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The LM Glasfiber wind pioneer retires after 20 years of professionalism and commitment to the wind industry.

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# NewsLetter

MÄY 2004



LM 61.5 P is the world's longest wind turbine blade to date.

## LM 61.5 P moves boundaries

**It is not the first time that LM Glasfiber has produced the largest blade in the world. Until today, LM 54.0 P held the lead in the race for developing blades that were bigger and bigger. However, LM 61.5 P now surpasses this record with a length of more than 60 metres. The blade is based on LM Glasfiber FutureBlade technology, and the discerning use of materials – including carbon fibre – has reduced the weight of the blade to less than 18 tonnes.**

The LM 61.5 P blade gives the wind turbine a rotor diameter of 126 metres, and generates wind energy equivalent to a nominal effect of 5 MW – sufficient to cover the annual power requirements of about 5,000 average households. These figures clearly show that the new mega blade from LM Glasfiber surpasses all existing blades in terms of size. LM Glasfiber has nevertheless managed to reduce the weight by using new, improved materials and designs.

LM Glasfiber worked closely with REpower Systems to develop the LM 61.5 P blade for their 5 MW turbine, which targets the off-shore market. Matthias Schubert, chief technical officer on the board of REpower adds: "The LM 61.5 P blade represents a huge development leap and has moved the boundaries in blade production."

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“... setting high targets and achieving them is one way to improve the products we use in our everyday lives”

## 2 Breaking new ground

Anders D. Christensen, Managing Director

When the first LM 61.5 P was demoulded the beginning of 2004, it was a moment of historic proportions for LM Glasfiber. The sheer size of the blade was obviously the most spectacular difference when you compare it with other blade types. The 61.5-metre-long blade quite simply dwarfs its 40-metre-long counterpart. However, for most of us who have had the chance to witness or participate in the project itself, we realise that the devil is in the detail – but so is the solution.

Our research department worked intensively with our key suppliers to develop new combinations of materials. These materials were then subjected to a full range of tests from tiny samples up to a 28-metre-long test blade. The production process was scrutinised again and again to shorten the moulding time and to reduce the manual labour involved in finishing the blade. Our tooling department undertook the entirely new challenge of building the mould itself. They achieved this with unparalleled accuracy – with deviations of as little as a few tenths of a millimetre. We worked closely with suppliers of production equipment to create the tooling to facilitate these new developments and to overcome the challenges that the sheer size presented.

A small but dedicated team of engineers worked closely with the customer's project team to design a blade that would match the machine perfectly.

Along the way, we found solutions that are now being included in other blade designs, tooling solutions and quality control measures – to mention just a few of the areas that have benefited from innovations and technological advances in the prototyping process.

It's almost like building a Formula One racing car: the features developed for Formula One cars will inevitably spread to other, more ordinary types of cars. Ultimately, setting high targets and achieving them is one way to improve the products we use in our everyday lives.

## ShortNews

### LM 37.3 P2 ready for the American market

LM Glasfiber's American factory in Grand Forks, North Dakota, has just made the first mould ready for production of the LM 37.3 P2 blade. More production moulds are in the pipeline, which will enable the factory to meet the demand for the 37-metre-long blade designed for 1,500 kW turbines.

LM 37.3 P2 is a redesign of the existing LM 37.3 P blade and was developed specially for the American market. This means that the weight of the blade has been reduced by 12% to 5,530 kg, and the dead weight torque has also been reduced.

LM 37.3 P2 was designed for wind class IEC2, which makes it ideally suited for erection on sites with average wind conditions.

### The world's largest blade to be presented at WindEnergy 2004

LM Glasfiber will present the LM 61.5 P blade at the WindEnergy 2004 trade fair to be held 11–14 May in Hamburg, Germany. The LM Glasfiber display is in hall 6 stand 550, where information about the new blade for 5 MW turbines will be available. Sales and marketing director Søren F. Knudsen will launch the blade at a presentation at the LM Glasfiber stand on Wednesday 12 May from 2 pm to 3 pm.

# Intelligent blades with LM BladeMonitoring

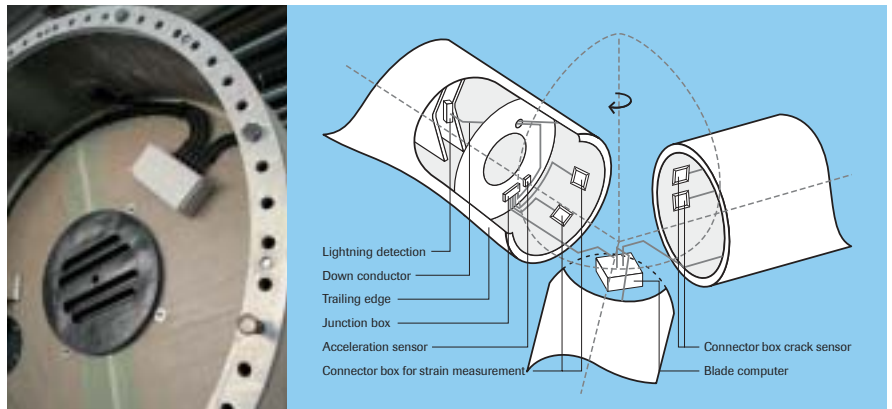
**LM Glasfiber is busy testing the wind turbine blades to come. In the future, wind turbine blades will be monitored via a computer and sensors incorporated in the blades themselves. This new technology can reduce service and maintenance costs and increase service life, and the use of signals from the system can potentially increase the efficiency of the blade.**

“We have already made good progress with the development of this system. We are in the process of testing the monitoring system on blades in our test halls,” says project manager Ivan Mortensen from LM Glasfiber. “During the test, the system is exposed to loads corresponding to twenty years of service life in the open. Reliable, safe operation is all-important for the use of such a system. We therefore test each and every detail against the extreme wind and weather conditions to which the wind turbine blades are exposed.”

The LM BladeMonitoring system is also currently being tested on the LM 40.0 P blade, and before long, LM Glasfiber will begin testing the system on the LM 61.5 P, the world’s largest blade to date. LM Glasfiber expects to increase the use of this technology during 2005, so that LM BladeMonitoring will become a standard blade component from around 2006.

### Tailor-made software monitors critical areas

The technology primarily consists of a number of thin, lightweight optical fibres that are incorporated into the blade laminate. These optical fibres are made from essentially the same raw material as the blades, which means that the optical sensor complies with the requirements to the blade as such. Sensors connected to the built-in fibres register process data about the current state of the blade. This information is then interpreted via a special software application custom-made by LM Glasfiber. The system is also integrated with the control and monitoring system via a wireless connection to the wind turbine.



LM BladeMonitoring provides accurate data about the current state of the blade – the system makes it possible to adjust the wind turbine control on the basis of current load conditions, which reduces the load exerted on the entire turbine structure

Ivan Mortensen explains: “One of the biggest challenges with the LM BladeMonitoring system has been to convert the relatively complex process data to clear, easily comprehensible information that can be transmitted to the turbine control system.”

Ivan Mortensen continues: “The LM BladeMonitoring system makes it easier to detect and analyse influences from the external environment at a very early stage. The new monitoring technology provides data about load, temperature, cracks and lightning strikes and makes it possible to quickly determine the consequences of these influences and any damage that may have occurred. In that way, LM BladeMonitoring provides an early damage warning. Using LM BladeMonitoring means that routine service will no longer be necessary and the only service needed to maintain the blades will be that caused by specific events. The result is lower service costs in respect of the blades and increased operating time for the wind turbine.”

### Future prospects

A system that can monitor the load on the individual blade will have considerable impact on the costs of operating wind turbines.

“There is a real possibility that the use of signals about the wind load can reduce blade

flap fatigue load by 10–30%. The fatigue load on other components like tower, yaw mechanism, gear, main bearings and axle can potentially be reduced by 10–45%. In other words: once our customers start using process signals from LM BladeMonitoring, they will in theory be able to fit larger blades to existing constructions and thereby increase the capacity of the individual turbine,” Ivan Mortensen concludes.

LM BladeMonitoring	
<b>The standard system can provide the following signals:</b>	
Warnings and alarm signals:	All temperatures, events, data about lightning and the optical fibres used to detect cracks are compared with threshold values on an ongoing basis.
Index values:	All twenty points are monitored and the data stored in a matrix using statistical calculations.
Lightning reports:	A report is generated on the basis of the process data from the last thirty lightning strikes.
Raw process data:	The LM Glasfiber monitoring system collects data from sensor points, e.g. the average wind speed and index values for each blade.

# LM 61.5 P – a huge challenge

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NewsLetter

**Right from the start, the design and construction of the LM 61.5 P blade was a challenge to the development engineers at LM Glasfiber. The final blade is therefore the result of new technological advances and optimal utilisation of blade materials.**

The larger the blade, the more important it is to focus on the weight, in order to reduce the stresses placed on the turbine during operation. To meet this challenge, all the materials were very carefully selected. The idea is to use the very best material for each individual part of the blade without making the solution unnecessarily expensive.

Project manager Peter Klindt explains: “As an example, we have focused even more than ever before on individual tailoring of the core material for the sandwich construction of the blade. And in a few key areas, we have chosen to use carbon fibre in the main laminate, as we have achieved excellent results with the use of hybrid fibres in the further development of the FutureBlade technology. In other words, it has been quite a jigsaw puzzle to combine the individual blade materials so that we make the most of their properties. The result is a blade of just under 18 tonnes that is able to withstand the stress to which it is exposed during its service life of twenty years.”

The LM 61.5 P blade design is currently undergoing a tough full-scale testing

programme to prove its capabilities. The blade has to pass both a static and a dynamic test during the coming months. During these tests, it will be exposed to loads corresponding to a service life of twenty years.

## Robot technology

Robot technology is one of many solutions used in the production of LM 61.5 P blades. LM Glasfiber uses robots to place glass fibre in moulds and to glue blade shells.

Peter Klindt explains: “The robot that dispenses the glue is programmed to adjust the amount of glue to the individual point of application. This means that we avoid using excess glue, and the weight of the final blade is reduced still further. In my opinion, automation is a prerequisite in the production of increasingly large blades to ensure a consistent, high quality.”

## SuperRoot

The LM 61.5 P incorporates the new LM Glasfiber SuperRoot design, which features improved bushings. The advantage of this new root design is to facilitate a stronger and more compact root connection to the wind turbine. The concept thus makes it possible to increase the length of the blade by about

20% compared with previous blades, without increasing the root diameter.

A smaller bolt circle diameter makes it possible to reduce hub and pitch bearing dimensions and thereby make the turbine more competitive overall. The SuperRoot design has the additional advantage that larger blades can be fitted on existing wind turbines without increasing the bolt circle diameter.

## LM BladeMonitoring and Lightning Protection

LM 61.5 P is equipped with a prototype of the LM Glasfiber blade monitoring system – LM BladeMonitoring. This system is able to automatically check whether the wind turbine blades are functioning optimally, as optical fibres within the blade laminate measure loads, damage and lightning strikes, amongst other things. The LM 40.0 P and LM 61.5 P blade designs are the first to incorporate LM BladeMonitoring technology, which represents a huge step towards “intelligent blades”.

The system is likely to be used primarily in multi-MW turbines and large wind turbine farms both onshore and offshore, typically in blades measuring 40 metres and more in

### LM 61.5 P

#### Product specifications

Blade type	LM 61.5 P
Rotor diameter (max.)	126.3 m
Blade regulation	Pitch
Length	61.5 m
Max. chord	4,600 m
Profiled area	183.0 m <sup>2</sup>
Weight	17,740 kg*
Number of bolts	128
Size of bolts	M36
Bolt circle diameter	3,200 mm

\*Preliminary data





The blade undergoes a static test as part of the test programme – the deflection at the tip of the blade was approximately 16 metres during this test.

length. Offshore wind farms, in particular, are expected to be an important market. This is because wind and weather conditions at sea are extremely demanding, and it is difficult to service and monitor the operation of wind turbines offshore.

The LM 61.5 P blade is equipped with the proven LM Glasfiber Lightning Protection system. The blade has a total of seven Multi-Receptors on each side and a special Drain-Receptor at the tip of the blade that intercepts lightning while simultaneously allowing condensate inside the blade to run off.

LM Glasfiber has worked hard on the continued development of the LM Lightning Protection system for blades using carbon fibre. Carbon fibre conducts electricity, and this

must be taken into account to ensure effective protection.

#### **Collaboration with REpower**

LM Glasfiber worked closely with REpower Systems to develop the LM 61.5 P blade. Matthias Schubert, REpower's CTO, explains: "Size is all-important for offshore wind farms, and three years ago, we decided to build the largest wind turbine that seemed feasible at the time from a risk assessment point of view. It was important to find a supplier that was able to handle this task in terms of finances and logistics, as well as in terms of technology. LM Glasfiber has experience with large blades and has the size necessary to be a reliable partner in such a major project. Our collaboration and the project as a whole have been a great success."

Peter Klindt, LM Glasfiber, adds: "REpower is good at making efficient wind turbines, and we are good at making blades. Together, we have developed the optimum solution, and we have not hesitated to go over our calculations one more time, when necessary."

The first prototype wind turbine is due to be erected in Northern Germany this year, and the first set of blades will be transported from Lunderskov in Denmark by special road transport. This will provide some initial experience with the 5 MW wind turbine.

"We expect to demonstrate the first turbines in 2005/2006, and that market demand for very large wind turbines will increase dramatically from 2006/2007. The LM 61.5 P blade and our reference turbine will give us initial experience with large wind turbines and will prepare us for the market of the future," Matthias Schubert concludes.

The first blades will be transported by road from the production premises in Lunderskov to Northern Germany.



# Advanced moulding technology means greater flexibility

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Newsletter

**A focus on moulding technology is a prerequisite for blade manufacture, and LM Glasfiber's FutureBlade technology is one of the results of this focus.**

A blade begins as bits and bytes in the development engineers' computers, but only takes on its physical form during the casting process. It is therefore essential that the moulding technology complies with all the strict quality standards required, so that the nominal geometry of each and every blade manufactured by LM Glasfiber is exactly as originally intended.

"Each blade is a perfect mirror image of the mould in which it was cast. The casting technology is therefore decisive for the quality of the finished blades. The 15 engineers and technicians in the casting department therefore work hard with the production staff to ensure that LM Glasfiber's moulding technology is of the highest standard," says Jakob Stautz, manager of LM Glasfiber's casting department.

Moulding technology is one of LM Glasfiber's core competencies and a top priority. The company has decades of experience, and new knowledge is gained continuously.

Jakob Stautz explains: "It is an obvious advantage for us that we have developed the moulding technology in-house. We can use our knowledge and competencies to adjust our moulds to meet precise production requirements, and to ensure compliance with demands for efficiency, quality and tolerance."

There are many requirements to consider during the development of a new mould. First of all, the quality must be guaranteed, i.e. the profiles of the cast blades must be correct and uniform. All blades leaving the mould, whether blade no. 1 or blade no. 200, must be identical. In addition, there are strict demands to the actual moulding process, such as a rapid throughput time during the casting of the blade.



Laser measurements used to check the plug. An accurate measuring technique is a prerequisite for complying with quality standards.

The introduction of new techniques and an increased focus on casting technology have considerably reduced the development time for new moulds compared with previous experience. As a result, bottlenecks are avoided, and LM Glasfiber's customers benefit from increased efficiency and flexibility.

## Quality from beginning to end

The challenges of building a new blade mould begin with the construction of a plug, which is a full-scale model in the shape of the final blade. The actual mould is cast on top of this plug. Previously, the plug was made of wood and its production involved a lot of joinery work. Today, the plug is produced using computer-controlled CNC milling, a process that is both faster and more accurate.

The plug is the basis of the final mould and determines the quality of the blade, so much emphasis is placed on the quality of the plug during its construction.

"A quality product requires the best possible components from beginning to end, and we are not afraid of making tough demands on ourselves. That is why we work with very strict quality standards and insist that the plug profile complies with specific tolerances described down to the last detail. One of the

quality checks is a laser measurement to make sure there are no deviations between the actual plug geometry and the nominal geometry. The major advantage of the laser measurement is that it enables us to measure differences of less than 1 millimetre," says Jakob Stautz.

The next step is to manufacture the mould that is subsequently used for casting the blade on top of the plug. Once this mould has been equipped with gangways and miscellaneous production equipment, it is ready for use.

Just like the plug, the mould must comply with strict specifications. A number of quality checks are carried out during the manufacture of the mould, which are all part of LM Glasfiber's ISO quality control system. These checks include laser measurements to ensure a correct profile.

"It is part of our day-to-day work to make sure everything is tested and documented. A blade is never better than the mould in which it is moulded, so the quality of our moulds is of paramount importance. Just as an aeroplane goes through a long list of checks before take-off, we also check that everything is correct and functional," Jakob Stautz explains.

# Focus on management training

LM Glasfiber's blade moulds are manufactured in a central location in Denmark for production sites in Denmark, the United States, Spain, India and China.

## FutureBlade technology leads the way in mould production

The manufacture of the large blades of the future represents a challenge. Meeting requirements for performance, weight, durability and manufacturing costs places unusually high demands on materials, design, processes, tools and production conditions. In addition to these demands, the sheer size of the blades is a huge challenge in terms of the manufacture of moulds and tools. The development of LM Glasfiber's FutureBlade technology for the manufacture of large blades has therefore included the development of a new mould concept.

The casting moulds used in the manufacture of the new large blades, for example, must be able to withstand higher temperatures. It is therefore important that both mould and blade materials have the same coefficients of expansion. The new moulds are consequently made of the same composite materials as the blades, with the result that the moulds are both lighter and more rigid than the conventional steel moulds. Lighter moulds are easier to handle during production and very large steel moulds are difficult to construct, as the weight of the steel alone places an unnecessary load on the construction.

The new mould concept was developed concurrently with the new large blades. In this way, any changes in the development process of the blades can be taken into account in the early stages of the development of the moulds. In addition, materials and components can be tested as early as the development phase. This is very important as design, processes and materials are all part of the overall production.

A technological leap of this nature requires considerable knowledge and resources, and by developing the FutureBlade technology, LM Glasfiber has created a foundation for the competitive rotor solutions of the future.



Management training at LM Glasfiber aims at ensuring quality at all levels.

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**Ever since 1997, LM Glasfiber has focused on training managers who are able to initiate and manage change. This has been achieved through systematic training and development of managers at all levels.**

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"Our management style and the way we handle staff relations have changed dramatically over the past 7-8 years," says factory manager Ole Johansen from LM Glasfiber Nordeuropa in Hammelev, Denmark. "This year, our Danish shop stewards have nominated the company for the Denmark's Best Workplace award. It proves that we employ a modern management style and involve our staff in what the company does. In the past, we were much less responsive."

Since then, LM Glasfiber has developed the company's management skills through a number of in-house management training modules that have helped increase productivity and cut costs. The management training programme revolved around a number of tool-based courses that ensured implementation in the individual companies and departments.

Ole Johansen: "Our management training programme concentrates on altering attitudes and creating a culture focused on change. I have no doubt that this process has contributed to breaking down barriers between different departments and functions, and has made it easier for all managers to see our day-to-day work in a broader perspective."

Current management courses focus on developing sustainable relations with customers and business partners. The key expression is "relationship management", and it is about developing the company's ability to meet customer needs and wishes to an even greater extent than is the case today.

"It is very important that we pay more attention to customer relations. Organisational changes have resulted in very close collaboration between LM Glasfiber production companies and their customers. We are therefore able to immediately apply the management tools we learn during the management training programmes," says Ole Johansen.

## “Where is Troels Thomsen?”

**That is the question colleagues and business partners around the world keep asking LM Glasfiber staff. The answer is that Troels Thomsen has retired. We spoke to the man who played an important part in twenty years of development at LM Glasfiber – from the pioneering spirit to today’s professionalism.**

“I am sure that the wind energy industry has a promising future. After all, there is not much chance that another, even better non-polluting energy source will be discovered. Young engineers in our industry must nevertheless be prepared to face new challenges all the time.”

These are the words of Troels Thomsen, who has just begun a new phase in his life after retiring. He recently retired after twenty years with LM Glasfiber – but still acts as a consultant for his former employer.

### **What was the industry like when you started?**

“It was an industry where we all worked together and helped each other. As you know, I joined LM Glasfiber when we first began working with the researchers at the Risø National Laboratory in Denmark. They had this very advanced piece of equipment – a computer – that was able to calculate the aerodynamics of the blades. We could transmit our data and have the calculations performed overnight. The information was returned to our printer via a modem the size of a shoe box!”

### **It sounds as though you were a group of pioneers.**

“Exactly. We had to support each other and we were all more concerned with helping

others in the industry than with competing. The first time I prepared a company brochure, most of the work was done on a spirit duplicator, and when I was asked who the target group was, I had to look the expression up in a dictionary! I was involved in everything from product development to marketing. We didn’t specialise much at that time, so I could get involved in everything. I couldn’t have asked for more.”

### **How would you describe the development of the market over the last twenty years?**

“Well, we all know how the market has kept on going up and up. Only a few visionaries could have predicted during the oil crisis in 1973 that a Danish initiative would have such an impact on pollution-free energy world-wide. LM Glasfiber understood at a very early stage what was required to construct durable blades for wind turbines, and we have developed the product on that basis. I have personally travelled and negotiated on behalf of LM Glasfiber and experienced first-hand how one market after the other opened up. The industry has changed over the past twenty years from being wide open to becoming a science in its own right, where product development and research are kept strictly confidential. The pioneering spirit has been replaced by professionalism – and that is, of course, how it should be.”

You joined the industry at a mature age, but LM Glasfiber now employs many young engineers. What can they expect from the future?

“They can expect the market to continue growing. We sell energy, and energy is a political product. Growth requires energy, and our energy is pollution-free and popular. Our industry therefore appeals to skilled



staff, even in a time characterised by uncertainty and the risk of redundancies. Future product development will be very demanding, and LM Glasfiber can offer a young engineer challenges in all areas of research.”

### **So what is the answer, when your former colleagues are asked: “Where is Troels Thomsen?”**

“The answer is that I have retired, but fortunately, I have been given the opportunity to continue working on a couple of international projects as a consultant for LM Glasfiber.”

### **Søren F. Knudsen, sales and marketing director, comments:**

“At LM Glasfiber, we are sorry that Troels Thomsen is no longer around on a daily basis. With his professional approach and commitment, Troels has had a huge impact on the development of LM Glasfiber. The combination of his extensive knowledge and pleasant manners has opened doors and created opportunities for LM Glasfiber worldwide. Fortunately, we haven’t completely cut the ties. Troels still assists us as a consultant on a few jobs, and LM Glasfiber therefore continues to benefit from his expertise.”



## Useful information

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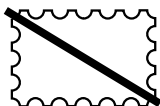
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