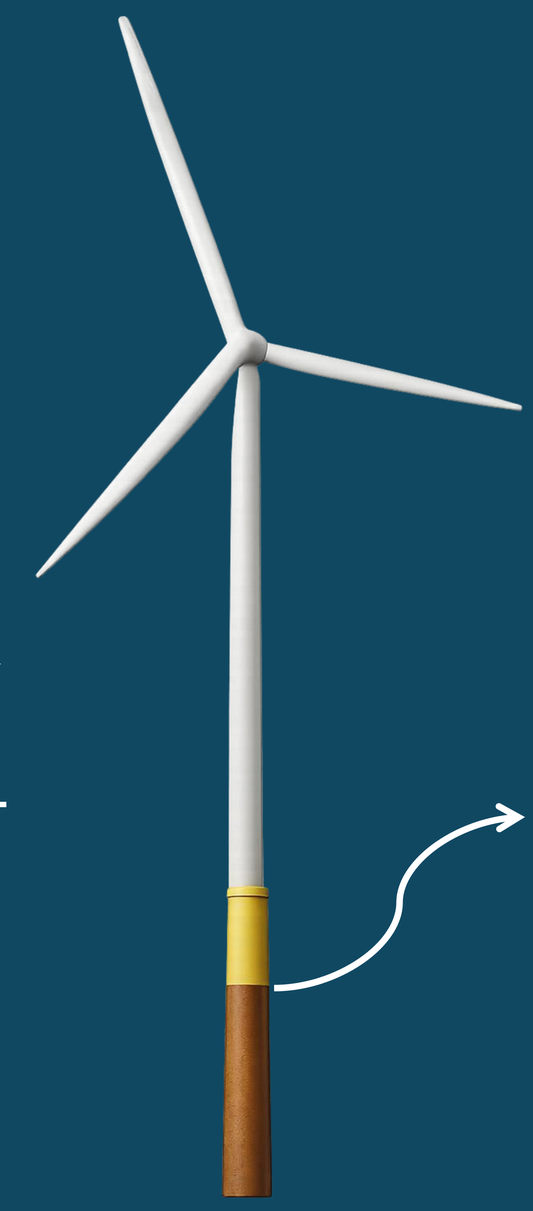
Comparative Structural Analysis: Bolted L-flange vs. C1 Wedge Connection

Offshore Wind Turbines

Introduction

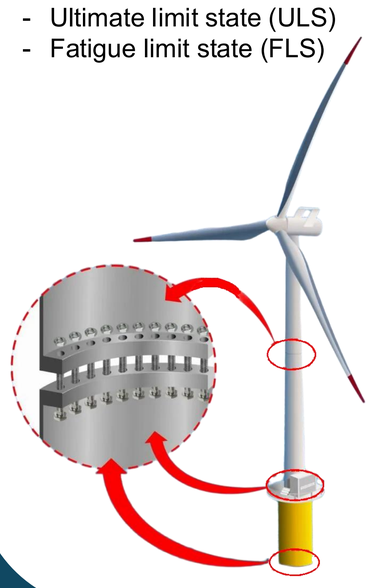
Driven by the expansion of the wind energy sector and growing demands for sustainable solutions, wind turbines continue to increase in size, accompanied by larger loads acting on them. As a result, the connections joining structural segments must be designed to provide a greater structural capacity against static and dynamic loads throughout the lifetime of the wind turbine. The increase in wind turbine size especially affects the most common connections such as the L-flange, used to connect the structural parts, as these are usually designed on the limit of feasibility.

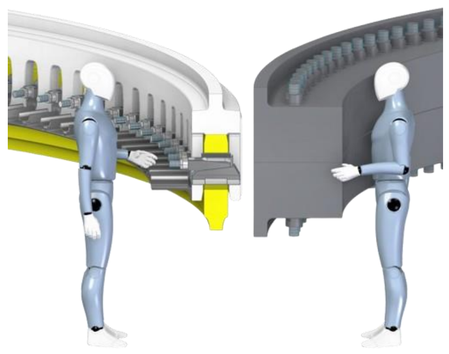


Purpose

Compare the structural performance of the conventional bolted L-flange and the innovative C1 Wedge Connection under the following limit states:

- Ultimate limit state (ULS)
- Fatigue limit state (FLS)





Methods

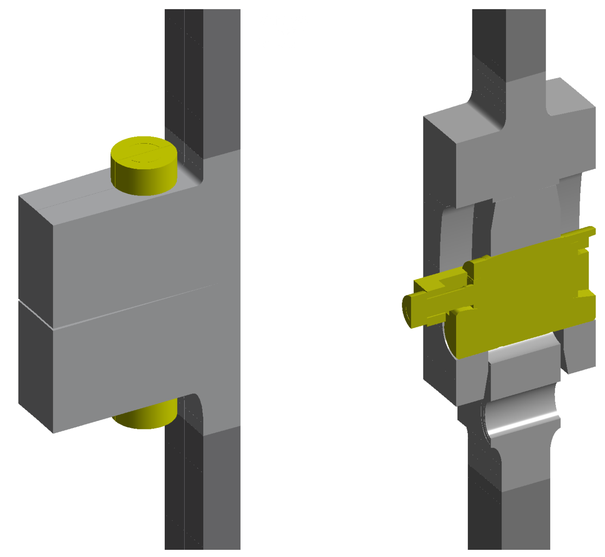
Segment model approach

Ultimate Limit State:

- Analytical Expressions using the principle of virtual work for L-flange
- Analytical Expressions assuming yielding of the smallest cross-sectional area in pure tension for C1 Wedge Connection
- Finite Element Analysis (FEA)

Fatigue Limit State:

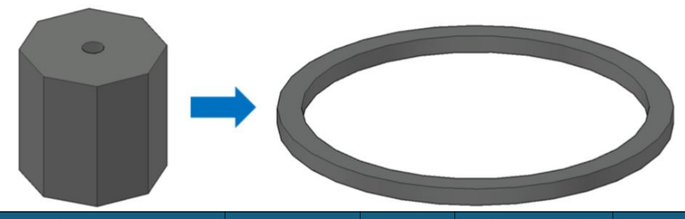
Accumulated fatigue damage (Miner's Rule) using Design Equivalent Moment (DEM) and Stress Concentration Factor's (SCF)



Industry considerations

The industry perspective:

- Production: Size and weight limits during production and production challenges.
- Installation: Installation process and bolt pretensioning sequence

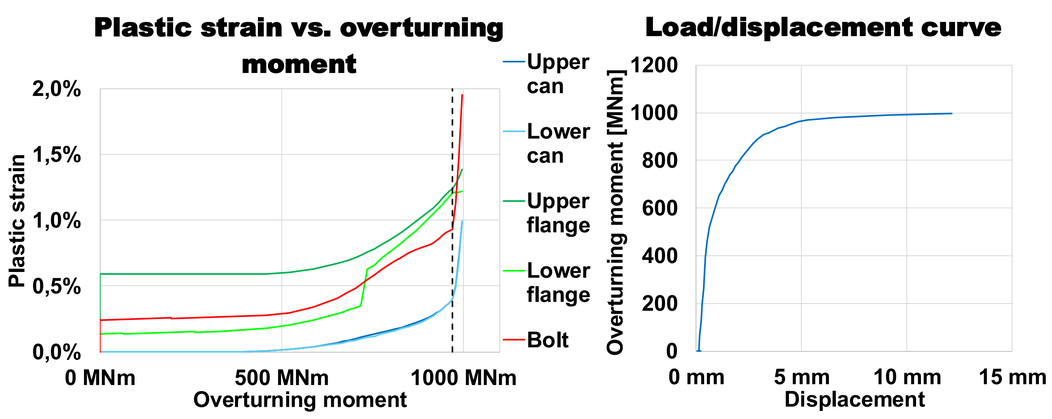


Connection	Segments	Flange	Volume [m³]	Mass [kg]
Bolted L-flange	152	Upper	4.19	32882
		Lower	4.79	37582
C1 Wedge Connection	100	Upper	5.88	46125
		Lower	3.20	25127

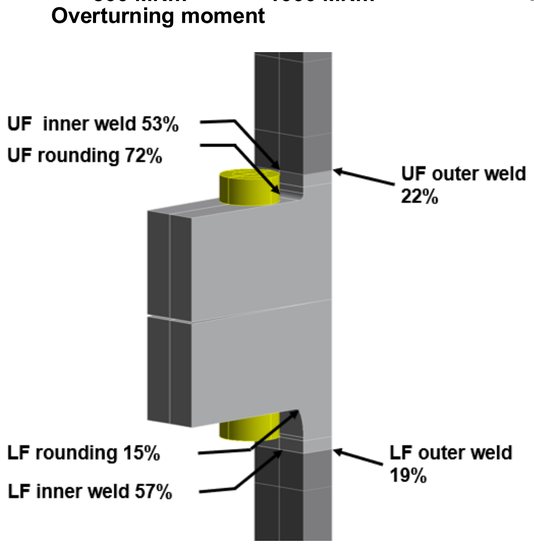
Results

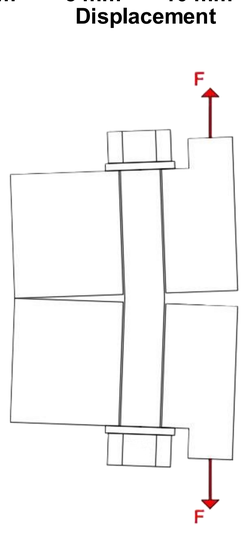
Bolted L-flange

ULS Assesment (Stresses, strains, deformation, contact gap)

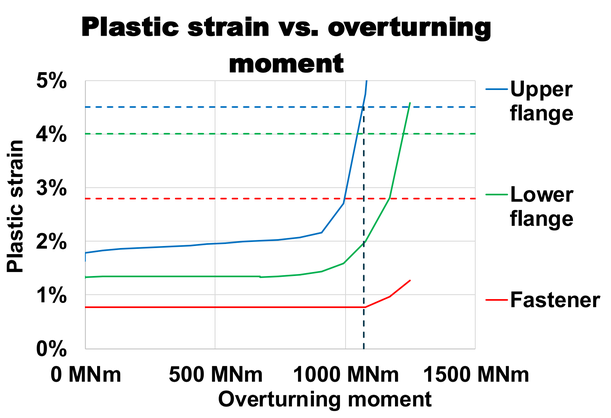


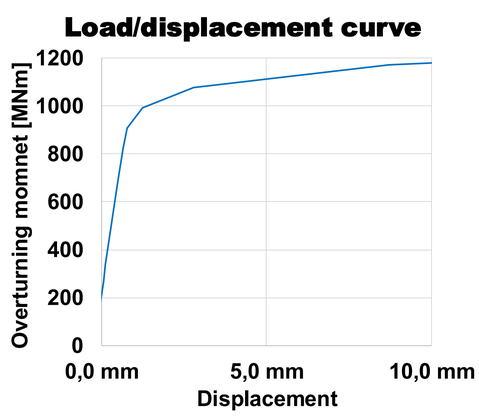
FLS Assesment (Design Equivalent Moment, Stress Concentration Factors)

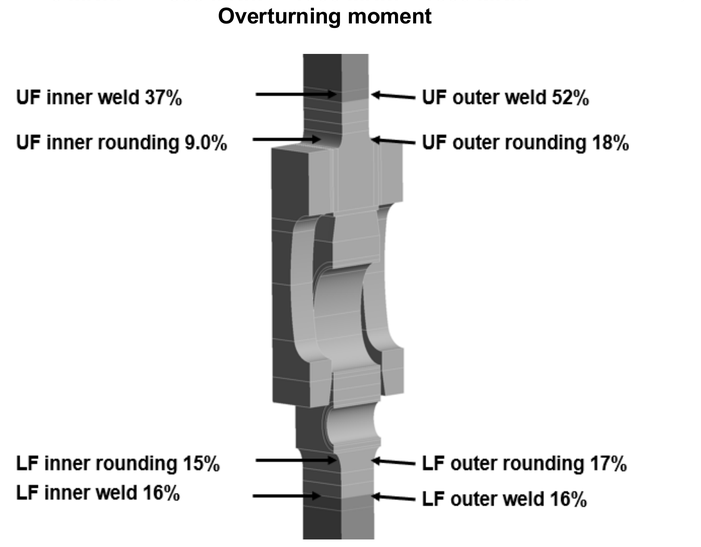


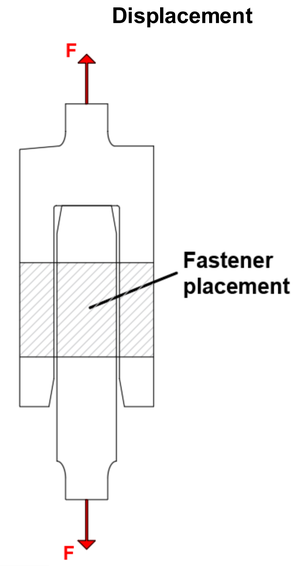


C1 Wedge Connection









Description	Bolted L-flange	C1 Wedge Connection
Analytical design moment (ULS)	653 MNm	740 MNm
Numerical design moment (ULS)	698 MNm	973 MNm
Highest accumulated fatigue damage (FLS)	72% (Rounding)	52% (Weld)
Considerations	Easy maintenance if failure occurs, normalized and faster production, more practical experience, less material usage	Faster on-site installation