풍력 발전용 Wind Turbine Blade의 응력, 좌굴 안정성, 피로수명을 고려한 최적설계

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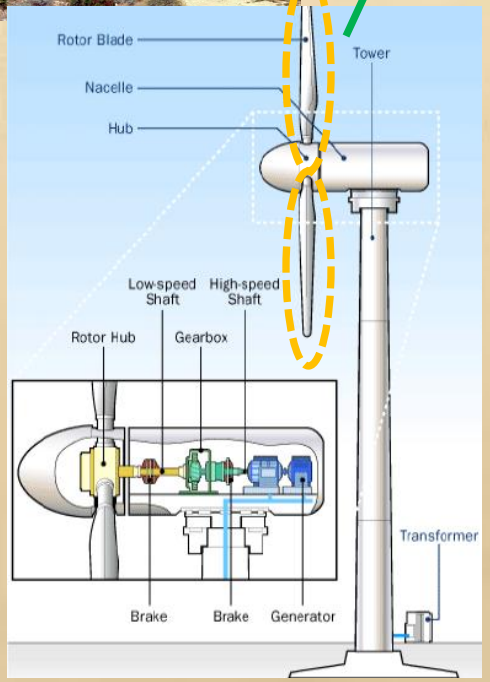
Contents

Abstract



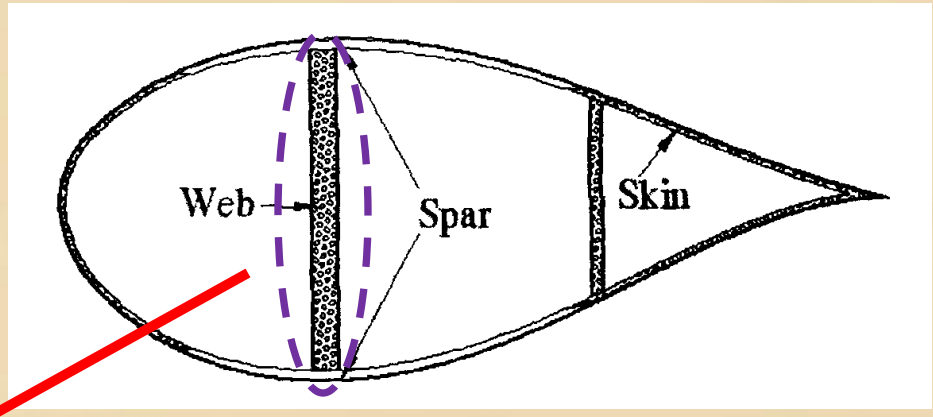
설계풍속에서 최적설계 기법을 이용하여 Turbine Blade를 설계한다.

구조해석, 좌굴해석, 피로수명 해석을 수행하여 최적의 목표 값을 최적설계이론을 통해 찾아낸다.

Problem Statement

1. Necessary Condition
   - Do not exceed allowable stress
2. Optimization
   - Minimize total turbine blade area

Introduction of Base model



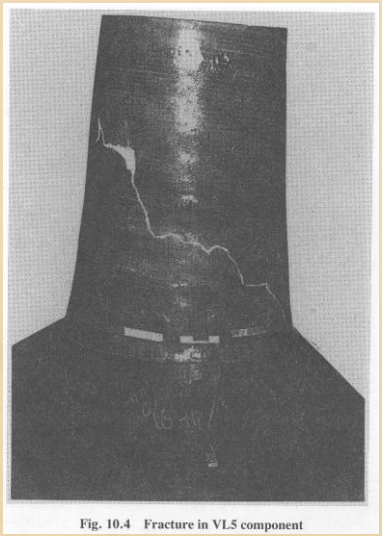
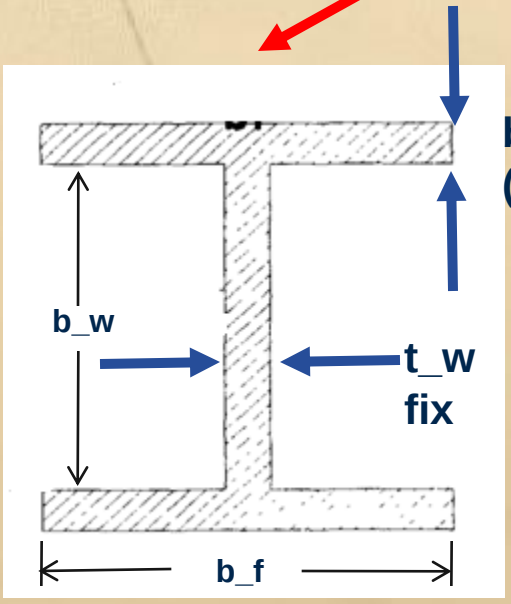
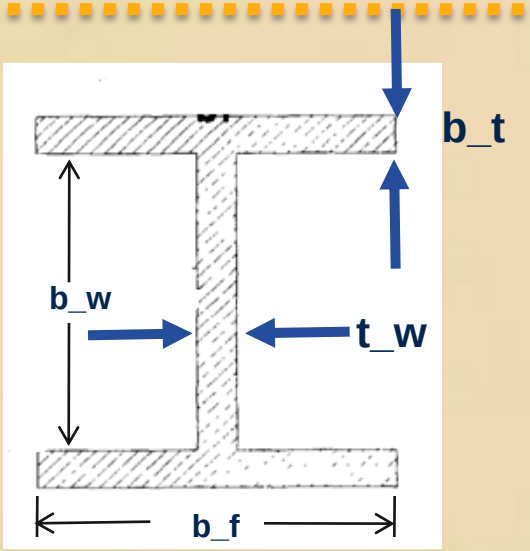


Fig. 10.4 Fracture in VL5 component



Station R	0.286	0.386	0.449	0.51	0.592
b_f [mm]	1031	941	851	783	692
b_w [mm]	803	661	526	465	363

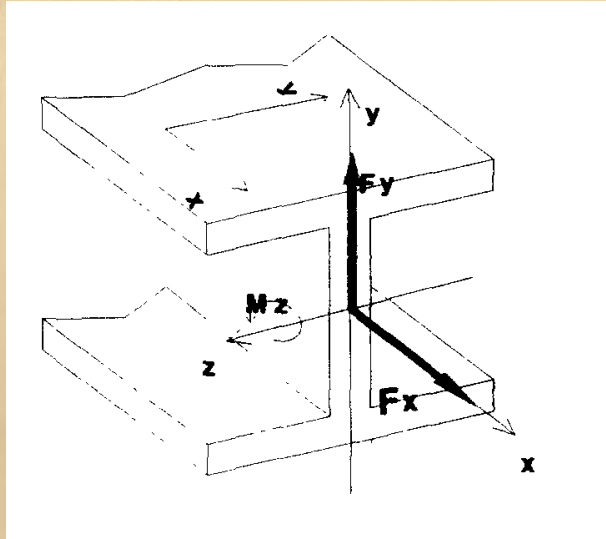
Data and Information 1



part	Material Proper-ties	E1 [N/mm²]	E2 [N/mm²]	ν	X_t [N/mm²]	X_c [N/mm²]	Y_t [N/mm²]	Y_c [N/mm²]
Flange	**UD-GFRP**	35700	10600	0.27	711	1200	38	183
web	**450-GFRP**	20000	2000	0.27	367.3	411	135.5	141

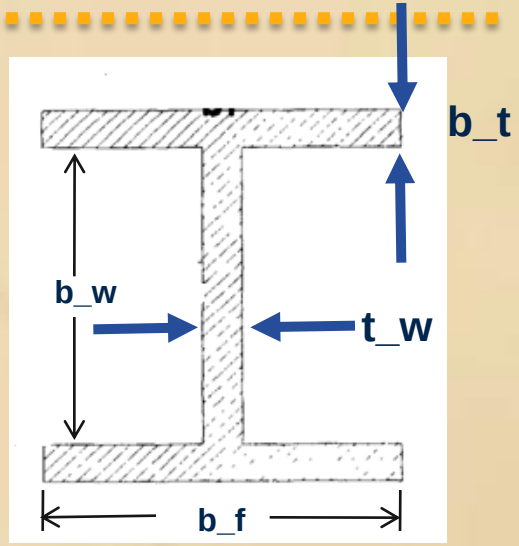
Data and Information 2

Station R	0.286	0.386	0.449	0.51	0.592	0.674	0.755	0.837
$F_x[kn]$	325.7	307.4	268.6	239.9	213.7	173.2	131.4	84.8
$F_y[kn]$	90.4	82.8	77.0	71.3	65.1	57.2	44.2	31.1
$M_z[kn\cdot m]$	1083.4	902.7	737.1	583.1	440.5	310.2	195.8	107.4



Data and Information 2

Assumption 1



* 재료는 isotropic, homogeneous.
* turbine blade가 20년 후면 초기강도의 20%로 저하.
  → 안전계수를 5로 가정함.
* 공력하중에서 바람의 평균풍속을 25m/s로 가정.
* Material : UD-GFRP(flange), 450-GFRP(web)

  → thickness of flange: b_t = 140 [mm]
  → thickness of web : w_t = 80 [mm]

* $\bar{E}_{xw}/\bar{E}_{x} = 10$
* $\bar{E}_{xf}/\bar{E}_{x} = 10$

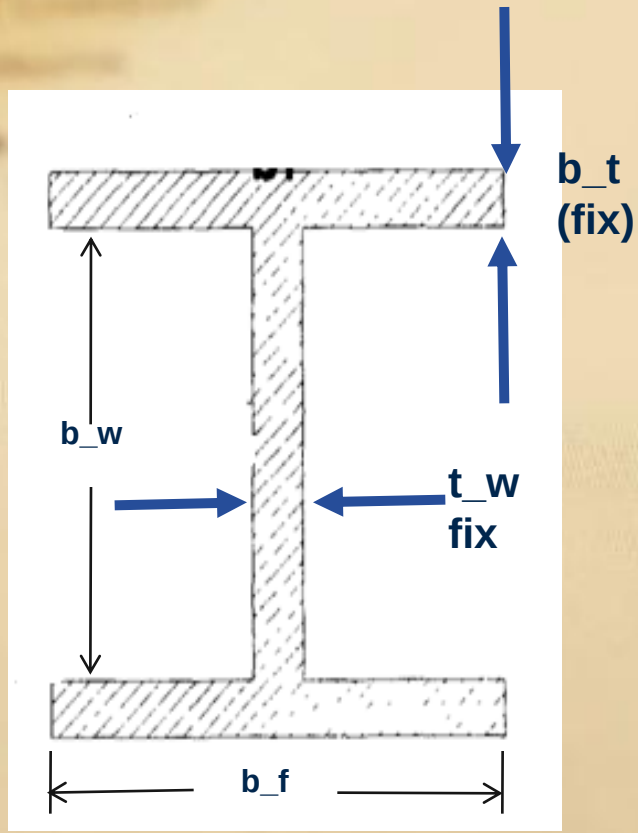
Data and Information 2

Assumption 2

Station	Flange		Web	
	(D11D22)^0.5	D12+2D66	(D11D22)^0.5	D12+2D66
0.286R	7.097e6	3.05e6	0.762e6	1.564e6

* Derived Values for buckling analysis
  ->기존 설계값 사용

Design Variables

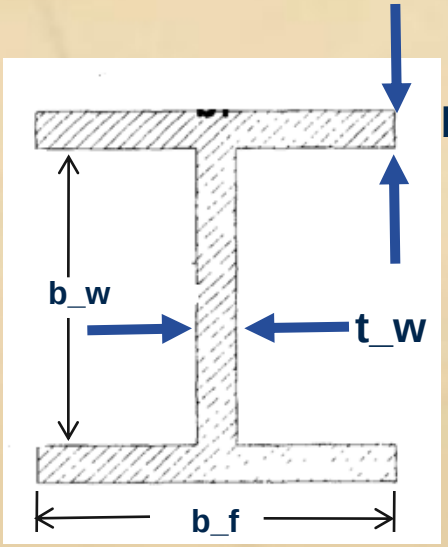


♣ b_f : I beam의 flange 길이

♣ b_w : I beam의 web 길이

Identification of the Criterion to be Optimized

$$f = 2b_f b_t + b_w t_w$$



Minimize total turbine blade area

Constrains 1

$$\frac{F_x}{A}+\frac{M_z(y)}{I_z}\le\frac{X_t}{5}$$

Flange의 인장 응력

$$-\left(\frac{F_x}{A}+\frac{M_z(-y)}{I_z}\right)\le\frac{X_c}{5}$$

Flange의 압축 응력

$$\tau_{xy}=\frac{Fy}{A}\le\tau^*_{xy}(allow)$$

Web의 전단응력

$$\sigma_{xf,total}*t_f\le\frac{K_0(D_{11}D_{22})^{0.5}}{b^2}+\frac{C\pi^2(D_{12}+2D_{66})}{b^2},b=\frac{b_f}{2}$$

Flange에 대한 좌굴해석

Constrains 2

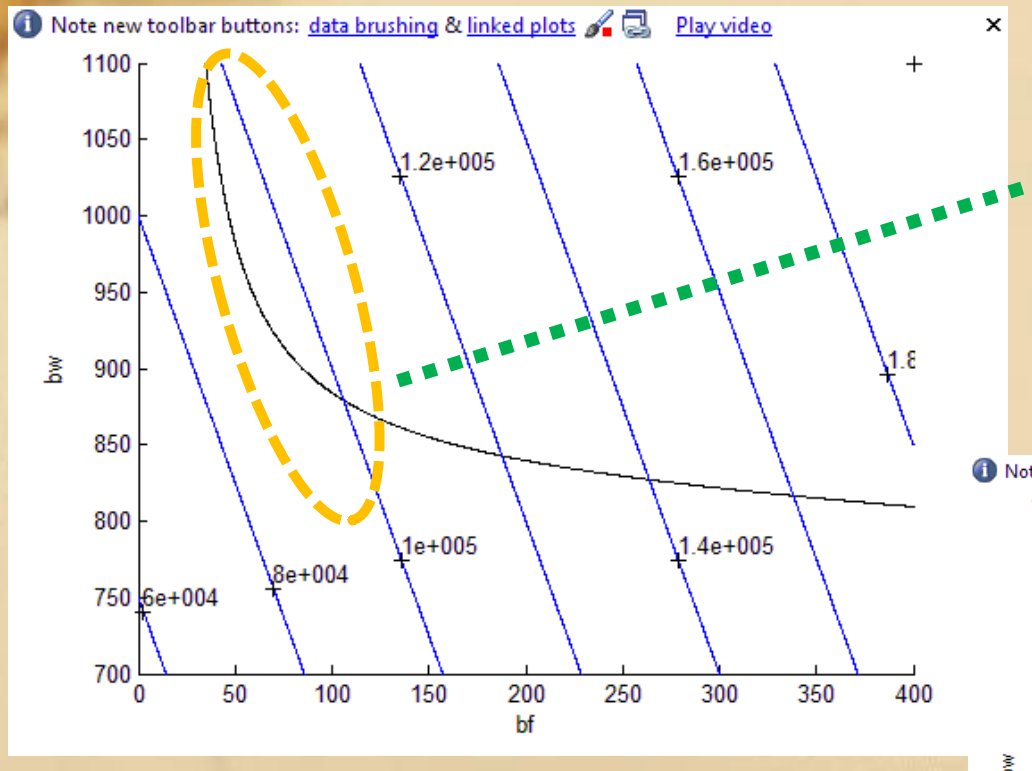
$$N_{xyw} \le \frac{135(D_{11}D_{22})^{0.5}}{ab}$$

Web에 대한 좌굴해석

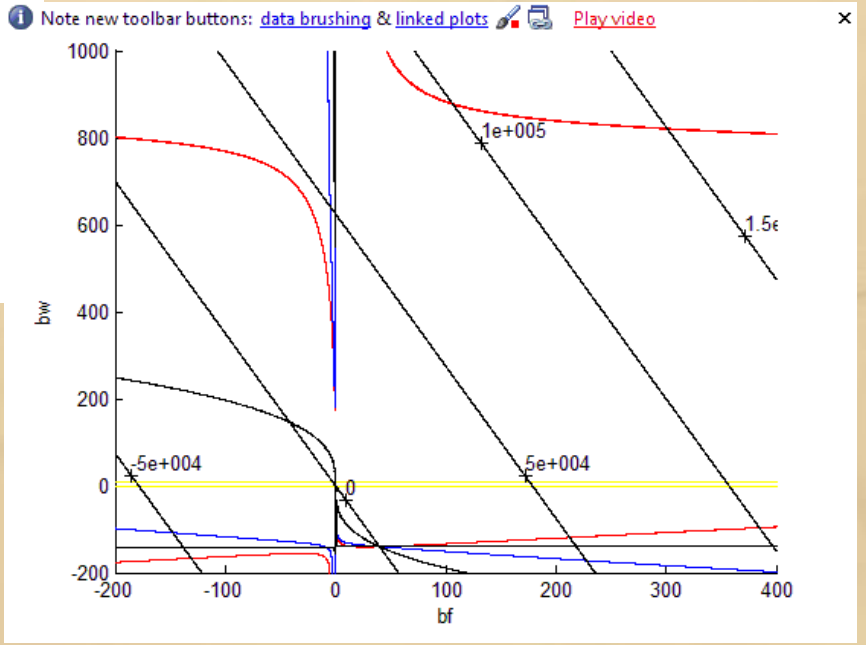
$$[where, N_{xyw} = 2 * \frac{F_y}{I_z} * t_f * \frac{b_w}{2} * \frac{b_f}{2} * \frac{E_{xf}}{E_x} + \frac{F_y}{I_z} * t_w * \frac{b_w^2}{8} * \frac{E_{xw}}{E_x}]$$

$$[where, I_z = \frac{b_f * (103.1)^3}{6} + 140 * b_f * (140 + b_w) + \frac{80 * b_w^3}{12}]$$

Predicted Conclusion



표시영역에서
최적해가 존재 한다.



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* IEC1400-1 국제표준을 적용한 대형 수평축 풍력 발전용 회전날개 설계개선/ 공창덕,방조혁,정종철,강명훙,정석훈,장병섭,안주연/ 2000년,조선대

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