6552	kg
Mass centre of hub	0	m
Hub inertia: about shaft	3899.7	kgm²
perpendicular to shaft	0	kgm²
Total Rotor Mass	11997.7	kg
Total Rotor Inertia	559150	kgm²

TOWER DETAILS

Station Number	Height (m)	Diameter (m)	Mass/unit length (kg/m)	Stiffness (Nm²)
1	0	4.42	1548	8.21E+10
2	2.29392	3.86647	1361	5.48E+10
3	6.86781	2.76277	1428	2.96E+10
4	9.1443	2.21344	1311	1.75E+10
5	11.4801	2.2	1311	1.75E+10
6	14.9872	2.2	1311	1.75E+10
7	17.9086	2.2	878	1.14E+10
8	21.4157	2.2	878	1.14E+10
9	24.3407	2.2	878	1.14E+10
10	27.2481	2.2	599	7.63E+09
11	30.7274	2.2	599	7.63E+09
12	33.6628	2.2	1311	1.75E+10
13	34.862	2.2	1311	1.75E+10

Total Tower Mass	37944	kg
Total Turbine Mass	73825.8	kg

Drag coefficient for tower	0	
Environment	Land	

No movement of tower foundation

Tower base translational motion?	No	
Tower base rotational motion?	No	

NACELLE MASS

Nacelle mass	23884.1	kg
Nacelle centre of mass lateral offset	0	m
Nacelle centre of mass above tower top	1.734	m
Nacelle centre of mass in front of tower axis	0.402	m
Yaw inertia (about tower axis)	36590	kgm²
Nodding inertia (about CoG)	0	kgm²
Rolling inertia (about CoG)	0	kgm²
Total Tower-head Mass	35881.8	kg
Total Yaw Inertia: 0° azimuth	533593	kgm²
Total Yaw Inertia: 90° azimuth	533593	kgm²

DRIVE TRAIN

Gearbox ratio	43.165	
Position of shaft brake	High speed shaft	(Gearbox End)
Generator inertia	46.01	kgm²
High speed shaft inertia:	0	kgm²
Gearbox inertia	0	kgm²
Low speed shaft	Flexible	
Low speed shaft torsional stiffness	2.47E+07	Nm/rad
Low speed shaft torsional damping	0	Nms/rad
High speed shaft	Stiff	

GENERATOR CHARACTERISTICS

Generator model	Variable Speed	
Power electronics time constant	0	s
Maximum generator torque	4000	Nm
Minimum generator torque	0	Nm
Phase Angle	0	deg

MECHANICAL LOSS TORQUE (kNm, referred to low speed shaft)

Loss torque	3	kNm

ELECTRICAL LOSSES

No load power loss	0	kW
Efficiency	93	%

POWER PRODUCTION CONTROL

Variable Speed Pitch Regulated Controller		
Minimum generator speed	430	rpm
Optimal mode quadratic speed-torque gain	0.088425	Nms²/rad²
Optimal mode maximum generator speed	1600	rpm
Generator torque set point	3524.36	Nm
Above-rated generator speed set-point	1600	rpm
Minimum pitch angle	3.7	deg
Maximum pitch angle	90	deg
Pitch direction	to Feather	
Speed transducer time constant	0	s
Power transducer time constant	0	s
Maximum negative pitch rate	-18	deg/s
Maximum positive pitch rate	18	deg/s
Torque controller	Discrete	
Pitch controller	Discrete	

Discrete Controller:

Communication interval	0.0025	s

PITCH ACTUATOR

Pitch actuator responds to	Rate demand	
Pitch Rate response	Passive	
First order lag time constant	0.016667	s
Lower pitch limit	-10	deg
Upper pitch limit	90	deg
Lower pitch rate limit	-18	deg/s
Upper pitch rate limit	18	deg/s
Pitch actuation	Individual	