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Assessment Report of TG3
18 month (period 1-1-2002 till 30-6-2003)

OB_TG3_R008 rev. 000

Confidential

OPTIMAT BLADES

TG3

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Change record

Issue/revision	date	Pages	Summary of changes
Rev 0	04 August 2003	Na	na

DETAILED REPORT FOR TASK Group 3

In the following, detailed information can be found regarding the activities for Task Group 3: 'Extreme conditions' (WP8 and WP9).

Report for Task Group 3

The experimental and theoretical work is carried out according to DPA, work package 8.

The main objectives of the reported period, as it follows from DPA, are listed in the section below, called, Specific objectives for this period. The overview of the obtained results is outlined in section, Overview of technical achievements. Furthermore, the updated time schedule and possible critical path (bottle neck) are addressed, list of produced deliverables are listed, and pre-draft version of Design Recommendations is discussed.

Specific objectives for this period

The main objectives for this 18 month period were as follows:

- generate the Detailed Plan of Action (DPA), which includes an overview of geometries, laminates, selected extreme conditions, and degradation parameters, an experimental plan and time schedule
- Identification of extreme conditions
- identification of degradation parameters
- phenomenological modeling and experimental determination

Overview of technical achievements

DPA of WP8 and WP9

After a considerable discussion, the DPA (document, OB_TG3_O004) has been drafted in accordance with the choices made regarding the specimen geometries for the whole project. The DPA has been approved by the Scientific Committee in their Stuttgart meeting of December 16.

Extreme conditions

Extreme conditions that are relevant to service conditions of wind turbines are determined. The determined conditions are: temperature variations at ambient relative humidity –40C, +60C and RT, as well as salt water environmental conditions. The salt water extreme conditions mean that the specimens are submersed in the salt water. One half of them is kept for 6 month and tested after, another half is kept 12 month, and tested after exposure. More details on Extreme conditions are reported in DPA (document, OB_TG3_O004) and in report on Definition of extreme conditions and procedures for testing under extreme conditions (document OB_TG3_R004).

Degradation parameters

Stiffness degradation as function of applied strain and number of loading cycles is identified as damage parameter. It allows to determine a rather small amount of damage long time before final failure of the specimen. Furthermore, damage mechanics and fracture mechanics based modeling can link stiffness degradation to different failure mechanisms acting on laminate and microscopic levels. With this method it is possible to study the damage evolution rate for different fracture mechanisms.

Phenomenological modeling and experimental determination

A variety of fatigue characterization methods for composite materials are found in literature, such as statistical description of fatigue life diagrams, statistical description of stiffness degradations, and damage mechanics based stiffness degradation.

The statistical methods, such as linear regression, maximum likelihood using pooled or censored data, statistics for conditioned random variables, Weibull statistics, or combination of mentioned are available to describe fatigue life diagrams and its tolerance bounds. All the methods will be analyzed theoretically and compared in order to formulate methods that satisfy the considered tests and its objectives.

Fatigue lifetime can be predicted using statistical stiffness degradation measurements. This method has been already used by several authors that we can find in the literature. The methods are acknowledged, and will be utilized and further developed to account for particular applied conditions. Detailed information is given in corresponding report, "Microstructural model and identification of degradation parameters", document, OB_TG3_R006. Further, the damage mechanics based modeling can be utilized to connect statistical stiffness degradation measurements to particular damage mechanisms acting on macro and micro scale. This approach is on its development stage. The isothermal formulation for laminates of particular lay-up only is available for the moment. It has to be generalized for arbitrary laminate, isothermal conditions to start with.

A corresponding test program is compiled. It renders all the data necessary for characterization of considered mechanical properties at selected extreme conditions.

Preliminary test series are carried out in order to test performance of particular specimen geometries to be considered as OPTIMAT standard geometry.

The static tests of ISO and OPTIMAT specimens are carried out according to DPA, WP8, in order to characterize mechanical properties of the basic material at reference and extreme conditions, as well as in order to compare performance of OPTIMAT specimen with ISO specimens in different tests.

The elastic properties and the strength of UD and MD composite are measured experimentally for reference material at ambient room conditions. Measurements of the stiffness degradation, that take place due to the damage accumulation, are carried out for UD and MD composite.

Using maximum stress criteria, the ply discount approach is used to describe the stiffness degradation and strain stress behaviour of MD laminates. The ply discount predictions were limited to single event transverse cracking and debonding in shear. There is a reasonable good agreement between experimental data and theoretical predictions, but the approach breaks down in describing behaviour of MD close to final failure.

A more sophisticated approach is needed to account for damage evolution laws, in order to give more realistic description of macroscopic and microscopic behaviour of UD and MD.

The detailed results are given in corresponding report, OB_TG3_R007_RISØ.

Bottle necks

The critical path in time chart, is the testing after salt water conditioning. Therefore, the delay of still missing Iosipescu and 30^o-off axis specimens, needed for determining shear properties, can result in delays at the end, or missing data.

New time schedule

The updated for TG3 is given below, **Figure 1**.

ID		Task Name	Duration
1		**WP 8MECHANICAL PROPERTIES AT EXTRE**	**475 days**
2		Administration	455 days
3		Received specimens	0 days
4		Specimen conditioning for submersed, star	0 days
5		Specimen ciónditioning for submersed, stop	0 days
6		Specimen conditioning for submersed, stop	0 days
7		Static, basic material, ref. Cond.	8 days
8		Fatigue, basic material, refer. Cond.	40 days
9		Fatigue, basic material, T60C.	30 days
10		Static, basic material, submersed-1	14 days
11		Fatigue, basic material, submersed-1	10 days
12		Static, basic material, submersed-2	14 days
13		Fatigue, basic material, submersed-2	10 days
14		Static, basic material, ref. Cond.	6 days
15		Static, basic material, T-40C	9 days
16		Fatigue, basic material, refer. Cond.	40 days
17		Fatigue, basic material, T-40C.	30 days
18		Data analysis, all	110 days
19		Static, basic material, ref. Cond.	7 days
20		Static, basic material, T60C	7 days
21		Static, basic material, T-40C	2 days
22		Fatigue, basic material, ref. Cond.	25 days
23		Fatigue, basic material, RH100%	15 days
24		Data analysis, all	87 days
25		Static, basic material, ref. Cond.	3 days
26		Sattic, basic material, T60C	3 days
27		Fatigue, basic material, ref. cond.	30 days
28		Fatigue, basic material, RH100%	35 days
29		Data analysis, all	92 days
30		Literature, modelling (dT=0)	229.33 days
31		Data analysis, modelling (dT=0)	180 days
32		Literature, modelling (dt>0)	63.64 days
33		Date analysis, modelling (dT>0)	30 days
34		Literature, modelling (dRH>0)	61.54 days
35		Data analysis, modelling (dRH>0)	40 days
36		SEM and image analysis, damage analysis	345 days

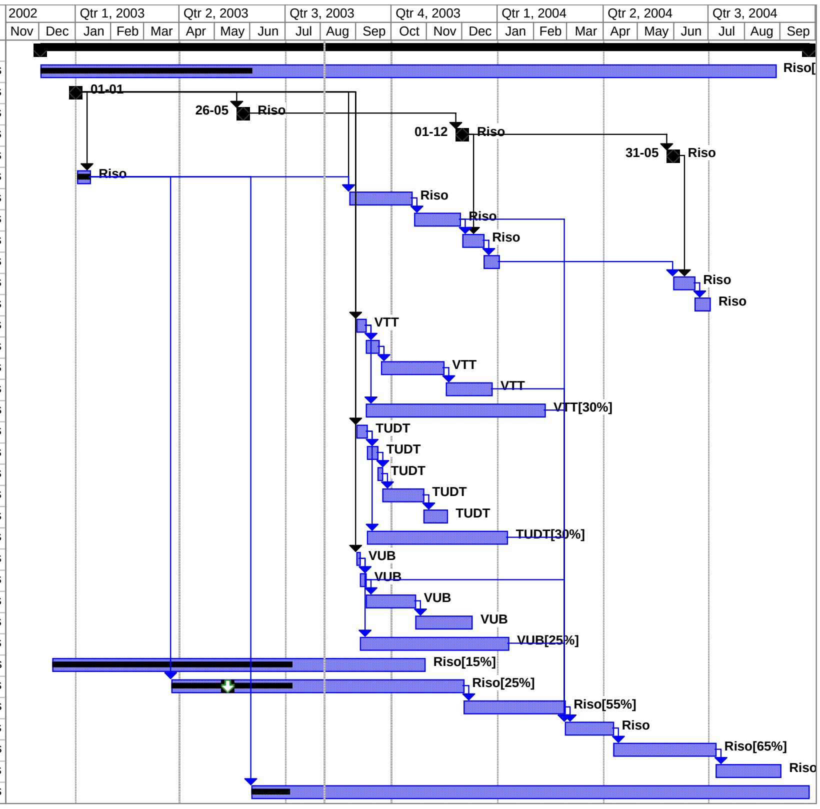

Figure 1. Time schedule.

Activities for the next half year

According to updated time schedule, testing on basic material at extreme conditions will continue in the second half of 2003 and first half of 2004. The phenomenological modeling and the damage analysis will continue parallel with testing as planned.

Deliverables

The produced deliverables are listed in Table 2 “List of Deliverables”.

Table 2-III List of Deliverables

No	Deliverable title	Form	Date	Document
1	Test report describing the material, laminates and fatigue tests	Report	5	OB_TG3_R005
2	Microstructural model and identification of degradation parameters.	Report	5	OB_TG3_R006
3	Definition of extreme conditions and procedures for testing under extreme conditions.	Report	5	OB_TG3_R004
7	DPA for phase 1	Report	6	OB_TG3_O003
9	Approved DPA for phase 1	Report	6	OB_TG3_O004

Pre-draft version of Design Recommendations

In the following a sketch is given of what the Design Recommendations could look like for the part addressed by TG3. No exact figures can be given at this moment.

The elastic properties, strength, and fatigue lifetime will be analyzed at different extreme conditions. Differences will be quantified, and the quantified values can be transformed into safety factors if necessary.

Analysis of damage mechanisms and evolution will be studied. This results in findings of what damage mechanisms are the most sensitive, and must be considered in design of the blade in order to ensure more predictable lifetime. Also the findings give basic understanding of what would happen if the lay-up of the laminate is changed.