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Shape Optimization of a Wind Turbine Airfoil by Using Genetic Algorithm

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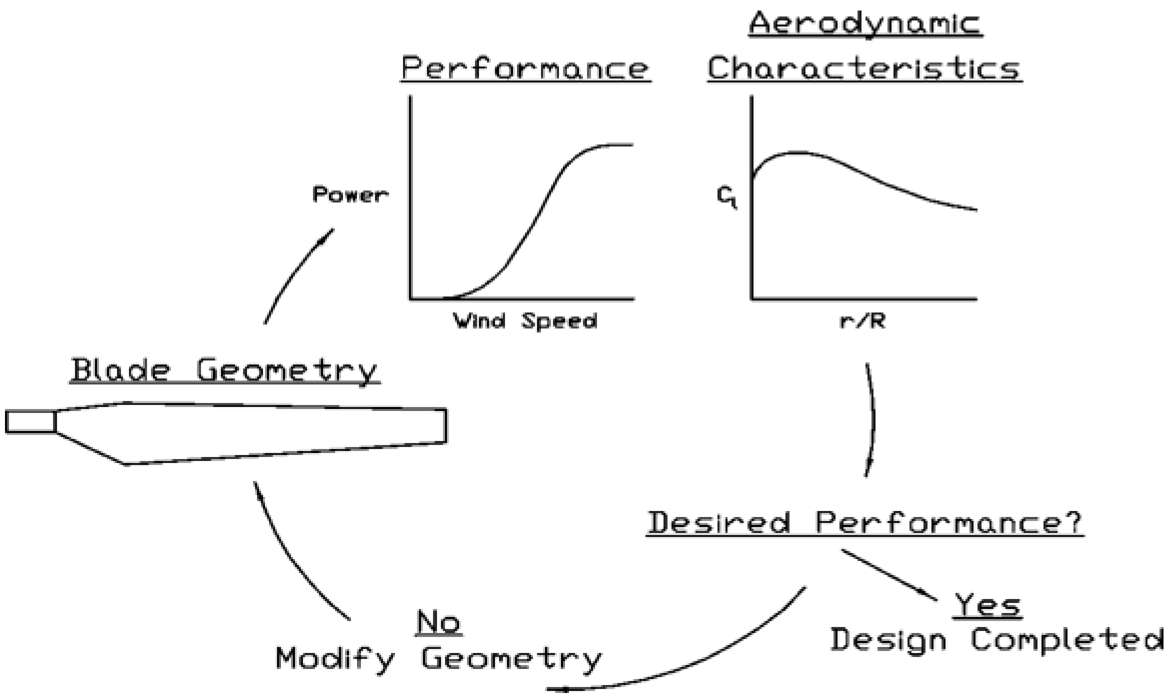
Anadolu University, Faculty of Aeronautics and Astronautics, Eskisehir, Turkey

Presentation Layout:

- Introduction: Airfoil Design
- PARSEC Airfoil Parameterization Method
- Optimization Algorithm: Genetic Algorithm
- Flow Analysis Program: XFOIL
- Results
- References

Direct Airfoil Design-Inverse Airfoil Design



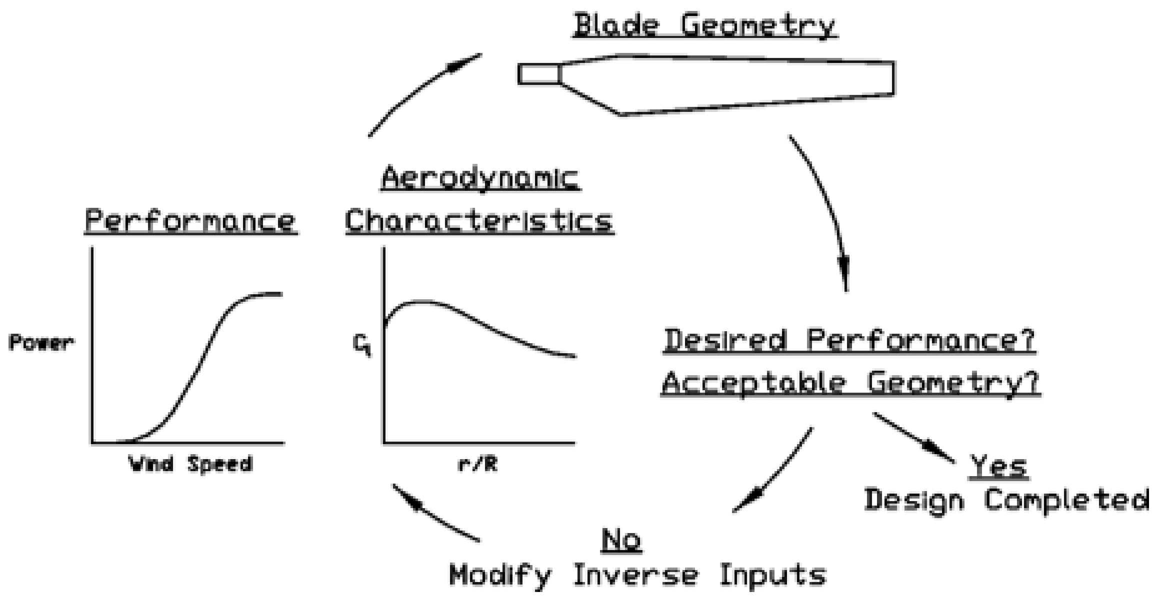


Figure 1: Direct and Inverse Airfoil Design Process

PARSEC Airfoil Parameterization Method

PARSEC Parameter Name	Range for NACA 4415	
	Lower Boundary	Upper Boundary
P1-(Rle-up) Upper Leading Edge Radius	0.028	0.032
P0-(Rle-lo) Lower Leading Edge Radius	0.012	0.018
P2-(Xup) Position of Upper Crest Point	0.31	0.37
P3-(Yup) Upper Crest Point	0.09	0.13
P4-(YXXup) Upper Crest Curvature	-0.85	-0.89
P5-(Xlo) Position of Lower Crest Point	0.15	0.19
P6-(Ylo) Lower Crest Point	-0.02	-0.06
P7-(YXXalt) Lower Crest Curvature	0.60	0.75
P11-(aTE) Trailing Edge Direction Angle	-8.2	-8.8
P12-(βTE) Trailing Edge Wedge Angle	27.4	27.6
P8-Trailing Edge Offset (Toff) and P9-Trailing Edge Thickness (TTE) are zero.		

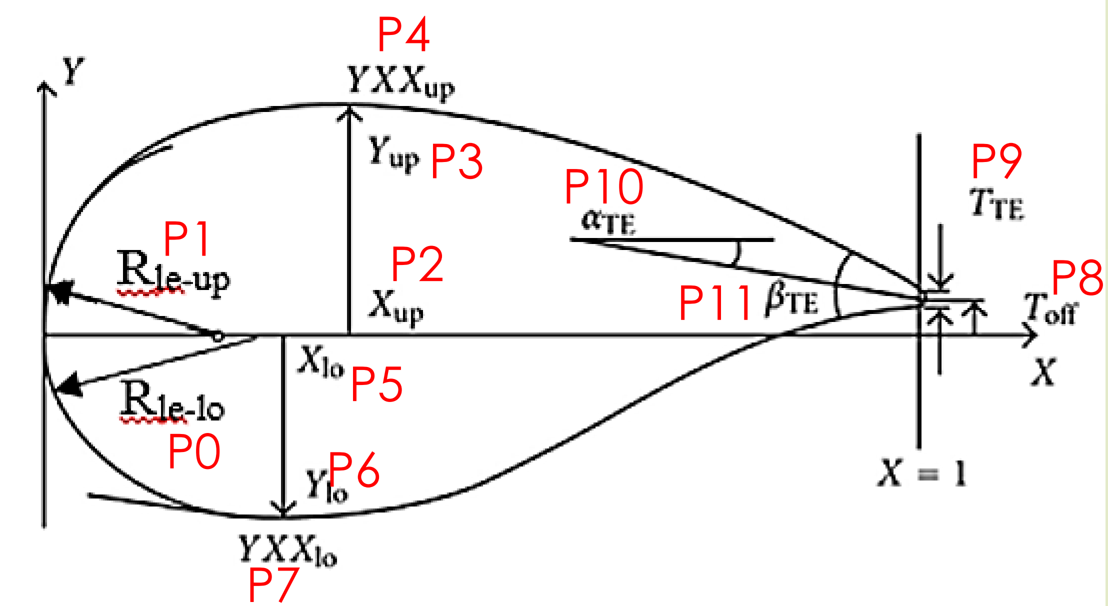


Figure 2: PARSEC parameters [5].

PARSEC Airfoil Parameterization Method

$$Y_{up} = a_{up}X^{1/2} + a_{up}X^{3/2} + a_{up}X^{5/2} + a_{up}X^{7/2} + a_{up}X^{9/2} + a_{up}X^{11/2} \quad [1]$$

$$Y_{lo} = a_{lo}X^{1/2} + a_{lo}X^{3/2} + a_{lo}X^{5/2} + a_{lo}X^{7/2} + a_{lo}X^{9/2} + a_{lo}X^{11/2} \quad [2]$$

$$C_{up} = \begin{vmatrix} 1 & 1 & 1 & 1 & 1 & 1 \\ p_2^{\frac{1}{2}} & p_2^{\frac{3}{2}} & p_2^{\frac{5}{2}} & p_2^{\frac{7}{2}} & p_2^{\frac{9}{2}} & p_2^{\frac{11}{2}} \\ \frac{1}{2} & \frac{3}{2} & \frac{5}{2} & \frac{7}{2} & \frac{9}{2} & \frac{11}{2} \\ \frac{1}{2}p_2^{-\frac{1}{2}} & \frac{3}{2}p_2^{\frac{1}{2}} & \frac{5}{2}p_2^{\frac{3}{2}} & \frac{7}{2}p_2^{\frac{5}{2}} & \frac{9}{2}p_2^{\frac{7}{2}} & \frac{11}{2}p_2^{\frac{9}{2}} \\ -\frac{1}{4}p_2^{-\frac{3}{2}} & \frac{3}{4}p_2^{-\frac{1}{2}} & \frac{15}{4}p_2^{\frac{1}{2}} & \frac{15}{4}p_2^{\frac{1}{2}} & \frac{63}{4}p_2^{\frac{5}{2}} & \frac{99}{4}p_2^{\frac{7}{2}} \\ 1 & 0 & 0 & 0 & 0 & 0 \end{vmatrix}$$

$$b_{up} = \begin{vmatrix} p_8 + p_9/2 \\ p_3 \\ \tan(p_{10} - p_{11}/2) \\ 0 \\ \frac{p_4}{\sqrt{2p_1}} \end{vmatrix}, \qquad b_{lo} = \begin{vmatrix} p_8 - p_9/2 \\ p_6 \\ \tan(p_{10} + p_{11}/2) \\ 0 \\ \frac{p_4}{\sqrt{2p_1}} \end{vmatrix}$$

$$C_{up} \times a_{up} = b_{up}, \qquad C_{lo} \times a_{lo} = b_{lo}$$

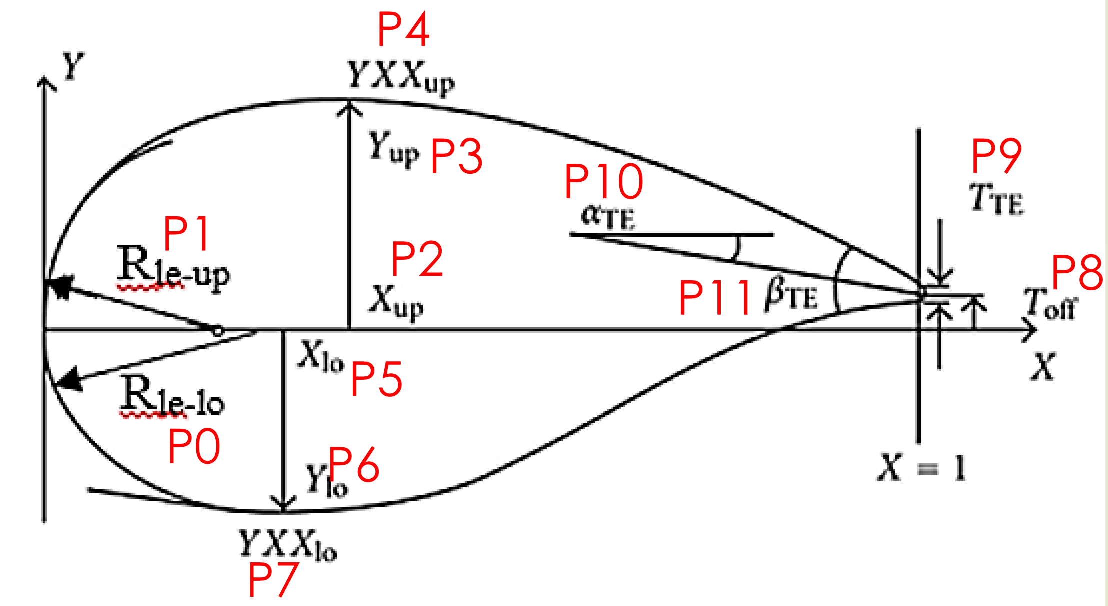
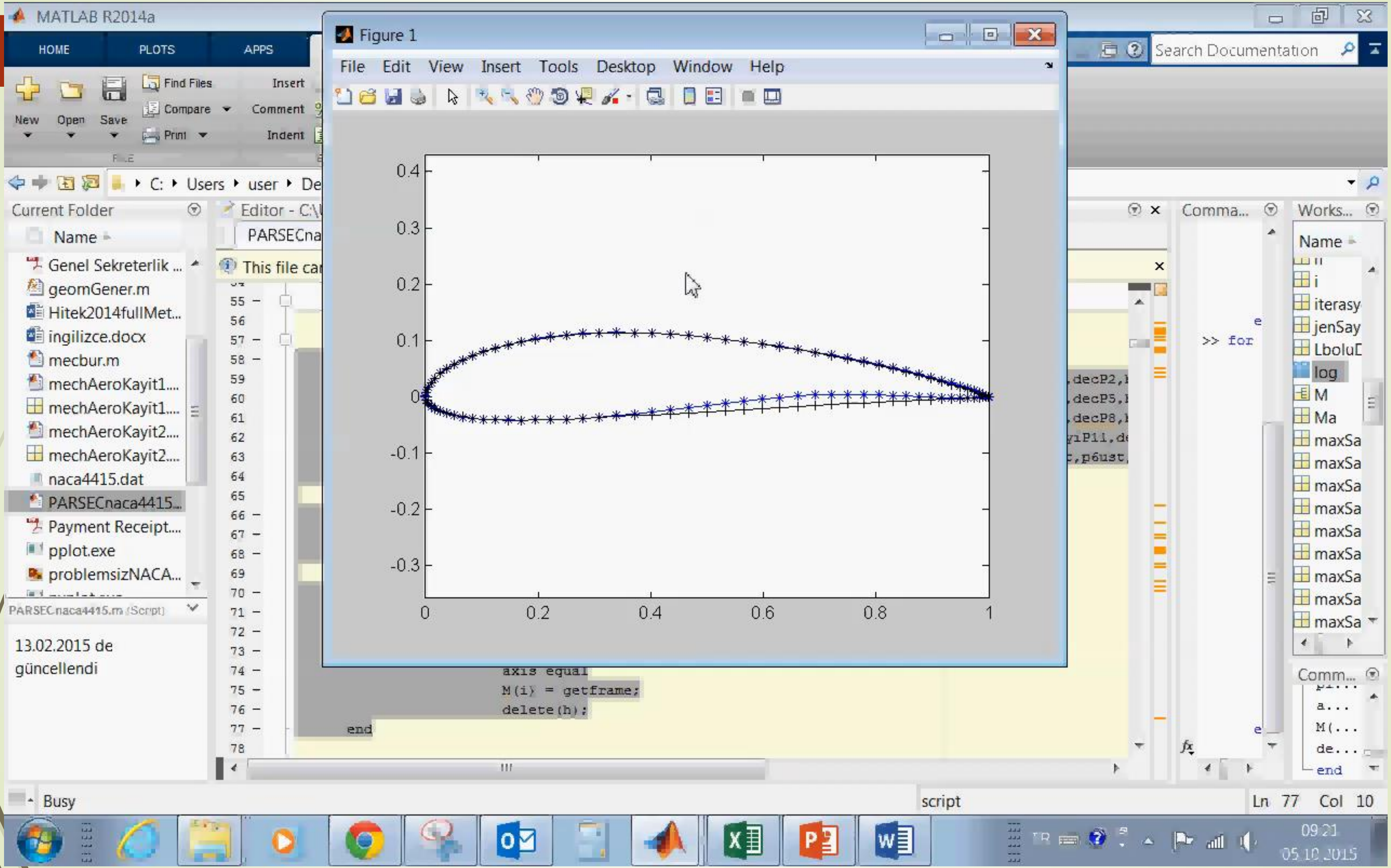


Figure 2: PARSEC parameters [5].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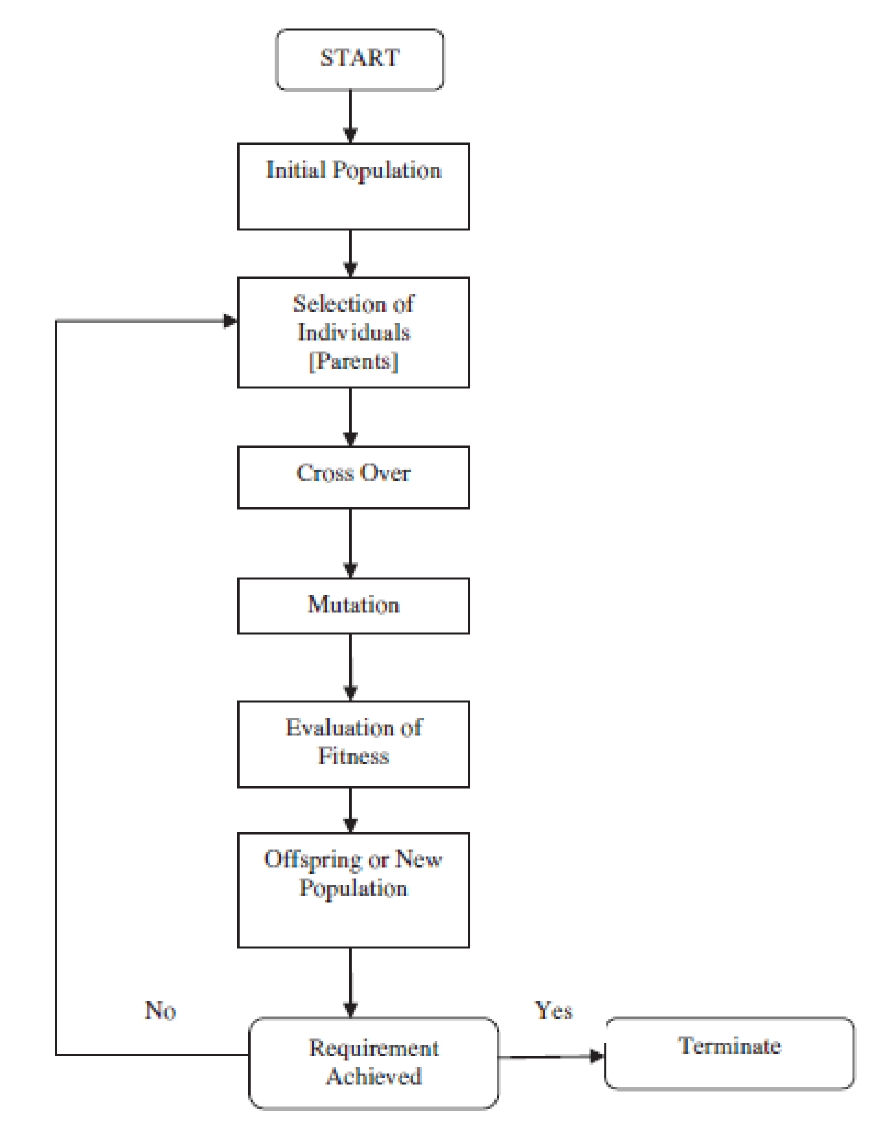
Optimization Algorithm: Genetic Algorithm



- Fitness function: cl/cd
- Pc: 0.45
- Pm: 0.05
- Selection Method: Tournament Selection
- Coding Method: Binary

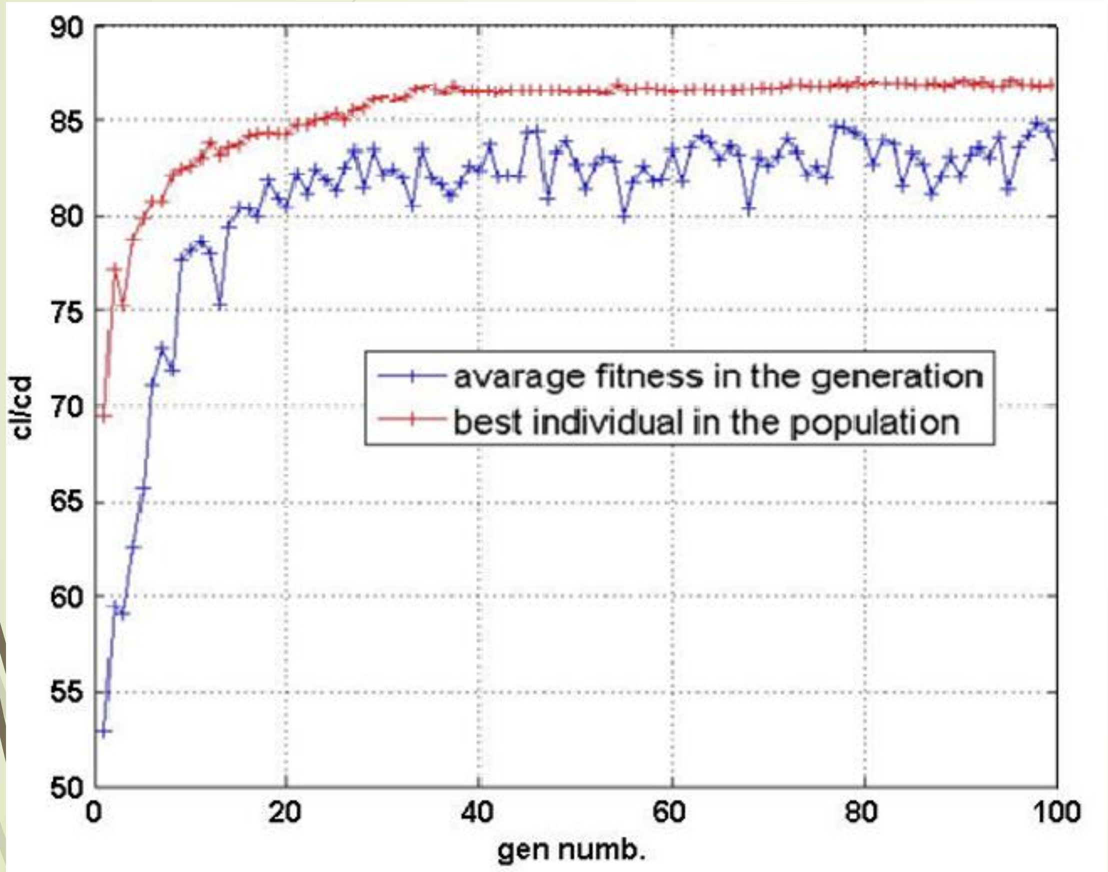
Flow Analysis Program: XFOIL

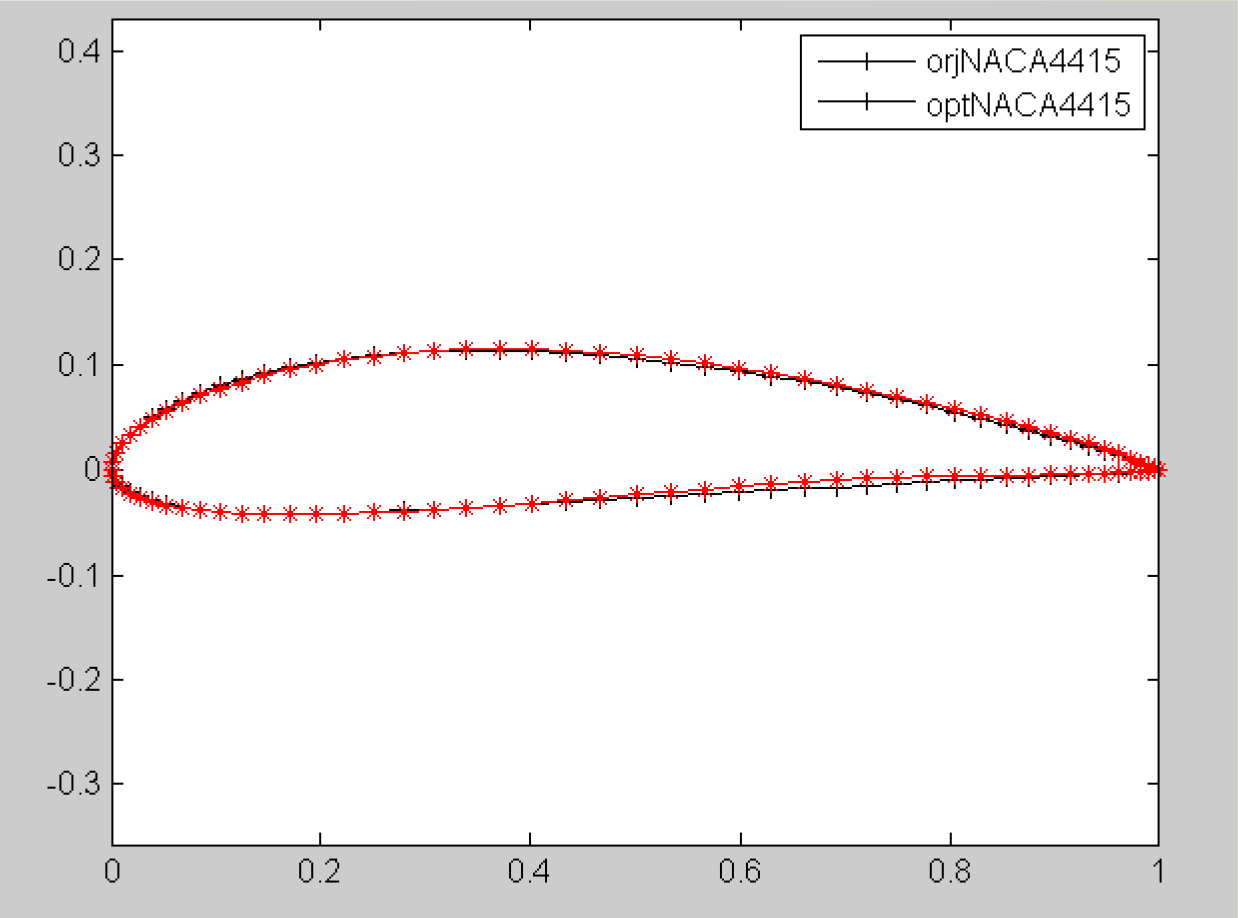
- Re: 350000
- AoA Interval: 2°-5°
- Mach Number: 0.03
- Flow: Inviscid, irrotational, incomppressible
- Flow Solution Method: Panel Method

Results (2-5 AoA Range)

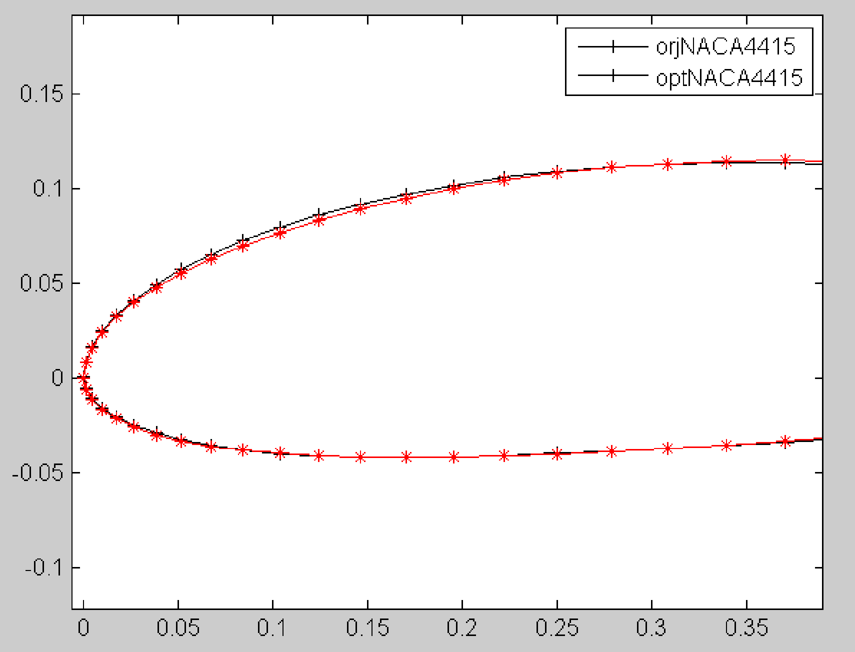
AoA	cLopt	cLorg	cL_inc(%)	cDopt	cDorg	cD_inc(%)	cL/cDopt	cL/cDorg	cL/cD_inc (%)
2	0,789	0,768	2,72	0,00974	0,00969	0,52	80,97536	79,23633	2,19
2,5	0,839	0,808	3,80	0,01002	0,01	0,20	83,70259	80,8	3,59
3	0,884	0,845	4,58	0,01029	0,0102	0,88	85,91837	82,88235	3,66
3,5	0,927	0,887	4,56	0,01052	0,01052	0,00	88,10837	84,26806	4,56
4	0,971	0,927	4,67	0,01085	0,01081	0,37	89,46544	85,79093	4,28
4,5	1,010	0,968	4,37	0,01108	0,01118	-0,89	91,13718	86,53846	5,31
5	1,052	1,006	4,58	0,01142	0,01148	-0,52	92,15412	87,65679	5,13
mean	**0,924**	**0,887**	**4,226**	**0,01056**	**0,010554**	**0,05**	**87,35**	**83,88**	**4,14**

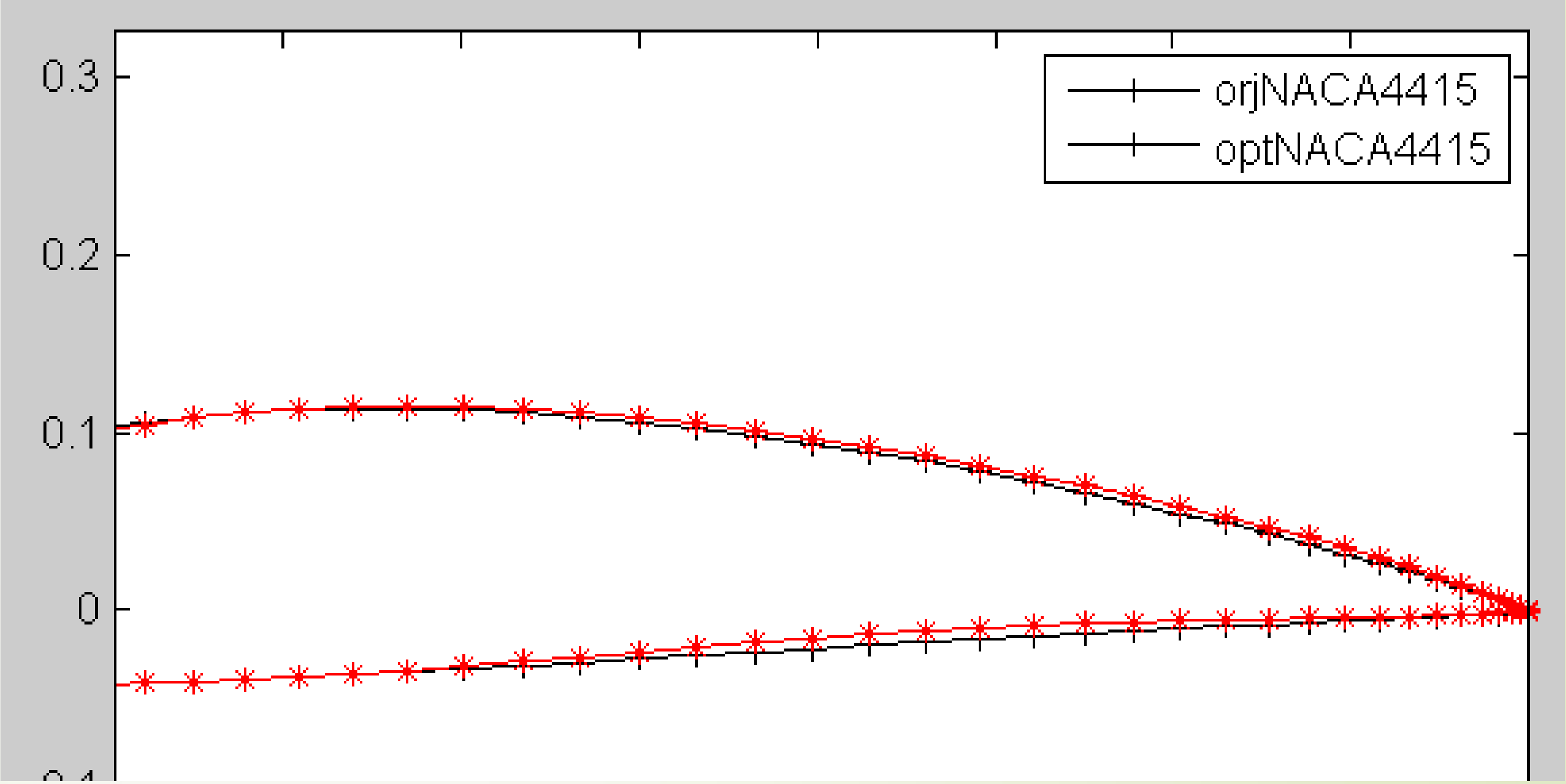
Results (2-5 AoA Range)





Results (2-5 AoA Range)





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- Thanks for your attention...