사각 단면 프로펠러의 형상 결정

OP. Course

2004006776 김 봉 태
2004006765 김 민 환

1. Contents

- 중간발표 요약
- 기존 문제의 수정
- 받음각(θ)의 영향
- 초기값의 영향 검토
- 알고리즘별 결과 비교
- 결과 및 고찰

2. Problem statement

- 프로펠러 전, 후의 공기의 운동량 차이만큼 추력(Trust)이 요구된다.
- 추력은 동일한 조건(엔진출력, 고도, 비행 속도 등)에서 프로펠러의 형상에 의해 그 크기가 결정된다.
- 사각 단면을 고려하여 최소의 크기 (경제성)를 고려한 최적의 형상을 결정하는 것에 이 프로젝트 수행의 목적을 둔다.

2. Problem statement

- **Physical Equations.**

  - Lift force : $\frac{1}{2}C_L\rho_f\int_0^L(\omega r)^2 D\cdot dr\times N=\frac{1}{2}C_L\rho_f\omega^2 DL^3$

  - Drag force : $\frac{1}{2}C_D\rho_f\int_0^L(\omega r)^2 D\cdot dr\times N=\frac{1}{2}C_D\rho_f\omega^2 DL^3$

  - Thrust : $L.F\times\cos\theta-D.F\times\sin\theta=\frac{1}{2}\rho_f\omega^2 DL^3(C_L\cos\theta-C_D\sin\theta)$

  - Solidity : $\frac{N\times\int_A dA}{\pi L^2}=\frac{N\times DL}{\pi L^2}=\frac{ND}{\pi L}$

  - Resistance force : $\rho Q(V_{out}-V_{in})=2\rho Q(\frac{Q}{\pi L^2}-V_{in})$

  - Total length : $L_{\text{total}}=L+\frac{D/2}{\sin(\pi/N)}$

- **Parameters**

Density	1.225 kg/m^3	**Speed of Wind**	400 km/h
Volume Flow (Q)	500 m^3/s	**Ang. Velocity**	2000 rpm

3. Modified problem

- Thrust

$$T = \frac{1}{2}\rho_f \omega^2 D L^3 (C_L \cos\theta - C_D \sin\theta)$$

- Resistance Force

$$F = \rho Q(V_{out} - V_{in}) = 2\rho Q(\frac{Q}{\pi L^2} - V_{in})$$

- Solidity

$$\sigma = \frac{N \times \int_A dA}{\pi L^2} = \frac{ND}{\pi L}$$

Cost Function : Area (L*D)

Design Variable : L, D

θ의 영향은?

- Constraint 1

  - Thrust ≥ Resistance Force

- Constraint 2

  - Solidity ≥ 0.1

- Constraint 3

  - L+D/2*sin(π/N) ≤ 1.5

Cost Function : Area (L*D)

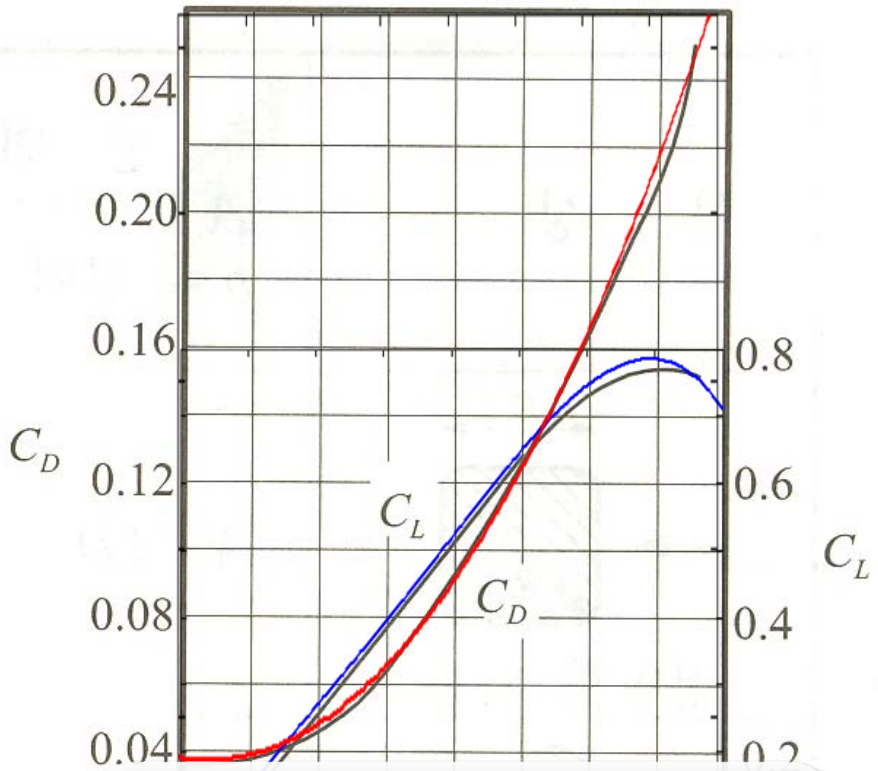
Design Variable : L, D, θ

4. Angle of Attack

- C_L, C_D의 결정
- 추력의 결정

$$T = \frac{1}{2}\rho_f \omega^2 D L^3 (C_L \cos\theta - C_D \sin\theta)$$

θ 변경



- Constraint 4

Lift Coeff.	$-3.79*10^{-5}\theta^4 + 8.96*10^{-4}\theta^3 - 0.0071\theta^2 + 0.0841\theta - 0.0035$
Drag Coeff.	$0.001\theta^2 - 0.0017\theta + 0.0375$

5. Excel solver

기존의 결과			
L (m)	D (m)	θ (deg)	Area (m^2)
1.180082	0.123578	12.841471	0.437496

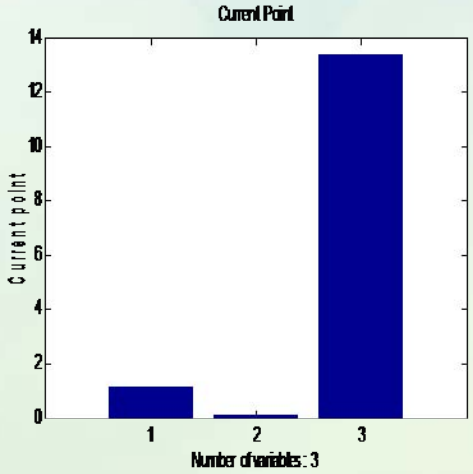
변수 θ 추가			
L (m)	D (m)	θ (deg)	Area (m^2)
1.180012	0.123571	13.364088	0.437444

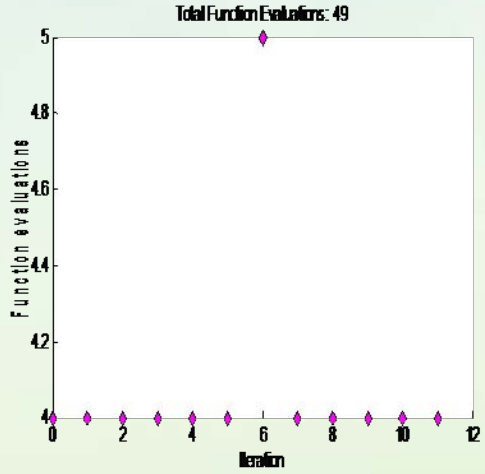
예상과 달리 적은 변화

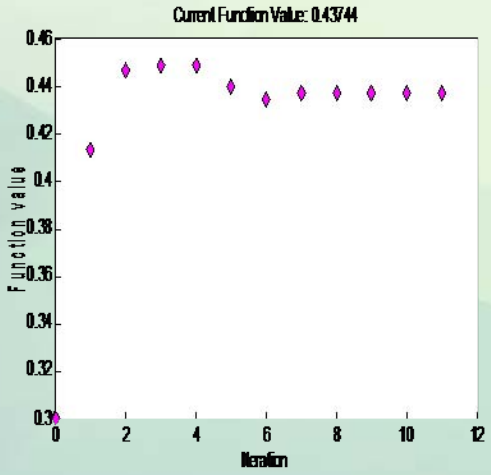
초기값의 영향은?

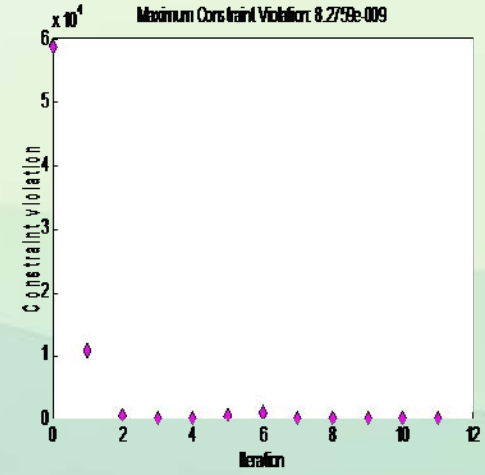
6. Change Initial Point

fmincon	
Infeasible (L, D, θ) = (1, 0.1, 1)	
x_optimum	L=1.1800 D=0.1236 θ=13.3641
F_value	0.4374
Exitflag	1
Lagrange Multiplier	2.96e-06 (Thrust) 4.26 (Solidity) 0 0 0 0 0





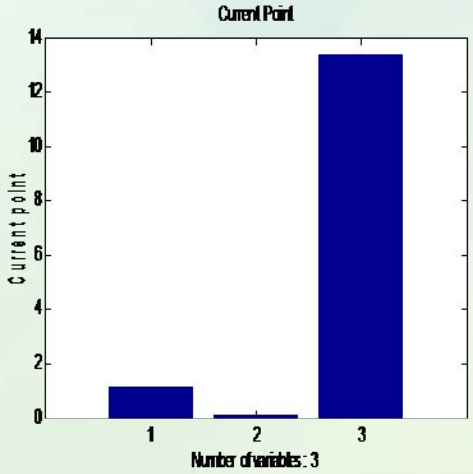


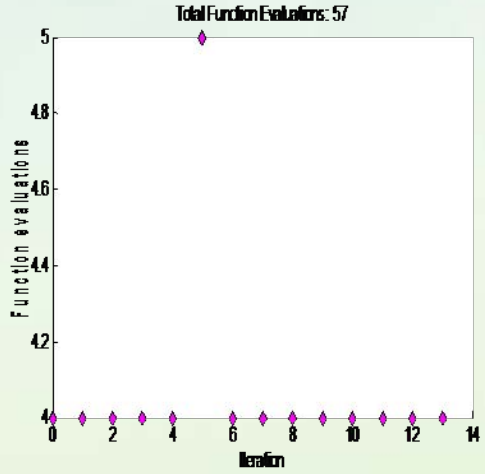


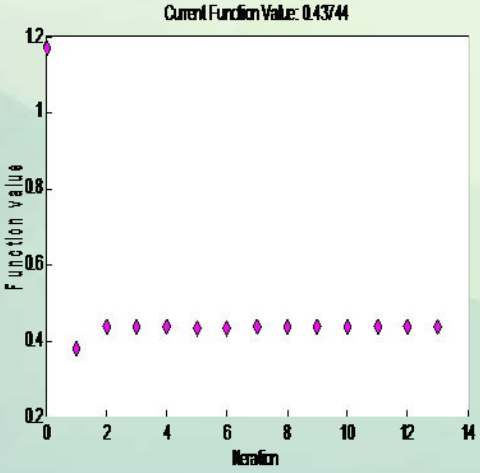
Stop Pause

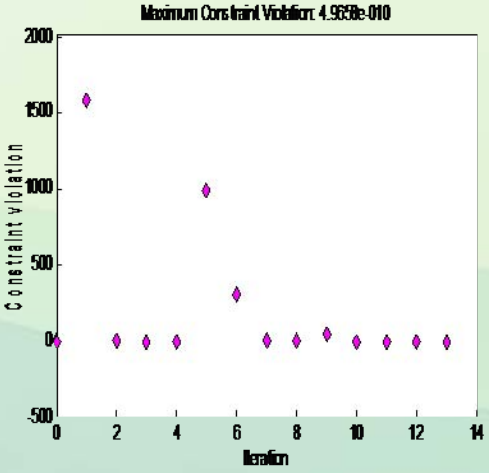
6. Change Initial Point

fmincon	
Feasible (L, D, θ) = (1.3, 0.3, 9)	
x_optimum	L=1.1800 D=0.1236 θ=13.3641
F_value	0.4374
Exitflag	1
Lagrange Multiplier	2.96e-06 (Thrust) 4.26 (Solidity) 0 0 0 0 0









Stop Pause

6. Change Initial Point

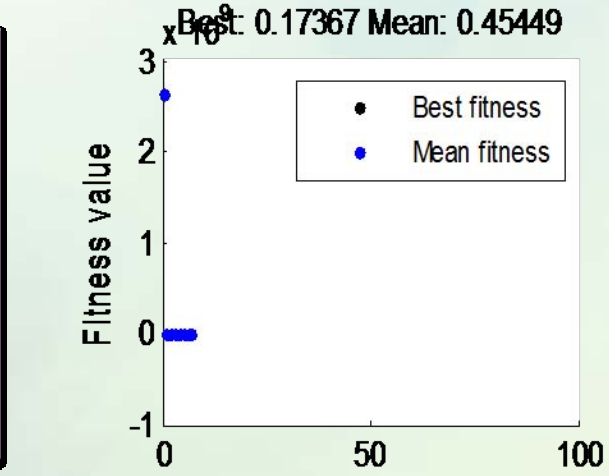
Excel Solver	
Infeasible (L, D, θ) = (1, 0.1, 1)	
L (m)	1.18001
D (m)	0.12357
θ (deg)	13.36409
Area (m^2)	0.43744
Feasible (L, D, θ) = (1.3, 0.3, 9)	
L (m)	1.18001
D (m)	0.12357
θ (deg)	13.36400
Area (m^2)	0.43744

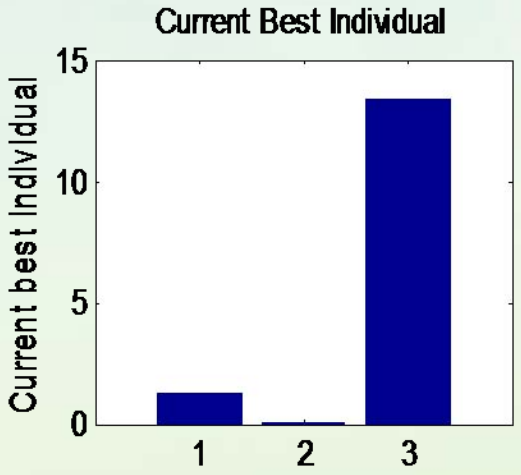
MATLAB fmincon	
Infeasible (L, D, θ) = (1, 0.1, 1)	
L (m)	1.18001
D (m)	0.12357
θ (deg)	13.36407
Area (m^2)	0.43744
Feasible (L, D, θ) = (1.3, 0.3, 9)	
L (m)	1.18001
D (m)	0.12357
θ (deg)	13.36407
Area (m^2)	0.43744

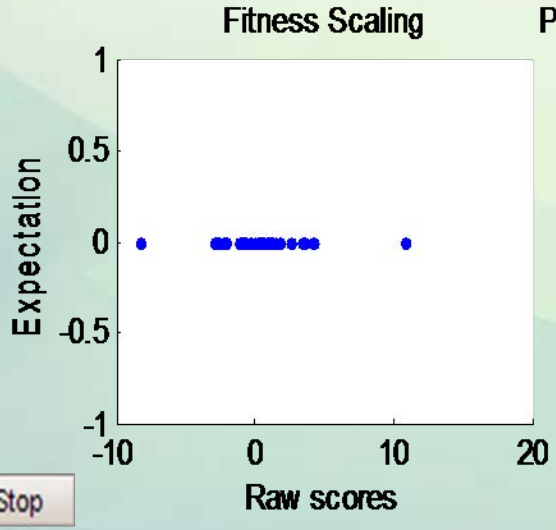
변수 θ의 변화에 따른 목적함수의 영향은 무시할 수 있을 정도

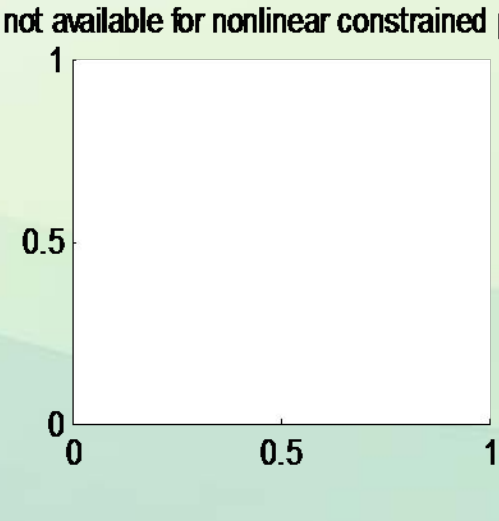
7. Comparing Algorithm

Genetic Algorithm	
x_optimum	L=1.1852 D=0.1255 θ=13.3644
F_value	0.4461
Exitflag	4



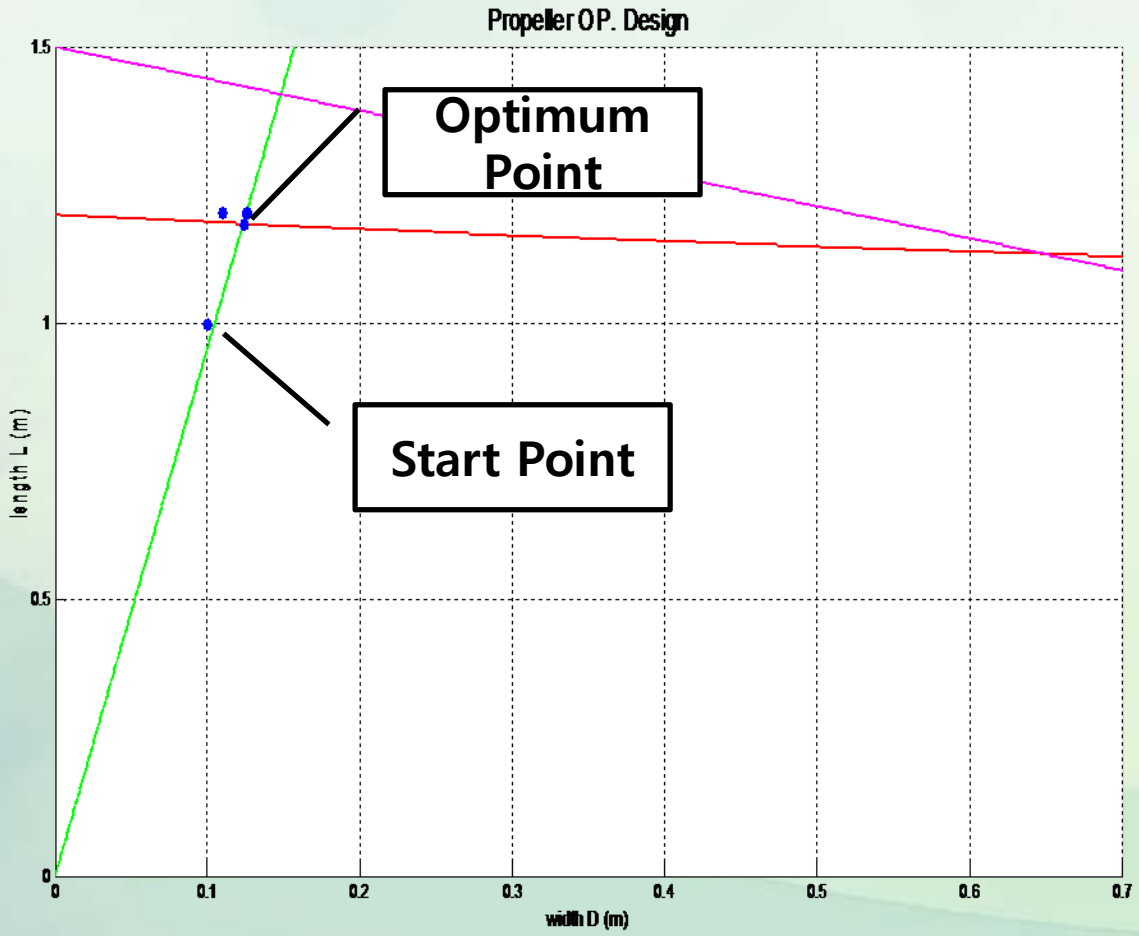






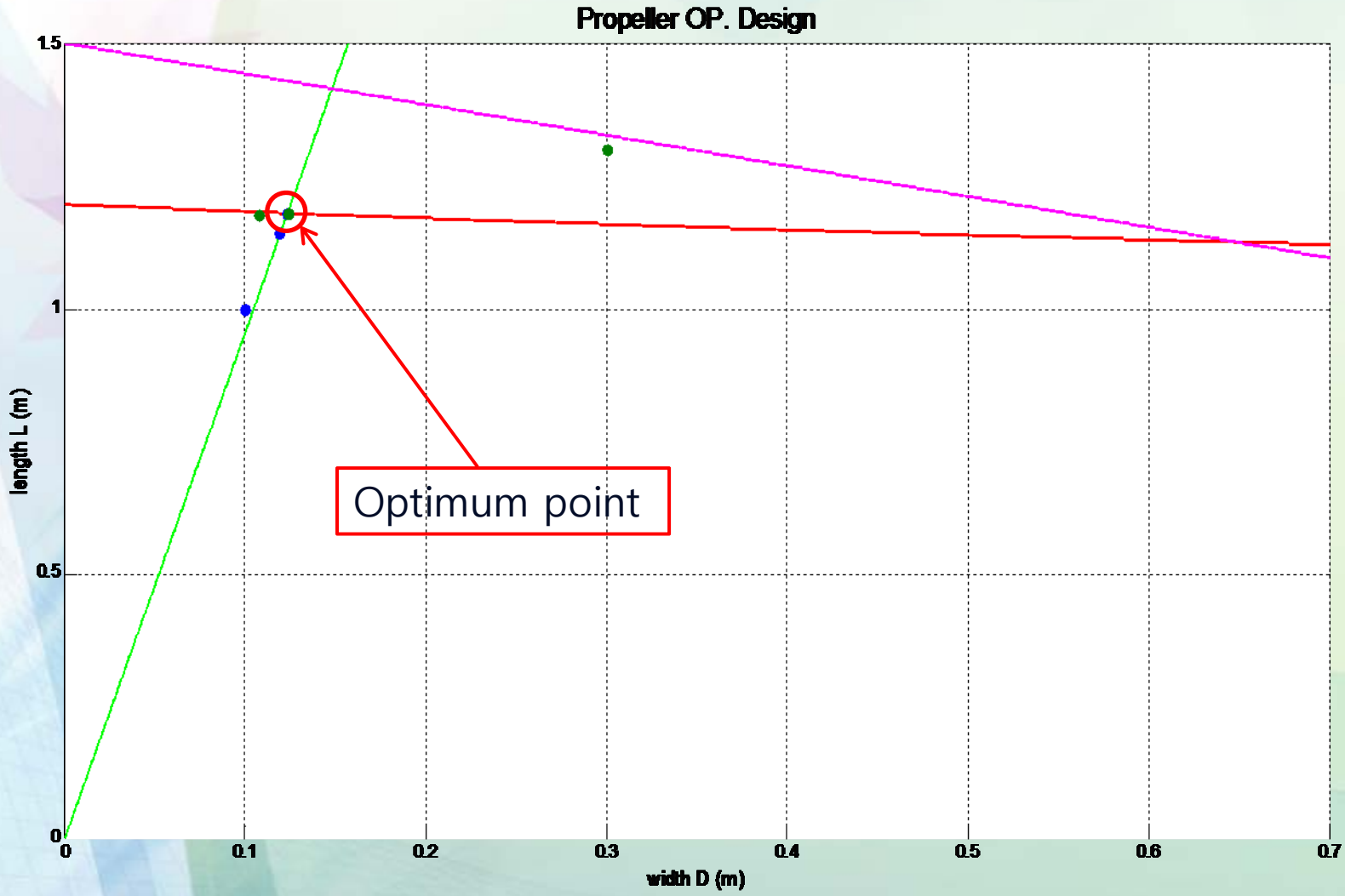
7. Comparing Algorithm

Excel Solver	
Infeasible (L, D) = (1, 0.1)	
x_optimum	L=1.1800 D=0.1236 θ=13.3641
F_value	0.4374
Lagrange Multiplier	2.96E-06 (Thrust) 4.26 (Solidity) 0 0 0 0 0

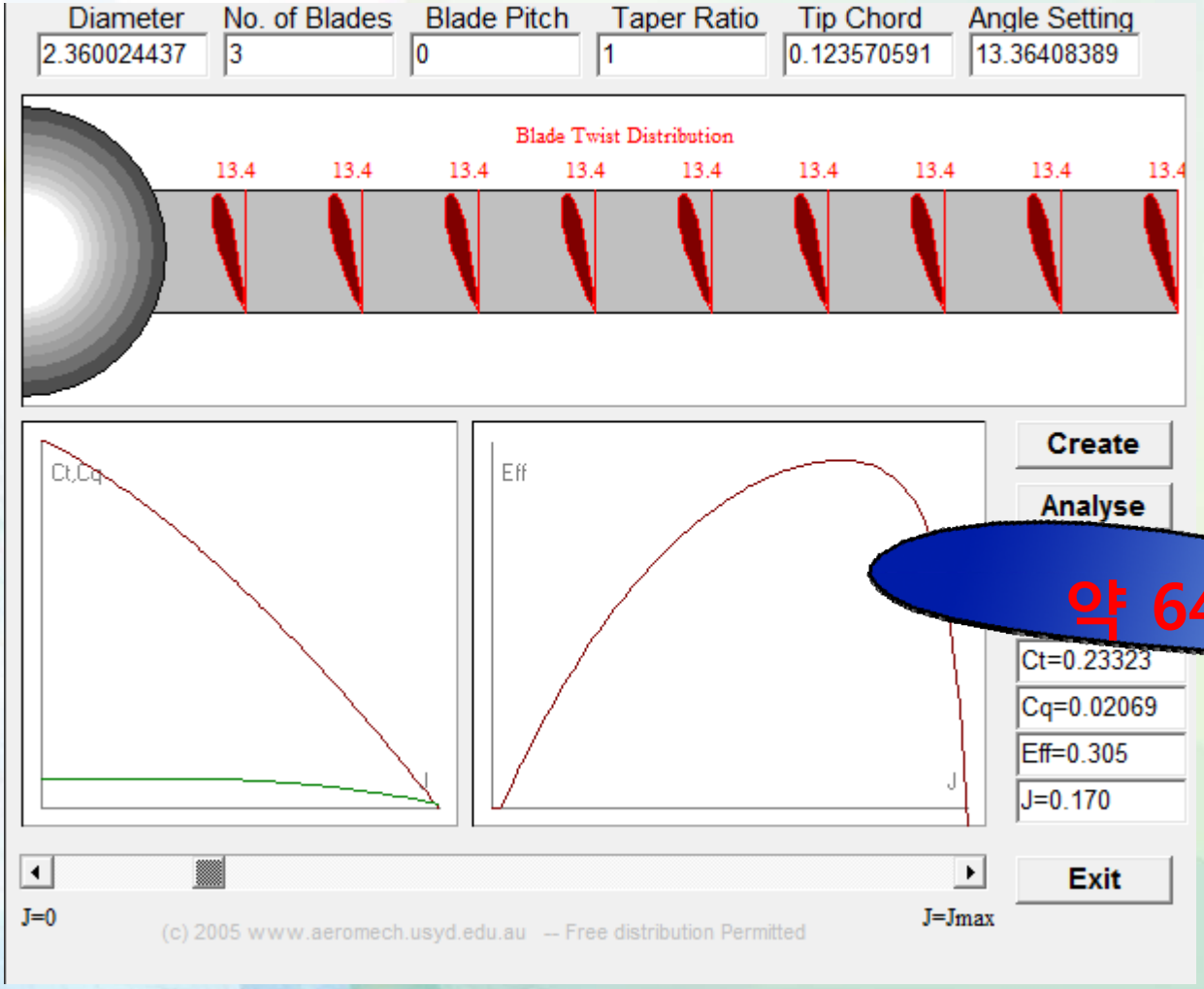


7. Comparing Algorithm

fmincon with 2 variables



8. Conclusion



Rectangle	
Trust (N)	3906.68
Airfoil	
Trust (N)	6441.27

약 64% 우수한 결과

9. Reference

- **Wind turbine engineering design** / Eggleston, David M / Van Nostrand Reinhold / 1987
- **Glauert Blade Element Theory /** www.aerodynamics4students.com
- **Propeller Design & Analysis Program** / www.aerodynamics4students.com
- **An Assessment of Propeller Aircraft Noise Reduction Technology /** NASA Contractor Report 198237
- **유체역학** / 맹주성/ 竝進 / 2001

Question??