Management Report
Period 1-1-2005 to 30-6-2005

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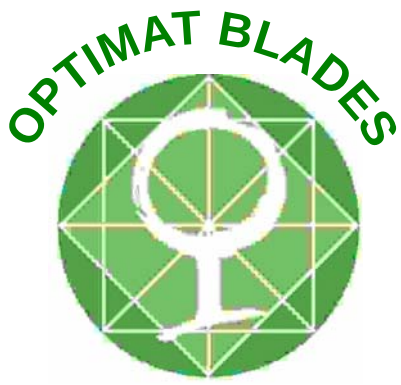

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ACRONYM : **OPTIMAT BLADES**

TITLE: **Reliable Optimal Use of Materials for Wind Turbine Rotor Blades**

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Change record

Issue/revision	date	pages	Summary of changes
1	1-9-2005	12	Updated table of Contents

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PROJECT CO-ORDINATOR :
Financial Administrative: Netherlands Energy Research Foundation
Scientific/Technical: Knowledge Centre Wind turbine Materials and Constructions

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13.	LM Glasfiber A/S, LMG.RD	(DK)
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15.	Gamesa Eólica SA, GAMESA.ED	(ES)
16.	GE Wind Energy GmbH	(DE)
17.	Vestas Wind Systems A/S, VESTAS.RD	(DK)

REPORTING PERIOD: FROM 1-1-2005 TO 31-06-2005

PROJECT START DATE: 1-1-2002 DURATION: 52 months

Date of issue of this report: 15-08-2005

1. OVERVIEW OF PROGRESS.

The technical research activities within the project are performed by Task Groups (TG), each of which performs a cluster of comprehensive Work Packages (WP).
The WP1 and WP 2 are the related to respectively the Steering Committee and the Technical Committee activities. These WPs are not part of one of the TG's activities. Furthermore the WP 16, "Production of test specimens" is not part of a TG because the test specimens are produced for all relevant WP's.

1.1. Summary of objectives for the relevant period

In this period the tests on standard OPTIMAT specimens should be finished for most TGs.

WP1 (SC)

- The activities of the SC and thus WP1 is finished in this period, since the MTA.

WP2 (TC)

- Update the TIP, using E-tip.

WP3 (TG1)

- The work on static tests will be finished.
- The work on the constant amplitude fatigue tests for the major stress ratios will be finished.
- Work on other stress ratios has less priority than work on variable amplitude, such as block tests.
- Work on life time prediction comparisons will be completed in this period.

WP4 (TG1)

- It is expected that the work WP4 will be finished at the end of this period.
- WP5 (TG1)Not yet started in the relevant period.

WP6 (TG2)

- Work on biaxial tests will continue at full speed in order to reduce delays observed in the modified time schedule.
- Testing of standard OB coupons will continue in several test rigs.
- The analysis on blade models will be carried out.

WP8 (TG3)

- Most tests under extreme conditions will have been done.
- The analysis of the results should be well under way.
- WP9 (TG3)Not yet started in the relevant period.

WP10 (TG4)

As mentioned in the MTA:

- The tests on thick specimens will be shifted to Phase II.
- The tests for specimens in thickness direction are dropped, just like the FE analysis for 4 point bending.

WP11 (TG4)

- WMC will test the first series of repaired specimens from LM (as Polymarin left OPTIMAT, due to bankruptcy).
- CRES will work on specimens by GAMESA.

WP12 (TG4)

- Not yet started in the relevant period.

WP13 (TG5)

- Continue residual strength tests on UD material.
- Continue to develop NDT methods.
- Begin to develop residual strength characterisation methodology.

WP14 (TG5)

- Continue residual strength tests on MD material.
- Continue to develop NDT methods.

WP15 (TG6)

- The work on the design recommendations will start at the end of this period, as enough test data is available to get started by that time.

WP16

- Finish the Production of standard Optimat Blade test specimens.
- Start production of the cruciform specimens and the first series of tubular specimens.
- Start production of repaired and thick test specimens for TG4.

1.2. Overview of the progress including survey of the work carried out during the reporting period and its main results

WP1 (SC)

The industrial partners are partaking in WP15 instead of the SC.

WP2 (TC)

The activities of the TC as coordinating committee for the technical work continue.

WP3 (TG1)

The benchmarking of the lifetime prediction methods has been completed. For constant amplitude, all static and nearly all fatigue tests have been completed as well. The block- and repeated block testing was continued, but is not yet finished. Load spectra tests with WISPER have started.

WP4 (TG1)

The synthesis of the NEW WISPER spectrum has been finished and reported. The NEW WISPER-sequence has been forwarded to the partners for testing.

WP5 (TG1)

Not yet started.

WP6 (TG2)

Work was continued according to the modified ANNEX I, as issued in the MTA report. OB and ISO coupon testing for phase I in the frame of TG2 is completed.
The tests on tubular geometries by DLR are about to be concluded. Phase I tests on cruciform geometries are also completed except 15 fatigue tests still pending due to problems related to the grip mechanisms of the biaxial test rig in fatigue. A comparison of methods used to perform stress analyses and analyse blades, based on measured and calculated (beam model) strains from a 35m Glass/Ep blade has been carried out, with the results and conclusions being worked on still.

WP7 (TG2)

According to the revised ANNEX I, WP7 comprises in addition to “Complex loading of alternative material” a test series investigating “Interaction effects in reference material”. Testing on interaction effects is about $^{2}/_{3}$ done, and currently are awaiting new test specimens from LM. No specimens made of alternative material were supplied and thus testing has not yet started.

WP8 (TG3)

The testing of reference material at extreme conditions has been finished with a few exceptions. Data is still pending from fatigue tests at 60°C. All data available have been analysed and reports on the main effects of the extreme conditions were concluded. The data analysis work has lead to more consistent methods to be used in the data evaluation and processing, and this form the basis for an improved detailed planning of WP9 in phase 2.

WP9 (TG3)

Plan of action for testing alternative material has been suggested. It was decided to focus only on temperature effects, which in WP8 have shown to be most detrimental. This is most pronounced found in changes in shear properties, hence mainly affecting the axial properties of multiaxial materials. Therefore, is has been suggested only to test multiaxial layered material in phase 2. The modelling, which was scaled down in the previous period due to changes in personnel will be taken up with the employment of a new senior scientist at Risoe.

WP10 (TG4)

WMC drafted a fully new DPA for TG4, eliminating much fundamental work on thickness properties and FE analyses, in lieu of a more direct approach to the effect of repair techniques and thick laminates.

WP11 (TG4)

The long and repaired specimens produced by LM were statically tested at WMC. A few static tests in other slopes remain to be done.
CRES continued testing the next series of repaired specimens from LM and GAMESA.
GAMESA has prepared a third series of repaired specimens based on prepregs, which will be tested by CRES within the next reporting period

WP12 (TG4)

Not yet started, waiting for results of first static tests in WP10.

WP13 (TG5)

The residual strength test programme for the uni-directional material has continued according to the schedule of the MTA report, except for tests on UD (R=10) due to difficulties in establishing a consistent S-N curve definition and bending-free test conditions. All partners are on course to complete their tests by end December 2005. Additional work has been done on the acoustic emission (AE) and thermo-elastic stress analysis (TSA) NDT methods by RAL and on AE by UP. Theoretical methods of characterisation are beginning to be applied to the data. The long-life tests (10^7 cycles) have not yet been started.

WP14 (TG5)

The residual strength test programme for the multi-directional material has continued according to the schedule laid out in Annex F (Updated description of work) to the MTA report. All partners are on course to complete their tests by end December 2005. Emphasis has been placed on tensile strength tests, since very little degradation of compressive strength was noted. Additional work has been done on the acoustic emission (AE) and thermo-elastic stress analysis (TSA) NDT methods by RAL and on AE by UP.

WP15 (TG6)

The first meeting was held in order to assess basic principles of design recommendations, such as following the current design method or drafting a radically new approach to blade design. It seems that the current tools like S-N line, Miner, Goodmann etc. will still be used, albeit with modifications and extensions based on the extensive test programme carried out.

WP16

Production of Phase I specimens is done, however, for Phase II also specimens in the reference material will be produced where needed and a few special test specimens will be made.

1.3. Comparison of planned activities and actual work accomplished during the reporting period

Work is progressing at excellent speed, making up some of the delays experienced earlier in the project.

Progress per TG

- Work in TG1 is going OK
- TG2 is going strongly, now that the problems with the biaxial test specimens are solved
- Work in TG3 is progressing well
- In TG4 work on the thick specimens is prepared and will be started in the next period, while work on the repaired specimens is going well.
- TG5 is proceeding according to the revised schedule given in the MTA report.

Table 1 Progress made in tests to date

Test type	Original plan	Current plan	Tests done	%	Cycles planned	Cycles done	%	Time planned	Time used	%
Static	1153	878	848	**97%**	-					
Constant Amplitude	731	765	709	**93%**	2.69E+08	3.78E+08	**141%**	19300	19100	**99%**
Variable Amplitude	315	295	177	**60%**	1.05E+08	0.45E+08	**43%**	2982	1120	**38%**
Residual strength	684	684	442	**65%**	2.52E+08	1.56E+08	**62%**	7156	7260	**101%**
Total Fatigue	1730	1744	1328	**76%**	6.26E+08	5.79E+08	**92%**	29438	27480	**93%**
RST fatigue failure	NA	NA	93	21%	NA	0.33E+08	21%	NA	1714	24%

NB: "Cycles planned" is based on the assumption that $^1/_3$ of all tests is for 5000 cycles, 50000 and 1000000 cycles respectively. "Time planned" is simply based on "Cycles planned" and a frequency of 6 Hz. for UD and 2.57 Hz. for MD (recommended OPTIMAT test frequencies for R=-1).

Constant Amplitude (CA): fatigue test where the test specimen is subjected to a fixed load range for the whole test.
Variable Amplitude (VA): fatigue test where the test specimen is subjected to a variable loads.
Residual Strength (RST): after a number of CA cycles, the test specimen is tested statically, unless the specimen failed already during the fatigue test (show as RST fatigue failure in the table above).

The progress in this period is easily shown by looking at the number of tests reported in OPTIDAT, which grew from about 1500 to about 2400, see Figure 1.

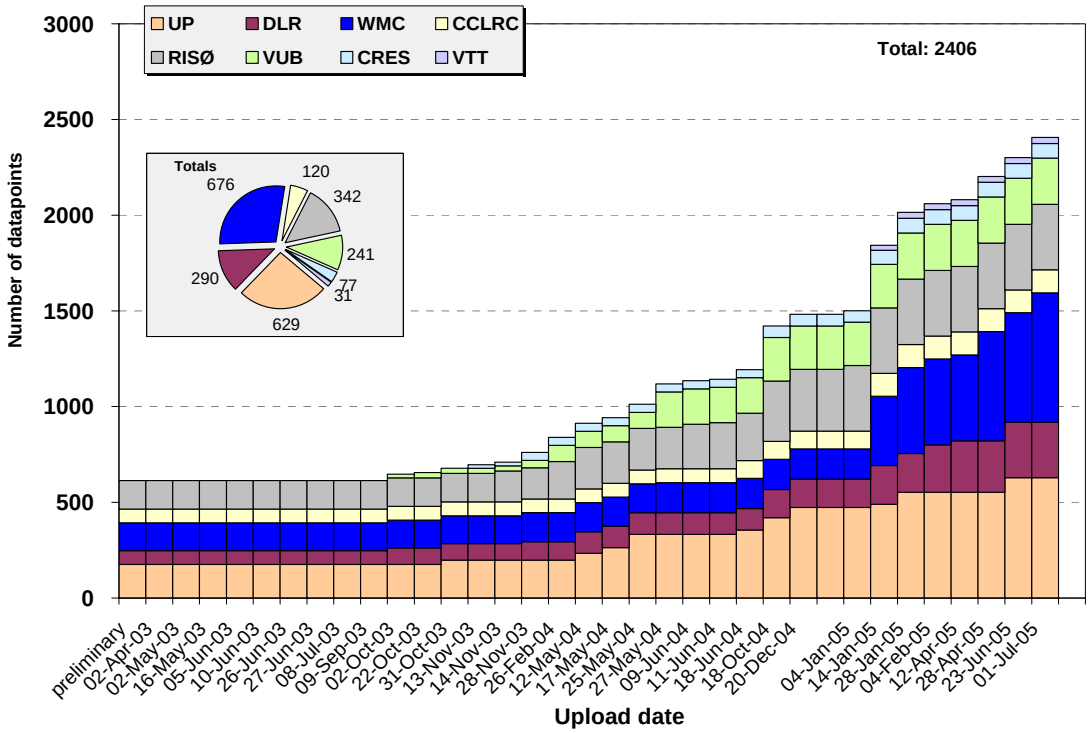

Figure 1 Overview of number of tests carried out

1.4. Planned activities for the next period including any proposed revisions to the Work plan

The work plan has been revised at the MTA in order to deal with the delays experienced to date, as well as for the second phase of the project.

WP2 (TC)

Update the TIP, using E-tip

WP3 (TG1)

The block tests and the load spectra tests with WISPER will be finished.

WP4 (TG1)

The experimental validation of NEW WISPER is carried out in full speed. An analysis of the block and load spectra test results will be performed, as well as a life time prediction comparing WISPER and NEW WISPER.

WP5 (TG1)

A detailed plan of action has been written describing the objectives to perform basic interaction tests with a selected alternative material (MD, however other resin than in phase I) to characterise the severity of combinations of aspects like load variation, extreme conditions and bi-axial loading on fatigue life in specifying the interaction to the Work Packages 7, 9 and 13 and type and amount of tests and specimens, as well. The tests will be started within the reporting period. They include a limited number of static tests, a basic S-N line for R = -1 and block testing performed by WMC and DLR. Static and fatigue tests at cruciform specimens will be carried out by VUB.

WP6 (TG2)

First priority is to conclude pending tests from phase I on reference material, i.e. few remaining tests on tubes and cruciform specimens. As soon as pending test results are properly reported, all

effort will focus on final validation of predictive models for static and fatigue strength. Reports for “optimised stress analysis” and “reliable strength prediction under static and dynamic loading”, part of deliverable #11, deliverables #17, 19, 20 are to be finalized in this period.

WP7 (TG2)

In the remaining period, test results on interaction effects of reference material are to be reported and evaluated. Tests on alternative material will be completed. Preparations for deliverable #33, “Interaction effects on multi-axial predictions” will be made.

WP8 (TG3)

The tests and reports from VTT will be finalized and procedures for test planning and data processing will be worked out. A few additional tests on Sea Water submerged specimen are considered at Risø, because additional specimens are available.

WP9 (TG3)

Testing and modelling of mechanical behaviour on alternative MD material will start. The DPA will be discussed among partners and a close time table will be worked out – and followed.

WP10 (TG4)

Static tests on thick laminates will be carried out, based on a geometry that matches the long, thick specimens of WP12. The possibilities for producing and testing these specimens will be investigated by LM and WMC, aided by FE analysis from ECN.

WP11 (TG4)

Static tests on LM specimens to be finished by WMC.
Fatigue tests on selected repair techniques from LM will be tested by WMC.
CRES will finish static tests on repaired specimens from GAMESA and start on the fatigue tests as well.

WP12 (TG4)

Static tests in WP12 will be carried out after the static tests of WP10, since the latter tests will act as reference tests for WP12.
Likewise, fatigue tests of WP12 will be started after the fatigue tests of WP10.

WP13 (TG5)

The UD residual strength test matrix will be completed and the predictive engineering model developed and used to predict results for the MD material.

WP14 (TG5)

The MD residual strength test matrix will be completed and results compared with predictions from the predictive engineering model.

WP15 (TG6)

First rough design recommendations will be drafted, based on a questionnaire to the TLs concerning the influence of their results on the design of rotor blades. Furthermore, some conclusions regarding material characterisation will be drawn and used as input for future research projects.

WP16 (TG6)

Production of test specimens is continuing but is expected to be almost finished in the coming period.

2. MANAGEMENT AND CO-ORDINATION ASPECTS

2.1. Co-ordination activities

- A fruitful Progress/MTA meeting was held at ECN in February. From the overviews of the different WP's, it could seen that the execution of experiments is now at full steam and that during 2004 a large number of experimental data points have been added to the OPTIDAT database. It was however evident that due to the delays it is not possible to achieve all the milestones and deliverables as presented in the original Description of Work (DoW). Therefore a new DoW is necessary for the remainder of the project. It was clear from discussion with the scientific officer that an extension of the project was not possible. During the last two days of the meeting the new DoW has been discussed and the TG-leaders presented their views on the work to be carried out during the remaining time frame. The PTA attended the MTA.
- Before the MTA the draft version of the New DoW was commented by the scientific officer and the PTA. These comments were discussed at the MTA meeting and a new version of the DoW was issued in April. This new version has been, unofficially, accepted by the Scientific Officer and acts now as the DoW for the project.
- Due to some budget changes and changes in partners a first Contract Amendment was necessary. The changes in the contract were prepared in 2004. In the first half of 2005, the Contract Amendment documents were signed by the partners. The counter signing on behalf of the EU could not yet be finalized.
  - ❖ The network of the Optimat partners has been successfully used to define a material research activity to be executed as a part of the 6th framework IP "Upwind".

2.2. Publications to date and planned

[1] Arno van Wingerde, Rogier Nijssen, Don van Delft, Bert Janssen, Povl Brondsted, Geoff Dutton, John Heijdra, Christoph Kensche, Theodore Philippidis, Torben Jacobsen, “Poster on Optimat Blades”, EWEC 2003, Madrid Spain (*Best of conference poster award*).

[2] Arwen Smits, Danny Van Hemelrijck, “Optimization of a cruciform test specimen for bi-axial loading of fibre reinforced material systems”, Student seminar of 25th International SAMPE EUROPE conference / JEC, Paris, France, April 2004 (*poster*).

[3] Arwen Smits, Danny Van Hemelrijck, Theodore Philippidis, Arno van Wingerde, Albert Cardon, “Optimization of a cruciform test specimen for bi-axial loading of fibre reinforced material systems”, ECCM, 11th European Conference on Composite Materials, Rhodes, Greece, May 2004, p.166-167 Vol.II in book of abstracts.

[4] Arwen Smits, Danny Van Hemelrijck, Theodore Philippidis, Arno van Wingerde, Albert Cardon, “Study of the usability of various cruciform geometries for biaxial testing of fibre reinforced composites, ICTAM, XXI International Congress of Theoretical and Applied Mechanics, Warsaw, Poland, August 2004, p. 293 in abstract book.

[5] Arwen Smits, Danny Van Hemelrijck, Theodore Philippidis, “The digital image correlation technique as full field strain technique on biaxial loaded composites using cruciform specimens”, ICEM 12, International Conference on Experimental Mechanics, Bari, Italy, September 2004.

[6] During the EWEC in London, a paper on OPTIMAT BLADES and related projects will be presented during a special workshop to be organised on Tuesday 23rd November morning at the Contractors Meeting.

[7] Christoph W. Kensche, “Fatigue of composites for wind turbines”, in “Third International Conference on Fatigue of Composites”, 13 – 15 September, 2004, Kyoto, Japan

[8] O. Krause, Ch.W. Kensche, R.P.L. Nijssen, P. Philippidis, A.P. Vassilopoulos . "Poster on A Benchmark on Lifetime Prediction of Composite Materials under Fatigue. EWEC 2003, Madrid Spain.

[9] H. Söker, N. Kaufeld, Chr. Kensche,O. Krause, New Wisper, Creating a New Load Sequence From Modern Wind Turbine Data. DEWEK 2004 Wilhelmshaven, Germany

[10] H.Söker. NEW WISPER: A new edition of the classic fatigue load sequence WISPER for variable amplitude testing on materials used in wind energy industry. DEWI Magazine, August 2004

[11] M. Mengis, P. Brøndsted. Life predictions of long fiber composites in extreme environmental conditions using damage evolution approach. ECCM-11, May 2004, Rhodes Greece

[12] M. Mengis, P. Brøndsted,L. Mikkelsen, Damage evolution in laminated composite materials. DMS, Jan 2004, Kolding Denmark

[13] Krasnikovs, Mengis. Fatigue damage accumulation in unidirectional composite under applied cycling tension load. ICF 11, Italy, 2005,

[14] A. vam Wingerde and others. Overview of wind energy projects supported by the European Commission. Aera "Blades and Rotors". EWEC Nov. 2004, Londen United Kingdom

[15] R. Nijssen and others. Optimat Blades, Introduction. ICCM-14, July 2004, San Diego, CA

[16] R.Nijssen. Spectrum loading in wind turbine rotor blade composites. ChBE 500 Seminar. September 2003, Montana State University, MT

2.3. Planned publications

[17] A. Antoniou, Th. Philippidis. Optimizing material use in blade design by improving failure prediction methodology and introducing damage tolerant concepts in FPR composites. EWEC 2006, Febr, Athens Greece

[18] A. van Wingerde and others. Optimat Blades: Results and perspectives. EWEC 2006, Febr, Athens Greece

[19] Th. Assimakopoulou, Th. Philippidis, Damage monitoring of FPR composites through combined NDT measurements. EWEC 2006, Feb. Athens Greece

[20] R. Nijssen, O. Krause, Chr.Kensche, Th.Philippidis. Basic static and fatigue data from the Optimat Blades project. EWEC 2006, Feb, Athens Greece

[21] R. Nijssen, V. Passipoularidis, A. Smits, G. Dutton, Th. Philippidis. Fatigue and residual strength of rotor blade materials. EWEC 2006, Feb, Athens Greece

[22] D. Lekou, I.Velasco Mateos, P. Vionis, A. van Wingerde, T. K. Jacobsen. Repair techniques for composite materials applicable to wind turbine blades. EWEC 2006, Feb, Athens Greece

[23] A. Smits, D. van Hemelrijck, Th. Philippidis, A. Antoniou, A. van Wingerde. Study of the behaviour of glass fibre reinforced epoxy composite system used for wind turbine rotor blades under biaxial load conditions. EWEC 2006, Feb, Athens Greece