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# TORSION IMPLICATIONS ON NEW MODERN LARGE BLADES FAILURES


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## INTRODUCTION

This abstract presents torsion as a central component of structural failure modes in new modern large wind turbine blades. Torsion was found to be the main driver for increased localized deformations in transition zone and max chord region of blades, hence driving structural related failures early on the lifetime of large new wind turbine blades, see ref.[1].

The latest media publications have highlighted an increase of failures, a fact (see ref. in Figure 1) recognized by the blade manufacturers, see Figure 1.

> "*It is expensive when offshore wind turbines need to be repaired during the warranty period. Vestas has noticed this in 2020, where DKK 5 billion has been set aside during the year, with a large part of the money going to repairing turbine blades*."
>
> "*Vestas thus had to set aside 4.7 per cent of revenue for guaranteed obligations in 2020 and expects to set aside a further 3 per cent in 2021. A few years ago, provisions accounted for less than 2 per cent of revenue*."

**Figure 1: Source: https://www.energy-supply.dk/article/view/776849/vestas_skal_bruge_fem_mia_pa_reparationer_der_er_nogle_leverandorer_der_har_svigtet**

The trend that structural related failures occur early in the blade's lifetime, confirms the methodologies used in the development and testing phase of blades are not sufficient, see ref.[2].

Structural driven failures in blades occurs mainly due to localized deformations, these being amplified significantly by the presence of torsion in the structural area of blades, see ref.[1].

As blades increase in size, torsion increases exponentially, as found in the scaling studies performed in CORTIR Project, see ref.[3].

The implications of torsion is translated to increased repair and downtime costs, as failure modes relevant for large blades are triggered when torsion is present on blades in operation, see Figure 2.

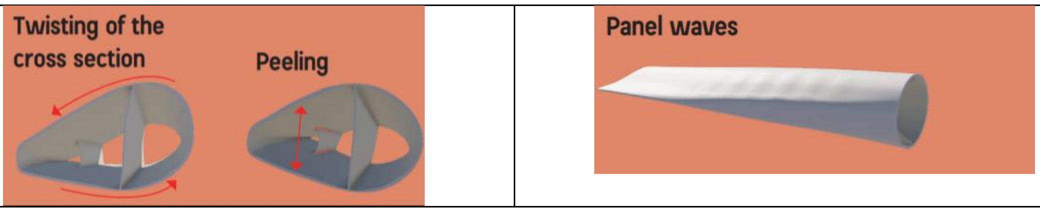


**Figure 2: Effects of torsion on blades in operation. Source:[3]**

The work described in this abstract highlight the importance of torsion in new modern wind turbine blades.

APPROACH

The methodology of torsion investigation is based on using already performed deformation measurements on blades in operation and testing: (i) field deformation measurements; (ii) full-scale testing with torsional loads; (iii) large scale testing with torsional loads deformations measurements.

In addition, a FE blade model was used to quantify the additional localized deformations and bending in the area of interest when torsional forces are used.

MAIN BODY OF ABSTRACT

Deformation measurements

1. Deformation measurements on a blade during operation.

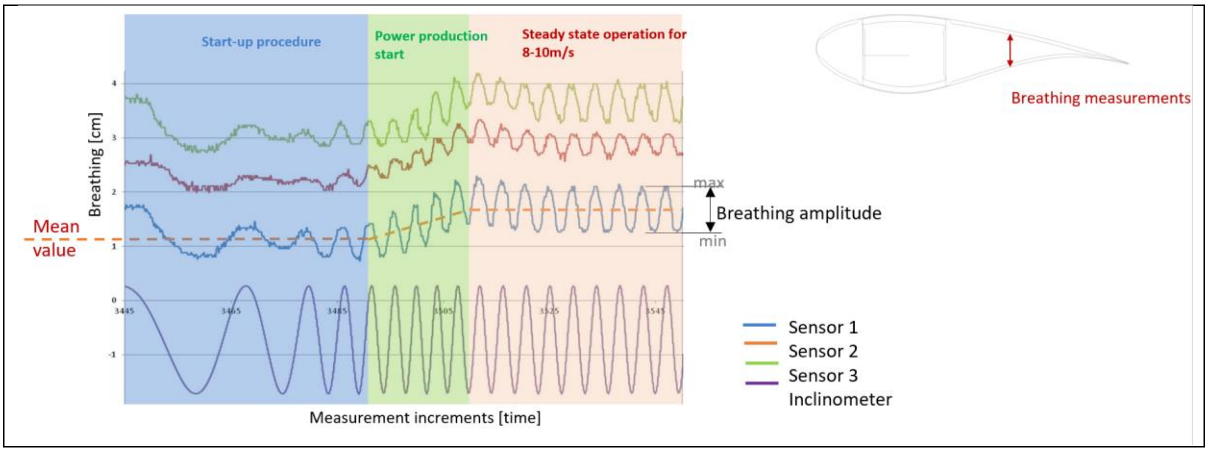


**Figure 3: Field measurements on a Vestas V80 during start-up procedure. Localized deformations (breathing) is measured. Source:[4].**

The deformation measurements in Figure 3, indicates that the *mean* component of the two main fatigue components (mean and amplitude) increases when power production begins, power production associated with increased flapwise loads, hence the blade being subjected to torsion.

## 2. Deformation measurements on a static full-scale test with torsional loads

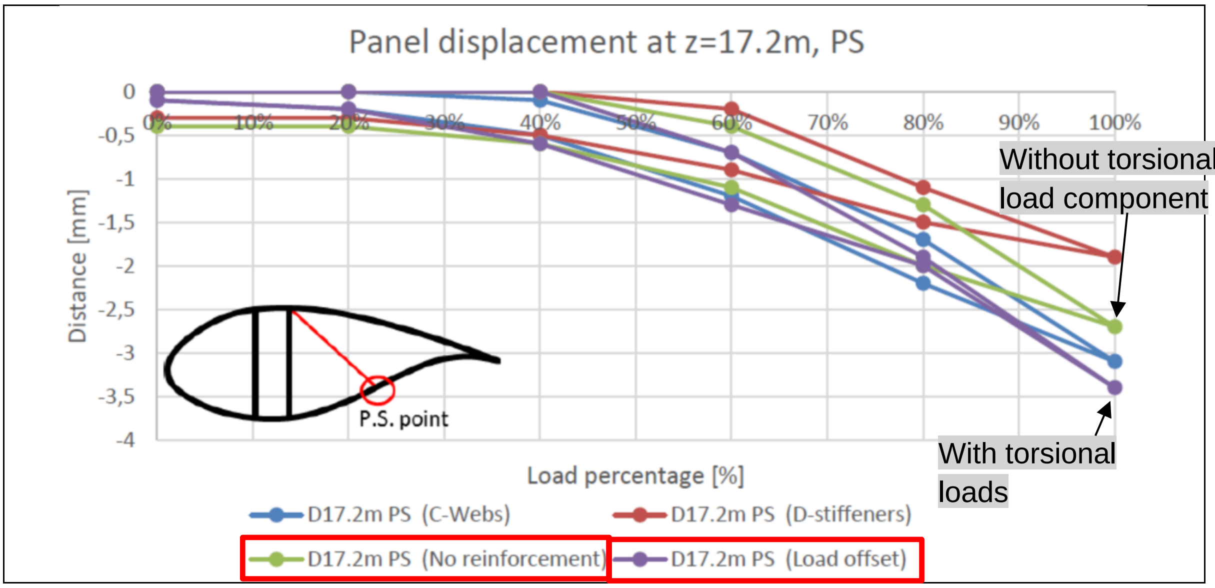


**Figure 4: Full-scale test measurements on a LM 58.7m during testing with torsional loads. Localized panel deformations is measured. Source: [1]**

The local deformation measurements in Figure 4 have confirmed that when torsion is introduced in the loading configuration during full-scale testing, the localized deformations magnitude increases. In the figure above, even relatively far out in the area where torsion has a major impact, at radius 17.2m, the effects are seen. It is expected that within the inner 1/3 of the blade the deformations are even larger.

## 3. Large scale testing

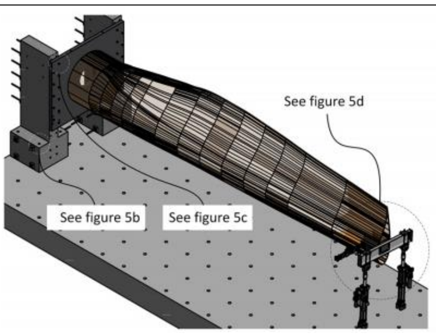


**Figure 5: Local deformation measurement on a SSP34m during large scale testing with torsional loads[1]**Fejl! Henvisningskilde ikke fundet.**.**

In Figure 5, a large-scale test was carried out with and without torsional loads and it was found out that an increase of 59% of the localized panel deformation was measured when torsional loads were considered in comparison to simple edge or flap, see ref.[1].

## FULL SCALE TESTING VS FIELD OPERATION

Part of certification of blades, a full-scale test is required for blades. The current procedures do not consider testing of blades with torsion, see Figure 6.

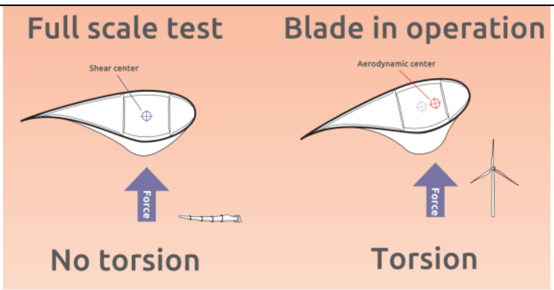


**Figure 6: Comparison of full-scale tests with a blade during operation. No torsion is considered when blades are tested during certification, see ref [3].**

According to IEC certification, the moments created by torsion in the blade *should* be considered when the full-scale test load is specified. However, it is still possible to perform the full-scale test intentionally letting out these torsional moments, therefore avoiding triggering failure modes governed by torsional moments, see ref.[6].

## CASE STUDY 70m blade FEM

The implications of torsional moments were studied on a conceptual 70m FEM blade model. The blade has a geometry where the shear web terminates in the transition zone, where the effect of the torsion is the highest. The analysis type is a comparative analysis where the end result is a comparison of the blade between 3 different load cases:

1.) Simple pure edgewise loads.
2.) Simple pure flapwise loads.
3.) Combined loading with torsional loads.

The detailed FE-model of the blade has been constructed based on the geometry and material properties measured on actual blades and as well as information available on blade manufacturer website. The blade has been modeled with HEX 20 solid elements and convergence in the area of investigation has been ensured. The model is densely meshed in the transition zone with a typical element size of approximately 10 x 10mm. The entire model has approximately 85000 elements. All FE-studies have been performed by applying a non-linear geometric algorithm.

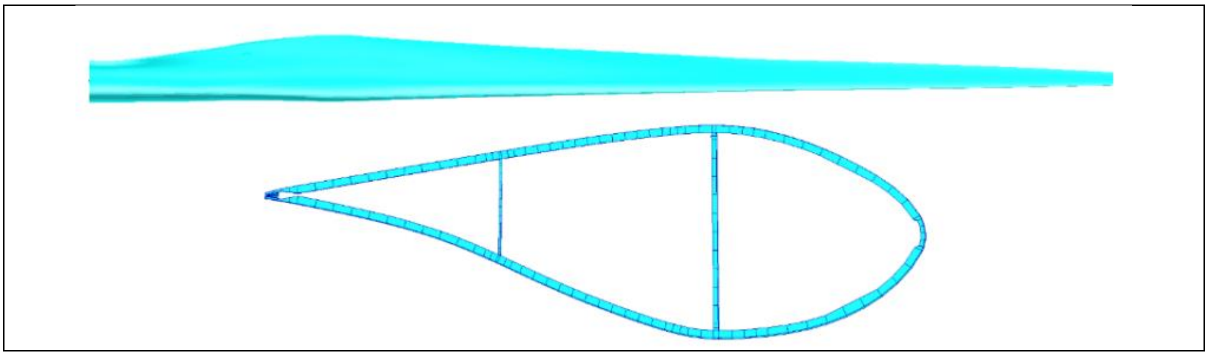

**Figure 7: FE-model of the 70m blade. Top overview. Bottom max chord cross section.**

RESULTS

The focus of the current analysis is on the area where the highest out-of-plane deformations occur, the max chord area. This is also where the highest stresses are likely to be present and where many of the structural damages are found on wind turbines blades in operation[3].

In Figure 8, the breathing magnitude in the trailing edge is used as a comparison parameter between the 3 load cases.

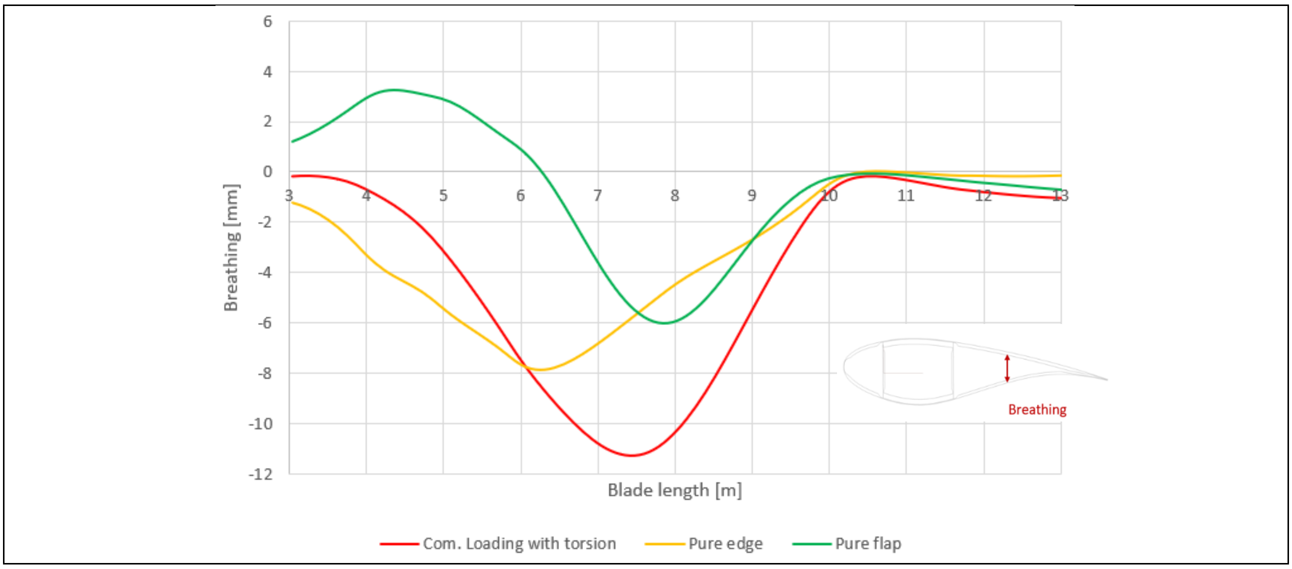


**Figure 8: Comparison of breathing in transition zone for 3 load cases: with red combined loading with torsional loads; with yellow simple edgewise loads; with green pure flapwise.**

It can be seen that torsion has a major impact on the localized response of the blade, hence on the expected lifetime. This result is in good agreement with statements from DNV[2] that current certification practices are not enough to fully capture the failure modes the balde are experiencing in the field.

## CONCLUSION

Torsion has a major impact on failure modes of wind turbine blades. Torsional driven localized deformations were measured on blades in operation and replicated on full-scale tests with torsional loads and large-scale tests with torsional loads.

A case study utilizing a 70m FEM blade model was used to highlight the implications of torsional moments as part as the loads on blades. It was found out that localized deformations are increased significantly when torsion is used.

Torsion is mentioned in the certification procedures; however, it is not mandatory to be included in a blade certification process. This has a negative impact on the expected blade lifetime, because not all failure modes are captured during the blade certification process.

## LEARNING OBJECTIVES

- Torsion in blades is described.
- The importance and relevance of torsion on large blades is addressed.
- An understanding about some of the limitations of the certification rules today and how they affect the blade performance in the field is given.

## ACKNOWLEDGEMENTS

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