BladeFS

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USER GUIDE

ALPHA RELEASE

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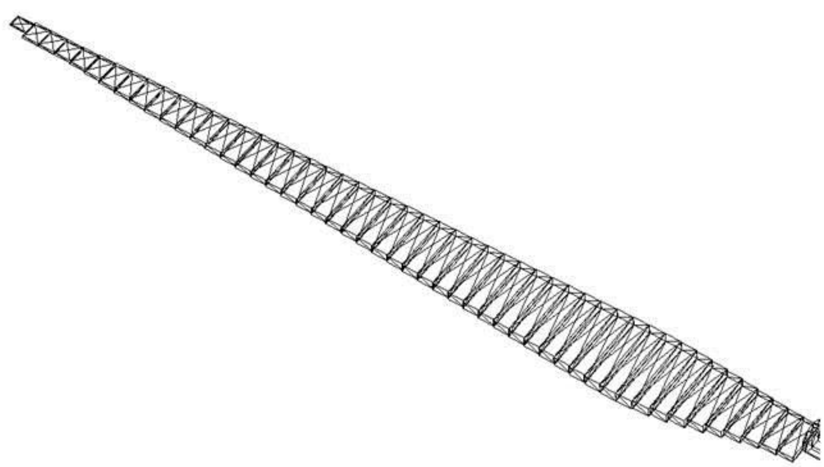
TABLE OF CONTENTS

INTRODUCTION

BladeFS (*Blade* *F*atigue *S*tatic) is a MATLAB® script that was developed to determine loads and deflections associated with fatigue and static structural testing of wind turbine blades using matrix based finite element analysis. Features include blade property and target test load generation functions, saddle and winch optimization routines, a simple graphical user interface, an easy to manipulate excel input file, and word and excel summary output files.

The finite element model of the wind turbine blade utilizes rigid-body, lumped mass, Timoshenko beam theory with six degrees of freedom (flapwise displacement and rotation, edgewise displacement and rotation, axial displacement, and torsion). Blade property and target test load generation functions are based on historical data from horizontal-axis, three-bladed, land-based, utility scale wind turbines with blades ranging 9 to 60 meters in length. Mode shapes and excitation frequencies are computed using Eigen analysis with a cantilever beam boundary condition (twist coupled using Euler angles). Work on a more detailed theory manual is currently in progress and will be made available in the near future.



Blade Finite Element Model

DISTRIBUTED FILES

Here is a list of the files included in the BladeFS archived distribution folder.

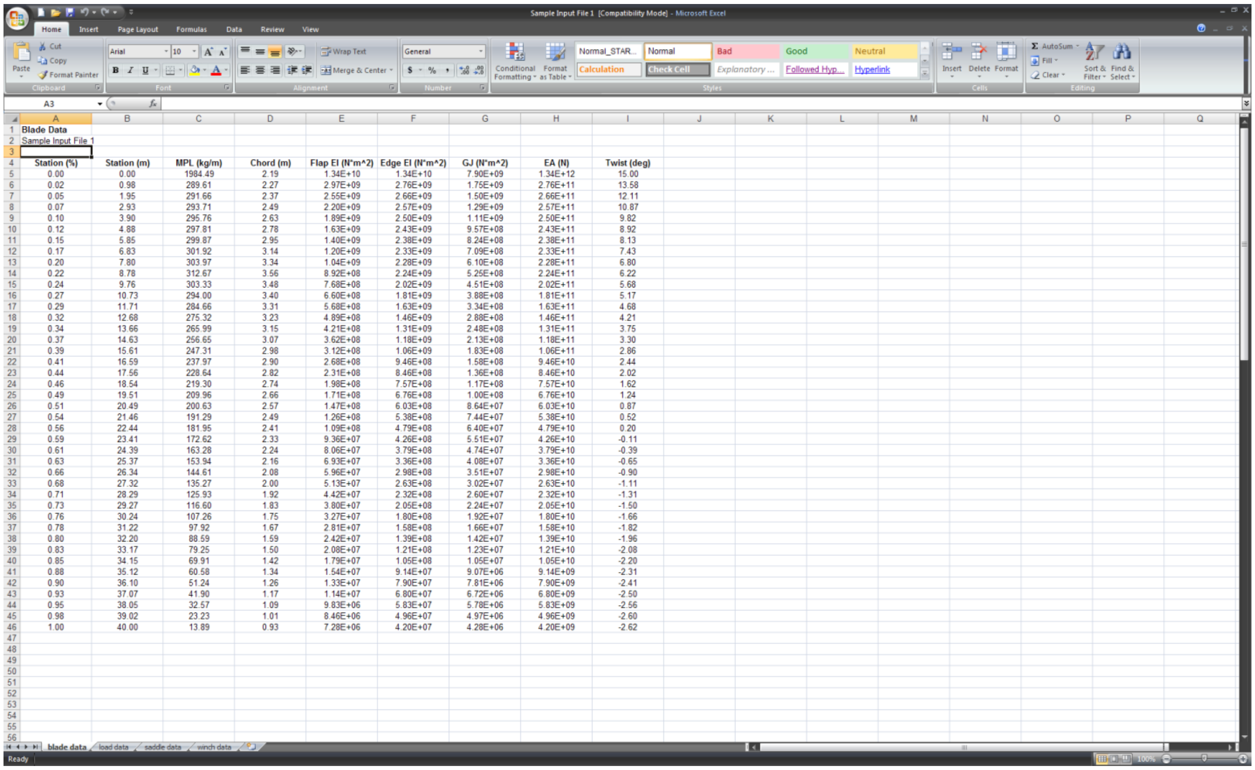
- BladeFS_UserGuide – This user guide in pdf format.
- BladeFS – Runtime application in executable format.
- SampleInputFile1 – Example input file with known blade/test parameters in excel format.
- SampleInputFile2 – Example input file with unknown blade/test parameters in excel format.
- AlphaChangeLog – Change log in text format.
- Disclaimer – Disclaimer agreement in text format.

INSTALLING THE CODE

In order to run BladeFS, the MATLAB® Compiler Runtime (MCR) must be installed first, which will require about 432 MB of hard drive space. The MCR is a standalone set of shared libraries that enables the execution of MATLAB® scripts on computers without an installed version of MATLAB® and associated licensing. This only needs to be installed once.

INPUT FILE

The input file is an excel spreadsheet, which was chosen for ease of data manipulation to help reduce setup time. The input file must contain the following worksheet tabs: blade data, load data, saddle data, and winch data. Additional worksheet tabs are allowed. The order of the tabs does not matter, the data does not need to start on a specific cell, and the length of the data does not matter. However, it must have the correct formatting and cannot be preceded by other numerical information. The two sample input files are explained in further detail as follows.

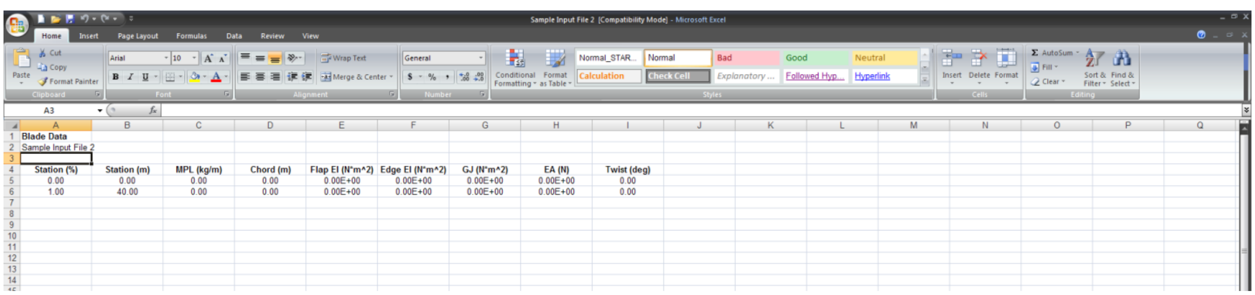


Blade Data

Sample Input File 1

Station (%)	Station (m)	MPL (kg/m)	Chord (m)	Flap EI (N*m^2)	Edge EI (N*m^2)	GJ (N*m^2)	EA (N)	Twist (deg)
0.00	0.00	1984.49	2.19	1.34E+10	1.34E+10	7.90E+09	1.34E+12	15.00
0.02	0.98	289.61	2.27	2.97E+09	2.76E+09	1.75E+09	2.76E+11	13.58
0.05	1.95	291.66	2.37	2.55E+09	2.66E+09	1.50E+09	2.66E+11	12.11
0.07	2.93	293.71	2.49	2.20E+09	2.57E+09	1.29E+09	2.57E+11	10.87
0.10	3.90	295.76	2.63	1.89E+09	2.50E+09	1.11E+09	2.50E+11	9.82
0.12	4.88	297.81	2.78	1.63E+09	2.43E+09	9.57E+08	2.43E+11	8.92
0.15	5.85	299.87	2.95	1.40E+09	2.38E+09	8.24E+08	2.38E+11	8.13
0.17	6.83	301.92	3.14	1.20E+09	2.33E+09	7.09E+08	2.33E+11	7.43
0.20	7.80	303.97	3.34	1.04E+09	2.28E+09	6.10E+08	2.28E+11	6.80
0.22	8.78	312.67	3.56	8.92E+08	2.24E+09	5.25E+08	2.24E+11	6.22
0.24	9.76	303.33	3.48	7.68E+08	2.02E+09	4.51E+08	2.02E+11	5.68
0.27	10.73	294.00	3.40	6.60E+08	1.81E+09	3.88E+08	1.81E+11	5.17
0.29	11.71	284.66	3.31	5.68E+08	1.63E+09	3.34E+08	1.63E+11	4.68
0.32	12.68	275.32	3.23	4.89E+08	1.46E+09	2.88E+08	1.46E+11	4.21
0.34	13.66	265.99	3.15	4.21E+08	1.31E+09	2.48E+08	1.31E+11	3.75
0.37	14.63	256.65	3.07	3.62E+08	1.18E+09	2.13E+08	1.18E+11	3.30
0.39	15.61	247.31	2.98	3.12E+08	1.06E+09	1.83E+08	1.06E+11	2.86
0.41	16.59	237.97	2.90	2.68E+08	9.46E+08	1.58E+08	9.46E+10	2.44
0.44	17.56	228.64	2.82	2.31E+08	8.46E+08	1.36E+08	8.46E+10	2.02
0.46	18.54	219.30	2.74	1.98E+08	7.57E+08	1.17E+08	7.57E+10	1.62
0.49	19.51	209.96	2.66	1.71E+08	6.76E+08	1.00E+08	6.76E+10	1.24
0.51	20.49	200.63	2.57	1.47E+08	6.03E+08	8.64E+07	6.03E+10	0.87
0.54	21.46	191.29	2.49	1.26E+08	5.38E+08	7.44E+07	5.38E+10	0.52
0.56	22.44	181.95	2.41	1.09E+08	4.79E+08	6.40E+07	4.79E+10	0.20
0.59	23.41	172.62	2.33	9.36E+07	4.26E+08	5.51E+07	4.26E+10	-0.11
0.61	24.39	163.28	2.24	8.06E+07	3.79E+08	4.74E+07	3.79E+10	-0.39
0.63	25.37	153.94	2.16	6.93E+07	3.36E+08	4.08E+07	3.36E+10	-0.65
0.66	26.34	144.61	2.08	5.96E+07	2.98E+08	3.51E+07	2.98E+10	-0.90
0.68	27.32	135.27	2.00	5.13E+07	2.63E+08	3.02E+07	2.63E+10	-1.11
0.71	28.29	125.93	1.92	4.42E+07	2.32E+08	2.60E+07	2.32E+10	-1.31
0.73	29.27	116.60	1.83	3.80E+07	2.05E+08	2.24E+07	2.05E+10	-1.50
0.76	30.24	107.26	1.75	3.27E+07	1.80E+08	1.92E+07	1.80E+10	-1.66
0.78	31.22	97.92	1.67	2.81E+07	1.58E+08	1.66E+07	1.58E+10	-1.82
0.80	32.20	88.59	1.59	2.42E+07	1.39E+08	1.42E+07	1.39E+10	-1.96
0.83	33.17	79.25	1.50	2.08E+07	1.21E+08	1.23E+07	1.21E+10	-2.08
0.85	34.15	69.91	1.42	1.79E+07	1.05E+08	1.05E+07	1.05E+10	-2.20
0.88	35.12	60.58	1.34	1.54E+07	9.14E+07	9.07E+06	9.14E+09	-2.31
0.90	36.10	51.24	1.26	1.33E+07	7.90E+07	7.81E+06	7.90E+09	-2.41
0.93	37.07	41.90	1.17	1.14E+07	6.80E+07	6.72E+06	6.80E+09	-2.50
0.95	38.05	32.57	1.09	9.83E+06	5.83E+07	5.78E+06	5.83E+09	-2.56
0.98	39.02	23.23	1.01	8.46E+06	4.96E+07	4.97E+06	4.96E+09	-2.60
1.00	40.00	13.89	0.93	7.28E+06	4.20E+07	4.28E+06	4.20E+09	-2.62

Sample Input File 1 – Blade Data Tab



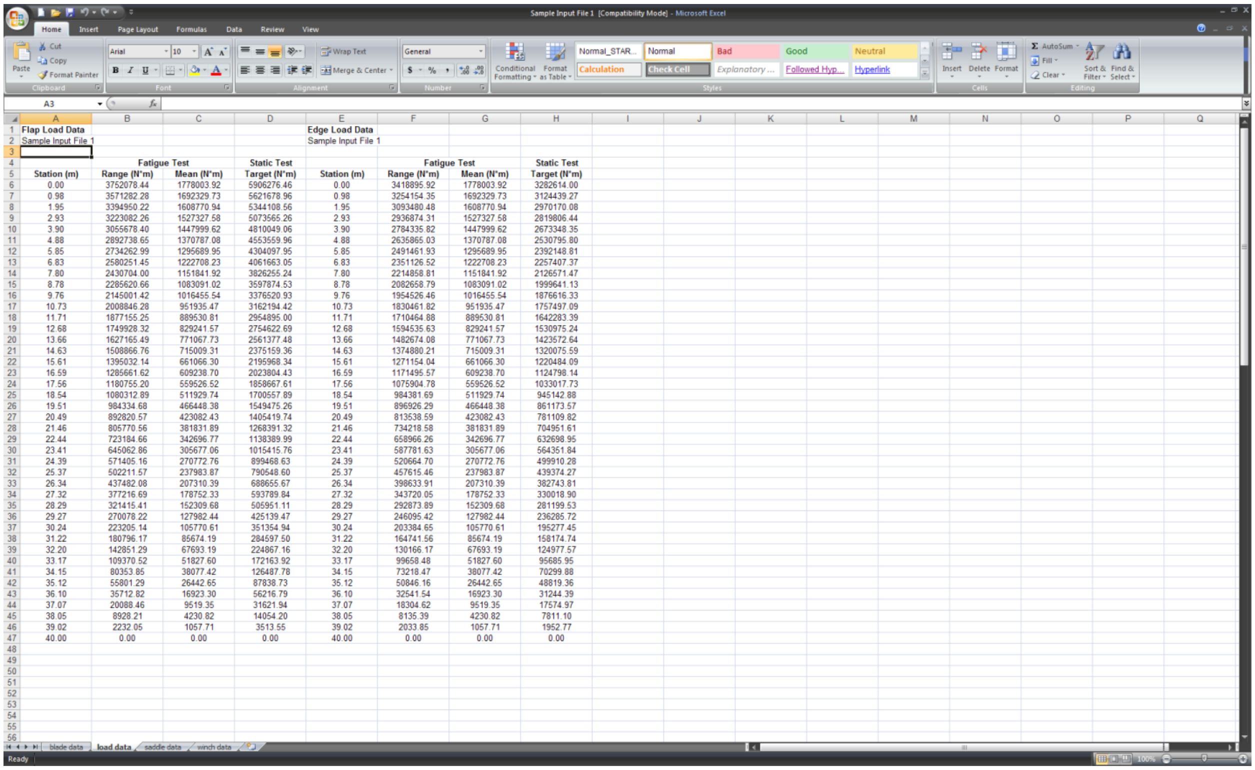
Blade Data

Sample Input File 2

Station (%)	Station (m)	MPL (kg/m)	Chord (m)	Flap EI (N*m^2)	Edge EI (N*m^2)	GJ (N*m^2)	EA (N)	Twist (deg)
0.00	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
1.00	40.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00

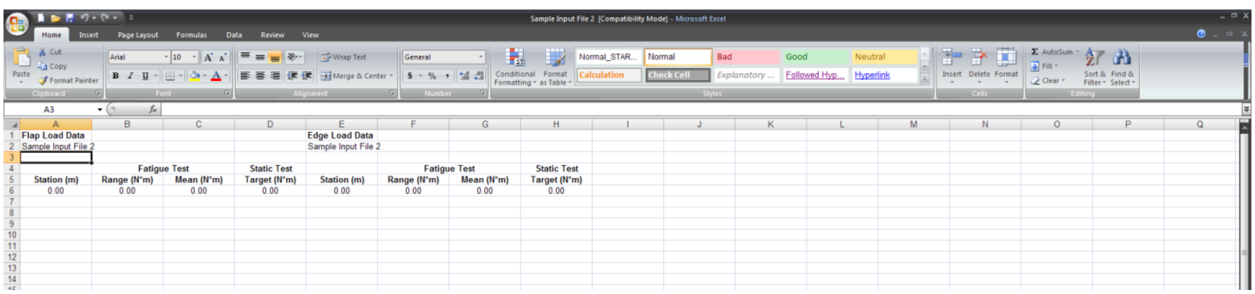
Sample Input File 2 – Blade Data Tab

The blade data tab (must be named "blade data") contains the blade properties which consists of the percent blade station (%), blade station (m), mass-per-unit-length (kg/m), chord length (m), flap stiffness (Nm^2), edge stiffness (Nm^2), torsional stiffness (Nm^2), axial stiffness (N), and twist (deg), in that order and those units. If a property parameter is unknown, put zero and the code will develop a prediction (except for twist). Since the predictions are based on blade length, the user must specify at least two blade stations – the root and tip (as shown in Sample Input File 2).



Flap Load Data				Edge Load Data			
Sample Input File 1				Sample Input File 1			
	Fatigue Test		Static Test		Fatigue Test		Static Test
Station (m)	Range (N*m)	Mean (N*m)	Target (N*m)	Station (m)	Range (N*m)	Mean (N*m)	Target (N*m)
0.00	3752078.44	1778003.92	5906276.46	0.00	3418895.92	1778003.92	3282614.00
0.98	3571282.28	1692329.73	5621678.96	0.98	3254154.35	1692329.73	3124439.27
1.95	3394950.22	1608770.94	5344108.56	1.95	3093480.48	1608770.94	2970170.08
2.93	3223082.26	1527327.58	5073565.26	2.93	2936874.31	1527327.58	2819806.44
3.90	3055678.40	1447999.62	4810049.06	3.90	2784335.82	1447999.62	2673348.35
4.88	2892738.65	1370787.08	4553559.96	4.88	2635865.03	1370787.08	2530795.80
5.85	2734262.99	1295689.95	4304097.95	5.85	2491461.93	1295689.95	2392148.81
6.83	2580251.45	1222708.23	4061663.05	6.83	2351126.52	1222708.23	2257407.37
7.80	2430704.00	1151841.92	3826255.24	7.80	2214858.81	1151841.92	2126571.47
8.78	2285620.66	1083091.02	3597874.53	8.78	2082658.79	1083091.02	1999641.13
9.76	2145001.42	1016455.54	3376520.93	9.76	1954526.46	1016455.54	1876616.33
10.73	2008846.28	951935.47	3162194.42	10.73	1830461.82	951935.47	1757497.09
11.71	1877155.25	889530.81	2954895.00	11.71	1710464.88	889530.81	1642283.39
12.68	1749928.32	829241.57	2754622.69	12.68	1594535.63	829241.57	1530975.24
13.66	1627165.49	771067.73	2561377.48	13.66	1482674.08	771067.73	1423572.64
14.63	1508866.76	715009.31	2375159.36	14.63	1374880.21	715009.31	1320075.59
15.61	1395032.14	661066.30	2195968.34	15.61	1271154.04	661066.30	1220484.09
16.59	1285661.62	609238.70	2023804.43	16.59	1171495.57	609238.70	1124798.14
17.56	1180755.20	559526.52	1858667.61	17.56	1075904.78	559526.52	1033017.73
18.54	1080312.89	511929.74	1700557.89	18.54	984381.69	511929.74	945142.88
19.51	984334.68	466448.38	1549475.26	19.51	896926.29	466448.38	861173.57
20.49	892820.57	423082.43	1405419.74	20.49	813538.59	423082.43	781109.82
21.46	805770.56	381831.89	1268391.32	21.46	734218.58	381831.89	704951.61
22.44	723184.66	342696.77	1138389.99	22.44	658966.26	342696.77	632698.95
23.41	645062.86	305677.06	1015415.76	23.41	587781.63	305677.06	564351.84
24.39	571405.16	270772.76	899468.63	24.39	520664.70	270772.76	499910.28
25.37	502211.57	237983.87	790548.60	25.37	457615.46	237983.87	439374.27
26.34	437482.08	207310.39	688655.67	26.34	398633.91	207310.39	382743.81
27.32	377216.69	178752.33	593789.84	27.32	343720.05	178752.33	330018.90
28.29	321415.41	152309.68	505951.11	28.29	292873.89	152309.68	281199.53
29.27	270078.22	127982.44	425139.47	29.27	246095.42	127982.44	236285.72
30.24	223205.14	105770.61	351354.94	30.24	203384.65	105770.61	195277.45
31.22	180796.17	85674.19	284597.50	31.22	164741.56	85674.19	158174.74
32.20	142851.29	67693.19	224867.16	32.20	130166.17	67693.19	124977.57
33.17	109370.52	51827.60	172163.92	33.17	99658.48	51827.60	95685.95
34.15	80353.85	38077.42	126487.78	34.15	73218.47	38077.42	70299.88
35.12	55801.29	26442.65	87838.73	35.12	50846.16	26442.65	48819.36
36.10	35712.82	16923.30	56216.79	36.10	32541.54	16923.30	31244.39
37.07	20088.46	9519.35	31621.94	37.07	18304.62	9519.35	17574.97
38.05	8928.21	4230.82	14054.20	38.05	8135.39	4230.82	7811.10
39.02	2232.05	1057.71	3513.55	39.02	2033.85	1057.71	1952.77
40.00	0.00	0.00	0.00	40.00	0.00	0.00	0.00

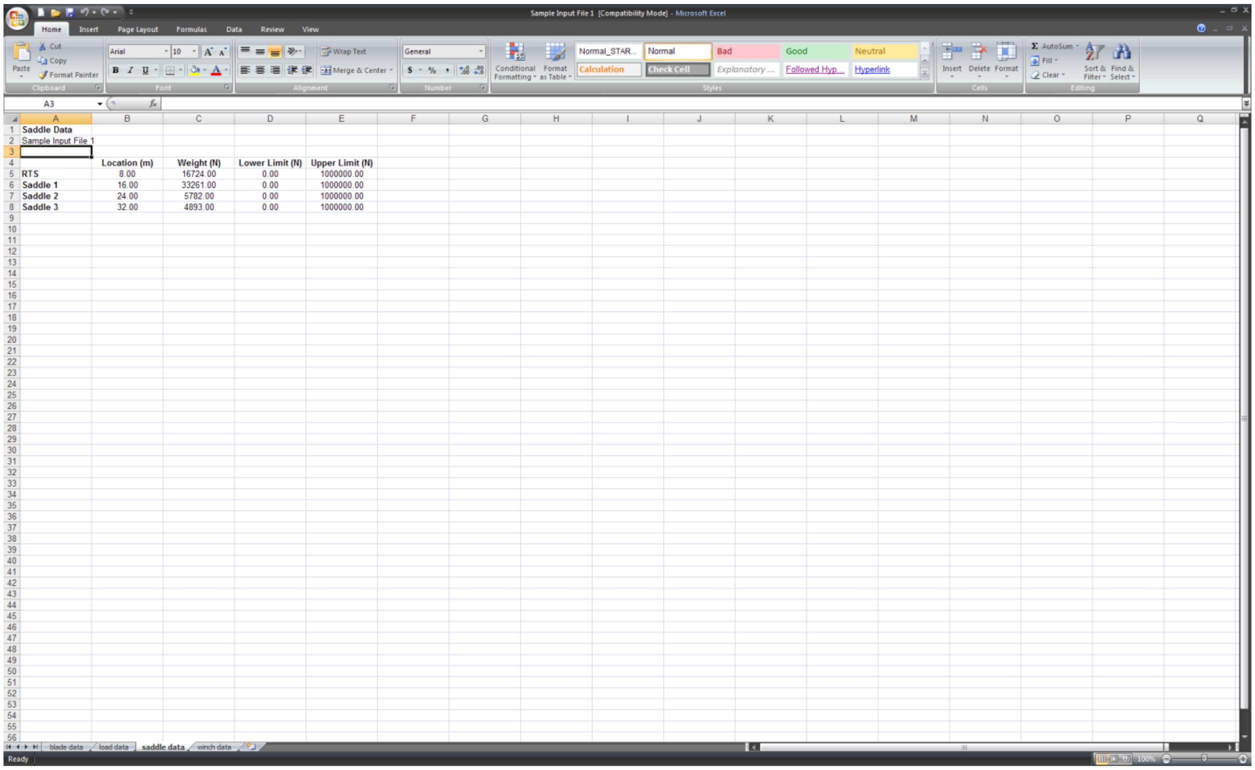
Sample Input File 1 – Load Data Tab



Flap Load Data				Edge Load Data			
Sample Input File 2				Sample Input File 2			
	Fatigue Test		Static Test		Fatigue Test		Static Test
Station (m)	Range (N*m)	Mean (N*m)	Target (N*m)	Station (m)	Range (N*m)	Mean (N*m)	Target (N*m)
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Sample Input File 2 – Load Data Tab

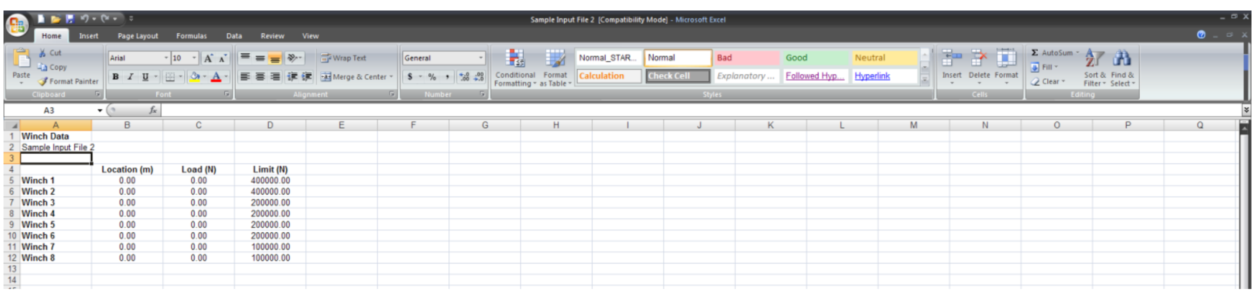
The load data tab (must be named "load data") contains the target test loads which consists of the blade station (m), fatigue range load (Nm), fatigue mean load (Nm), and static load (Nm), in that order and those units, for both the flapwise and edgewise directions. If a load parameter is unknown, put zero and the code will develop a prediction (you do not need to specify stations as the code will obtain blade length from the blade data tab).



Saddle Data
Sample Input File 1

	Location (m)	Weight (N)	Lower Limit (N)	Upper Limit (N)
RTS	8.00	16724.00	0.00	1000000.00
Saddle 1	16.00	33261.00	0.00	1000000.00
Saddle 2	24.00	5782.00	0.00	1000000.00
Saddle 3	32.00	4893.00	0.00	1000000.00

Sample Input File 1 – Saddle Data Tab

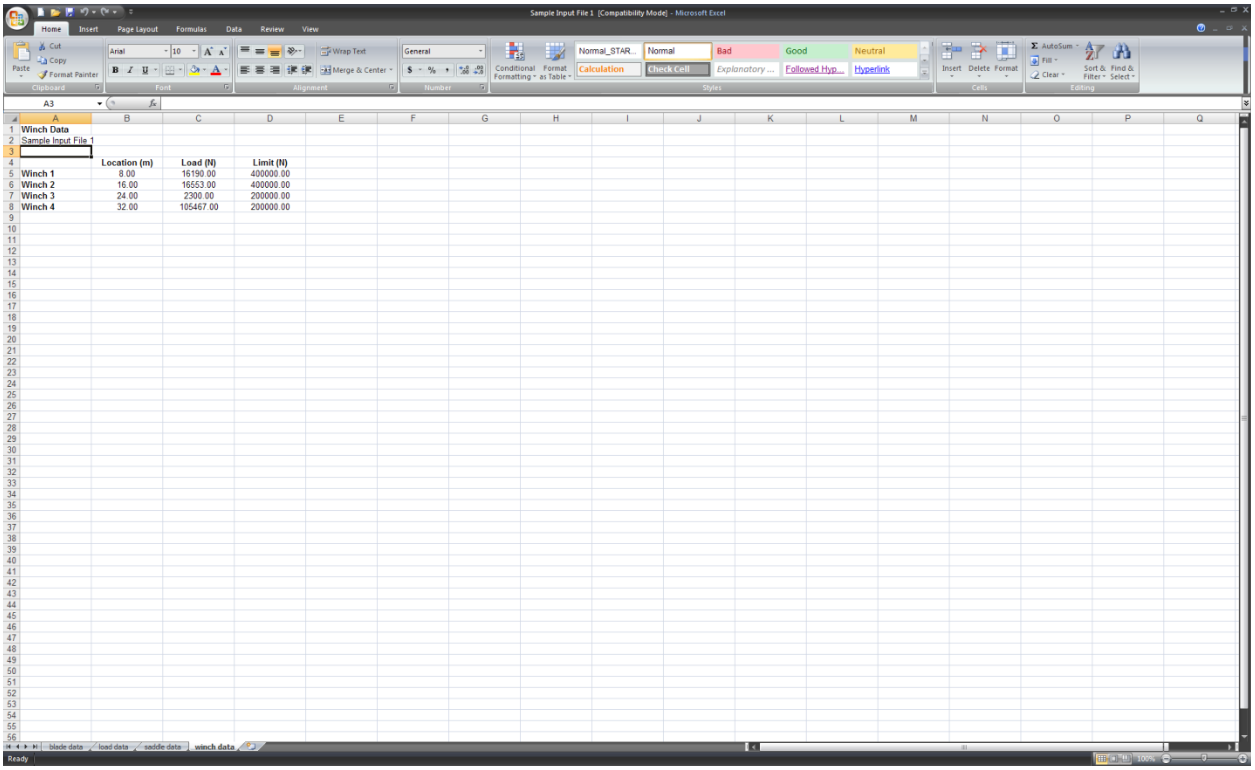


Winch Data
Sample Input File 2

	Location (m)	Load (N)	Limit (N)
Winch 1	0.00	0.00	400000.00
Winch 2	0.00	0.00	400000.00
Winch 3	0.00	0.00	200000.00
Winch 4	0.00	0.00	200000.00
Winch 5	0.00	0.00	200000.00
Winch 6	0.00	0.00	200000.00
Winch 7	0.00	0.00	100000.00
Winch 8	0.00	0.00	100000.00

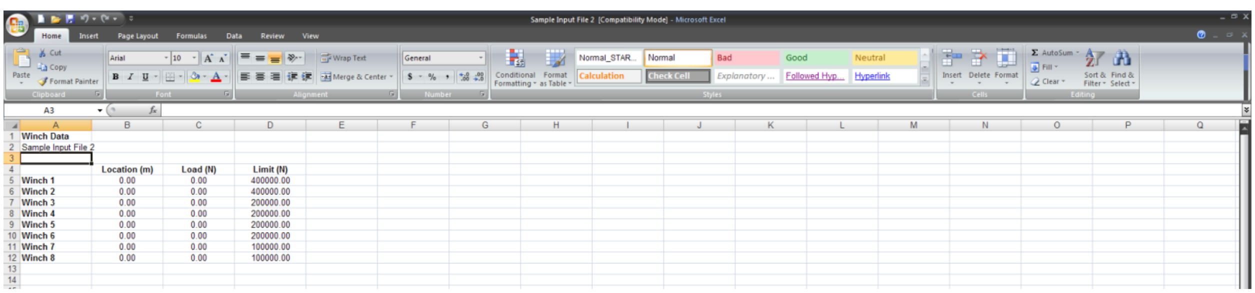
Sample Input File 2 – Saddle Data Tab

The saddle data tab (must be named "saddle data") contains the saddle configuration which consists of the location (m), weight (N), lower weight limit (N), and upper weight limit (N), in that order and those units. For a fatigue test simulation, the resonant test system (RTS) must be specified in the first row with additional saddles in subsequent rows (as shown in the sample input files). If a saddle parameter is unknown, put zero and then select the yes option for the saddle optimizer to optimize the saddle locations and weights based on the selection of either the range or mean option in the saddle optimizer target load box. There must be a row for each saddle in order for the code to determine the desired number of saddles.



	Location (m)	Load (N)	Limit (N)
Winch Data			
Sample Input File 1			
Winch 1	8.00	16190.00	400000.00
Winch 2	16.00	16553.00	400000.00
Winch 3	24.00	2300.00	200000.00
Winch 4	32.00	105467.00	200000.00

Sample Input File 1 – Winch Data Tab



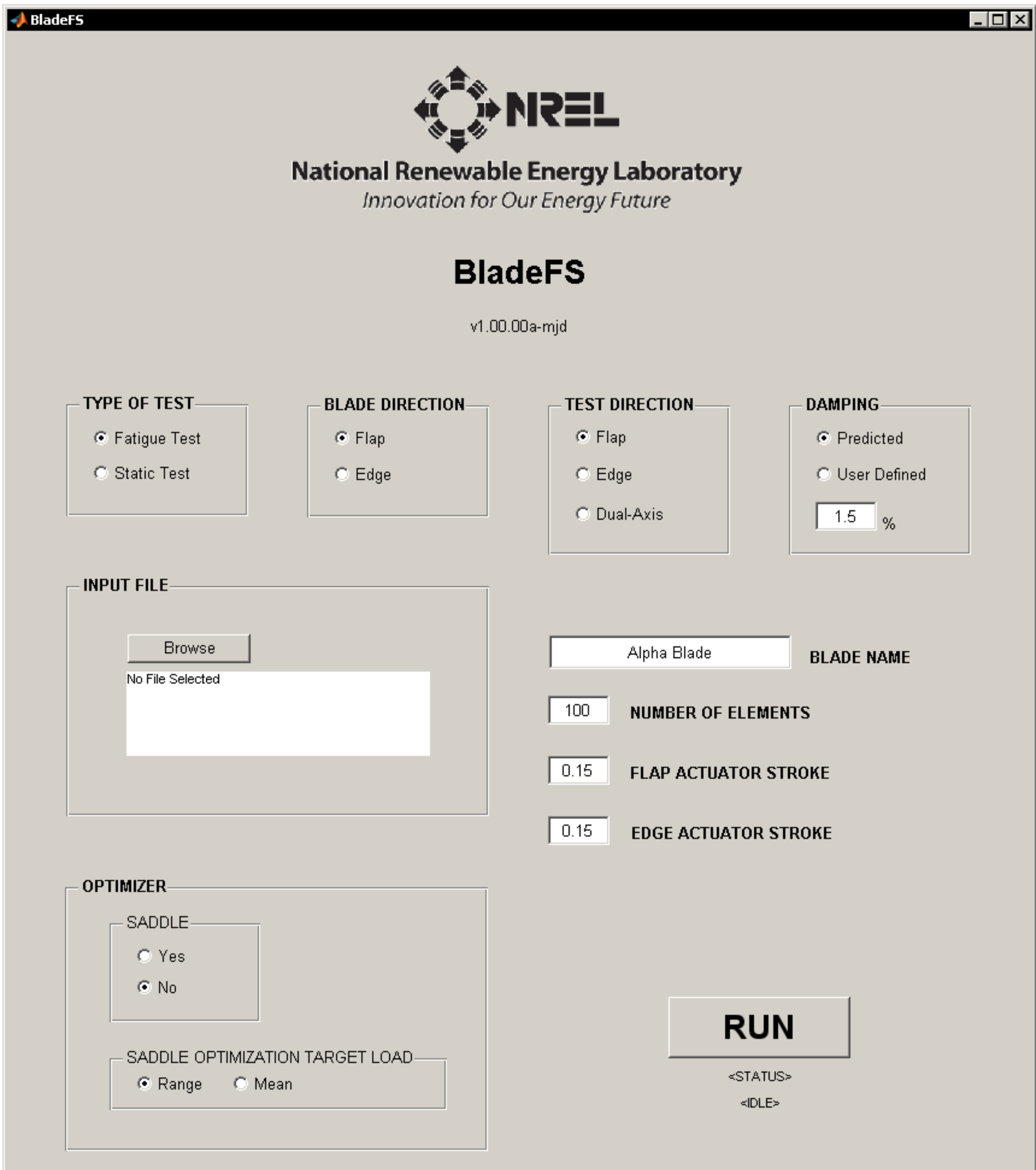
	Location (m)	Load (N)	Limit (N)
Winch Data			
Sample Input File 2			
Winch 1	0.00	0.00	400000.00
Winch 2	0.00	0.00	400000.00
Winch 3	0.00	0.00	200000.00
Winch 4	0.00	0.00	200000.00
Winch 5	0.00	0.00	200000.00
Winch 6	0.00	0.00	200000.00
Winch 7	0.00	0.00	100000.00
Winch 8	0.00	0.00	100000.00

Sample Input File 2 – Winch Data Tab

The winch data tab (must be named "winch data") contains the winch configuration which consists of the location (m), load (N), and load limit (N), in that order and those units. If a winch parameter is unknown, put zero and the code and then select the yes option for the winch optimizer to optimize the winch locations and loads based on the static target load and test direction. If the blade direction and test direction are the same, then the saddle weights will contribute to part of the applied test load.

RUNNING THE CODE

Once the input file is created and MCR is installed, the code may be run by double-clicking on the BladeFS application executable icon. This will initiate the BladeFS graphical user interface (GUI) accompanied by a command prompt window. Selecting the type of test (fatigue or static) will automatically adjust the available GUI options.



BladeFS – Fatigue Test Option

The blade direction option allows the user to select the primary orientation of the blade with respect to horizontal. This affects the mean loads for fatigue tests and the contribution of gravity loads for static tests. For example, if the blade direction = flap and the test direction = flap, then there would be a mean load component for fatigue tests and the applied test load would be the combination of winch loads and the gravity load for static tests.

The test direction option allows the user to select the primary test direction, which defines the targets for the saddle optimization routine (with the assumption that the saddles should be optimized in the flap direction for a dual-axis test).

The damping option allows the user to select whether the code should estimate the damping or use the specific damping value provided. If the user defined option is selected, the damping value must be between zero and one hundred.

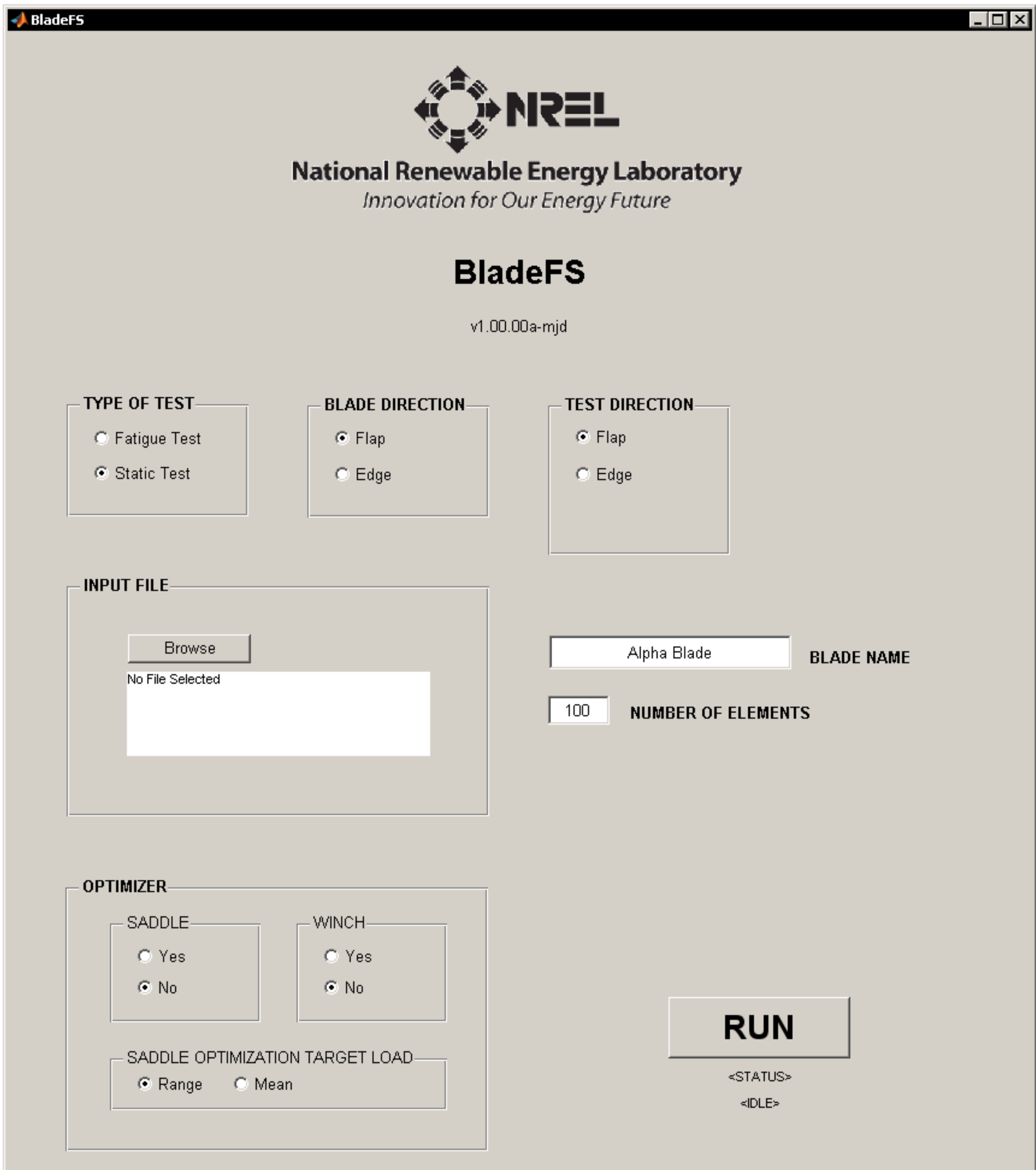
The input file option allows the user to select the input file, which can be located in any folder or directory.

The blade name option allows the user to specify the blade name. This can be used to identify specific runs as the output files will be located in a folder with that name. No special characters are allowed.
The number of elements option allows the user to specify the number of elements used for the blade finite element model. The number of elements value must be equal to or greater than one. Note that increasing the number of elements will increase the computation time, but generally provides more accurate results.

The flap and edge actuator stroke options allow the user to specify the dynamic stroke lengths of the resonant test system actuators.

The saddle optimizer option provides the user with a built-in optimizer tool to determine saddle locations and weights based on either the range or mean fatigue target test loads. If the optimizer is selected and the saddle locations are specified in the input file, the code will only optimize the weights. If the saddle locations are not specified, then the code will optimize both the locations and weights.

Pressing the run button will initiate the test simulation. The button will turn green during computation, and then back to gray when idle. If an option is not properly selected, the button will turn red. There is status indicator text below the run button which will display a brief description of any error.



BladeFS – Static Test Option

Since most of the GUI options are the same for the static test option, only the differences will be explained here.

Again, the test direction option allows the user to select the primary test direction, which defines the targets for the winch optimizer (with the assumption that if the blade direction and test direction are the same, then the applied test load and corresponding winch loads will be reduced by the combined blade and saddle loads).

The winch optimizer option provides the user with a built-in optimizer tool to determine winch locations and loads based on the static target test loads. If the optimizer is selected and the winch locations are specified in the input file, the code will only optimize the loads. If the winch locations are not specified, then the code will optimize both the locations and loads.

OUTPUT FILES

The results are compiled in a word document and an excel spreadsheet. Both output files can be found in the same directory as the BladeFS executable under a folder with the specified blade name. The word document provides a summary report with figures of the blade properties, loads, and deflections. The excel spreadsheet contains the numerical values for the blade properties, loads, deflections, saddles, winches, and other test parameters.

FEEDBACK

We are interested to hear your feedback about the code. Please send your comments and questions via email to:

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