Evaluation of fatigue loads of horizontal up-scaled wind turbines

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Aim:

- Identify key influences on fatigue and extreme loads

- Reveal and quantify effects

- Develop a general trend
(Ideally in the form of simple power law curves)

- Devel...)

How do fatigue loads change due to the up-scaling?

Key factors a...

- Wind c...
(mean win... ...ind shear and turbulence intensity)

- Structural parameters
(mass and stiffness)

- Operational parameters
(design tip speed, TSR, operational modes – pitch, stall, variable speed etc.)

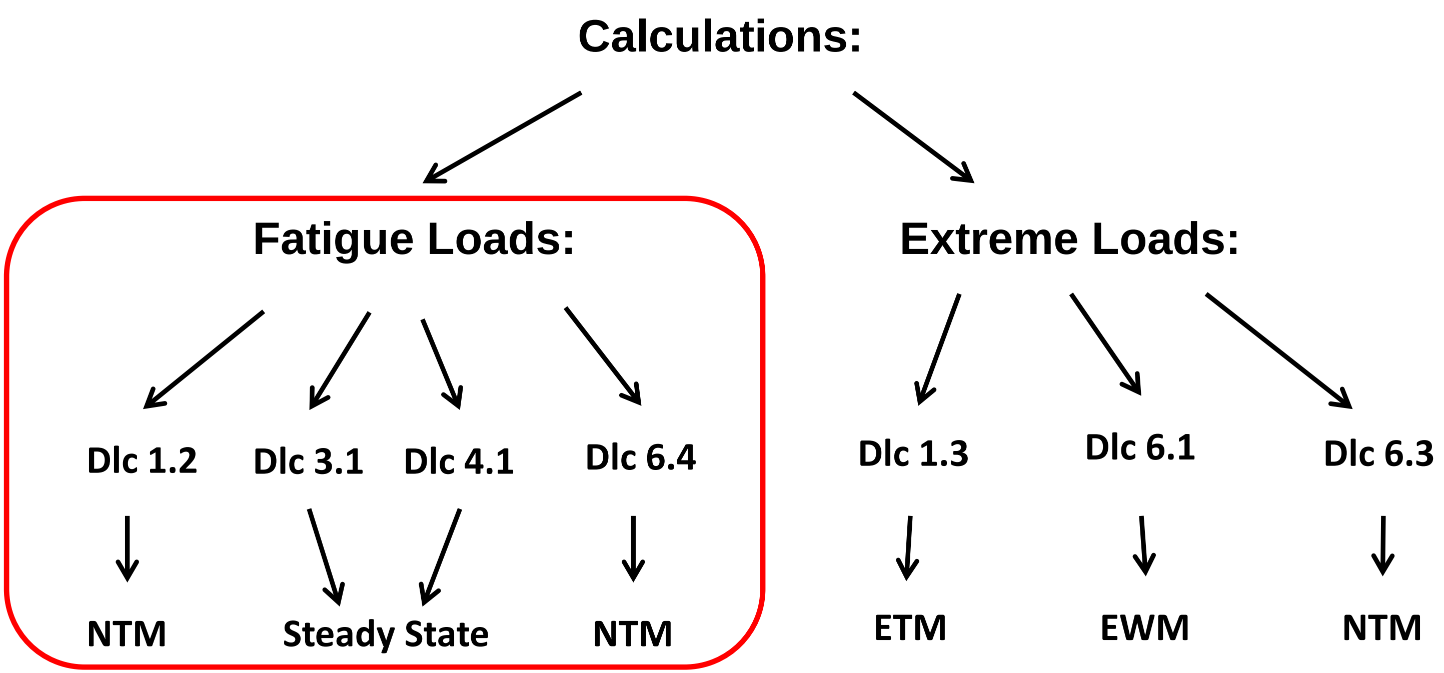
- Scale (size)

Boundaries of study:

- Reference WT is 3MW rated power, upwind, variable speed, and pitch regulated wind turbine
- Linear scaling method is applied to up-scale the reference model
  - Preserve the original tip speed ratio,
  - Geometry modifies linearly,
  - Aerofoils and materials are unchanged

Technology challenges:

- Changes of WT scale will require redesign of the control systems. It is important this can be done relatively quickly and efficiently perhaps in simplified way.
- However commercial designs will seek to reduce weight and cost using the new technology to avoid the mass penalties from scaling with similarity.
- This may be considered by looking at a few designs in 7-10 MW range using parameters considered representative of commercial designs.



- **Dlc 1.2** – design load case, WT is at power production range and connected to the electrical load at normal turbulence model (**NTM)**. Wind speed ϵ [4:2:24] with a mean yaw misalignment of $\pm 8°$.
- **Dlc 1.3** – WT is running and connected to the electrical load at extreme turbulence model (**ETM**) . Wind speed ϵ [9.2, 11.2, 13.2, 20, 25].
- **Dlc 3.1 –** WT starts up from standstill or idling to power production conditions .
- **Dlc 4.1 -** WT normal shut downs from power production to a standstill or idling to conditions.
- **Dlc 6.1 –** WT is at an idling condition (50 m/s) with a mean yaw misalignment of $\pm 8°$ using the turbulent extreme wind model (**EWM**).
- **Dlc 6.3 –** WT is at an idling condition (40 m/s) with extreme yaw misalignment of $\pm 30\ °$ using the turbulent extreme wind model (**EWM**).
- **Dlc 6.4 –** WT is at an idling condition (3, 30, 35 m/s) with a yaw misalignment of $\pm 8\ °$ using the turbulent normal wind model (**NTM**).

Wind condition:

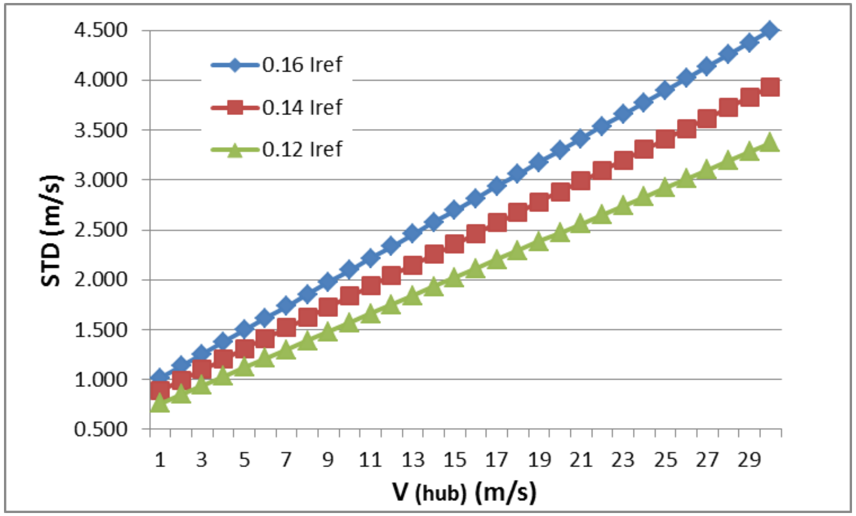
Wind turbulence was based on Kaimal:

Where, β is longitudinal scale parameter. β= 0.7*z if z≤ 60m or β= 42 m if z > 60m

- XLu is longitudinal direction or along the average wind flow velocity
- XLv is lateral or perpendicular to the longitudinal direction
- XLw is upward direction or perpendicular to both above mentions directions.

Axis components	XLu	XLv	XLw
Standard deviation	σ	0.8* σ	0.5* σ
Length scale	8.1*β	2.7*β	0.66*β
Coherence decay constant	12		
Coherence scale parameter	8.1*β		

Determination of parameters for Kaimal model



Normal Turbulence model (NTM):

$$\sigma_1 = I_{ref}(0.75V_{hub} + b); \quad b = 5.6\ m/s$$

Where, V_{hub} is wind speed at the hub height, σ_1 is a fixed turbulence standard deviation, I_{ref} is expected value of turbulence intensity at 15 m/s.

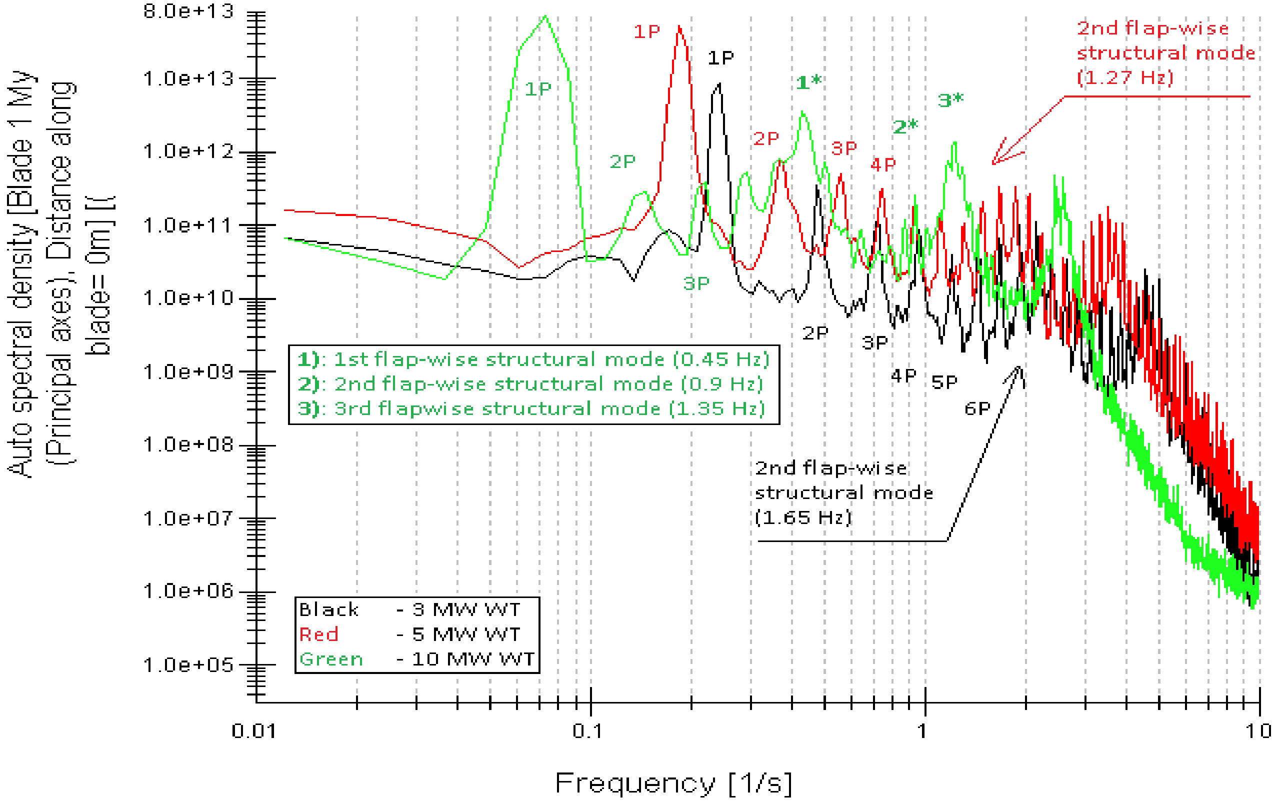
$I_{ref} = 0.16$ for high turbulence characteristics
$I_{ref} = 0.14$ for medium turbulence characteristics
$I_{ref} = 0.12$ for low turbulence characteristics

Wind turbulence class	I	II	III
V_{ref} (m/s)	50	42.5	37.5

Accuracy of up-scaling

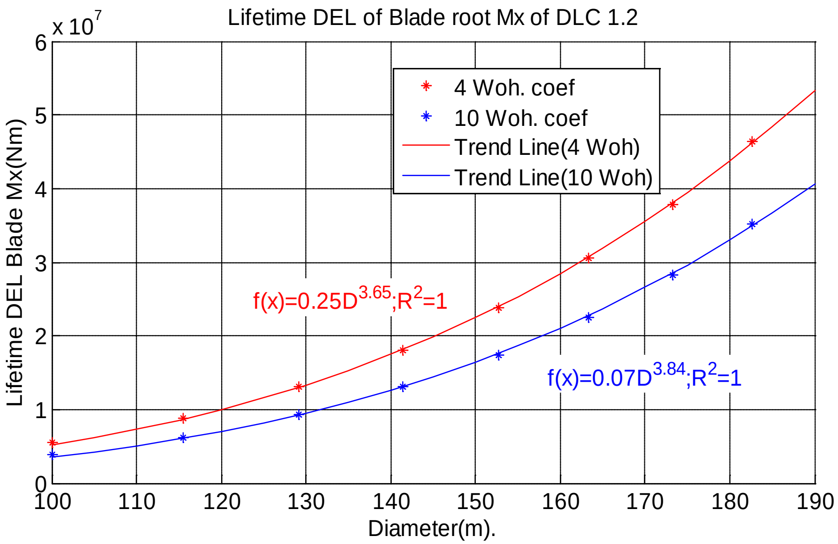
- Steady state and Auto spectra density

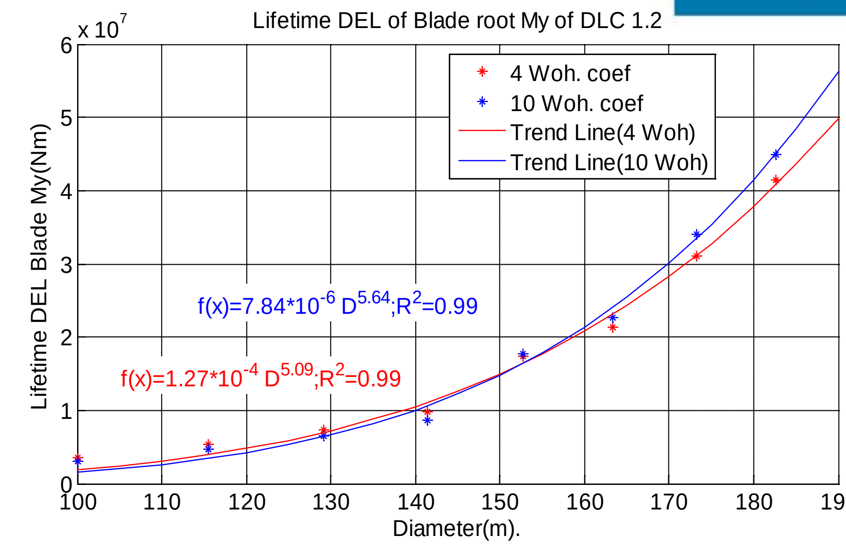
Fatigue calculations : **Dlc 1.2**;

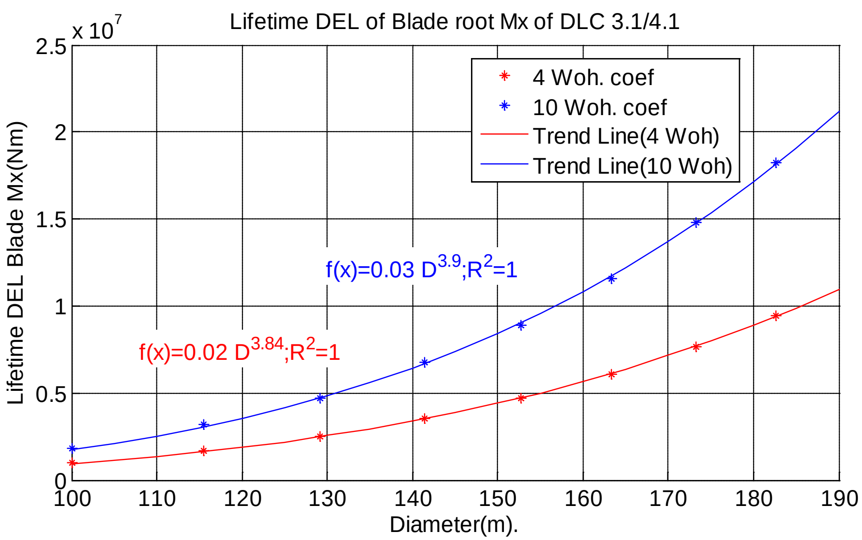


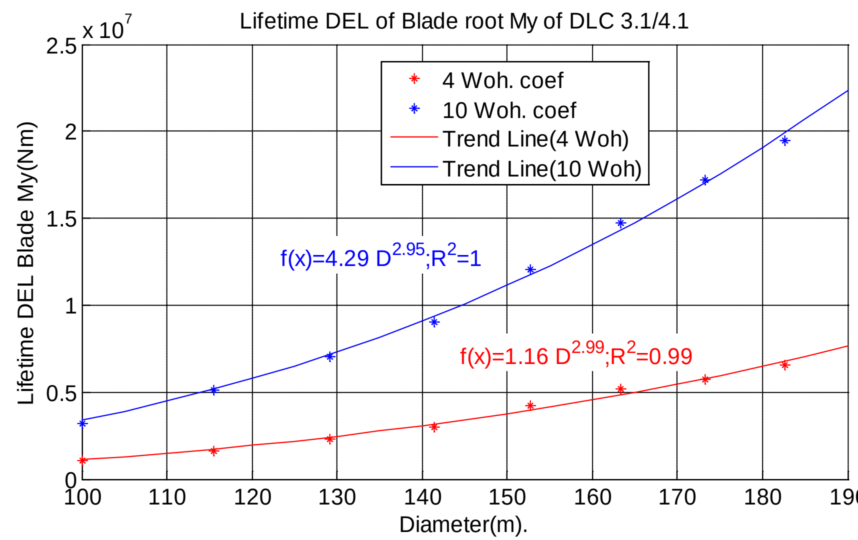
Lifetime DELs:

Fatigue loads calculations are **Dlc 1.2 , 3.1/4.1** ;



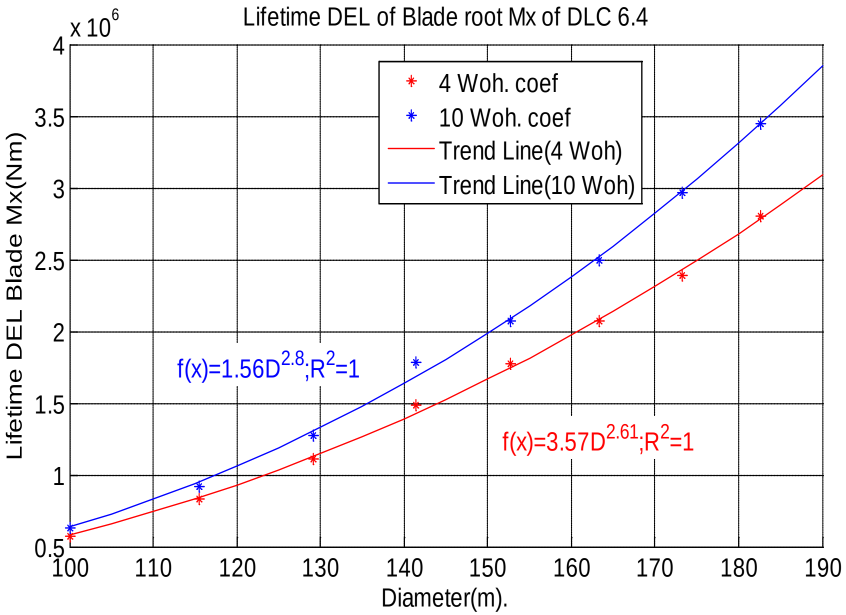


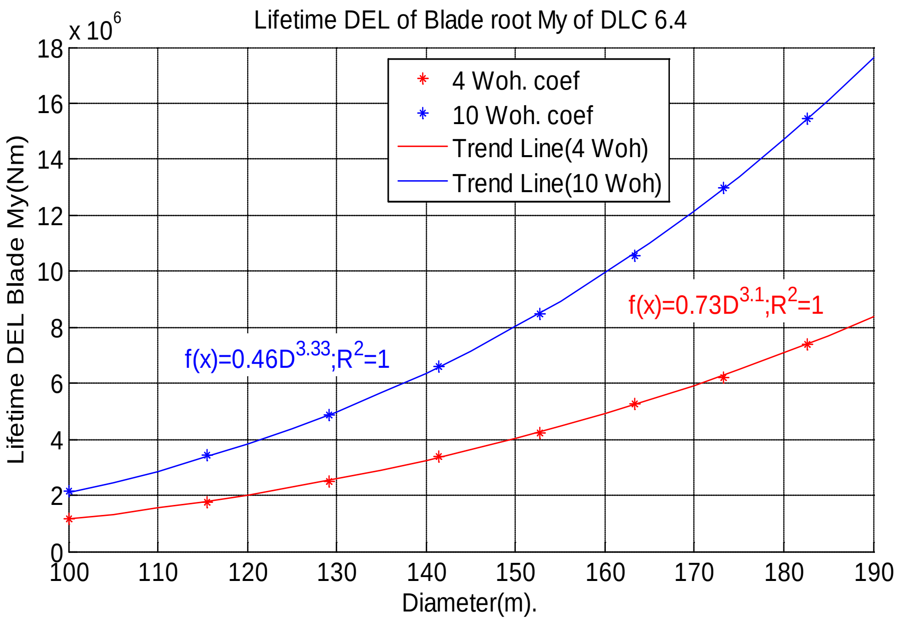




Lifetime DELs and Extreme Loads:

Fatigue loads (**Dlc 6.4**) ;





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Conclusion:

- The variation of the exponents of trend equations is reasonable at different DLCs , because the exponent is a product of the deterministic and stochastic loads. As a result the future work is required to divide the value exponent onto deterministic and stochastic parts by switching off one part loads in the simulations of DLCs .

Future work:

- Run simulations without the deterministic part of loads.
- Investigate the impact from:
  - Wind conditions
  - TSR
  - Rotor solidity

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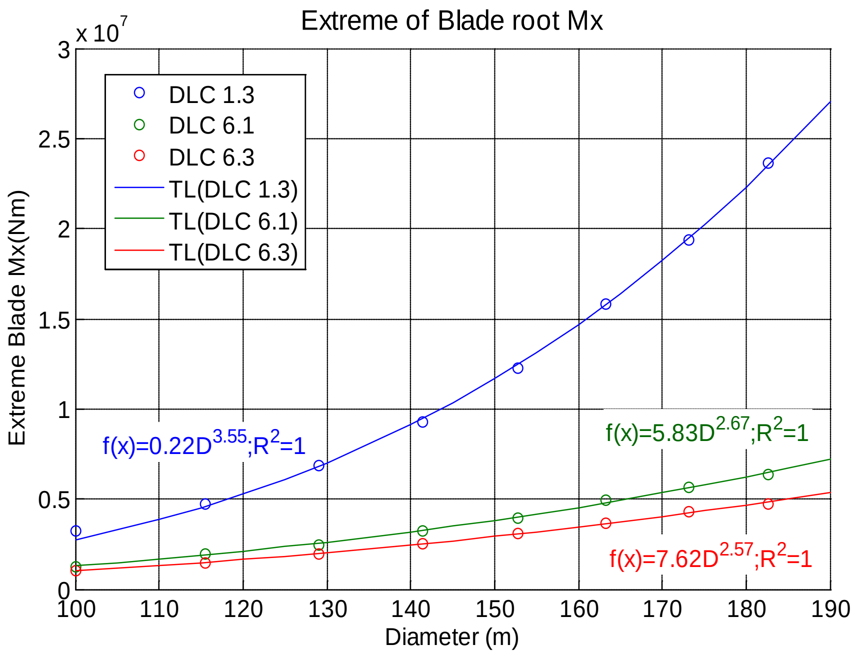
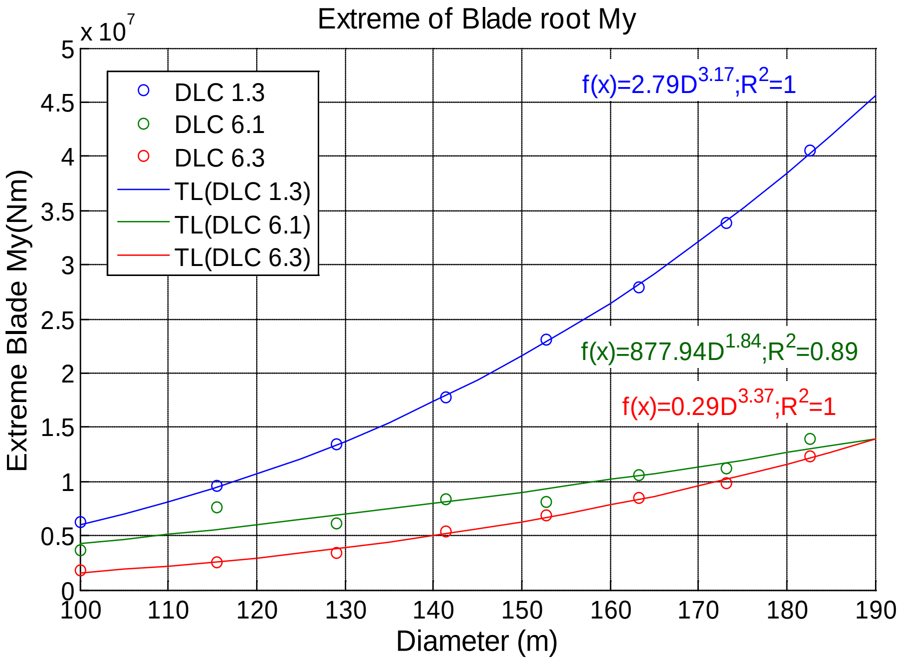
Lifetime DELs and Extreme Loads:

Extreme (**Dlc 1.3, 6.1, 6.3)**





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