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Stochastic Models for Strength of Wind Turbine Blades using Tests

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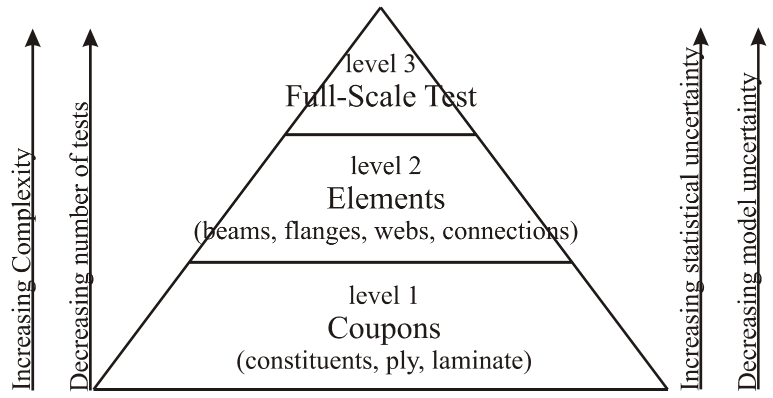
Introduction

To verify the ultimate and fatigue strength of new wind turbine blades full-scale certification tests must be performed. Tests for certification and material qualification can be divided into three levels.



Normally several tests are performed with small coupons of the base material and a limited number of tests are performed with elements of the blade.

Normally, only one non-destructive test is performed for the full-scale blade. Only one test leaves a considerable amount of statistical uncertainty which must be taken into account in the assessment of the partial safety factor.

Also the physical uncertainty related to the material properties and the model uncertainty due to e.g. size effects must be taken into account.

Updating of Partial Safety Factor

A stochastic model for strength of wind turbine blades in ultimate and fatigue loading can be formulated based on the limit state function.

$$g = R - S$$

The limit state function g expresses the difference between the resistance R and the load S. By modelling the resistance and load as stochastic variables the probability of failure can be determined.

$$P_f = P\left(g \le 0\right)$$

A similar limit state function h can be formulated for the wind turbine blade during full-scale testing.

Based on the two limit state functions the probability of failure can be calculated under the assumption that all test blades survive the test loading.

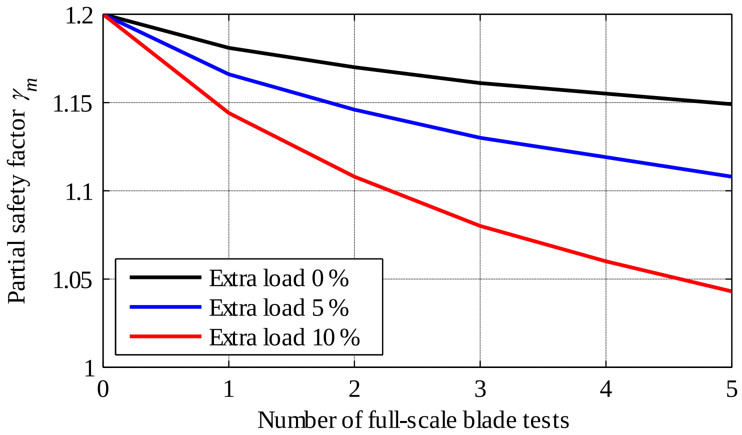
$$P_f^u = P\left(g \le 0 \,\middle|\, \bigcap_{i=1}^{n} h_i > 0\right)$$

By calibrating the partial safety factor γ_m so the updated probability of failure is equal to the original probability of failure the updated partial safety factor can be determined.

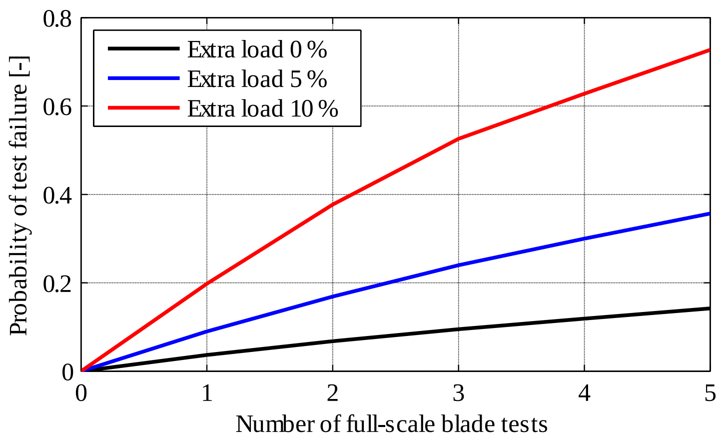
The updating is among other things dependent on the correlation between the material properties of the test blade and the actual blade.

Ultimate Limit State

The updated partial safety factor in ultimate loading is dependent on the number of full-scale tests and the magnitude of the test load.

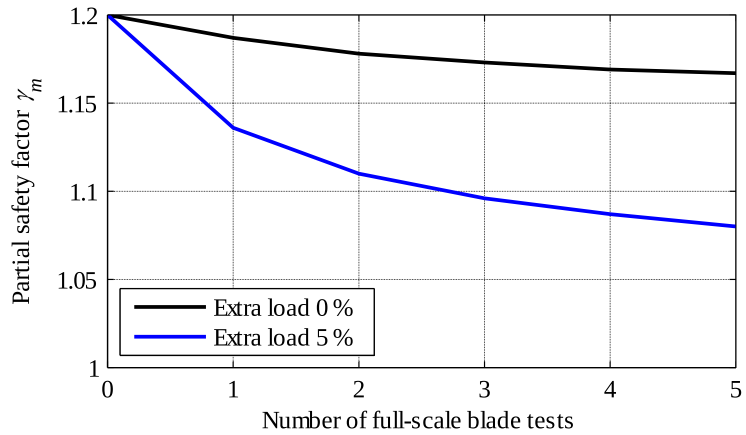


Probability of failure during full-scale tests.



Fatigue Limit State

Updated partial safety factor in fatigue loading.



Conclusion

For both ultimate and fatigue limit states there is a decrease in the partial safety factor when additional full-scale tests are performed. If a extra load in the magnitude of 5 - 10 % is applied during testing it leads to a a significant decrease in the partial safety factor.

However, for a higher test load the probability of failure during testing increases significantly. The updated partial safety factor is based on the assumption that the blade survives the test. If this is not the case – the partial safety factor will increase significantly.

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