

First operating results with LM 54.0 P

The world's largest blade in serial production undergoing tests on a 4.2 MW test turbine.

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Looking inside the blade

Heat-sensitive technology means improved levels of quality in blade production.

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Test bed with room for expansion

LM Glasfiber extends its test bed for blades of up to 80 metres in length.

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NewsLetter

MARCH 2004



The first LM 40.0 P blade is ready for delivery.

LM Glasfiber's first intelligent blade is born

The first set of the new LM Glasfiber blade for 82-metre rotors – the LM 40.0 P – has just been delivered to REpower Systems. This is the first blade ever to be equipped with a prototype of the LM BladeMonitoring system.

The very first set of the new LM 40.0 P blades was dispatched from LM Glasfiber's production facility in the course of March. However, this will not be the last time that completed 40-metre turbine blades leave the plant. The

LM 40.0 P is specifically designed for use with the 2 MW size of turbine, which is expected to gradually supersede 1.5 MW units.

Urs Bendel, the manager responsible for blade development at REpower, points out "The LM 40.0 P blade was designed for our MM82 turbine, which has been very well received. The MM82 is intended for use both onshore and offshore, and we expect it to contribute considerably to REpower sales.

The LM 40.0 P blade is equipped with a prototype of LM BladeMonitoring, the second generation of intelligent blades. This system monitors the condition of the blade on an ongoing basis. In the short term, data from the system will be used to optimise service and maintenance and as data input for the development of new blades. In the long term, the system can be integrated with the turbine control system.

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“It goes without saying that the current circumstances require any management team to review its company strategy.”

2 We believe in “the fundamentals”

Anders D. Christensen, Managing Director

Our industry is going through extremely turbulent times. Limited economic growth in Europe, coupled with budget and trade deficits in the US, have led to an increasingly conservative approach to power generation. This is causing a slowdown in market growth compared with the growth rates our industry experienced during the second part of the 1990s. For LM Glasfiber, the effects have been intensified by the process of consolidation among our customers – a trend that represents both threats and opportunities.

It goes without saying that the current circumstances require any management team to review its company strategy. In this respect, LM Glasfiber is no exception. However, I am pleased to confirm that in spite of the fact that 2003 was a very tough year, and although we still face a number of challenges in the years to come, our basic strategy remains unchanged. Our aim is to strengthen our position as the leading blade supplier to turbine manufacturers around the world. To achieve this objective, we need to work on “the fundamentals”.

We continue to invest in materials and process research, to improve and enhance our design and simulation tools, and to increase the accuracy and durability of our tooling. Last, but not least, we try to incorporate quality into every step taken in the design and manufacturing processes. We believe that every little step will bring us closer to our goal.

We must continue to optimise the way we use our resources and to keep our organisation agile and “fit for fight”. We are in no doubt that the future holds very demanding challenges that are nevertheless very exciting for a highly qualified organisation like ours. Our suppliers hold the key to solving some of these challenges, and we expect to work closely with them in the future.

Our determination to gradually improve our performance may ultimately prove to be more important than an aim to win in a world that is changing at an ever-faster rate.

Positive result of ISO audit

A periodical audit was carried out towards the end of 2003 with positive results.

“It is the opinion of the audit team that the staff and management of LM Glasfiber A/S are working hard to implement the management system. The audit team would especially like to mention the work done to introduce KPIs (Key Performance Indicators) as an important parameter for the future development of the company.”

This was the conclusion drawn by Det Norske Veritas (DNV) in conjunction with the most

recent audit of LM Glasfiber – carried out in late 2003 – and the result is clearly satisfactory for LM Glasfiber.

LM Glasfiber A/S became certified according to ISO standard DS/EN ISO 9001:2000 towards the end of 2002, and the latest audit is an annual follow-up of the quality control system.

The periodic audits help ensure that LM Glasfiber continues to meet the required standards for quality control. The system thus guarantees that LM Glasfiber supplies blades of a consistently high quality. As part

of the audit process, a number of staff members were interviewed regarding their particular area of responsibility, to assess whether the activities carried out met ISO standards. No major deviations were noted during the audit. In fact, there were only five minor deviations, and these were already attended to before the completion of the audit.

The next DNV audit at LM Glasfiber is scheduled for June 2004, when LM Glasfiber’s environmental management system is expected to become certified according to ISO 14001.

Initial tests of LM 54.0 P completed

The 54-metre-long LM Glasfiber blade is having a tough time. The first set of blades is being tested on an NEG Micon test turbine, and at the same time a blade is undergoing an extensive test programme in LM Glasfiber's test beds.

"I am satisfied with the results obtained so far. The blade lives up to our expectations, and we are now ready to undertake measurements of the turbine's power curve and verify the wind turbine loads. We expect to have completed these tests by the end of June".

These are the words of Frank Goezinne, senior mechanical engineer at NEG Micon in the Netherlands about initial experience with the largest LM Glasfiber blade for serial production, to date.

Frank Goezinne continues: "We have not encountered any real problems, and if anything cropped up that required an explanation, we received good, rapid feedback from LM Glasfiber."

Late in 2003, the first set of blades was mounted on an NM110/4200 test turbine. This was erected at Høvsøre in Denmark, and the experience gained from this site is the first step towards the next generation of very large offshore wind turbines.

The LM 54.0 P blade undergoes dynamic flap testing



Since December 2003, the test turbine has completed the first phase of the test procedure.

"We have carried out some precision adjustments of the blades and the turbine, and the turbine is now ready for the next test phase," explains Frank Goezinne.

Det Norske Veritas (DNV) monitors the tests very carefully and only grants its approval once all the required tests have been completed.

The first full-scale test of the LM 54.0 P blade was completed prior to the erection of the test turbine. Rene van den Berg, project manager at LM Glasfiber, says:

"In August 2003, the blade completed its first major strength test. It was tested statically at LM Glasfiber's test bed in Denmark, where it was exposed to a load equal to an extreme wind load that statistically only occurs once in 50 years. During this test, the deflection at the tip of the blade amounted to approximately 10 metres".

For safety reasons, this initial test has to be passed before the blade can be mounted on the test turbine. The LM 54.0 P blade has to undergo more than static tests, however. At the moment, it is undergoing a dynamic test in the test bed. In this test, the blade is exposed to five million oscillations in both edge and flap directions. During this testing procedure, the load is the equivalent of 20 years of service life. The test is therefore an essential part of the LM Glasfiber quality assurance procedures for new blades. When the blade has passed the dynamic test, it is again submitted to a static test to ensure that it also meets requirements towards the end of its planned service life.

Additional preparations were necessary in connection with the dynamic test of the LM 54.0 P blade, as the oscillations were particularly big due to the length of the



The LM 54.0 P blade is now turning on a 4.2 MW NEG Micon test turbine

blade. We therefore had to make a recess in the floor surface beneath the blade to ensure that it would not hit the floor during the test.

The full-scale test in the test bed is scheduled to be completed during the first half of 2004.

LM 40.0 P blade developed in close collaboration with the customer

LM Glasfiber worked closely with the turbine manufacturer REpower Systems to develop the LM 40.0 P blade. Rothe Erde, the company that delivers the pitch bearing for this wind turbine, is also actively involved in the test phase.

In the course of the development of the LM 40.0 P blade, LM Glasfiber's experience with blade development helped perfect the rotor. The result is a light blade that weighs only 6,290 kg and is custom-made for the MM82 turbine. The weight of the blade is thus the same as for the 1.5 MW turbines, but with a higher power output.

"The LM 40.0 P blade is optimized for the MM82 turbine. In the process, we made the best possible use of material properties in order to reduce the material quantities used. This was achieved in collaboration with REpower by making a number of design loops – i.e. a number of comprehensive," says Klavs Jespersen, the project manager at LM Glasfiber.

LM Glasfiber has developed an advanced computerised design tool that allows optimisation of blade design via several design loops. As a result, the calculation time for a blade design analysis has been reduced to 2–5 days, compared with three weeks in the past.

When the weight of a blade is reduced, the blade becomes softer, as there is less material to support it. This, in turn, increases the risk of the blade flexing in towards the tower during operation. LM Glasfiber has solved this problem by using a curved blade. When

"In the process, we made the best possible use of material properties in order to reduce the material quantities used."

unloaded, the blade bends forward, but during operation it is straightened by the wind pressure. The LM 40.0 P blade curves by over 2 metres, which contributes to improving blade performance with no need to use expensive materials.

Close collaboration – including the pitch bearing

"I am very pleased with this project. LM Glasfiber met all agreed deadlines, and the collaboration between the LM Glasfiber project team and the staff at REpower was excellent," says Urs Bendel, blade development manager at REpower.

Collaboration has been extended still further in conjunction with the LM 40.0 P blade, with the result that Rothe Erde, the pitch bearing supplier, also works with LM Glasfiber on bearing testing. The pitch bearing is incorporated in the LM 40.0 P blade during testing in the LM Glasfiber test bed, and it is the first time a full-scale test of this bearing has been carried out on a blade.

"This is a good opportunity to test the bearing properly mounted on the blade, as the type of mounting has an impact on the bearing. The effect of the mounting will be closely examined when the bearing is taken apart and analysed on completion of the test," explains Jörg Rollmann, R&D manager at Rothe Erde.

The combined blade and bearing test should be as true as possible to real life. Automatic lubrication equipment has therefore been mounted on the test blade, as is the case under normal operation. A servo-hydraulic pump turns the pitch bearing several times over a 24-hour period.

In the absence of a full-scale test installation, it would be necessary to conduct a long-term test on a working turbine – a testing process that would take at least ten years. The tests in LM Glasfiber's test bed, on the other hand, accelerate this process by simulating twenty years of operation in a matter of months.

The first set of LM 40.0 P blades will be thoroughly tested on a test turbine



LM 40.0 P

Technical data

Wind class:	GL 2
Weight:	6,290 kg
Lightning system:	Two receptors and one DrainReceptor
Capacity:	For 2 MW turbine
Rotor diameter:	82 metres



Source: REpowerSystems AG, photographer: Jan Dölker

The LM 40.0 P blade is specially designed for REpower's MM82 turbine

"In the test bed, the system is tested as one complete unit, which is important, as all the components must work together. This new partnership benefits all parties, as it results in new knowledge that can later be used for further product improvements," says Alf Trede, manager of the MM turbine platform at REpower.

LM 40.0 P – an intelligent blade

The LM 40.0 P blade has been equipped with a prototype of LM BladeMonitoring, and the system will be tested in the course of 2004. LM BladeMonitoring is a blade monitoring system in which a number of optic fibres work with special LM Glasfiber software to monitor critical parameters such as load, temperature, damages and lightning strike on an ongoing basis.

In the short term, these data allow us to provide the best possible service and maintenance. In the long term, the possibilities are endless. In combination with the turbine control system, it will be possible – for example – to turn the blade according to the measured loads and thereby utilise the wind force to the maximum.

"Initially, the test of LM BladeMonitoring allows us to validate the system. At a later stage, it will be possible to improve the overall efficiency of turbine operation if the system is integrated into turbine control," explains Urs Bendel from REpower.

In addition to the new blade monitoring system, the LM 40.0 P blade is equipped with LM Glasfiber's special DrainReceptor, which provides improved lightning protection. The DrainReceptor is a new lightning receptor that combines the ability to intercept the lightning at the tip of the blade where the risk of lightning strike is greatest with the ability to drain away the water that condenses on the inside of the blade. Finally, the blade has two additional lightning receptors at the tip of the blade.

The first set of LM 40.0 P blades will be mounted on a test turbine in northern Germany in March, and test measurements will begin immediately after.

Meet LM at Global WINDPOWER

The Global WINDPOWER™ Conference and Exhibition in Chicago, USA, takes place on 28–31 March. LM Glasfiber will be present at booth 767, in addition to holding three presentations at the conference itself. These will give those attending opportunities to hear about the very latest technological progress in the development and production of wind turbine blades.

ShortNews

Changes in the structure of the organisation

LM Glasfiber has altered its organisational structure with effect from 1 January 2004. Group management and Group functions have been combined within the LM Glasfiber Group, whereas production, sales and other line functions for the Northern European market have been placed under LM Glasfiber Northern Europe. As a result of these changes, the production organisations are now structured in the same way in all markets, and have the same chains of command in relation to the LM Glasfiber Group. The new structure makes it easier to benchmark the individual companies and to compare markets in terms of our focus on revenue and efficiency.

Meet LM at WindEnergy 2004

On 11–14 May, LM Glasfiber will be present at the WindEnergy 2004 trade fair in Hamburg, Germany – at stand 550 in hall no. 6. Here LM Glasfiber will be presenting the very latest products and breakthroughs relating to rotor solutions for multi-Mw wind turbines.

New newsletter design

LM Glasfiber's newsletter has been given a facelift. The aim is to make the newsletter more appealing and to provide information about the professionalism behind LM Glasfiber's way of doing things. The design changes, which will also be featured in LM Glasfiber's advertisements and brochures, will be implemented throughout the Group worldwide in the course of this year.

LM 28.6 P blade certified

Germanischer Lloyd WindEnergie has now approved the LM 28.6 P – a pitch blade designed for 800 kW output and for placing in areas classified as GL wind class 3, i.e. in areas with little wind and annual mean wind velocities of up to 7.5 m/s.

Infrared scanning reveals blade details

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NewsLetter

LM Glasfiber uses infrared scanning to ensure the quality of glue joints.

A chain is only as strong as its weakest link. Similarly, the strength and durability of a blade are the result of checks and quality assurance at different stages of the manufacturing process. One very important process is the gluing together of the upper and lower parts of the blade.

To ensure the quality of the gluing process, LM Glasfiber uses infrared scanning to investigate whether the glue joints meet the strict requirements. A portable infrared scanner is used to examine the entire length of the blade using temperature differences in the glue to indicate possible weak points. The glue gives off heat during hardening, and the technique detects variations in the glue joints where lower temperatures are recorded.

“Our equipment detects differences in heat, and it is very easy to see when a glue joint is defective. This check is part of standard work procedures, and the results are included in the documentation that substantiates the condition of the blade and guarantees that it meets quality requirements. The results of the scanning process are stored electronically for easy retrieval,” says Michael Stahl, quality control manager.

Infrared scanning is part of LM Glasfiber’s NDT (Non Destructive Testing) programme. NDT is a general term that describes test methods that do not damage the item tested.

LM Glasfiber checks all blades thoroughly before they leave the factory in order to guarantee durability and a long service life



LM Glasfiber uses heat-sensitive technology to ensure the quality of the blades

All staff members using the scanner have completed either a certified NDT level 1 training course in accordance with the requirements of SNT-TC-1A set out by the American Society for Nondestructive Testing or an in-house training course based on the same requirements. The course is both practical and theoretical and includes training in wave theory.

The scanner takes a number of pictures. If the scanner reveals doubtful glue joints, the joints can be marked and the picture subsequently analysed further using electronic imaging techniques to determine the quality of the glue joint with maximum certainty. Any defective glue joint becomes the subject of a report, and any defective joints can usually be repaired. In a very few cases, an entire blade has been discarded.

“The infrared scanner allows us to see through the laminate and check the glue joint. This tool has provided us with the means to focus further on the quality of the glue joint and thereby prevent defects that would otherwise be very hard to detect,” says Michael Stahl.

Infrared scanner

Technical data

Infrared scanner:	Visual representation of temperature measurements
Sensitivity:	The scanner can measure temperature differences of as little as 0.1°C
Method:	Measurements over the entire length of the blade to check the quality of the glue joint

Test bed extended to test blades of up to 80 metres long



Building a structure that meets the requirements for testing very large blades is quite a challenge

One of the world's strongest liquid concrete constructions and a seven-metre extension of the test hangar enable LM Glasfiber to test its largest blades.

LM Glasfiber has recently extended its test capacity to allow testing of even larger blades. The world's largest commercial blade – LM 54.0 P – is currently being tested, but bigger blades are planned for the future, and LM Glasfiber is therefore increasing its capacity.

An impressive concrete giant is now under construction in LM Glasfiber's test hangar. The new test bed is the strongest liquid concrete construction in Denmark and one of the strongest in the world. It will be used for the dynamic testing of LM 61.5 and future large blades.

"The importance of the test capacity increases with the size of the blades. The bending moment of the blade root more than doubles in relation to the length of the blade. A disproportionately large extension of the test bed is therefore required to meet requirements, and the capacity of the test bed is more important than ever before," says Carsten Nymann, technical test manager at LM Glasfiber.

The new concrete test bed is much stronger than the previous steel construction. The test bed has been designed to withstand more than 2.5 times the load of LM Glasfiber's existing test beds, and the new bed will have the capacity to test blades of 80 metres and more.

The construction of the anchor block on which the blade is mounted during the test was quite a challenge, as the casting of such a large liquid concrete construction is extremely complex.

"The design and casting of an anchor block of this size must be planned down to the last detail, and is not something you rush into," says Carsten Nymann. "Constructions of this magnitude cannot be changed in a hurry if something goes wrong. It would take months just to demolish the defective construction. We are therefore extremely pleased that the casting process went well thanks to our detailed preparations," Carsten Nymann adds.

LM Glasfiber has also extended the test hangar. An extra 7 metres have been added to accommodate the increasingly large blades. This is a flexible solution, as both the gable and the doors can be raised by a crane, and another section added to the test hangar if more room is required.

LM Glasfiber has extended its test hangar and increased the capacity for testing large blades



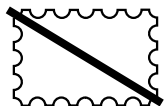
LM Glasfiber currently has a total of 7 test beds and the necessary capacity and flexibility to carry out full-scale tests of the company's blades. The new extension therefore means that LM Glasfiber can continue to test the world's largest blades.

Test bed

Technical data

Casting process:	More than 24 hours
Amount of concrete:	290 m ³
Total weight:	750 tonnes
Cooling hoses:	1.8 km

No stamp required



Modtageren
betaler porto

LM Glasfiber
Rolles Møllevej
+++6863+++
6640 Lunderskov
Denmark





Useful information

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