Identification of damage types in wind turbine blades tested to failure

Debel, C.P.

Published in:
Materialeopførsel og skadesanalyse

Publication date:
2004

Document Version
Publisher's PDF, also known as Version of record

Link back to DTU Orbit

Citation (APA):


Abstract

Wind turbine blades are usually made of fibre composite structures, including sandwich structures, joined by adhesive bondings. A number of failure mechanisms are possible. The present work concerns the identification of different damage types caused to a wind turbine blade tested to failure under quasi-static loading, by means of carrying out a post mortem cutting-up of the failed sections of the blade. It is concluded that the processes of formation and growth of damages are very complex.

Types of damage observed: an overview

Regarding damages caused to wind turbine blades, it is concluded - based on the studies described below - that processes of formation and growth of damages are very complex, and that the processes involved in the failure of a specific blade may include several types of damage in the load-carrying structural members of the blade: the skins and the main spar. The types of damage found were:

Type 1: damage formation and growth in the adhesive layer (bond) joining skin and main spar flanges (skin/adhesive and/or main spar/adhesive layer debonding), see figures 1, 4 & 7.

Type 2: damage formation and growth in the adhesive layer (bond) joining the up-and downwind side skins along leading and trailing edges (adhesive joint failure between skins), see figures 1 & 5.

Type 3: damage formation and growth at the interface between face and core in sandwich panels in skins and main spar web (sandwich panel face/core debonding), see figures 6 & 7.

Type 4: internal damage formation and growth in laminates in skin and/or main spar flanges, under a tensile or compression load (tension or compression delamination), see figures 1 & 4.

Type 5: splitting and fracture of separate fibres in laminates of the skin and main spar (tensile failure & splitting of skin laminate and main spar fibres), see figures 1 & 7.

Illustrations of observed damage types

Type 6: buckling of the skin due to damage formation and growth in the bond between skin and main spar under compressive load (buckling, skin/adhesive debonding, a specific type 1 case), see figure 7.

Type 7: formation and growth of cracks in the gel-coat as well as peeling-off of the gel-coat from the skin (gel-coat cracking and gel-coat/skin peeling), see figures 1 & 7.

Figure 1: Illustration of some of the damage types found during the examination. At the adhesive layers: type 1 (skin/adhesive and/or main spar/adhesive layer debonding) and type 2 (adhesive joint failure between skins). In the skin under compressive load: type 4 (delamination), type 5 (splitting & tensile failure of fibres in laminates) and type 7 (gel-coat cracking and gel-coat/skin peeling). (BSQR_Skitser_of_brunder_Vestasvinge.doc)

Figure 2: The damage at the leading edge. The blade is still under load by the unengaged outer yoke. (P9250083m.jpg)

Figure 3: The test section after disengagement and cutting-up. The main damage is visible across the blade in the middle of the test section, at a distance from the root of about 20.1 metre (arrows). (P9250093.jpg)

Figure 4: Skin and main spar flange. Damage type 1: main spar flange/adhesive layer debonding, and type 4: compression delamination. (skin-main spar adhesive layer debonding and main spar laminate debonding.jpg)

Figure 5: Trailing edge. Damage type 2: adhesive joint failure between skins. (trailing edge adhesive joint failure.jpg)

Figure 6: Main spar sandwich. Damage type 3: web sandwich panel face/core debonding. (2-sandwich face-core delam P1290043.jpg)

Figure 7: Outer surface of the main spar facing towards the leading edge, as well as a cut in the upper skin (loaded in compression). Damage type 3: skin sandwich panel face/core debonding; types 4 & 6: compression delamination & buckling; skin/adhesive debonding; type 5: splitting & tensile failure of fibres in laminate; type 7: gel-coat cracking and gel-coat/skin peeling in the upper skin. (A-l-outer surf web vs. lead-edge.jpg)