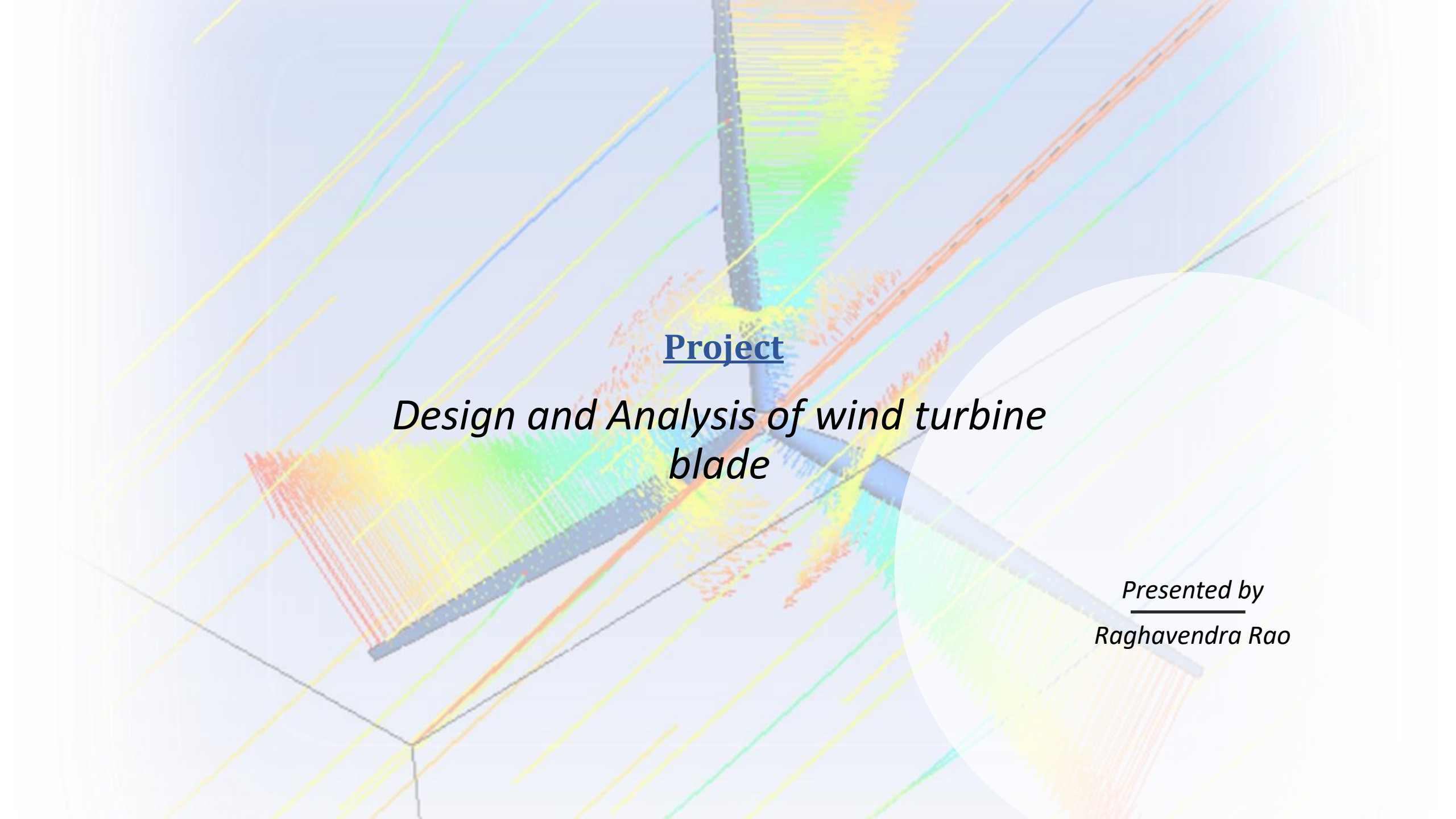


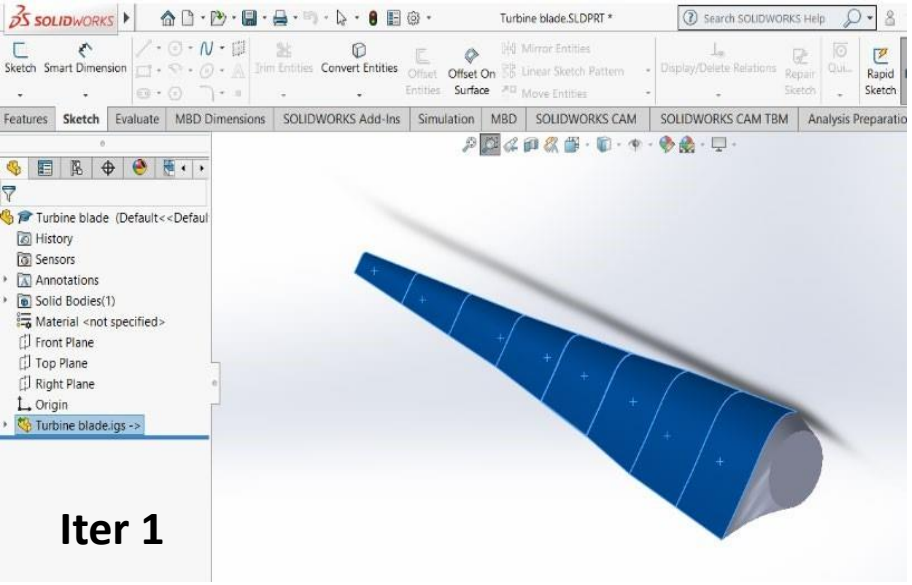
Project

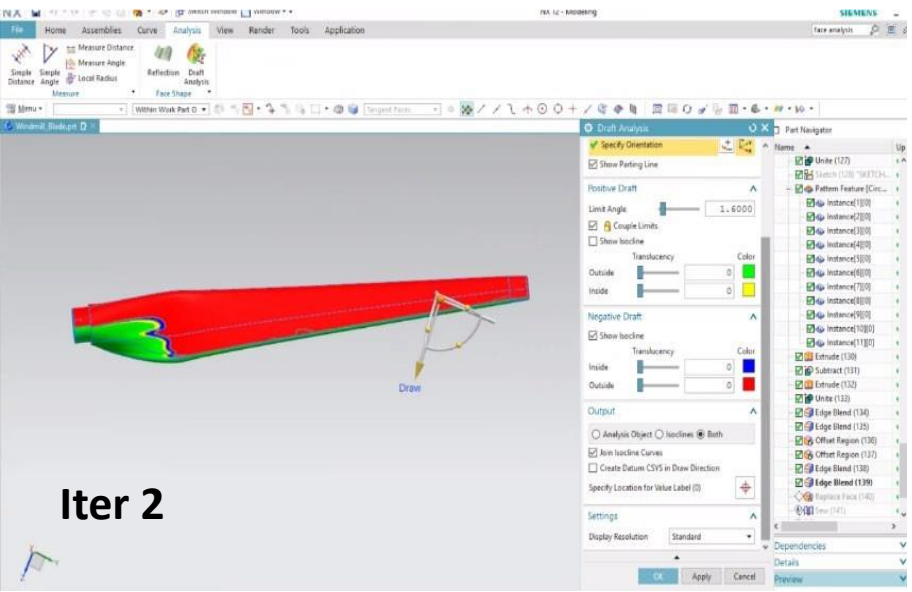
Design and Analysis of wind turbine blade

Presented by

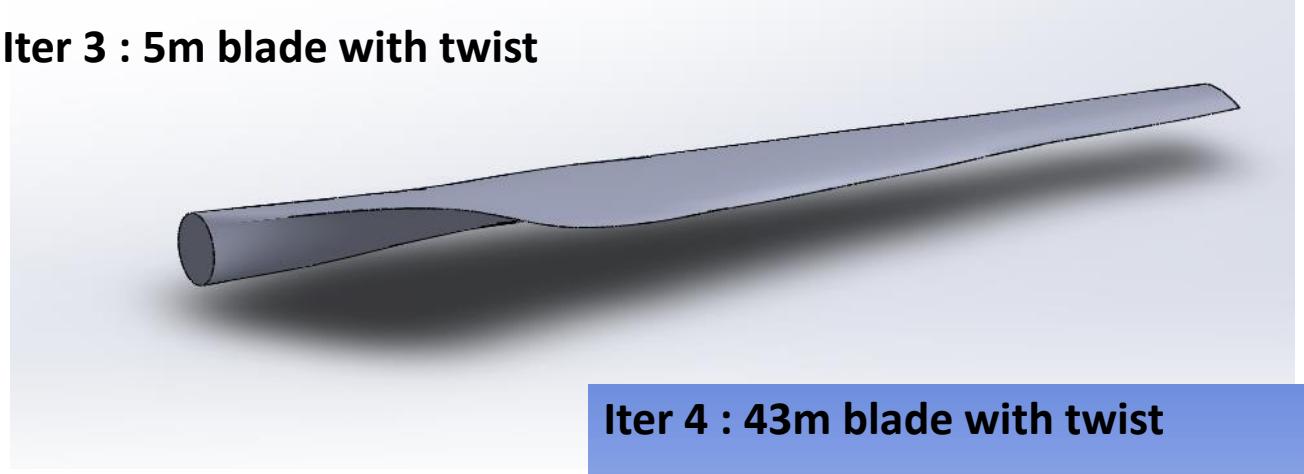
Raghavendra Rao

Initial design

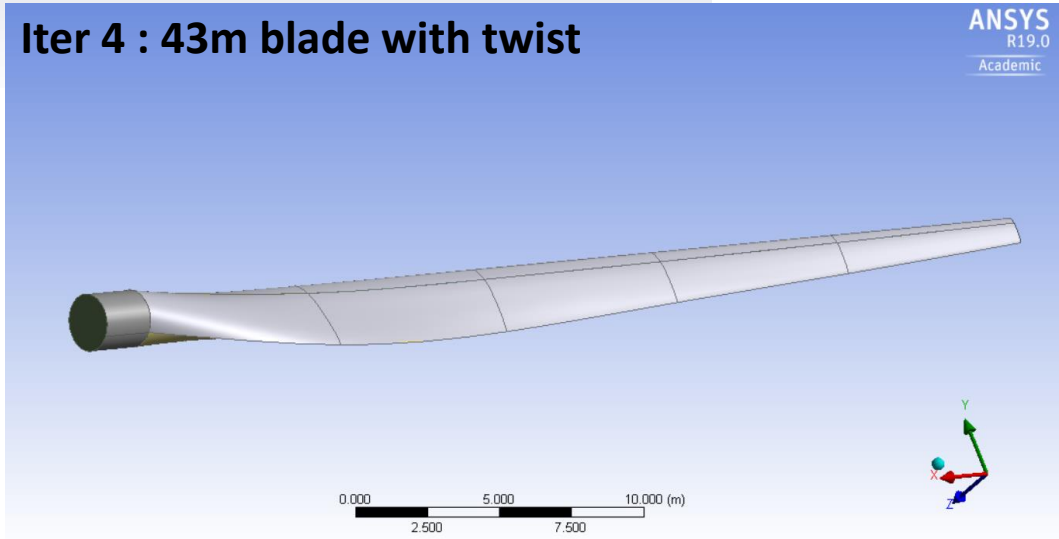




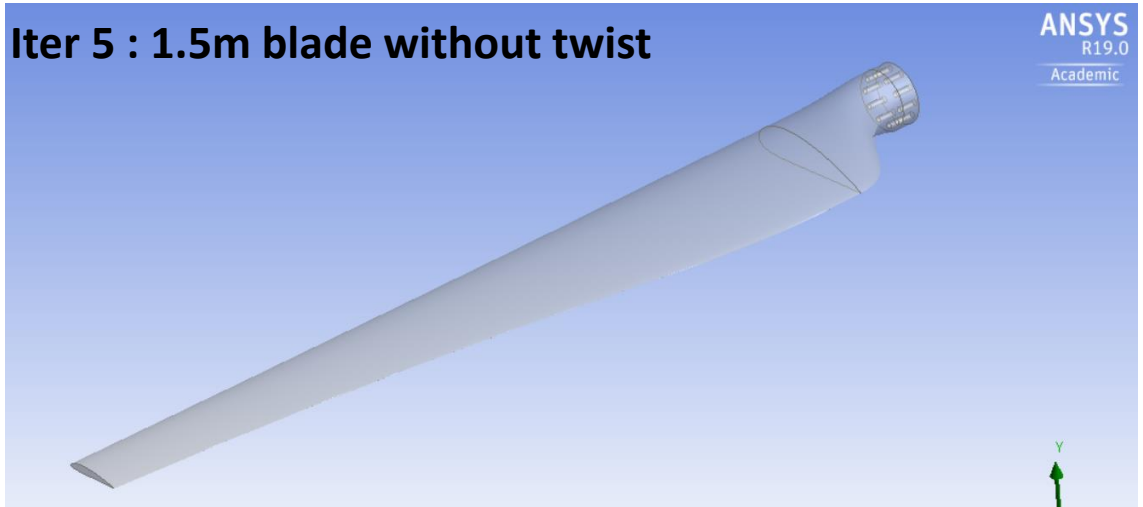
Iter 3 : 5m blade with twist



Iter 4 : 43m blade with twist



Iter 5 : 1.5m blade without twist

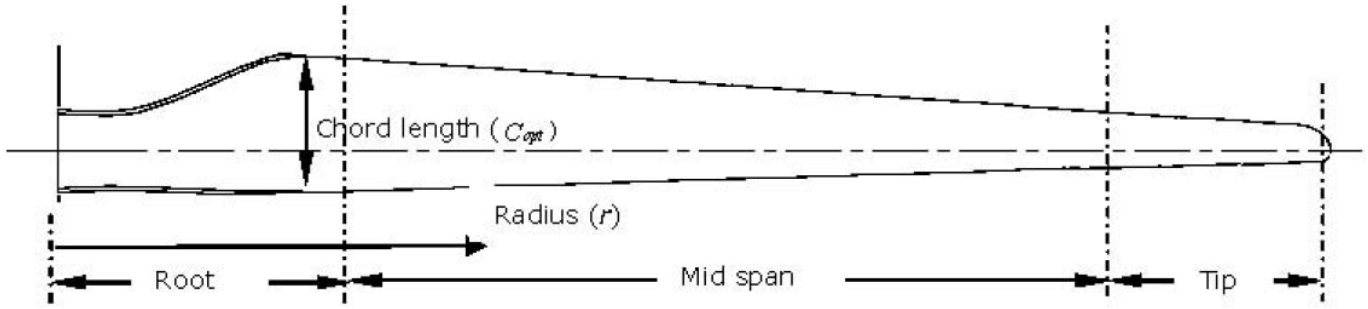


Objective: Design the wind turbine blade to increase or maintain the power output and optimize the same by minimizing the amount of blade material and hence the manufacturing cost.

- Reduce stress concentration and deformation
- Increase lift and reduce drag

Optimization Problem:

The wind turbine blades are dynamic components and the forces created by the rotation of the blades leads to several stress concentration points. The excess inertia forces and the torsion will lead to the failure of the component. To compensate these loss in energy meanwhile not compromising on the performance and efficiency, we perform optimization to maintain or increase the power output while minimizing the weight stress concentration and deformation. We plan to use approximations to reduce computational burden.



Design Variables:

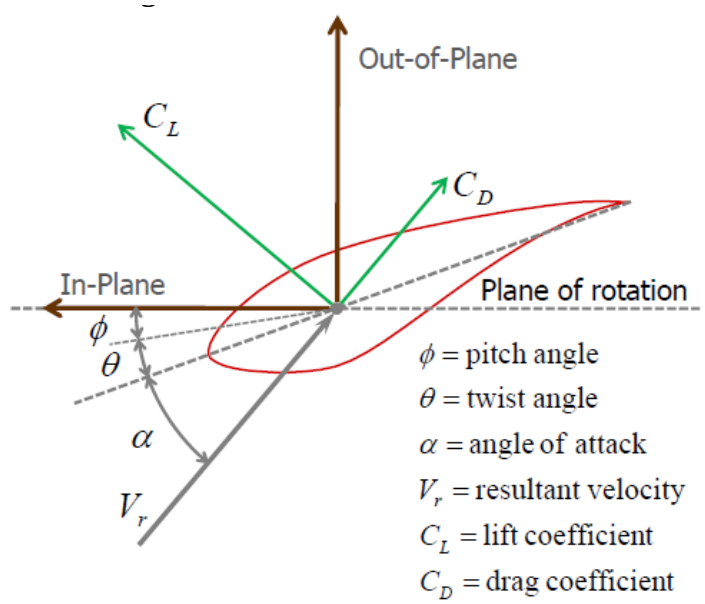
Blade Radius, R

Chord length, L

Objective:

Equivalent Stress

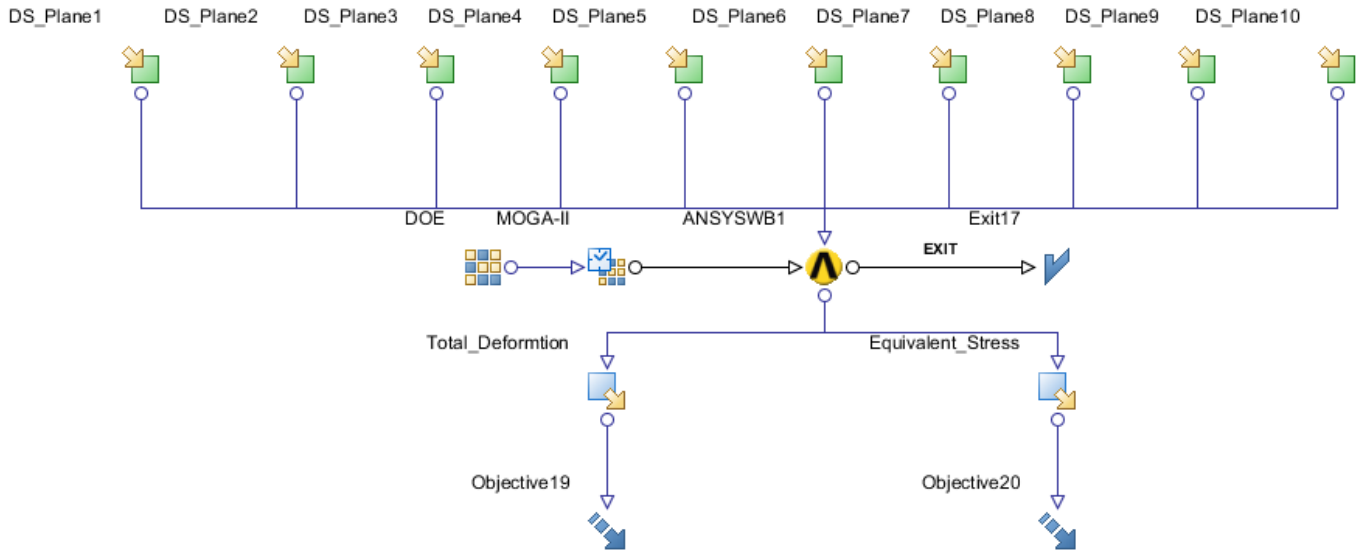
Total Deflection

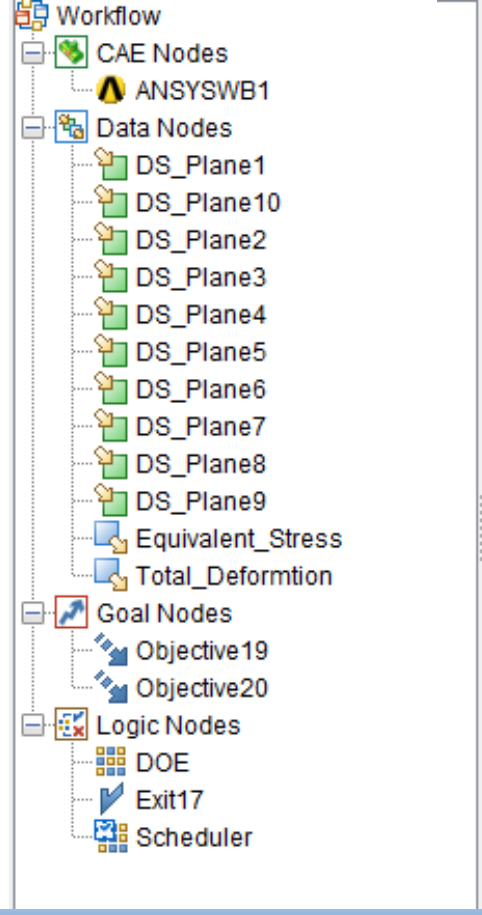


5m blade

Modefrontier setup

FEA Model





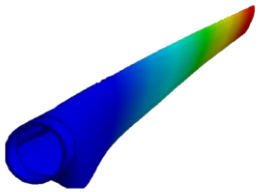
Logic Log

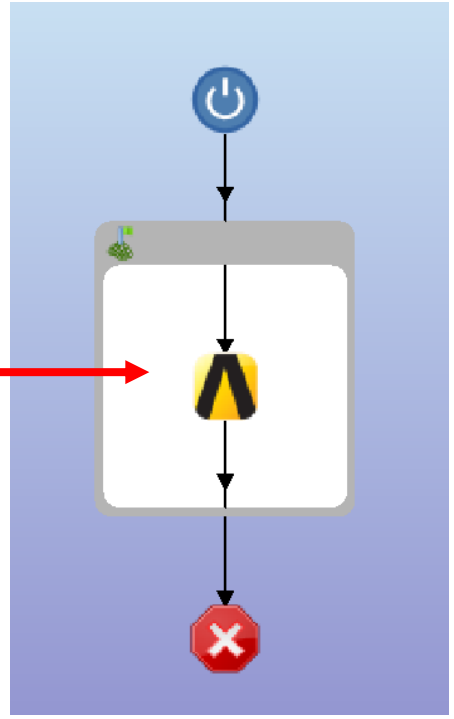
Input Variable

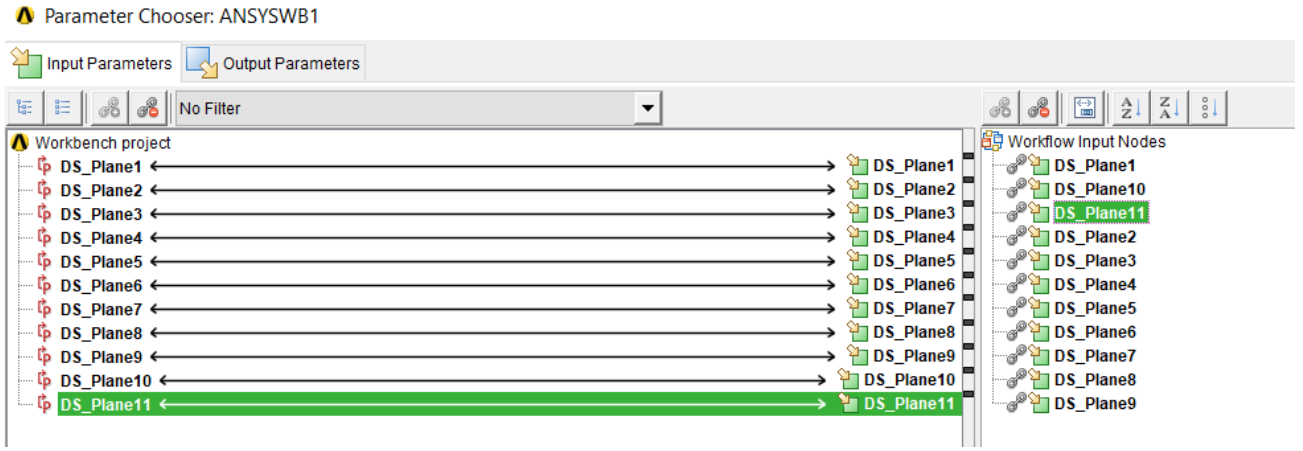
	Name	Variable Type	Default Value	Expression	Lower Bound	Upper Bound	Central Value	Delta Value	Base	Step	Arrangement	Format	Tolerance	Distribution	Scale	Shape1	Shape2
0	DS_Plane1	Variable	0.0		0.8	0.9	0.8500000...	0.0499999...	0	0.0	Ordered	0.0000E0	0.0	None	0	0	0
1	DS_Plane2	Variable	0.0		1.3	1.45	1.375	0.0749999...	0	0.0	Ordered	0.0000E0	0.0	None	0	0	0
2	DS_Plane3	Variable	0.0		1.85	2.0	1.925	0.0749999...	0	0.0	Ordered	0.0000E0	0.0	None	0	0	0
3	DS_Plane4	Variable	0.0		2.0	3.0	2.5	0.5	0	0.0	Ordered	0.0000E0	0.0	None	0	0	0
4	DS_Plane5	Variable	0.0		2.8	3.2	3.0	0.2000000...	0	0.0	Ordered	0.0000E0	0.0	None	0	0	0
5	DS_Plane6	Variable	0.0		3.2	3.8	3.5	0.2999999...	0	0.0	Ordered	0.0000E0	0.0	None	0	0	0
6	DS_Plane7	Variable	0.0		4.0	4.3	4.15	0.1499999...	0	0.0	Ordered	0.0000E0	0.0	None	0	0	0
7	DS_Plane8	Variable	0.0		4.4	4.8	4.6	0.1999999...	0	0.0	Ordered	0.0000E0	0.0	None	0	0	0
8	DS_Plane9	Variable	0.0		5.0	5.3	5.15	0.1499999...	0	0.0	Ordered	0.0000E0	0.0	None	0	0	0
9	DS_Plane10	Variable	0.0		5.3	5.8	502.65	497.35	0	0.0	Ordered	0.0000E0	0.0	None	0	0	0

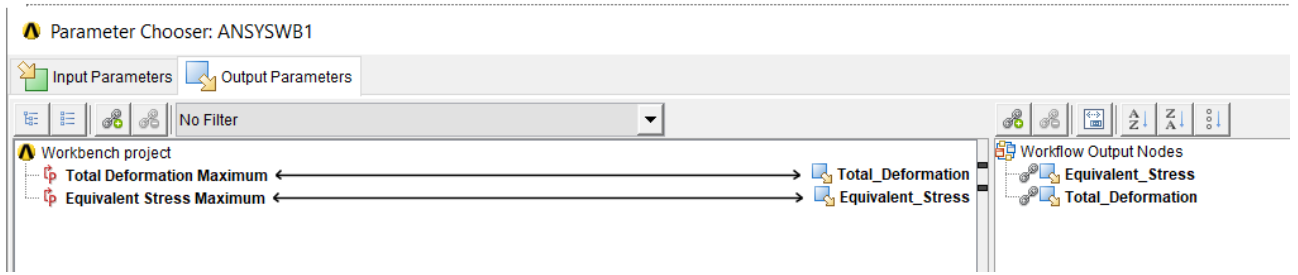
1.5m blade

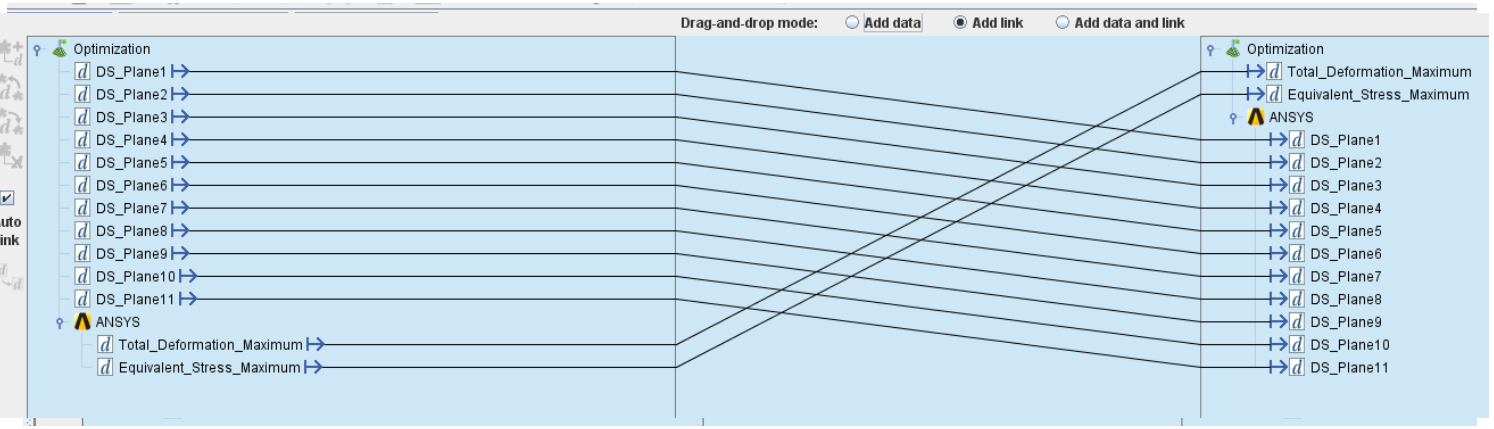
VisualDOC setup











Index	Source Model	Source Data	Dest. Model	Dest. Data	Status
1	Optimization	DS_Plane1	ANSYS	DS_Plane1	Ok
2	Optimization	DS_Plane2	ANSYS	DS_Plane2	Ok
3	Optimization	DS_Plane3	ANSYS	DS_Plane3	Ok
4	Optimization	DS_Plane4	ANSYS	DS_Plane4	Ok
5	Optimization	DS_Plane5	ANSYS	DS_Plane5	Ok
6	Optimization	DS_Plane6	ANSYS	DS_Plane6	Ok
7	Optimization	DS_Plane7	ANSYS	DS_Plane7	Ok
8	Optimization	DS_Plane8	ANSYS	DS_Plane8	Ok
9	Optimization	DS_Plane9	ANSYS	DS_Plane9	Ok
10	Optimization	DS_Plane10	ANSYS	DS_Plane10	Ok
11	Optimization	DS_Plane11	ANSYS	DS_Plane11	Ok
12	ANSYS	Total_Deformation_M...	Optimization	Total_Deformation_...	Ok
13	ANSYS	Equivalent_Stress_M...	Optimization	Equivalent_Stress_...	Ok

VisualDOC Results

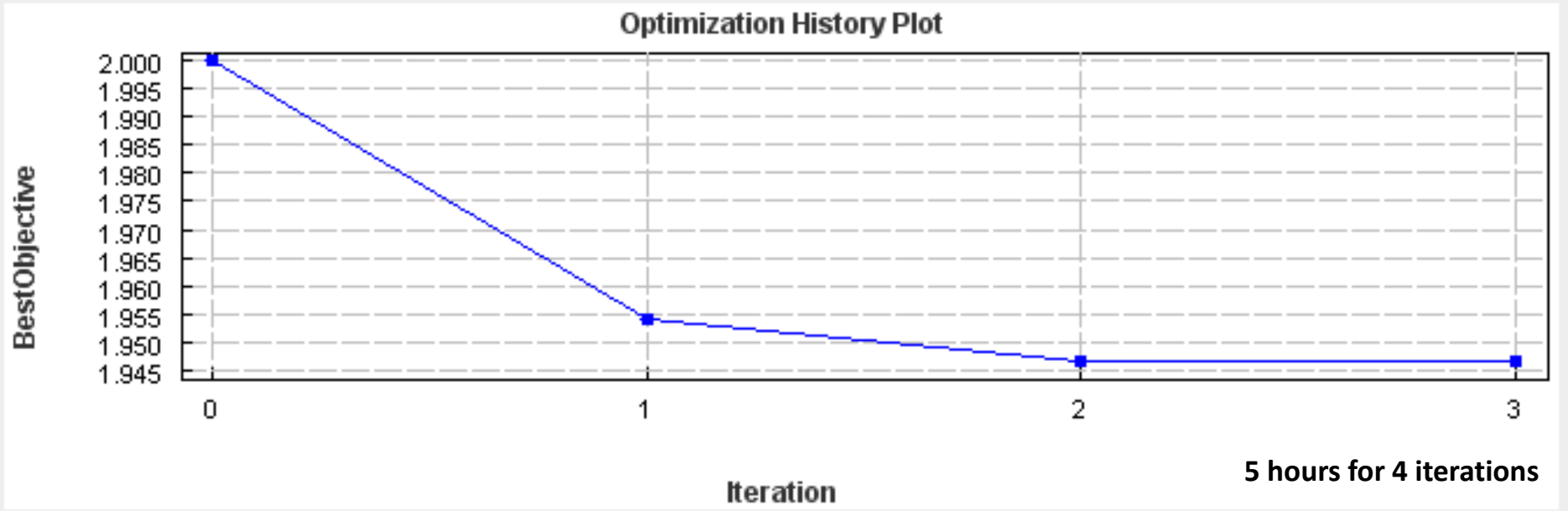
File Edit Run Tools Database Help

Work Flow | Component Editor | Data Linker | Simulation Monitors | Post Processing

- Flowchart Components
  - Start
  - Optimization
    - ANSYS
  - Stop

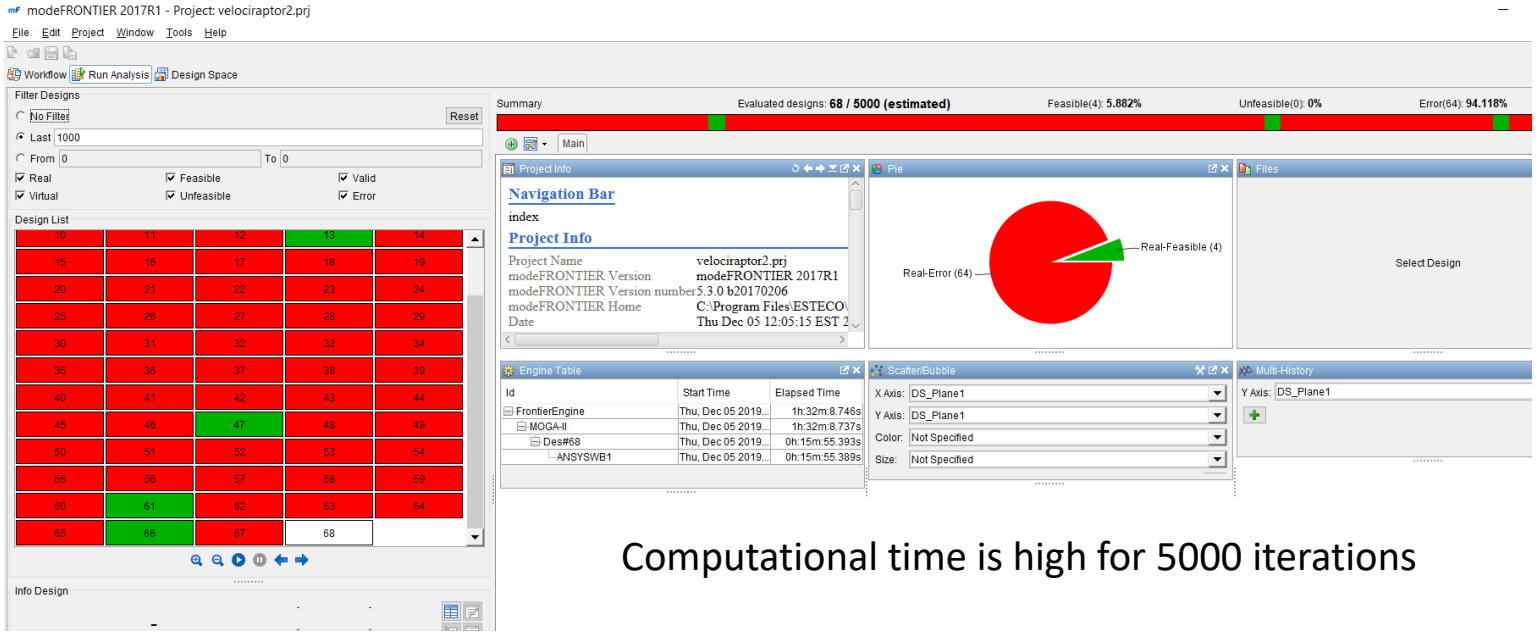
Basic | Attributes | Scaling | Objective

Name	ıe Type	Adv. Attribute	Variable	Objective	Constraint	Lower Bound	Initial Value	Current Value	Optimum
DS_Plane1		None	☑	☐	☐	0.0	0.15	0.14983004027	0.14983004027
DS_Plane2		None	☑	☐	☐	0.0	0.3	0.299999771471	0.299999771471
DS_Plane3		None	☑	☐	☐	0.0	0.45	0.44950416822	0.449725220511
DS_Plane4		None	☑	☐	☐	0.0	0.6	0.6	0.6
DS_Plane5		None	☑	☐	☐	0.0	0.75	0.74996869352	0.74996869352
DS_Plane6		None	☑	☐	☐	0.0	0.9	0.9	0.9
DS_Plane7		None	☑	☐	☐	0.0	1.05	1.05	1.05
DS_Plane8		None	☑	☐	☐	0.0	1.2	1.2	1.2
DS_Plane9		None	☑	☐	☐	0.0	1.35	1.35	1.35
DS_Plane10		None	☑	☐	☐	0.0	1.5	1.499678480654	1.499678480654
DS_Plane11		None	☑	☐	☐	0.0	0.2	0.200053338343	0.200253391682
Total_Deformation_Maximum		None	☐	☑	☐		0.001484728989	0.001482235051	0.001482582493
Equivalent_Stress_Maximum		None	☐	☑	☐		1.01715521E7	9.72184758E6	9.64579998E6

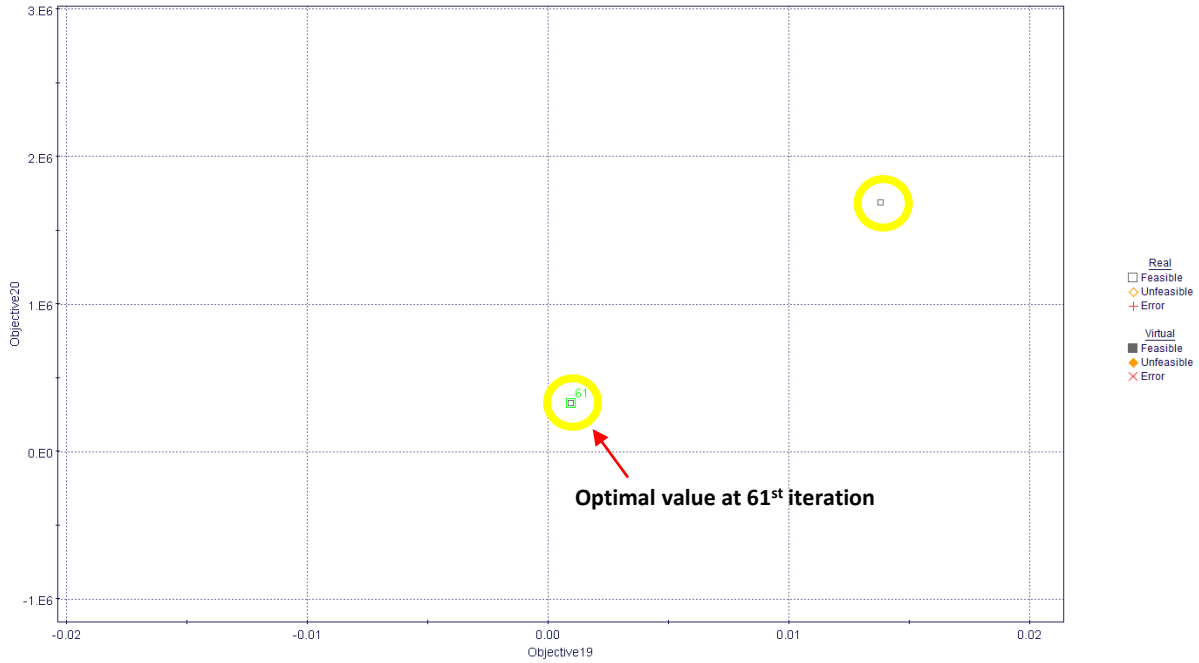


5 hours for 4 iterations

ModeFrontier Results

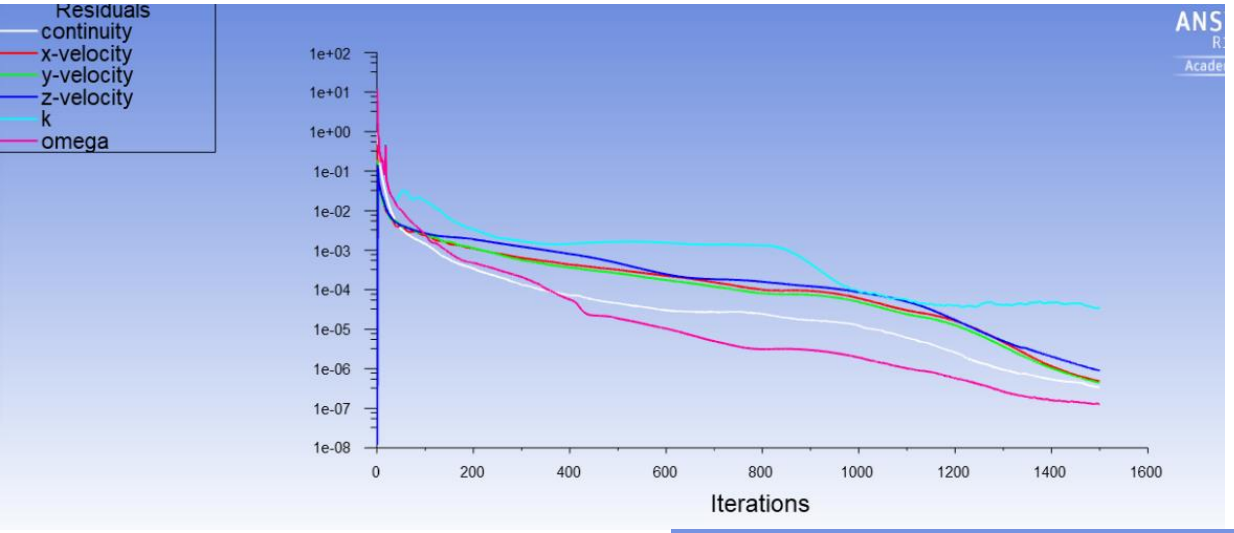


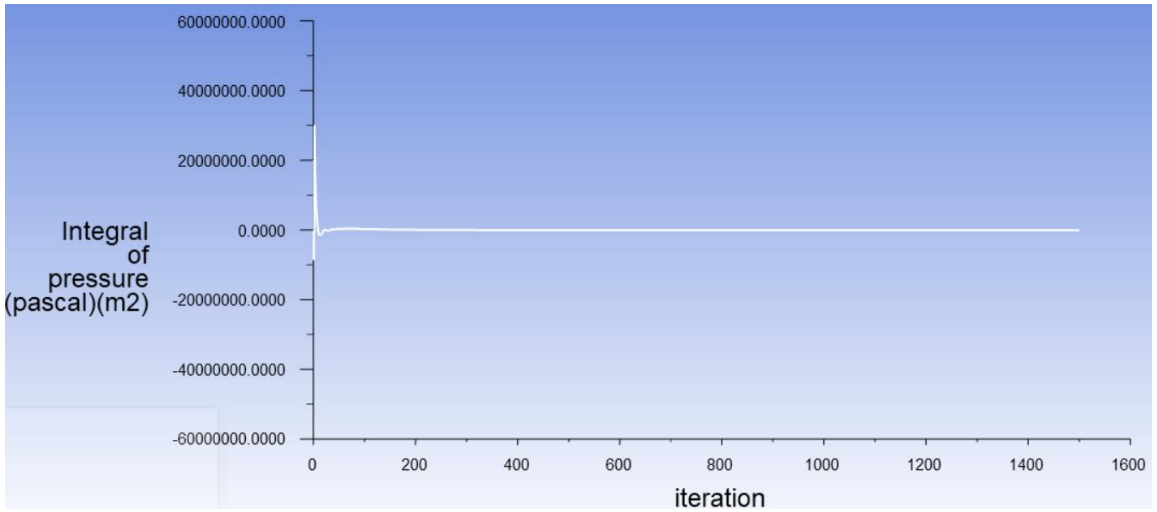
Computational time is high for 5000 iterations

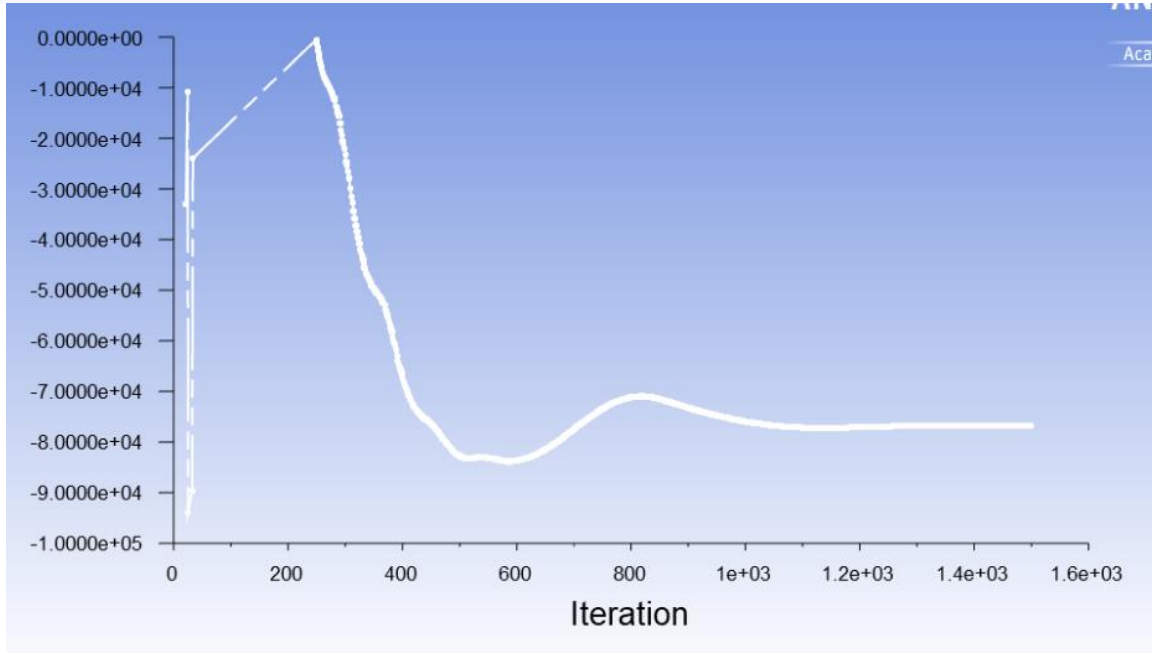


Design variable/Objective	Initial value	Optimal value
Plane 1	0.84	0.84959
Plane 2	1.375	1.3589
Plane 3	1.925	1.9324
Plane 4	2.47	2.1061
Plane 5	3.025	3.0461
Plane 6	3.575	3.5736
Plane 7	4.125	4.1831
Plane 8	4.675	4.5869
Plane 9	5.225	5.0911
Plane 10	5.5	7.8265
Equivalent stress	3.842E+05	3.3E+05
Total Deformation	19.907E-4	9.317E-4

Analysis results for 43m blade for initial values

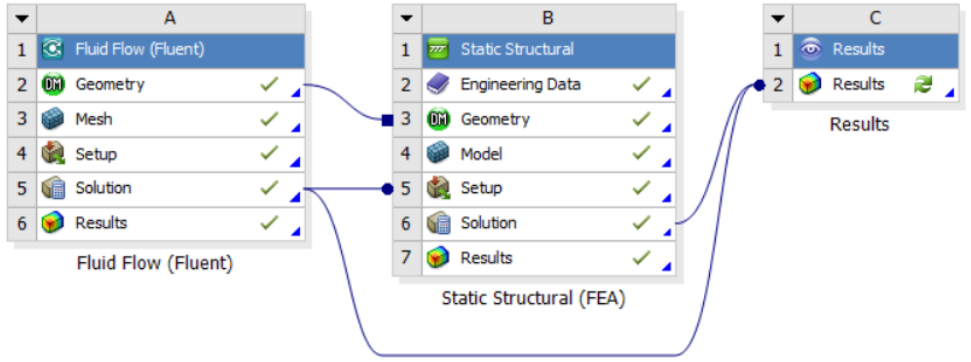


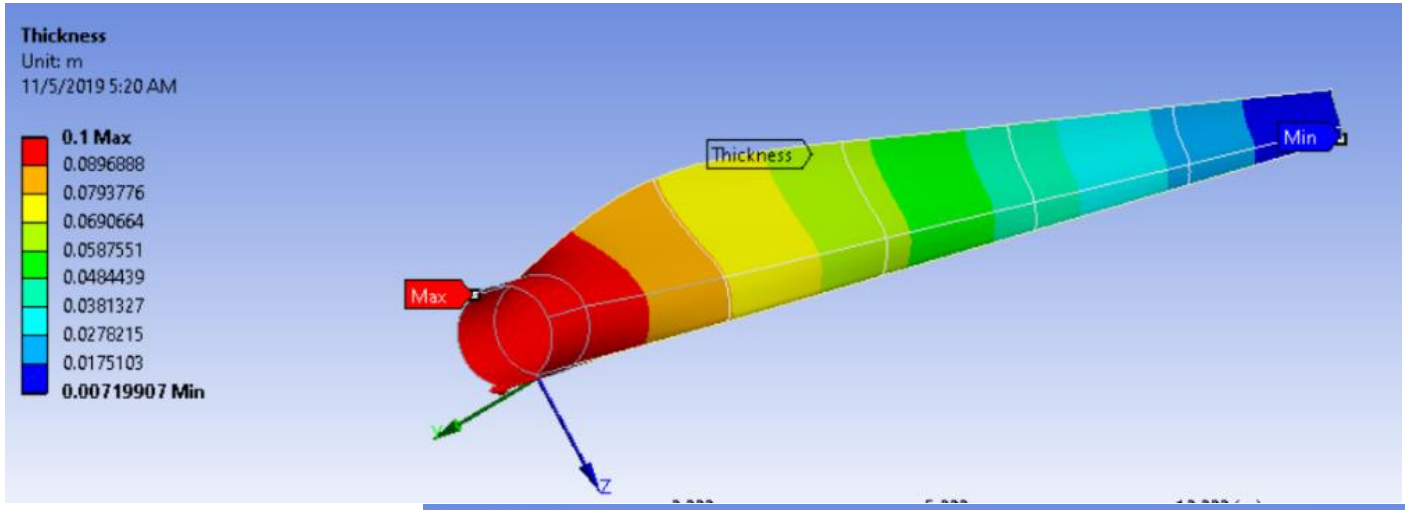


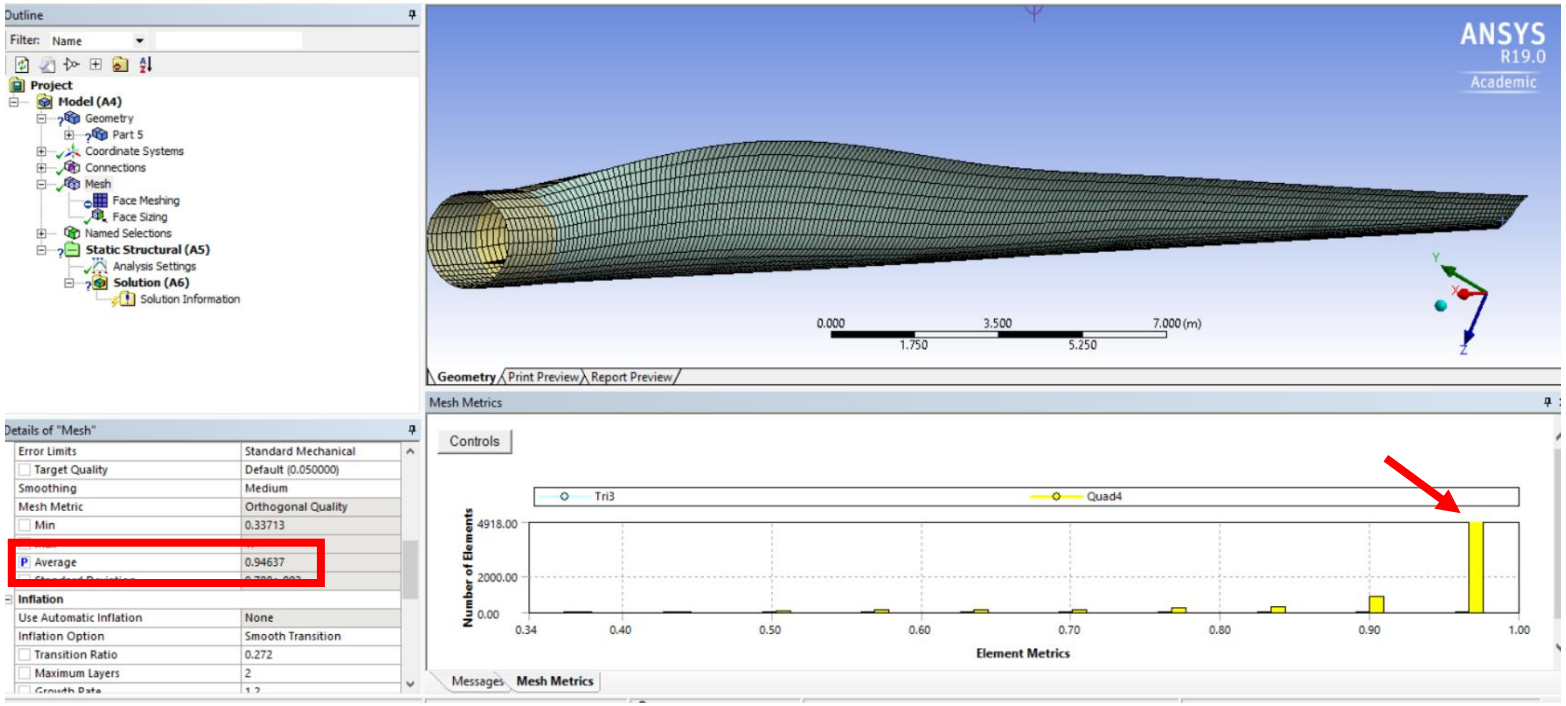


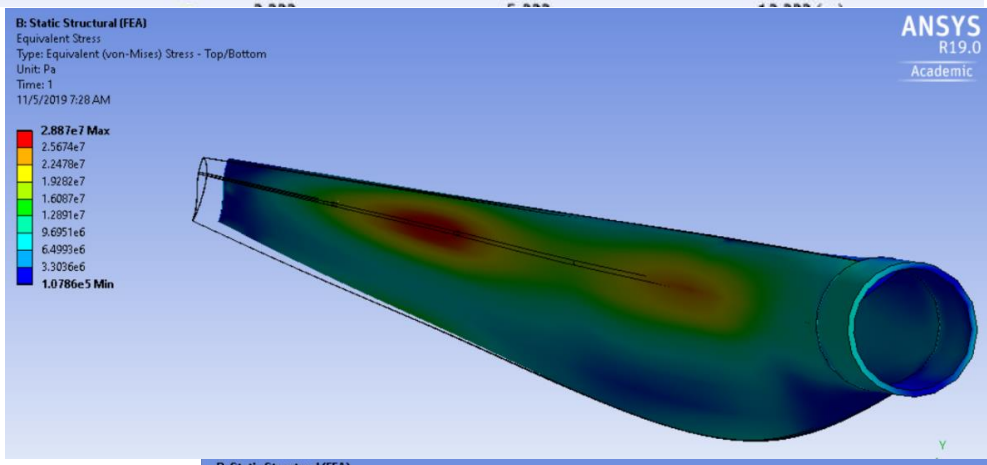
The above graphs shows residual continuity, pressure variation and convergence

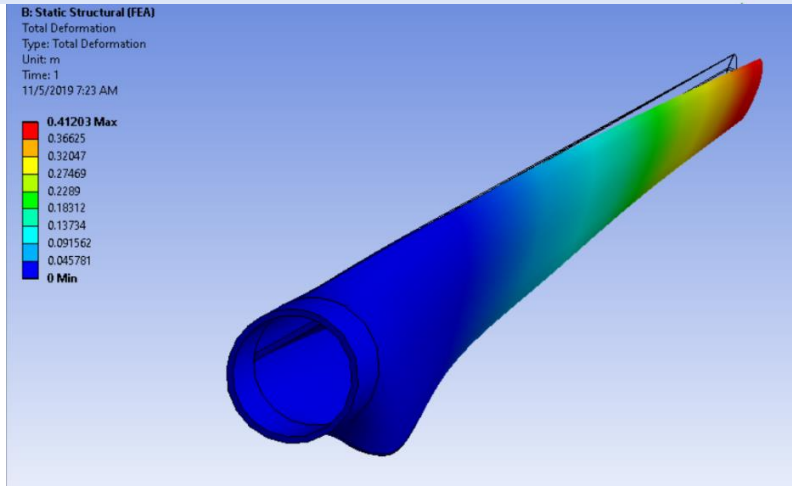
Analysis



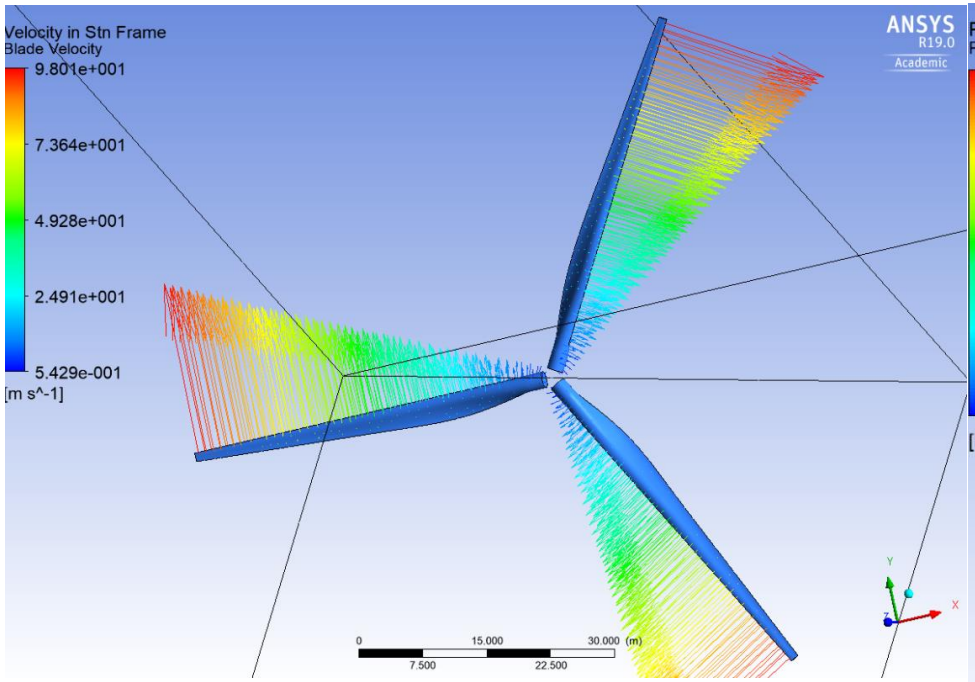


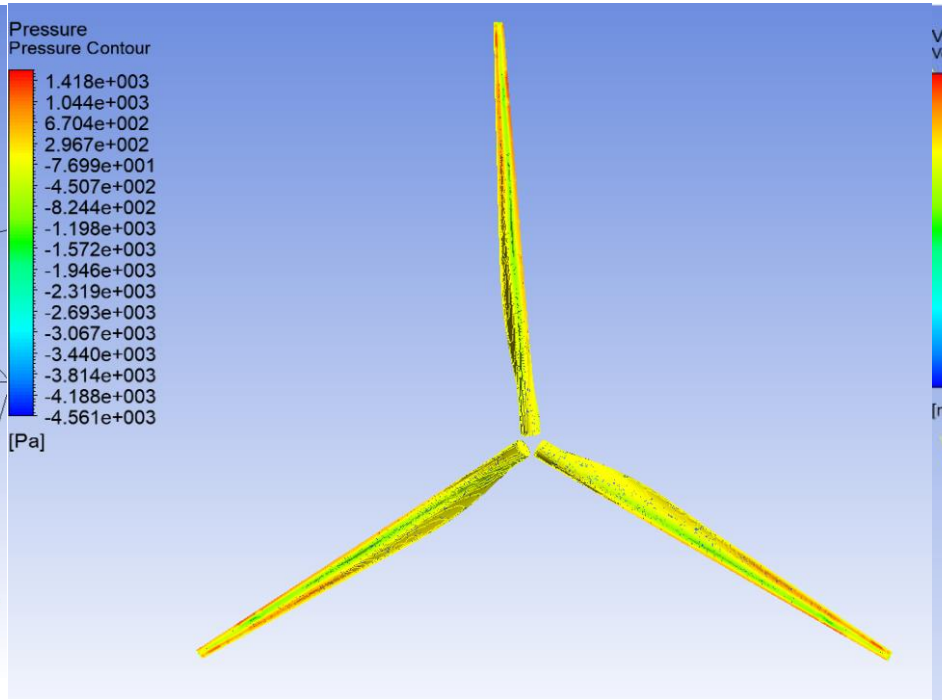


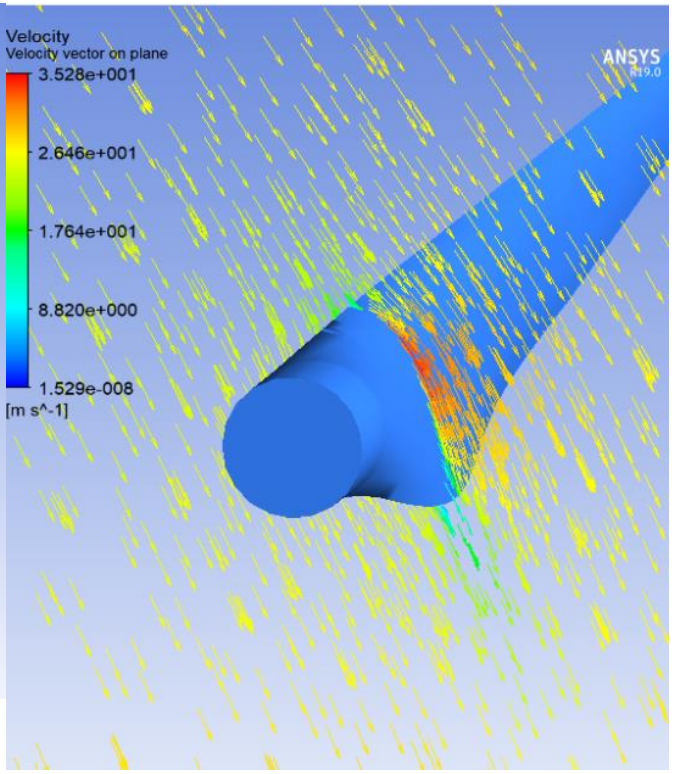


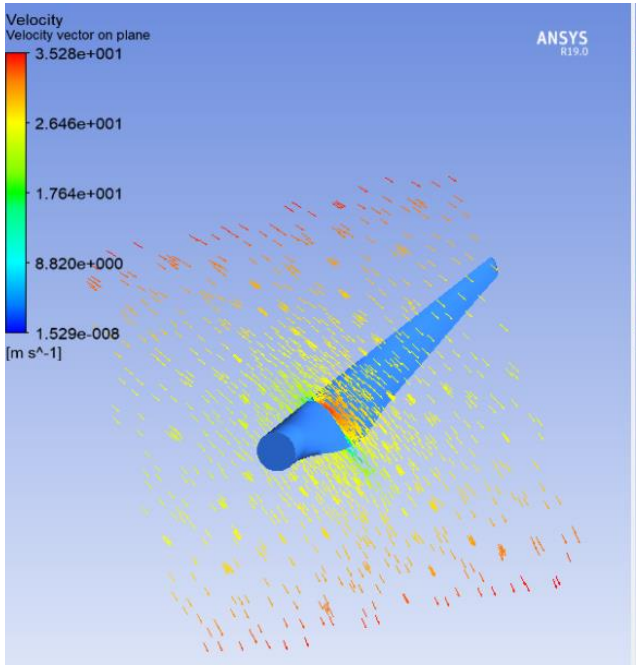


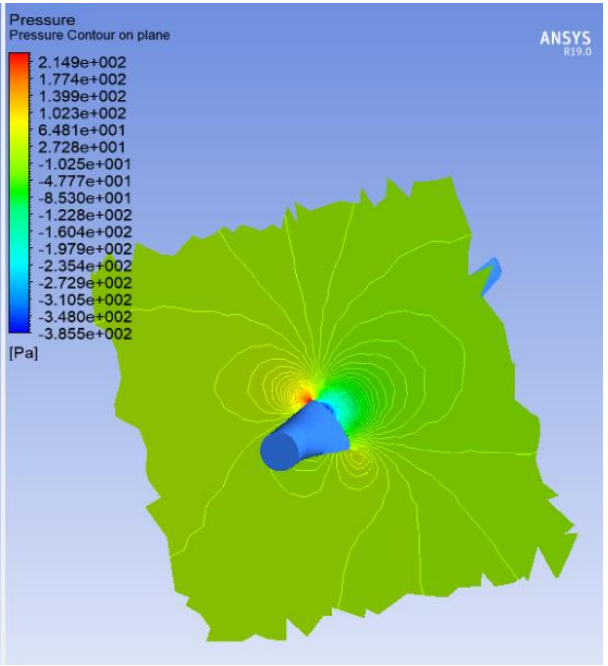
The orthogonal quality mesh average size is 0.946 which is close the max value of 1 for a good mesh of the component











Net mass flow rate is almost constant

	Mass Flow Rate (kg/s)
inlet	220323.86
outlet	-884683.37
top	664359.5
Net	-0.015206419

Torque on blade

-120801 [N m]

Negative torque because the flow was considered In negative Z direction

Moments - Moment Center (0 0 0)

Zone	Moments (n-m) Pressure	Viscous
blade	(-4319.4624 -2564015.7 -138373.76)	(209.15024 -2596.2325 17572.67)
Net	(-4319.4624 -2564015.7 -138373.76)	(209.15024 -2596.2325 17572.67)

Moments - Moment Center (0 0 0) Moment Axis (0 0 1)

Zone	Moments (n-m) Pressure	Viscous	Total	Coefficients Pressure	Viscous	Total
blade	-138373.76	17572.67	-120801.09	-225916.35	28690.074	-197226.27
Net	-138373.76	17572.67	-120801.09	-225916.35	28690.074	-197226.27

Conclusion:

43m blade:

- The max stress concentration is 2.887E+07 under the influence of fluid pressure and assumed wind velocity of 12m/s
- Better optimized result but may not be feasible as profile is complicated

5m blade:

- Optimum value is close to the initial value
- Better result than ModeFrontier but more computational time
- Cannot compare between the MF and VisualDOC results as the design variables considered were different depending on CFD or FEA performed

Learning: Introduction to different optimization techniques and the usage of optimization software

Thank you